# GUIDE

TO EARLY GROWTH AND SURVIVAL IN

**PLANTATIONS OF 64 TREE SPECIES**

NATIVE TO PANAMA AND THE NEOTROPICS

JEFFERSON S. HALL

MARK S. ASHTON

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NATIVE TO PANAMA AND THE NEOTROPICS

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Mark S. Ashton

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This guide is a synthesis of PRORENA's largest single research initiative, the species selection trials. It also represents a transition of putting PRORENA research into practice through Smart Reforestation®, a Smithsonian initiative aimed at managing land to maximize the flow of goods and services to different stakeholders in an era of global change. We are grateful to all the PRORENA and Smart Reforestation® donors who have contributed in different ways to the realization of this guide.

The PRORENA vision of bringing together different public and private partners to confront and overcome the socio-economic and biophysical barriers to reforestation with native species was conceived by Mirei Endara (then Administrator of INRENARE, and current Minister of the Environment in Panama), Ira Rubinoff (former Director of the Smithsonian Tropical Research Institute, STRI), Cristián Samper (former Deputy Director of STRI), and Mark Ashton (Professor of silviculture at the Yale School of Forestry and Environmental Studies). Mark Wishnie was PRORENA Director from 2000–2006 and was responsible for making a good idea take root. We are grateful to all these individuals for their continued support and encouragement over the last decade and a half since PRORENA began.

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# Preface

Combating climate change is the most important environmental challenge of our era. To achieve success, it is critical that we reduce our greenhouse gas emissions, although that alone will not be enough. We must also look for ways to mitigate and offset increases in carbon dioxide. Carbon sequestration, when done efficiently, is currently the most cost-effective method of removing carbon from our atmosphere. Growing forests are natural carbon sinks in the tropics. Consequently, over the past several decades, there has been much discussion about tropical reforestation, which can have a net positive impact on the global carbon balance, produce much-needed timber, and help protect biodiversity.

However, relatively little effort has gone into the basic studies necessary to advance our knowledge of tropical reforestation, which is more than a simple matter of planting more trees. The overwhelming majority of trees planted in the tropics come from just four genera that have timber value: teak (*Tectona grandis*), *Acacia*, *Pinus*, and *Eucalyptus*. And while wood is a renewable resource, timber trees must be harvested responsibly—overexploitation, mismanagement, or conversion of tropical forests to single-species plantations can exacerbate carbon losses, while threatening biodiversity, water security, and the livelihoods of rural farmers and indigenous peoples.

As a lack of knowledge on how to germinate seeds, produce seedlings, and grow trees can lead to reforestation failure, there is risk involved in working with species about which little is known. Given the costs associated with planting forests, catastrophic failure can lead to financial ruin for rural farmers and great losses to commercial operations. Thus, there is a high incentive to continue planting a limited number of species whose silviculture is well known. Yet these species may grow poorly on many sites and may not produce the desired goods and services.

Thus, the more tree species we can add to the list of commercially viable reforestation choices, the more robust and advantageous reforestation can be for our environment, beyond the benefits of carbon sequestration. Adding more species could increase the overall area that is reforested, as different species are specially adapted to different soil and climate conditions.

Against this backdrop, Mark Ashton from the Yale School of Forestry and Environmental Studies and colleagues from the Smithsonian Tropical Research Institute (STRI) in Panama undertook the Native Species Reforestation Project (known by its Spanish acronym, PRORENA). Mark Wishnie, with a fresh master's degree obtained under Ashton's supervision, set out to Panama as the leader of PRORENA and began the hard work of overcoming the key socioeconomic barriers and biophysical knowledge gaps that stood in the way of making reforestation with native species a viable and attractive alternative to the status quo. Thanks to his entrepreneurial drive, knowledge of forestry, and ability to work with a diverse group of people, Wishnie was able to assemble a unique coalition of individuals and organizations—their collective, long-term commitment to the project advances our knowledge of how to reduce risks when planting native species.

In 2006, Jefferson Hall arrived on the scene to take the helm of PRORENA. Hall moved the coalition forward. His greatest contribution has been to work with a series of postdoctoral fellows, students, and others to publish PRORENA results in the scientific literature, as well as in forms accessible to practitioners. This guide, as well as the companion nursery guide published in 2012, result from his determination to put PRORENA data in the hands of practitioners.

The Grantham Foundation for the Protection of the Environment is proud to have been a founding partner and long-term supporter of the PRORENA Project. Several other organizations and individuals have helped along the way. PRORENA could not have been undertaken without the vision of Ira Rubinoff, then director of STRI; Frank Levinson, another long-term supporter of STRI; Mirei Endara, an early supporter and advisory board member of PRORENA (and now the Minister of the Environment of Panama); and Rick Condit, STRI staff scientist. The project also received support from early adapters who, with PRORENA's assistance, took a leap of faith in investing in the concept on private land—they include Ovidio Díaz Espino, Vernon Scholey of IDB Forestal, and Nick Nickson of Eco Venao (ecovenao.com). This is a small sample of the groups that have put PRORENA's research into practice and used it to further the knowledge base of commercial, social, and environmental applications of native tree species in reforestation.

Over the years, PRORENA has produced numerous technical reports and scientific papers related to native species reforestation. PRORENA began a series of annual conferences in Panama aimed at bringing together practitioners and decision makers, which has now evolved into a series co-sponsored and largely led by the Environmental Leadership and Training Initiative (ELTI). The native species reforestation research begun by PRORENA has evolved into Smart Reforestation® research and work undertaken by the Agua Salud Project in Panama, with support from the Panama Canal Authority, Stanley Motta, Levinson, and the Heising-Simons Foundation, among others.

The work presented in this guide book synthesizes data from the largest single experiment in the PRORENA portfolio. Over 50,000 trees from some 75 species were planted in a soil fertility and rainfall matrix, to screen native species for their survivorship and growth. The data obtained will allow foresters and other land management practitioners to make informed decisions about species planting choices depending upon their site conditions and management objectives. Further information continues to be published in the scientific literature, but the authors have presented data in this book in an easily understood and accessible format. It is a companion to the nursery guide published in 2012, which contains basic information on how to germinate and manage 120 native species. Together, these guide books help complete the PRORENA vision of making native species reforestation research accessible to practitioners.

The Grantham Foundation is committed to combating climate change by whatever efficient and effective means necessary. The use of trees to sequester carbon is one of the important tools in our planet's tool belt, and a method the Foundation has invested in commercially, as well as through PRORENA's research. But the silviculture of native tropical species remains poorly understood and deserves considerably more research and extension support. I encourage others to contact Jefferson Hall, STRI staff scientist and current head of the PRORENA project, PRORENA, or STRI to learn more about how they can get involved. For example, much of this work is site-specific, and huge benefits can be gained by extending the research to more locations.

This well-presented and user-friendly guide will continue to encourage reforestation efforts and knowledge transfer. I am excited to follow the progress.

***Oliver Grantham***
The Grantham Foundation for the Protection of the Environment

# 1

# Chapter One

# Introduction

## Overview

Reforestation and forest restoration are now global-scale resource issues. Today, it is estimated that over 2 billion hectares of originally forested land cleared for human use is now categorized as degraded, open, or under-utilized. Degraded land can be defined in several different ways but ultimately means land that has decreased in site productivity from its baseline condition as an undisturbed forest. Degradation can be more superficial in nature, meaning that rather than an inherent decrease in site productivity there are structural or compositional changes (e.g., loss of a species, loss of seed dispersal, or decline in forest stature). Forest **restoration** can be defined broadly as any treatment that improves site productivity, species composition, or forest stature. It can also be narrowly defined: literally, restoring a forest to a baseline condition. The broader definition includes treatments such as rehabilitation and reclamation (see Figure 1). **Rehabilitation** restores ecological processes, species composition and structure on the same trajectory as restoration (narrowly defined) but at a lower level than when compared to the original ecosystem. **Reclamation** restores soil and site productivity with new and novel assemblages of plants on severely degraded sites that have no original vegetation cover remaining. In this guide book we define restoration using the broader and more inclusive term.

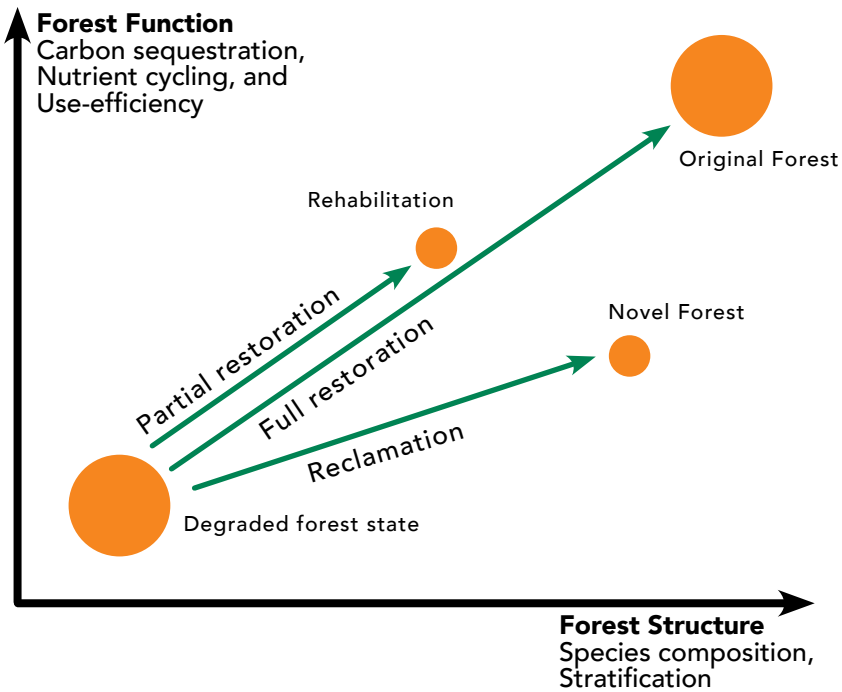


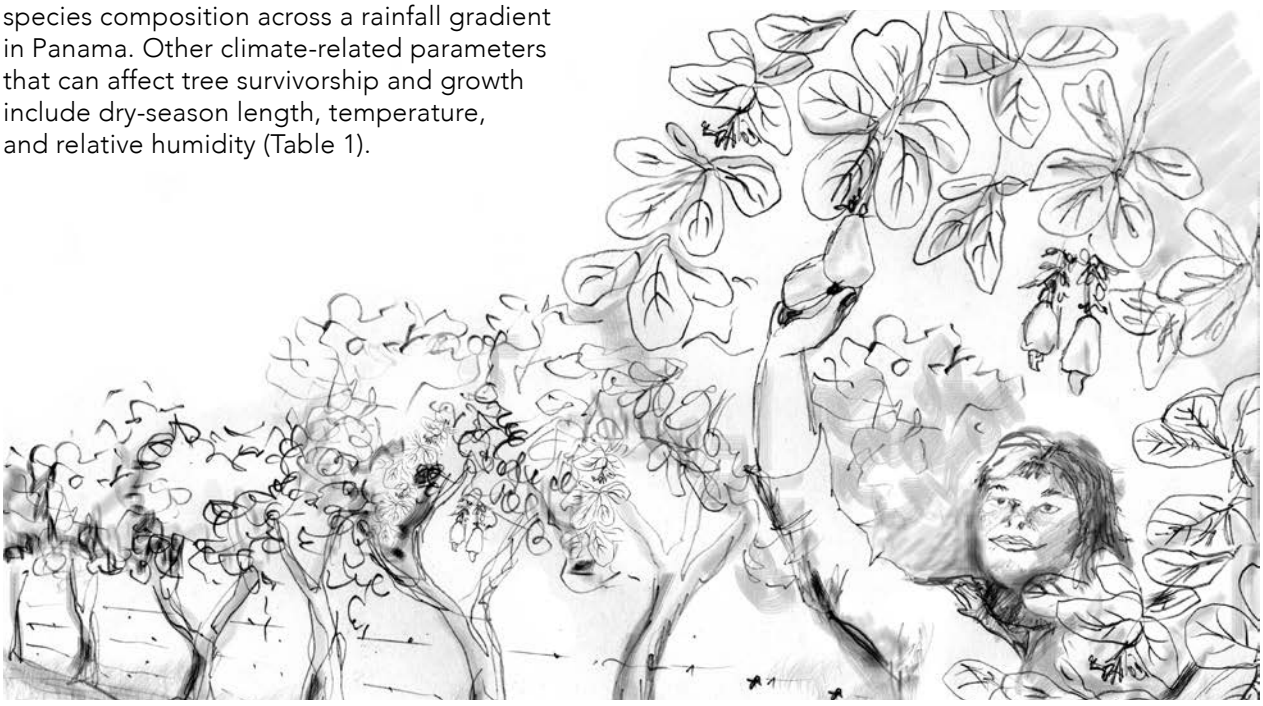

**Figure 1**
**A conceptual representation of the degradation and restoration processes that are possible when expressed by two broad ecosystem attributes —structure and function.**

**Reforestation** is an even broader term that literally means the natural or intentional restocking of existing forests and woodlands that have been depleted, usually through deforestation in the recent past. The definition therefore includes second-growth forests as well as tree plantations, and any combination of both. **Afforestation** is the planting of trees on land that was always non-forest (e.g., native grassland), or on land that has not had any tree cover for hundreds to thousands of years.

Choosing which species of trees to plant at a given site depends on socioeconomic as well as biophysical factors. This guide describes the ecological characteristics of seedlings as they survive and grow into young trees and is a companion to Roman et al. (2012), which provides information on seed germination and seedling production for a larger species set. Because survivorship and growth are intimately linked to site conditions, it is important to understand the different biophysical characteristics of a site before selecting species. This guide begins with a brief description of regional and local biophysical parameters that should be considered when planting trees in Panama and other tropical countries. Subsequent sections explain the importance of thinking about natural processes of forest growth and development, and other design considerations when planting for different management objectives. Examples of planting scenarios are included. The chapter follows with a description of the data source: the species selection trials of the Native Species Reforestation Project (known by its Spanish acronym, PRORENA); data for the individual species descriptions in Chapter 2 come from these trials. The chapter concludes with an explanation of how to read the species data presented in Chapter 2. Chapter 2 details survivorship and early growth descriptions of 64 tree species native to Panama, based on what has been learned from PRORENA and related research in Panama.

## Regional or Broad Biogeographic Patterns

Like many countries in the tropics, Panama encompasses a diverse set of climatic conditions, with annual rainfall varying from very dry areas along the dry arc to very wet areas, such as those along much of the country's Caribbean coast (Figure 2). Ecologists have long noted the changes in forest type associated with water availability, and Engelbrecht et al. (2007) found rainfall to be an important factor in determining seedling survivorship and species composition across a rainfall gradient in Panama. Other climate-related parameters that can affect tree survivorship and growth include dry-season length, temperature, and relative humidity (Table 1).



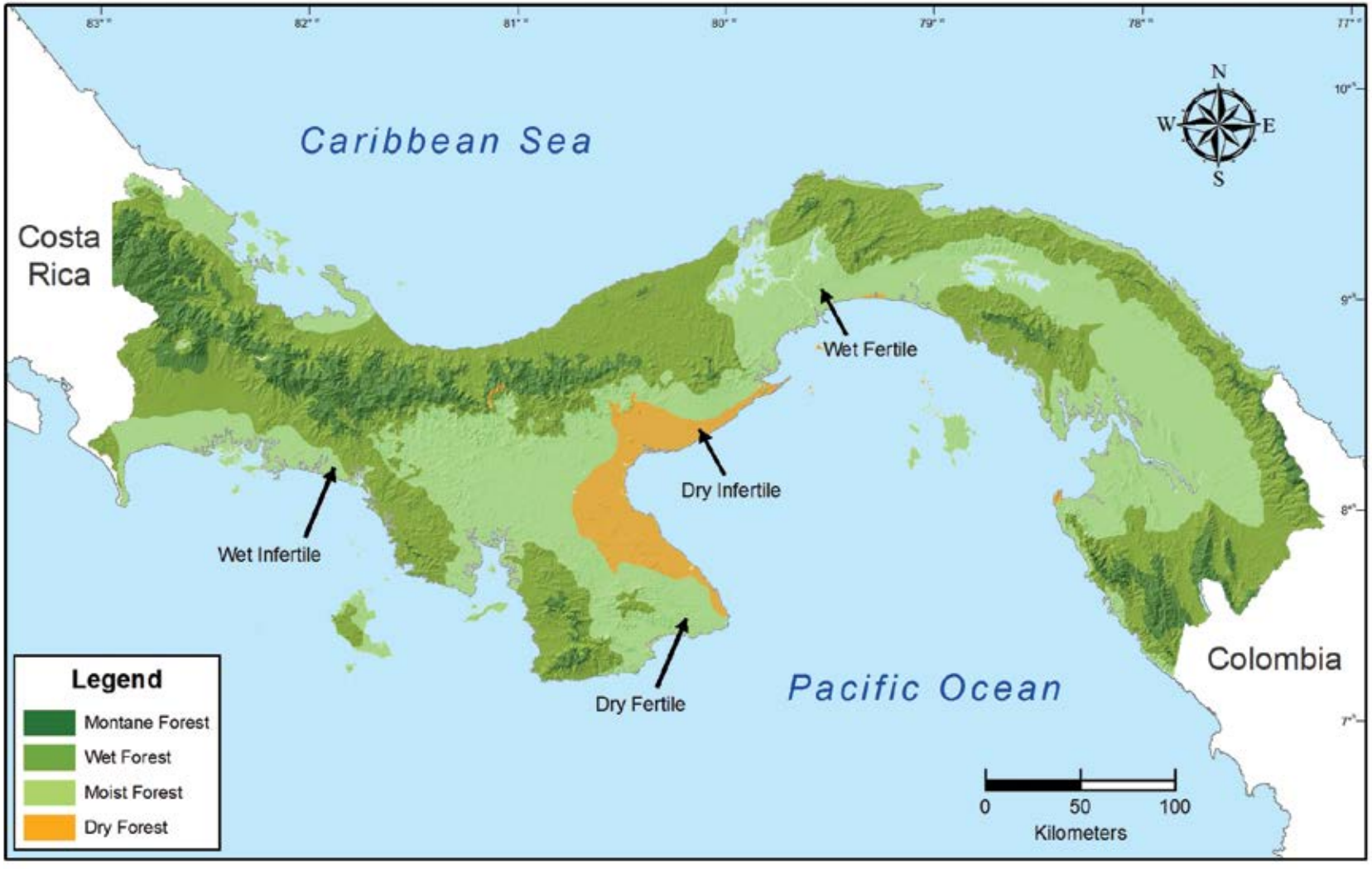



**Figure 2**
Map of forest types within Panama with the location of the PRORENA species selection trial sites.

**Table 1**
**Climate variables to consider when selecting tree species for reforestation and restoration.**

| Climate | Explanation |
|---|---|
| Rainfall | Within Panama and across other tropical countries, rainfall can vary from very low to very high. In Panama it ranges from approximately 1,100 mm to over 4,000 mm per year. |
| Dry season length | Dry season length is related to but different from total rainfall, as substantial rain can fall during just a few months of the year, followed by a dry season that can last six months or more. Trees have different strategies to survive extended dry periods, including the ability to avoid drought (e.g., *Pachira quinata* uses abundant water during the wet season but drops its leaves during the dry season) and to endure drought (e.g., *Dalbergia retusa* can hold its leaves for much of the dry season). |
| Temperature | In Panama and other countries close to the Equator, temperature is often determined by elevation rather than seasonality. With increased elevation, as with cold seasons, trees need to be able to tolerate cold conditions, including frost or snow in some countries. |
| Relative humidity | Very low relative humidity can lead to desiccating conditions; the highest risk is faced by species that are unable to tightly regulate water loss through leaf pores (stomata). |

**Table 2**
**Geographic features that can influence tree species selection in reforestation and restoration initiatives.**

| Geography | Explanation |
|---|---|
| Location in relation to geographic features | Geographic features such as mountains can cause rain shadows on one side and thus drier conditions than on the side receiving moisture-laden air. Close to the Equator, rainfall is also driven by convective thunderstorms, thus reducing the severity of rain shadows. Areas adjacent to lakes and rivers can be prone to seasonal flooding. |
| Elevation | Increases in elevation can lead to different environmental conditions that trees need to be adapted to, such as temperature, relative humidity, solar radiation, and even the persistence of clouds. |

In addition to broad climate patterns, regional or local geographic features can affect the landscape, weather patterns, and localized climate in ways that merit mention. Mountains, lakes, and rivers can all have an impact on regional weather patterns, soil types, and other environmental variables (Table 2).

Soils in the tropics are every bit as diverse as those of the Northern Hemisphere yet soil maps of tropical countries often do not reflect their complexity and diversity, with broad areas classified as homogeneous. This can often be due to lack of data rather than homogeneity. Several soil classification systems are used by soil scientists, agronomists, foresters, and ecologists to characterize and compare different soils. While seemingly logical to the expert, most of these systems are complex and not easily understood by people unaccustomed to working with soils. Unfortunately, with respect to Panama, the soil maps available in the two most commonly used classification systems (USDA and FAO) have been found either to be too broad or to contain important misclassifications. Thus, they are not useful for more than a preliminary and regional approximation of the possible soil types in Panama.

## Physical Conditions and Ecological Aspects of Site

While it is important to understand regional biophysical patterns and processes, it is imperative that practitioners have a good understanding of local site conditions before undertaking tree planting activities. Given the expense of planting and managing a hectare of land, establishment failure could result in the loss of hundreds of thousands of dollars. Ignoring local threats to ongoing plantation management could also lead to catastrophic loss, such as the millions of dollars' worth of investments lost in Panama due to fire in recent years. Physical site conditions important for consideration largely relate to local soil conditions.

### *Soils*

Soils are a product of bedrock geology, climate, living organisms, topography, and time (Brady 1990). The bedrock geology forms the substrate from which soils are derived. The Panama Canal and adjacent lands are underlain by a variety of geological formations (Stewart and Woodring 1980), with the bedrock helping to determine both soil fertility and texture. For example, the Argos cement plant and plantations along the Trans-Isthmian Highway are underlain by limestone resulting in relatively fertile soils with high sand content compared to soils of the Smithsonian Tropical Research Institute's Agua Salud Project, which are just 8 kilometers to the northwest and underlain by basalt (Figure 3). Topography determines whether soil surface layers or nutrients can easily slide down a hill slope or accumulate in a valley bottom. Living organisms modify the soil in different ways; for example, by mixing up soil layers as they move through it. Climate also helps determine soil type; for example, a wet climate with heavy rains increases mineral leaching or washing away of nutrients. Soil characteristics may also be determined by the amount of time a soil has been subject to climatic and biophysical processes.

**Figure 3**
**Examples of soil profiles formed over three different bedrock formations within the Panama Canal watershed. All profiles are within 15 kilometers of one another and are: an Oxisol formed over Miocene basalt (far left), a Mollisol formed over calcareous sandstone (middle), and an Alfisol formed over marine sediments (right). Courtesy of Ben Turner, STRI.**

Notwithstanding challenges related to proper soil classification, it should be easy for the uninitiated to grasp the potential importance of soil properties for plant or tree growth. For example, it will be difficult to grow most crops on infertile or very low-nutrient soils. Sandy soils are both infertile and drain readily, so plants on deep sands may experience some degree of drought stress even in moist climates. Further, one need only try to plant a tree or a garden on a former road bed to envision how soil compaction may affect plant survival and growth. Table 3 summarizes the physical site conditions important to consider when undertaking reforestation and restoration activities.

In Panama, the Instituto de Investigación Agropecueria de Panamá published a booklet of maps (IDIAP 2006) illustrating different levels of soil fertility for specific nutrients, with a qualitative assessment of their suitability for agriculture. However, these maps should be used with caution when attempting to interpret nutrient values for specific sites, since the data are derived from soil samples linked to heavily clustered human population centers. The authors of this guide therefore recommend a laboratory analysis of soil samples and consultation with a soil specialist before making significant investments in reforestation.

**Table 3**
**Physical conditions of site to consider when planting trees.**

| Physical Conditions of Site | Explanation |
|---|---|
| Slope | The actual slope angle (or percent slope) can affect the kinds of activities that can be carried out on a site (see Shaxson 1999) and can also affect tree growth. For example, landslides can lead to loss of topsoil, which in turn can affect tree growth. |
| Soil fertility | Soils hold the nutrients essential for plant growth, and species vary in their nutrient requirements; thus soil fertility is important to consider. |
| Soil texture | Texture is determined by the different proportions of sand, silt, and clay in a soil. These proportions can impact soil properties, including water and nutrient retention. |
| Organic matter | Organic matter can hold water and nutrients in the soil, and can help determine tree survivorship and growth. |
| Rockiness | The amount of stones and rocks at a site can affect tree growth (see e.g., Park et al. 2010) through aeration, rooting zone, etc. |
| Soil compaction | Soil compaction can affect tree establishment and growth, as more compact soils can be difficult for roots to penetrate and for water to move through. |
| Depth of soil | The depth of the soil at a given site is important. Sites with thin soils above either bedrock or a very hard layer (such as a hard pan) can impact root development. This can also lead to such things as a perched water table, where apparently deep soils become locally waterlogged. |

In addition to understanding the physical characteristics of a site when planting trees, it is also important to understand the ecological context. For example, restoring a forest on a site adjacent to a mature forest may simply require enrichment planting of shade-tolerant canopy species, while restoring a forest on a former cattle pasture far from the nearest forest would require more intensive interventions. Indeed, the latter might require extensive site preparation and species selection to reestablish the nutrient cycle. Factors important to understanding the ecological context of a site include disturbance, existing vegetative competition, and proximity to forest.

## *Disturbance*

Both the type and frequency of disturbances need to be considered when planting trees for different purposes. For example, frequent wild fires can make it virtually impossible to reforest a site, or require a vigorous and vigilant fire protection program (Figure 4). Floods, wind storms, and hurricanes (though not in Panama) are other types of disturbances to consider (see e.g., Ashton 2001). For example, areas that experience frequent flooding would warrant trees resistant to periodic inundation. Areas that experience one-off selective logging might not require any tree planting at all, or only enrichment planting of timber species.

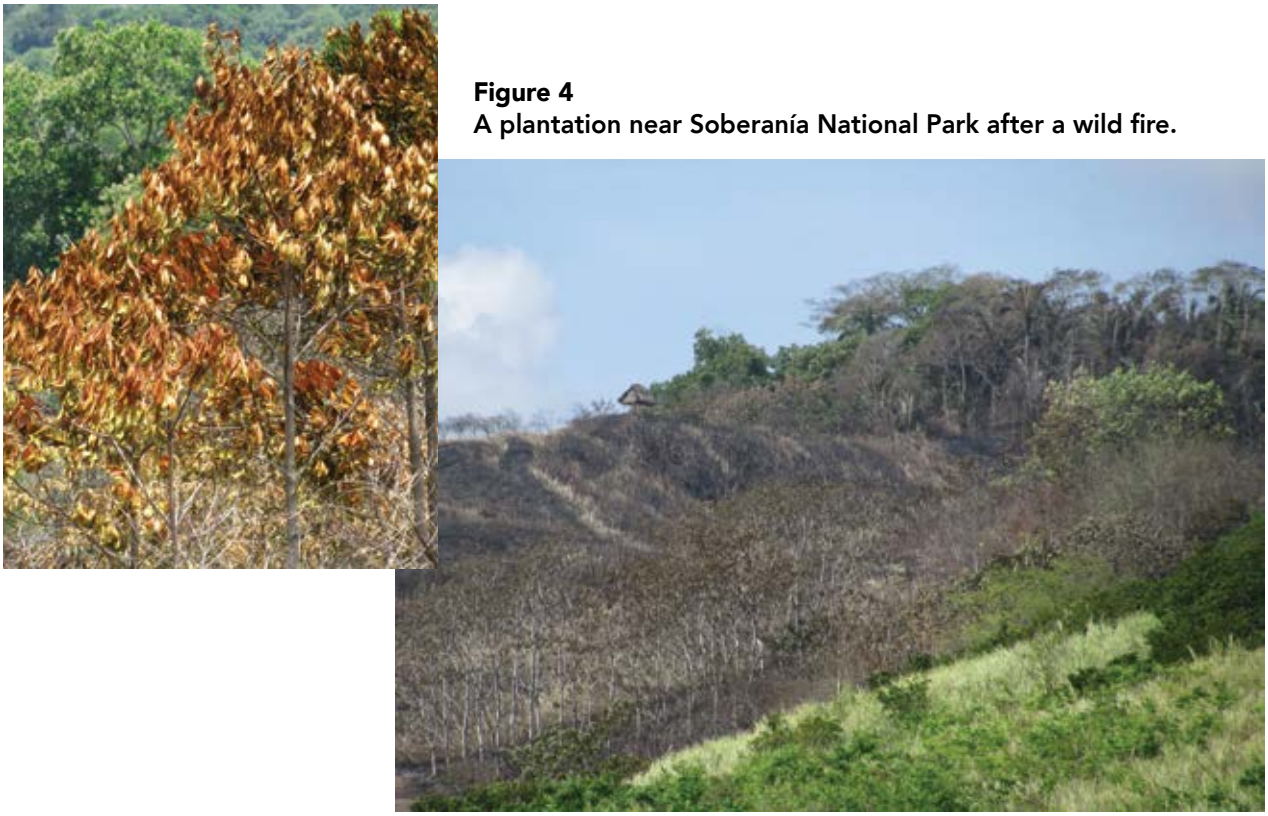


**Figure 4**
**A plantation near Soberanía National Park after a wild fire.**

## *Existing vegetative competition*

The type of existing vegetation can help determine the extent to which tree planting is necessary. If secondary forest exists on the site and the objective is forest restoration, little or no planting may be required. In contrast, overcoming grass competition can be a particular challenge on cattle pastures (see e.g., Holl 1998, Celis and Jose 2011, and references therein) and other areas. In Panama, the invasive grass, *Saccharum spontaneum*, known locally as Canal grass, can grow over 3 meters tall and produce 20 tons of biomass per hectare in just six months after a fire (Saltonstall and Bonnett 2012); fast-growing

trees with broad crowns are thus required to produce the shade conditions necessary to eliminate the grass from a site. Even with fast-growing trees, management can be a challenge. Craven et al. (2008) found that herbicide use was necessary to improve growth of *Tectona grandis* and *Terminalia amazonia* planted on land covered with Canal grass, even when the grass was manually cleared seven times a year (Figure 5).

**Figure 5**
***Terminalia amazonia* planted on a site where *Saccharum spontaneum* has been cleaned four times a year for three years and without herbicide treatment. *Terminalia amazonia* grown here receiving seven cleanings a year and annual herbicide treatment are twice as big.**

### *Proximity to forest and adjacent land uses*

If the goal of forest restoration is to approximate a natural forest, being adjacent to existing forests can be useful, since it facilitates natural colonization and secondary succession of wind- and animal-dispersed seeds. Van Breugel et al. (2013) show how protecting land from fires can lead to robust regrowth when pastures within a forest matrix are allowed to regenerate naturally. Holl et al. (2010) have tested different methods of reforesting pastures far from forests, including nucleation, where trees are planted in patches to attract seed-dispersing animals so that the patches might develop and spread, reestablishing forest in a more cost-effective manner.

## The Importance of Mimicking Natural Processes

Forests are dynamic. Trees grow and die; trunks and branches fall. Seedlings and small trees in the understory take advantage of the light gaps thus created to grow. Seeds stored in the forest soil germinate and grow to fill the spaces created by fallen trees. This process is known as forest gap phase dynamics (Whitmore 1989, Hartshorn 1980). Forests that have been cleared of trees can also regrow through the process of secondary succession. Seeds arrive at the sites, germinate, and form a thick vegetative cover of small-stemmed individuals. Over time, these saplings grow into ever larger trees, with some species growing very rapidly to occupy the canopy (pioneers), others dying as they lose the race to the fill the growing space, and still others—the more shade-tolerant—slowly and steadily growing to occupy their place in the multi-strata stand of the new forest.

The process by which seeds germinate, and seedlings establish and grow into a forest stand in gaps and on agricultural fields is characterized by forest stand dynamics (Oliver and Larson 1996; Box 1). An understanding of stand dynamics helps foresters and others interested in planting trees to determine the most efficient way to replace a stand or regrow a forest or plantation. Indeed, foresters try to work with natural processes to meet their management objectives.

**Box 1**

**Forest stand dynamics**

As tree seedlings establish or understory saplings are released through the creation of a large gap or clearing, they begin to compete for light, water, and nutrients. Individual trees exert their competitive advantages over others such that there are winners and losers as trees race for the canopy. The process of stand development or stand dynamics can be characterized by four different phases for simplicity:

**1) stand initiation**
**2) stem exclusion**
**3) understory reinitiation**
**4) old growth**

(See Oliver 1981, Oliver and Larson 1996, and Smith et al. 1997)

The ***stand initiation*** phase follows a disturbance that creates a gap or clearing, and is characterized by the arrival and germination of seeds and their subsequent seedling establishment, or the release of advanced regeneration. The following or ***stem exclusion*** phase is characterized by intense competition for resources by saplings. Here, many trees die (or are excluded), while slower-growing and more shade-tolerant species fall behind in height growth, becoming overtopped by species that grow to form the canopy. The ***understory reinitiation*** phase follows once the stand has matured; it is so-called because it marks the dispersal and germination of seeds from existing trees, including shade-tolerant species in the forest understory. The ***old growth*** phase is that of a fully formed and mature forest, when long-lived trees begin to senesce and die, forming new gaps within the forest.




## Design and Spacing Considerations

There are many reasons why one may wish to plant trees, ranging from habitat restoration to establishing commercial plantations. There is also a broad spectrum of planting methods, ranging from passive reforestation (where land is protected and trees naturally establish) to active tree planting with extensive site preparation. Prior to determining the methodology, it is important to establish the management objective and evaluate the cost of different activities. Once the decision has been made to actively plant trees, it is important to consider a species' silvicultural characteristics, which determine its ability to survive and thrive at a given site and set of conditions (Table 4). All of these parameters—from practical management considerations to a species' ecological characteristics—will help inform decisions about the types of species to be grown, as well as how close or far to plant individuals from their neighbors.

**Table 4**
**Silvical or autecological measures of performance important when planting trees.**

| Autecological Characteristics of Seedlings and Saplings | Importance |
|---|---|
| Survival | Seedlings and saplings can die for a variety of reasons, including lack of water, insect attack, or fire. It is important to understand the potential rate of mortality when planting to avoid financial losses and restoration failures. |
| Height and diameter growth | Species exhibit different height and diameter growth rates depending on the type of site they are planted on. To meet management objectives, it is important to take into account these site-specific growth attributes before deciding on the type, number, and spacing of species to be planted. |
| Shade tolerance | Some trees grow best in full sunlight, while others can withstand shade or require partial shade for best growth. Pioneer trees typically grow fast and well in full sunlight, while more shade-tolerant trees are best planted in partial to full shade. Future shade conditions can be inferred and manipulated through species choice and spacing. |
| Crown morphology | Crown shape, diameter, height, and leaf density are all aspects of crown morphology that may be useful in determining which combinations of species to plant, as well as spacing considerations. |
| Susceptibility to insect attack | Some tree species are very susceptible to insect attack while others are not, owing to chemical and physical leaf defenses. Some species have specialist herbivores that attack them. For example, trees in the mahogany family are attacked by a specialist shoot borer and should be planted in low densities. |
| Moisture or rainfall requirements | Seedling and sapling tolerance of drought can affect both survivorship and growth. |
| Nutrient or soil fertility requirements | Seedling and saplings of different species vary in their ability to grow well on infertile soils; many tend to do better on more fertile sites. Species' nutrient requirements can therefore be important to consider for a given site and management objective. |
| Root characteristics | Little is known about the root characteristics of most species, but whether or not a tree has a tap root or produces an abundance of fine roots could be useful information in determining species choice. |

The following paragraphs provide examples of how trees might be planted given four different management objectives: 1) monoculture timber plantation, 2) mixed-species timber plantation, 3) forest restoration far from mature forest, and 4) forest restoration adjacent to mature forest. All treatments use real species and are envisioned as plantings on cattle pasture, on moist or wet, infertile sites, with clay soils similar to those in STRI's Agua Salud Project (see van Breugel et al. 2103 for site details).

## *Spacing in high-value monoculture timber plantations*

Trees planted in monocultures are of the same species, such that that all individuals have the same ecological characteristics, including growth rates, crown architecture, and rooting morphology. As a result, they can compete intensely for light, water, and nutrients. A land manager can control this competition by spacing the trees at distances that minimize intense crown and root competition, or by thinning trees periodically. As timber prices generally increase with tree diameter, timber plantations tend to maximize growth over time on selected individuals through thinning. A common spacing arrangement would be to provide sufficient distance between individuals to allow several years' growth between thinning, designed to give more growing space to the remnant trees. Figure 6 provides an example of *Terminalia amazonia* planted with an initial spacing of 3 x 3 meters, shown at 4, 10, and 20 years after planting.

## *Spacing in mixed-species stands in timber plantations*

In mixed-species stands, neighboring trees may be from one to several different species. As these species have different ecological characteristics, a manager will use the available information on expected growth at the site, combined with information on crown morphology, shade tolerance, and root architecture (if known). A mixed-species timber plantation may be designed to harvest crop trees all at the same time—after which the plantation is replanted or the land repurposed. Alternately, the plantation may allow for different species maturation rates, with harvests occurring years to decades apart. Additionally, some species in the stands may be planted solely to improve growing conditions for the target timber or crop species. Examples include: a species planted to provide some level of shade to the crop species, thereby improving its form or growth; or a nitrogen-fixing species used to capture and convert atmospheric and biologically unavailable nitrogen—the subsequent decomposition of this plant matter produces biologically available nitrogen to the neighboring target species. In mixed-species timber stands it is important to manage competition that hinders crop tree growth; for example, using thinning and spacing to minimize light competition for shade-intolerant crop trees. Depending upon species composition and desired products, harvest times may be staggered or occur at the same time. The example depicted in Figure 7 has four species planted at an initial spacing of 3 x 3 meters. Here, three of the species planted are high-value timber trees and one species is planted only for its potential nitrogen-fixing benefits. One of the timber species is also a nitrogen-fixing tree.

## *Spacing in mixed-species reforestation for forest restoration where land is far from seed sources*

Irrespective of site conditions, reforestation or forest restoration on land far from potential seed sources poses a particular problem in that one cannot rely on natural processes like wind and animal dispersal of seeds to increase plant species diversity. This complicates long-term efforts to generate a stratified forest that includes understory herbs, shrubs, and different-sized trees. This is a significant challenge, particularly when a manager is unsure of his or her ability to return, over time, to plant shade-tolerant species below the initially planted trees and shrubs. In such cases, trees need to be planted sufficiently close to each other that they will fill the space in a reasonably short period of time. Neighbors have to be chosen carefully, accounting for growth rate and form, crown architecture, shade tolerance, and future position in the canopy. Emergent species that grow taller than the typical canopy should be included. Managers should also include species that will attract birds, bats, and other mammals from around the landscape. As the ability to thin trees may be limited, it is important to pick and space species appropriately to reduce the potential for growth stagnation through competition. The example depicted in Figure 8 includes 19 species (including one species represented by two individuals) and represents a potential sub-sample of a larger treatment.

## *Spacing in mixed-species reforestation for forest restoration where land is adjacent to mature forest or mature-forest patches*

The advantage of reforestation adjacent to existing mature forest is that a manager can rely on nature to do much of the work. In such a scenario, animal- and wind-dispersed seeds can be expected to arrive over time to such a degree that the most cost-effective option may simply be to protect the land from fire and anthropogenic disturbances and rely on natural secondary succession. However, even in such circumstances it will take many decades for forest structure to recover and species composition to resemble adjacent mature forests. Thus, it may be worth considering some sort of enrichment planting where canopy species that have poor dispersal ability are planted on the land.

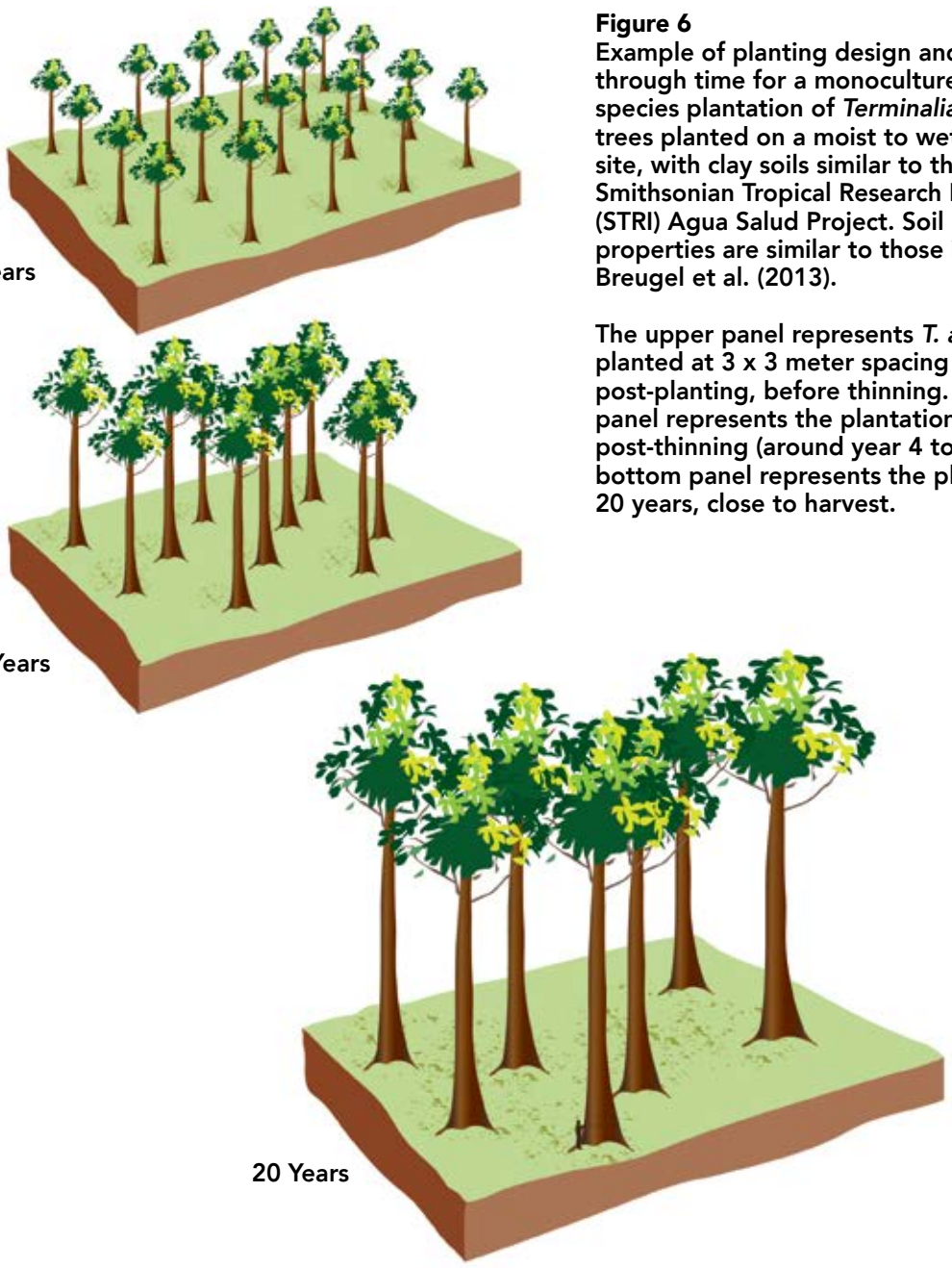



**Figure 6**
**Example of planting design and growth through time for a monoculture timber species plantation of *Terminalia amazonia* trees planted on a moist to wet, infertile site, with clay soils similar to that of the Smithsonian Tropical Research Institute (STRI) Agua Salud Project. Soil chemical properties are similar to those in van Breugel et al. (2013).**

**The upper panel represents *T. amazonia* planted at 3 x 3 meter spacing at 4 years post-planting, before thinning. The middle panel represents the plantation at 10 years, post-thinning (around year 4 to 5), and the bottom panel represents the plantation at 20 years, close to harvest.**

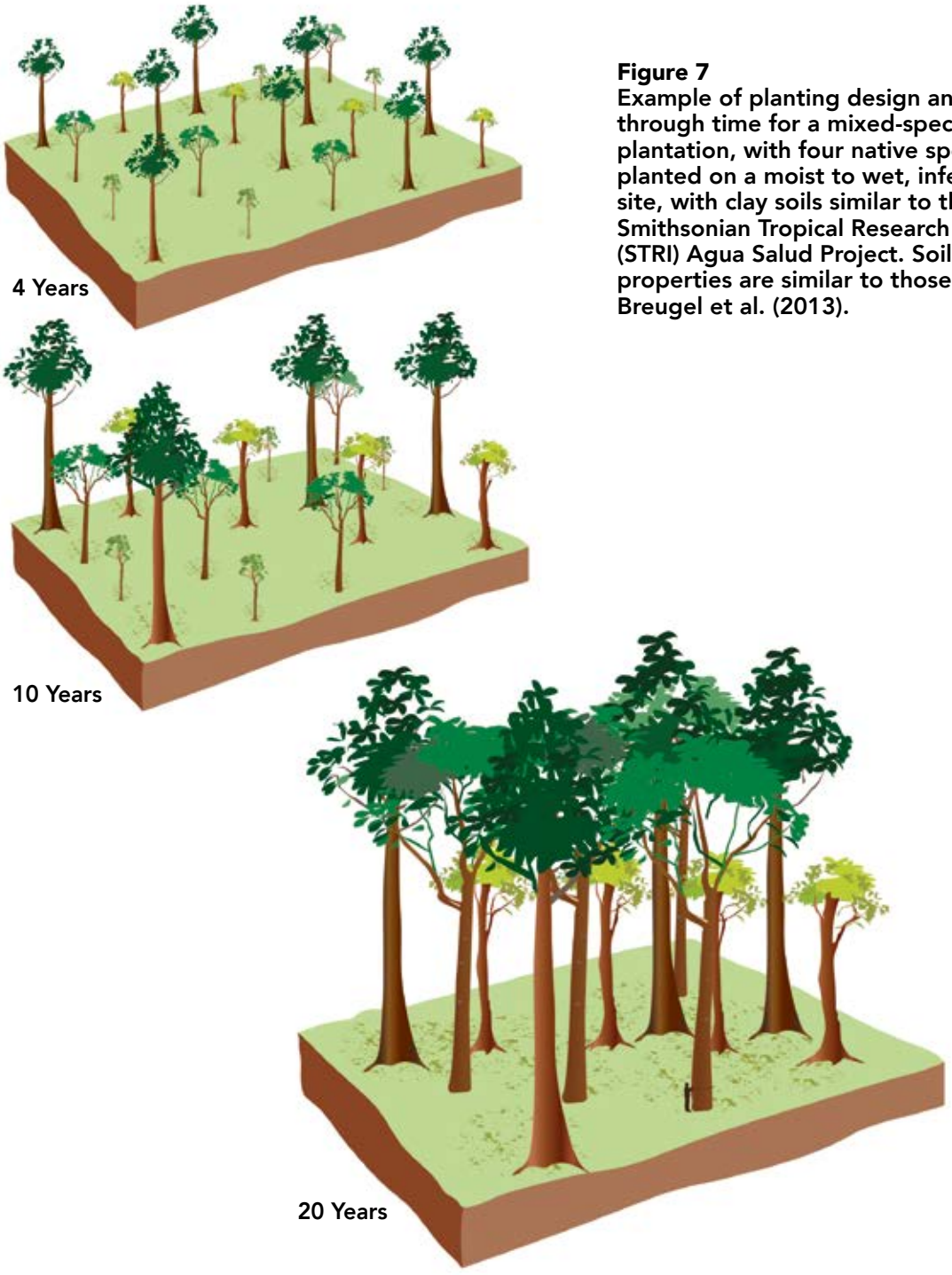



**Figure 7**
**Example of planting design and growth through time for a mixed-species timber plantation, with four native species planted on a moist to wet, infertile site, with clay soils similar to that of the Smithsonian Tropical Research Institute (STRI) Agua Salud Project. Soil chemical properties are similar to those in van Breugel et al. (2013).**

**Species planted include *Terminalia amazonia* (upper left-hand corner of top panel, and trees of similar design), *Dalbergia retusa* (second from left in upper left-hand corner of top panel, and trees of similar design), *Ormosia macrocalyx* (small tree second from upper-right corner of top panel, and trees of similar design), and *Hieronyma alchorneoides* (top-right corner of top panel, and trees of similar design). *O. macrocalyx* is a small-statured, nitrogen-fixing species. Other species are high-value timber species; *D. retusa* also fixes atmospheric nitrogen. Panels represent 4, 10, and 20 years post-planting. *T. amazonia* and *H. alchorneoides* can be harvested at around 20 years; *D. retusa* can be harvested around 30 years.**

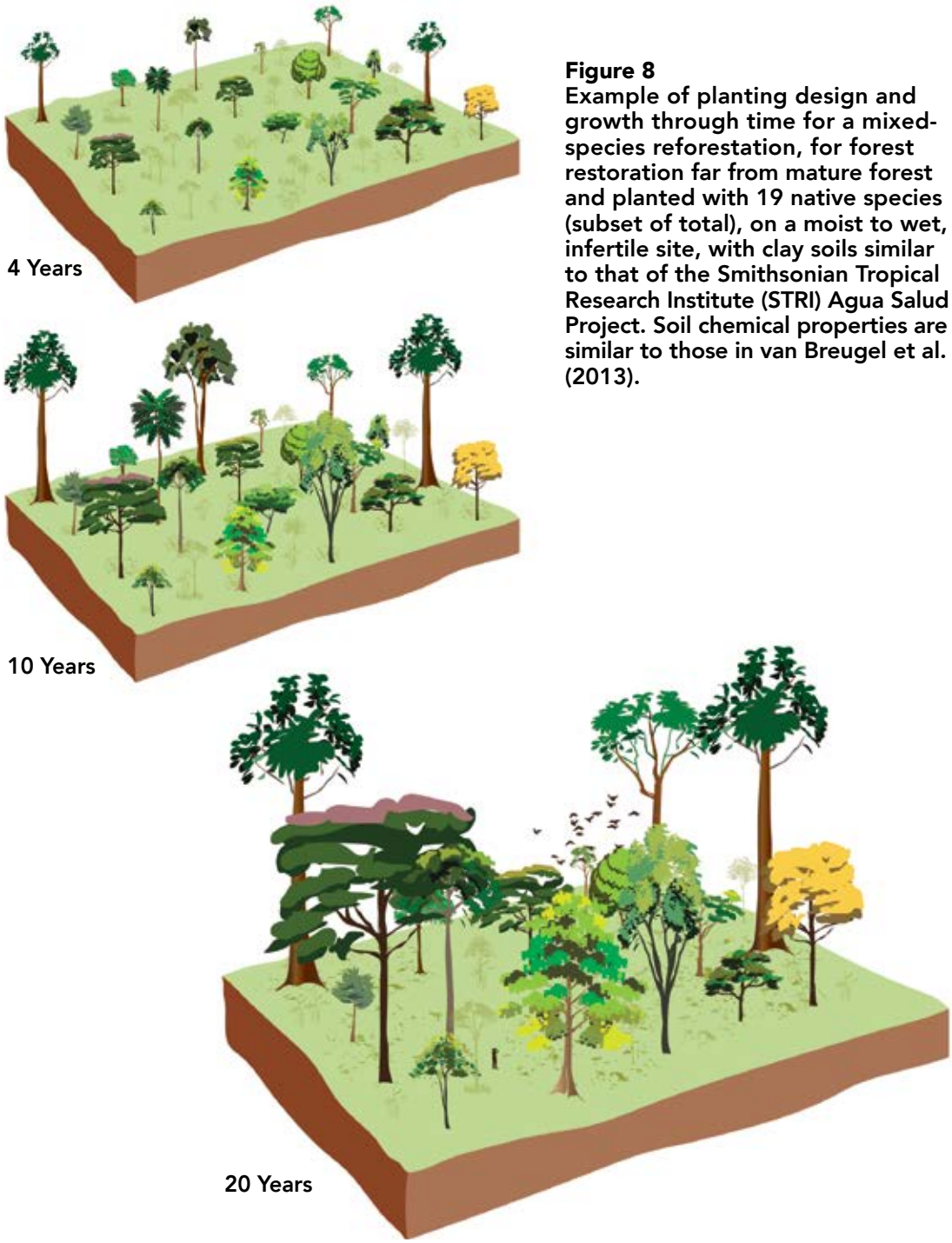



**Figure 8**
**Example of planting design and growth through time for a mixed-species reforestation, for forest restoration far from mature forest and planted with 19 native species (subset of total), on a moist to wet, infertile site, with clay soils similar to that of the Smithsonian Tropical Research Institute (STRI) Agua Salud Project. Soil chemical properties are similar to those in van Breugel et al. (2013).**

**Panels represent 4, 10, and 20 years post-planting. Species planted are from left to right, starting from the upper left-hand corner in the top panel. Row 1: *Terminalia amazonia*, *Protium tenuifolium*, *Ochroma pyramidale*, *Ormosia macrocalyx*, and *Hieronyma alchorneoides*. Row 2 (second from back): *Xylopia frutescens*, *Schizolobium parahyba*, *Platymiscium pinnatum*, *Anacardium excelsum*, and *Manilkara zapota*. Row 3: *Dipteryx oleifera*, *Vochysia guatemalensis*, *Zygia longifolia*, *Byrsonima crassifolia*, and *T. amazonia*. Row 4 (bottom row): *Pterocarpus officinalis*, *Sterculia apetala*, *Albizia adinocephala*, *Anacardium occidentale*, and *Tabebuia guayacan*.**

## Species Data Presented in this Guide

This guide presents data from the PRORENA project and Smart Reforestation® research conducted on native tree species in Panama. Data is presented in graphical form summarizing survivorship and growth from the PRORENA species selection trials. These trials were established in Panama between 2003 and 2006 and contain 64 native species that were planted in blocks across slopes on: ridge or hill top, mid-slope, and lower slope positions (Figure 9). The 64 species represent a combination of timber species, and those used in agroforestry systems and home gardens, including species that provide fruits and other practical or social values (Aguilar and Condit 2001, Wishnie et al. 2007, Garen et al. 2009).

**Figure 9**
**Block design of the PRORENA species selection trials at the wet fertile site.**

In the PRORENA common garden species selection trials, nine plots of 20 individuals at 3 x 3 meter spacing were planted such that a total of 180 seedlings of each species were planted per site. Thus, the graphics summarize data from over 46,000 trees. All plots were thinned by 50 percent at two years to ensure free-to-grow conditions without competition from neighbors. The data presented in each graph represents site averages (calculated as averages of plot averages) for a given species. The species selection trial data is summarized in the text where other observations on growth and survivorship from PRORENA and Smart Reforestation® sites are also shared.

The locations of the PRORENA growth trial sites are presented in Figure 2 and represent a rough rainfall-fertility matrix that includes: dry infertile, wet infertile, dry fertile, and wet fertile sites. All sites are in the lowlands, with the highest elevation not more than a few hundred meters above sea level. Basic soil fertility parameters are presented in Table 5. While these sites represent stark differences in rainfall and soil fertility, they do not cover the entirety of Panama and neighboring countries. For example, levels of plant-available phosphorus (an essential plant nutrient that can control growth) at the infertile sites are over two times higher than the plant-available phosphorus levels at the Smart Reforestation® site of the Agua Salud Project in Panama. Thus, caution should be used so as not to extrapolate data inappropriately to sites far outside the boundaries of the elevation, soil fertility, and rainfall values observed at the PRORENA sites.

**Table 5**
**Climate and soil chemical properties at the four PRORENA study sites in Panama.**

| Site | Las Lajas Wet Infertile | Soberanía Wet Fertile | Playa Venado Dry Fertile | Río Hato Dry Infertile |
|---|---|---|---|---|
| **Climate** | | | | |
| Mean annual rainfall (mm year$^{1}$) | 3500 | 2200 | 1500 | 1100 |
| Mean number of months with < 100 mm rainfall | 3-4 | 4.1 | 5.2 | 6.7 |
| **Soil properties** | | | | |
| N (%) | 0.2 | 0.2 | 0.2 | 0.1 |
| C (%) | 2.5 | 3.0 | 2.6 | 1.1 |
| P (ppm) | 2.6 | 12.0 | 12.1 | 2.4 |
| K (ppm) | 58.1 | 496.6 | 186.1 | 89.2 |
| Ca (ppm) | 185.6 | 3873.3 | 6512.2 | 752.1 |
| Mg (ppm) | 89.3 | 1158.4 | 1355.0 | 153.1 |

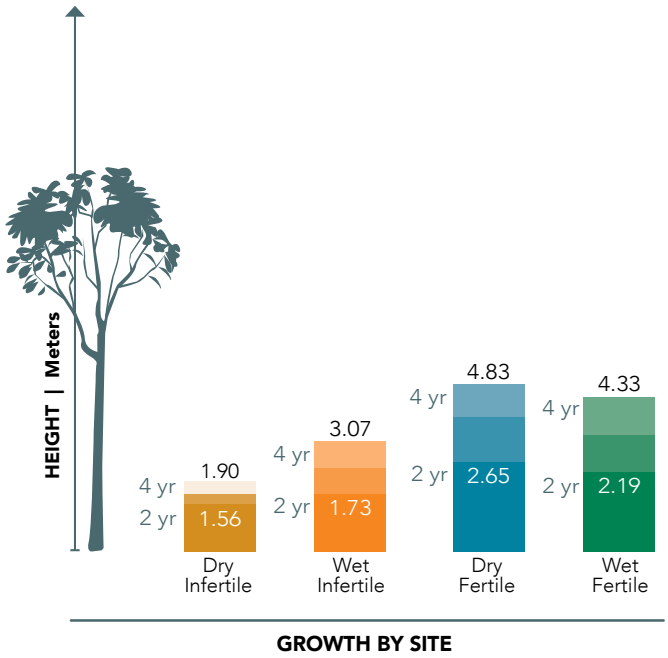
See van Breugel et al. (2011) for further details.

Data and observations provided herein come from scientific literature published by PRORENA authors, including: Jones et al. (2004), Wishnie et al. (2007), Garen et al. (2009 and 2011), Park et al. (2010), van Breugel et al. (2011), Craven et al. (2011 and 2013), and Hall et al. (2011); other manuscripts are forthcoming. Data for shade tolerance of approximately one-third of the species included in this guide are inferred from graphs published in Ruger et al. (2011). The World Agroforestry Centre website was also consulted to complement uses for species for which data were available: http://worldagroforestry.org/regions/southeast_asia/resources/db/AFTdatabase.

# How to Read the Graphs in this Guide

**Five graphs are presented for each species in this guide. All of these data are basic information to help guide reforestation and forest restoration initiatives.**

**The upper-left graphic provides height growth data by year averaged by site**, with data from the 2003 plantings containing measurements for up to six years, 2004 plantings up to five years, and 2005 plantings up to four years. If a tree species experienced complete mortality during the course of measurements at a particular site, the last data point represents the last year any individuals were alive. As noted previously, height data at two years is for up to 180 individuals per site, but only 90 individuals per site at three years and beyond. If all 90 individuals survive at three years but half die per plot between year 3 and 4, the data in this graph contains measurements for only 45 individuals in year 4.




In general, the highest part of the bar coincides with the last measurement, with the year of measurement post-planting indicated by "yr". However, in some graphs the years are inverted, with an earlier measurement (represented by a dotted line) shown above a later measurement (represented by a shaded bar). In such instances, the dotted line represents the tallest height obtained, at an earlier time than the final year of measurement; the individuals of this species have experienced dieback between measurement years.

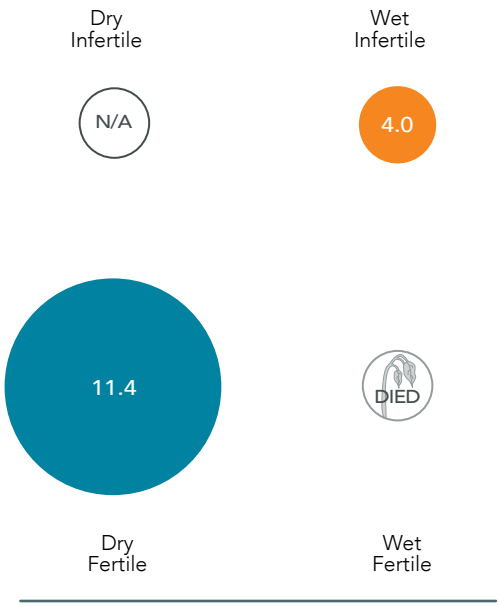
N/P

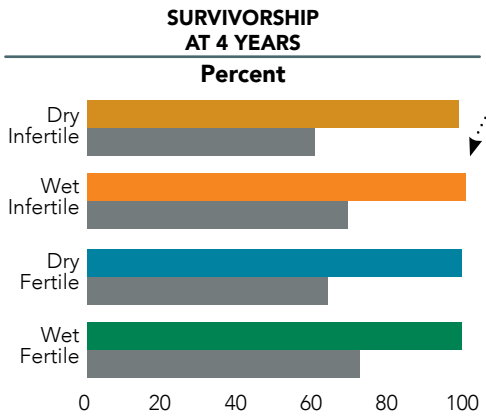
In some instances, in place of the colored height growth bars, the symbol "N/P" is used to indicate that a species was not planted at a given site.

**The example graph for height growth shown here represents actual site averages for all species combined. When comparisons are made in the text between a given species' growth with the site average, the reader can refer back to this graph.**

**The upper-right graphic presents data for either diameter at breast height (DBH: 1.3 meters above the ground) or basal diameter (BD: 10 centimeters above the root collar).** Basal diameter is used instead of DBH for trees that have multiple stems coming out of the base, or in cases where it is difficult to distinguish a single, principal stem. The data represent the last year that trees were measured at a given site. "N/P" indicates that a species was not planted at that site. "N/A" indicates that individuals did not grow tall enough for their DBH to be measured (i.e., they were less than 1.3 meters tall). A symbol indicating plant mortality is used to note cases where all individuals at the site died before the last measurement year. Thus, it is possible for a species at a site to have a height recorded at year 2, but have no DBH value recorded, because either the trees did not grow to reach 1.3 meters or they all died before the last measurement year.

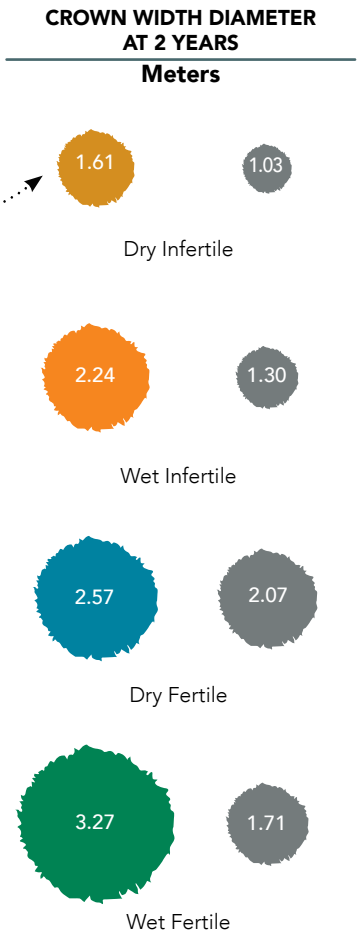


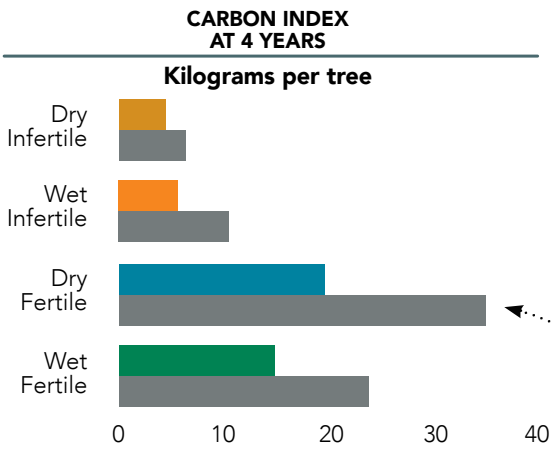



**The middle-left graphic uses horizontal bars to present survivorship data for four year of growth.** Four years was chosen because it represents the oldest and last measurement for the last set of trees planted (2005). The actual survivorship for trees of a particular species (colored bar) is juxtaposed against the site mean (grey bar) to allow a visual comparison of individual species survivorship against all 64 species planted at that site. "N/A" and "N/P" are used to indicate if a species died or was not planted—in these instances, no colored bar is shown. Survivorship is calculated as a percentage of trees that died beyond those surviving at two years and post-thinning. For example, if 80 percent of the trees survived until two years but then experienced no subsequent mortality, then the survivorship at four years remains 80 percent. However, if half of the post-thinning trees die in each plot then this is compounded such that survivorship at that site is half of the surviving 80 percent at two years, or 40 percent.

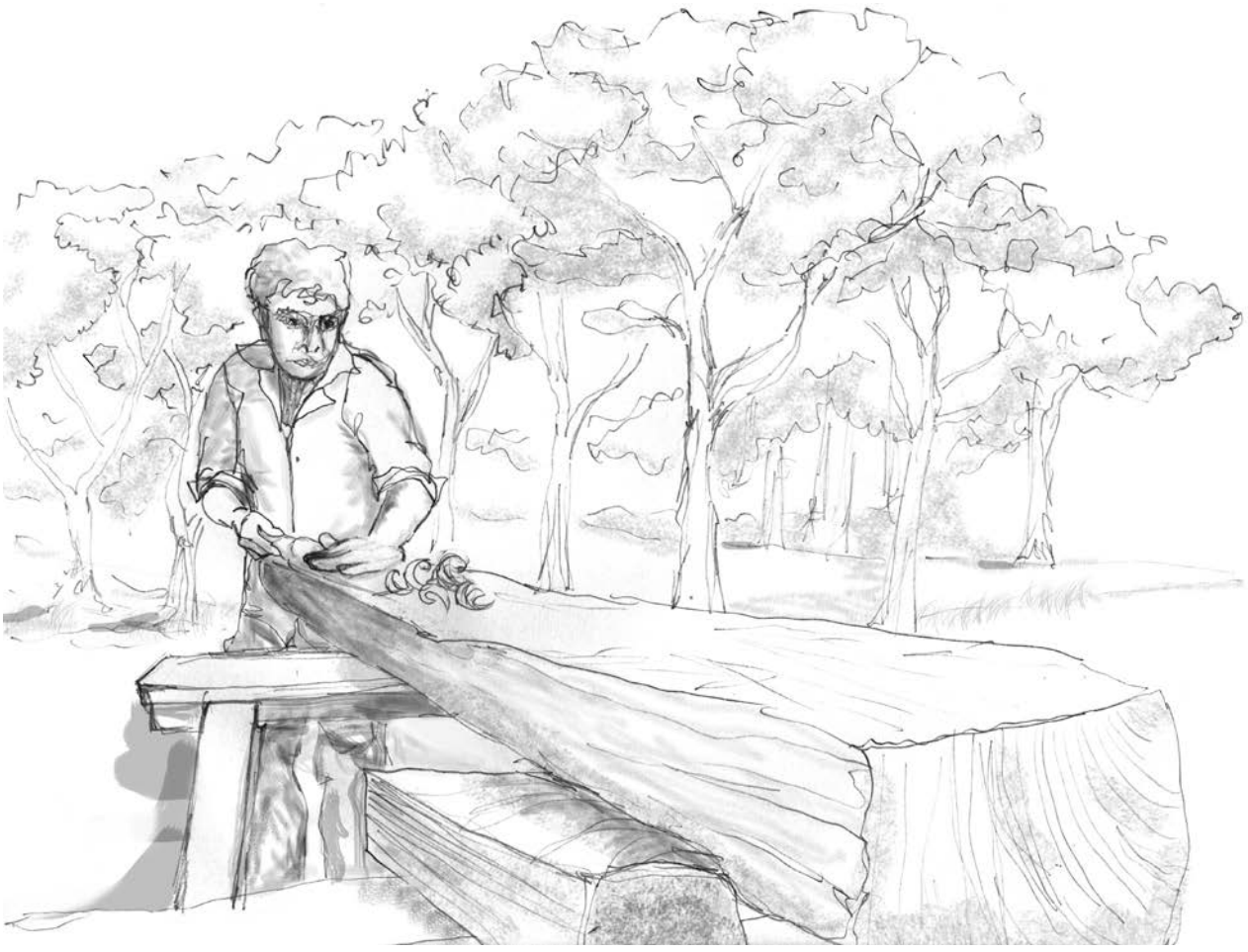
**The lower-right graphic presents data on crown diameters measured after two years of growth.** This is the last time crown diameters were measured on the plots. The species site averages are depicted in color on the left, and the collective site average is in grey to the right. Diameters are given in meters, and are a useful metric to determine both spacing and growth vigor.




**The lower-left graphic is a carbon index that shows the amount of carbon dioxide ($CO_2$) that can be sequestered by a species at a given site.** These values are displayed using horizontal colored bars, and are compared to the site means using horizontal grey bars. Values in kilograms per tree can be read off the x-axis. The data are calculated using a composite equation derived from the harvest of individuals of six of the native species found in this guide, where sizes and ages span the young and relatively small trees (Sinacore et al. unpublished). The data are presented in kilograms of $CO_2$ because this is what is traded on carbon markets; they illustrate the carbon sequestration potential of these young trees.

Actual tree data were used to calculate the carbon index for individual trees, with site averages then calculated as heights and diameters above. The allometric equation used was derived from the Sinacore et al. (unpublished) multi-species data set and includes wood density as well as basal diameter. Basal diameter was used instead of diameter at breast height as the trees harvested included one species (*Dalbergia retusa*) that had more of a shrub-like form when open grown; using simply one stem from a multi-stemmed tree or shrub does not accurately represent the actual diameter of all the stems. Wood density was included in the equation to account for the fact that trees have very different wood density values—ignoring this would result in inaccurate measures of carbon index for trees that had the same basal diameter. In an example from the Sinacore et al. study, harvested individuals of *Pachira quinata* and *D. retusa* had basal diameters of 21.0 and 21.2 cm respectively. However, the wood density of *P. quinata* (0.42 g $cm^{-3}$) is less than half that of *D. retusa* (0.86 g $cm^{-3}$). Discounting this difference would undervalue the amount of carbon stored in the wood of *D. retusa*. Indeed, the correct carbon index values are 48.6 kg $CO_2$ and 120.2 kg $CO_2$ for *P. quinata* and *D. retusa*, respectively.



# 2

# Chapter Two

SCIENTIFIC NAME

# *Albizia adinocephala*

FAMILY

Fabaceae-Mimosoideae

COMMON NAMES

Frijolillo, guábilo (Panama); barbona, chaperno blanco (Nicaragua); conacaste blanco (El Salvador); gavilancillo (Costa Rica, Honduras, Guatemala).

DESCRIPTION

*Albizia adinocephala* is a medium to tall (10 to 20 meters), deciduous tree found in dry to moist, low- to mid-elevation areas from Mexico to Panama. It exhibited high to very high survivorship in the PRORENA species selection trials. It had high height and diameter growth in all but the dry infertile site, where it experienced some dieback in years four through six. Four-year height growth far exceeded averages at all sites. In all but the dry infertile site, it was markedly taller—but not wider—than related *Albizia* species. It formed narrow crowns, with two-year crown diameters far below average at the fertile sites and roughly equivalent to those of the infertile sites. Four-year carbon indices were far below average at all sites.

RECOMMENDATIONS

Data from the PRORENA trials suggest that this species can be used in restoration and reforestation treatments in all but the driest sites. It has additional value on suitable sites because it fixes atmospheric nitrogen, thereby potentially improving soil quality. Its performance on particularly infertile, acidic soils is unknown, and should be tested before any large-scale plantings on such sites. Although it will likely only be a co-dominant canopy species, its initial height growth suggests it can give early canopy structure to a future forest.

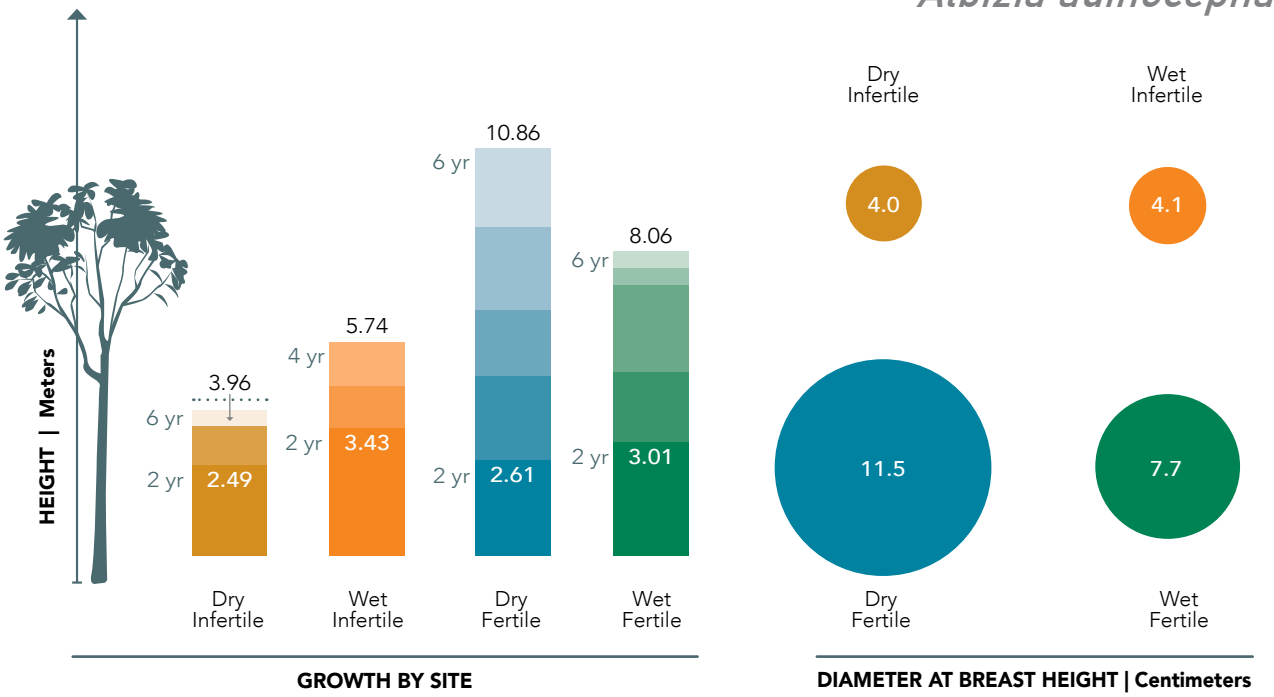
SPACING

This species can be initially spaced as close as three meters to neighbors. Given its narrow crown, it can be planted next to slower growing neighbors, serving as a nurse tree for shade-tolerant species.

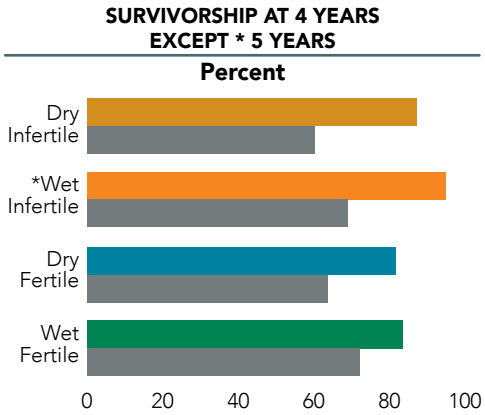
SELECTED USES

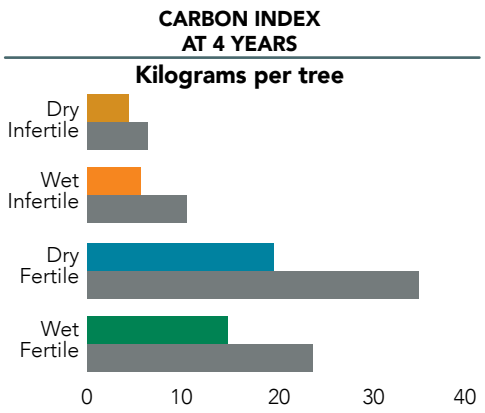
Fence posts, firewood, ornamental tree, early canopy structure in reforestation, nurse tree for shade-tolerant species, shade tree (in pastures), potential soil improvement through nitrogen fixation and use as green manure.

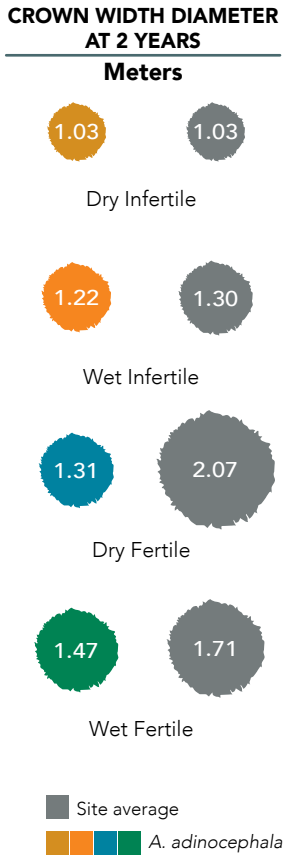
# *Albizia adinocephala*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Albizia guachapele*

FAMILY
Fabaceae-Mimosoideae
SYNONYM
*Pseudosamanea guachapele*

COMMON NAMES
Guachapalí, guábilo, frijolillo (Panama); guayaquil (Costa Rica); carreto (El Salvador, Honduras); lagarto (Guatemala); samanigua (Venezuela); guachapele (Ecuador).

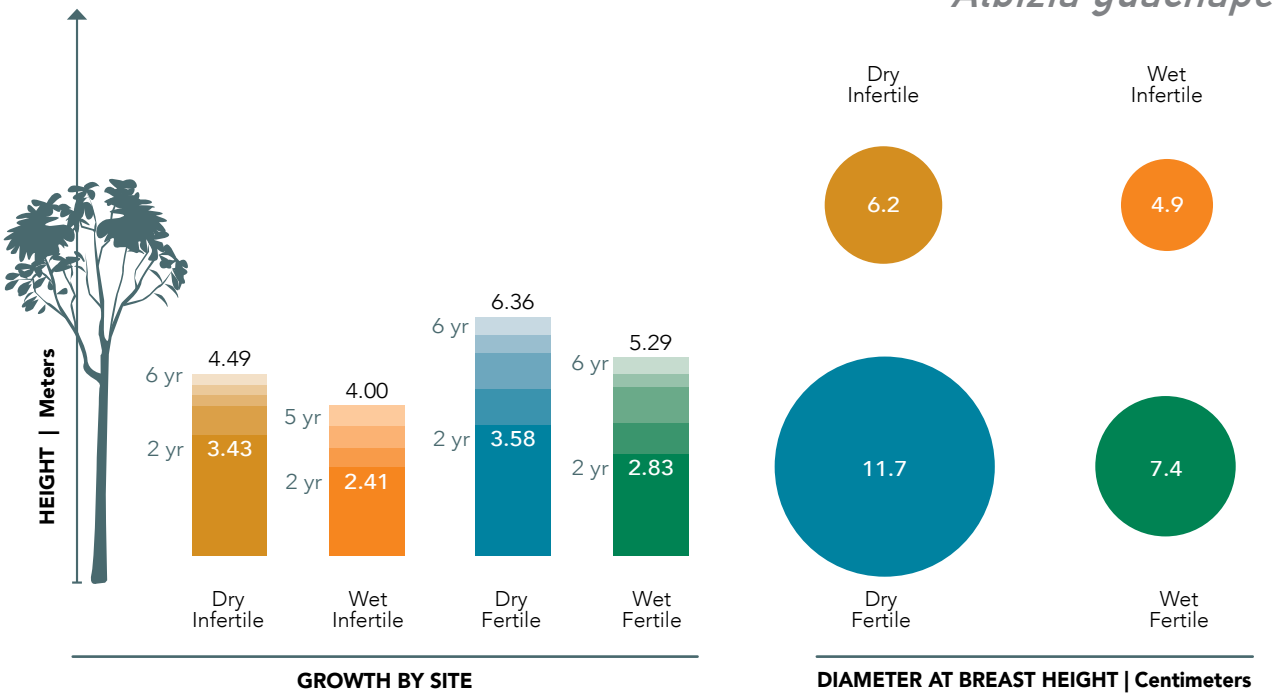
DESCRIPTION
*Albizia guachapele* is a tall (20 to 30 meters), deciduous tree found in low-altitude, dry to moist forests from Mexico to Ecuador. It exhibited very high survivorship across all sites in the PRORENA species selection trials. It grew best at the dry fertile site. It also grew relatively well at wet fertile and dry infertile sites, with height and diameter growth in the former only slightly better than that of the latter; growth at the wet infertile site was only slightly poorer. Four-year height growth was above average at all sites. This species formed relatively narrow crowns early in life, with the two-year crown diameters close to averages at all but the dry infertile site, which was markedly higher than average. Its four-year carbon index was more than double the average at the dry infertile site, roughly equivalent to the averages at the wet infertile and dry fertile sites, and about two-thirds that of the wet fertile site.

RECOMMENDATIONS
The data suggest that this species shows high potential in reforestation and restoration treatments, helping to give early structure to the forest stand, particularly on dry sites where it spreads its crown area. Its ability to fix atmospheric nitrogen can be useful for site restoration and agroforestry systems. Its growth and four-year carbon index suggest that it may be particularly well suited for dry infertile sites similar to those of the PRORENA trials. Its multiple uses suggest that it can also be part of reforestation treatments that are harvested for local products.

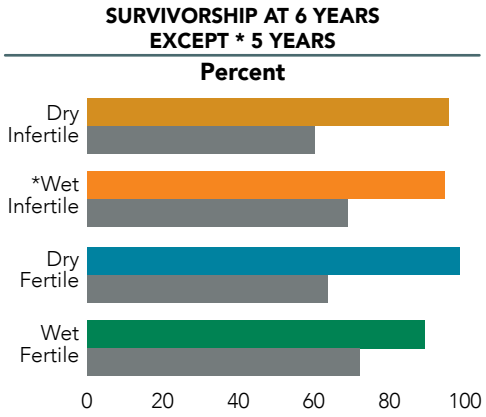
SPACING
Two-year crown diameter data suggest that it can be planted at three-meter spacing at most sites.

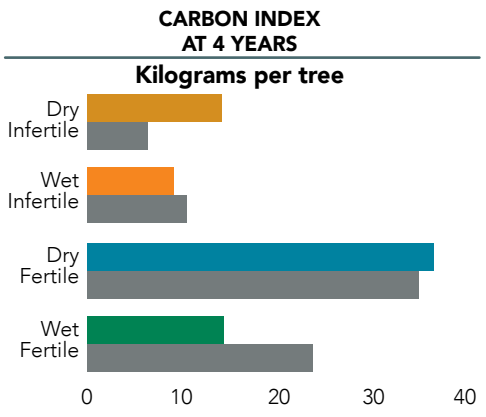
SELECTED USES
Cabinetry, construction (rural), firewood, flooring, posts, railroad ties, early stand structure in reforestation, potential soil improvement through nitrogen fixation and use as green manure.

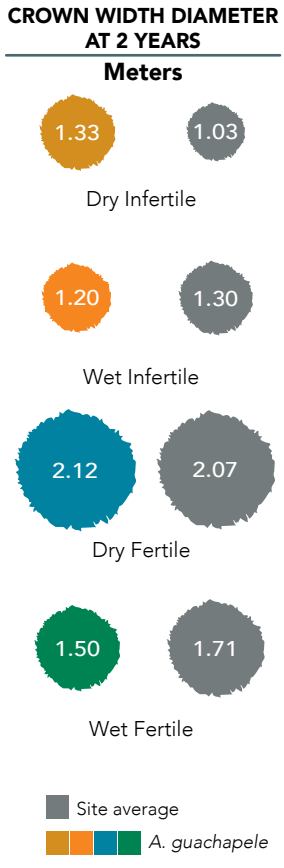
# *Albizia guachapele*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Albizia saman*

FAMILY
Fabaceae-Mimosoideae
SYNONYM
*Samanea saman*

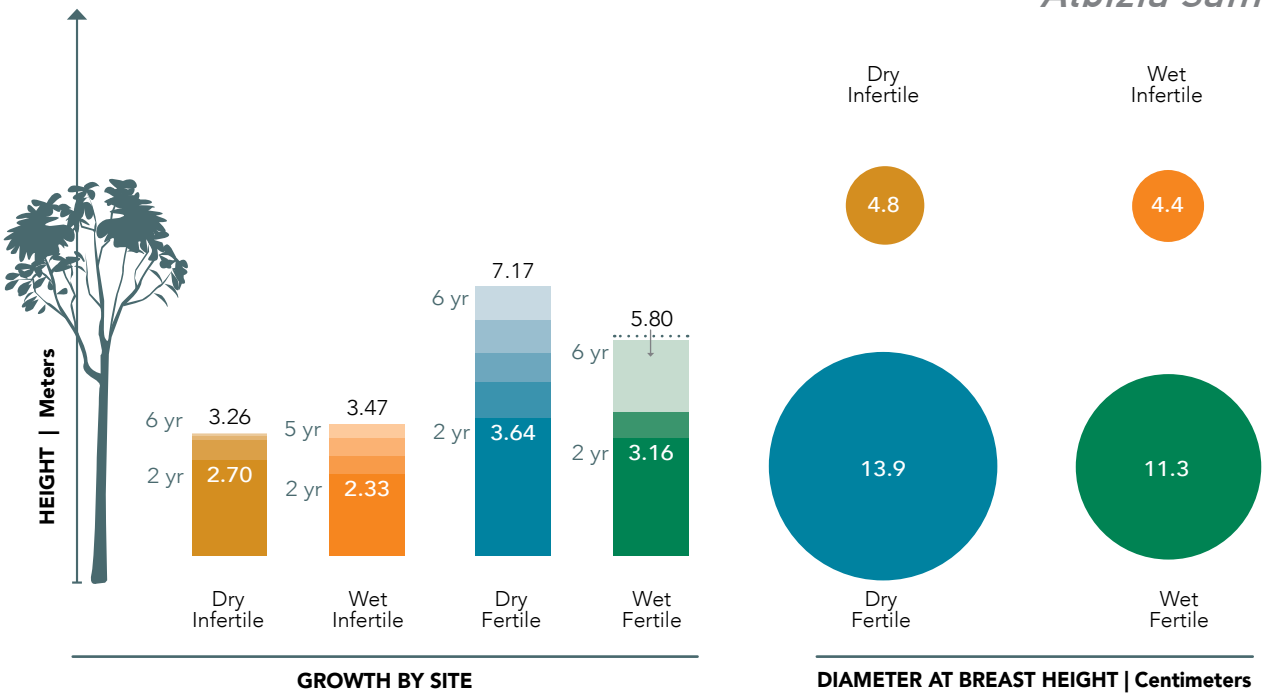
COMMON NAMES
Guachapalí, cenízaro (Panama, Costa Rica); algarrobo (Mexico, Guatemala, Cuba); dormilón guango (Puerto Rico); campano, saman (Colombia, Venezuela).

DESCRIPTION
*Albizia saman* is a tall (20 to 35 meters), deciduous tree found in low-altitude, dry to moist forests from Mexico to Bolivia. In Panama it is common in open areas and regenerating forests, and along the Pacific side of the country. It exhibited high to very high survivorship in the PRORENA species selection trials. Irrespective of rainfall, it grew best at the fertile sites, doubling the height and diameter growth observed at the infertile sites. Four-year height growth was well above average for all but the wet infertile site, where it was equivalent to the average. It also performed well in trials with farmers in areas near the dry sites, despite the lower phosphorus values of the agricultural soils. This species tended to form relatively narrow crowns early in growth, particularly at infertile sites; however, two-year crown diameters exceeded averages at fertile sites. Four-year carbon indices exceeded averages at all but the wet infertile site.

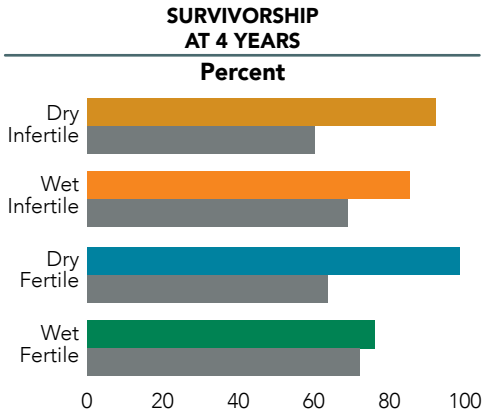
RECOMMENDATIONS
This multi-use species is often found in pastures, as it has a broad, spreading crown at maturity. Data from the PRORENA species selection and farmer trials suggest that it can be incorporated in reforestation and restoration treatments, where its nitrogen-fixing properties may also improve soil quality. It is not recommended for large-scale use on infertile sites with acidic soils without further testing. Its height suggests that it will become part of the canopy in reforestation treatments, but its tendency to form broad, spreading crowns suggests that it should not be planted in high densities. It can act as an effective nurse for shade-tolerant underplantings or for silvopastoral agroforestry systems.

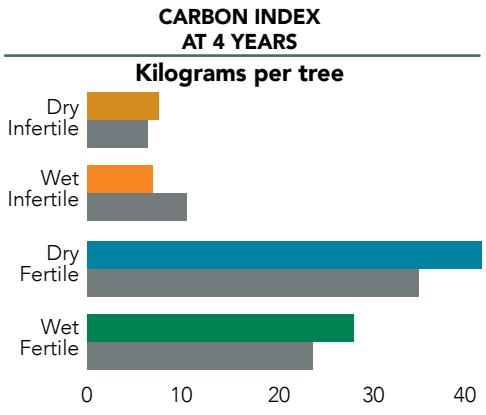
SELECTED USES
Boat construction, boards (decorative), cabinetry, carpentry, fence posts, furniture (fine), ornamental tree, canopy structure in reforestation, nurse tree for shade-tolerant species, shade tree (in pastures), potential soil improvement through nitrogen fixation and use as green manure.

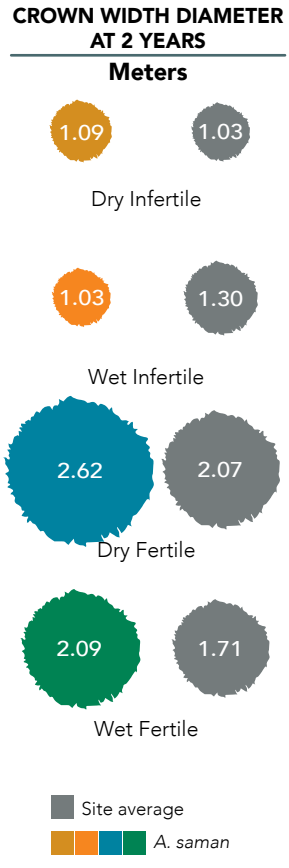
# *Albizia saman*




Diameter at breast height taken in the last year of height growth measurement




SPACING

This species can be planted within three meters of neighbors in most sites, but its crown growth suggests it might compete with other fast-growing species within three to four years. A wide spacing of five meters or greater is more suitable for nurse trees or silvopastoral systems.



SCIENTIFIC NAME

# *Anacardium excelsum*

FAMILY
Anacardiaceae

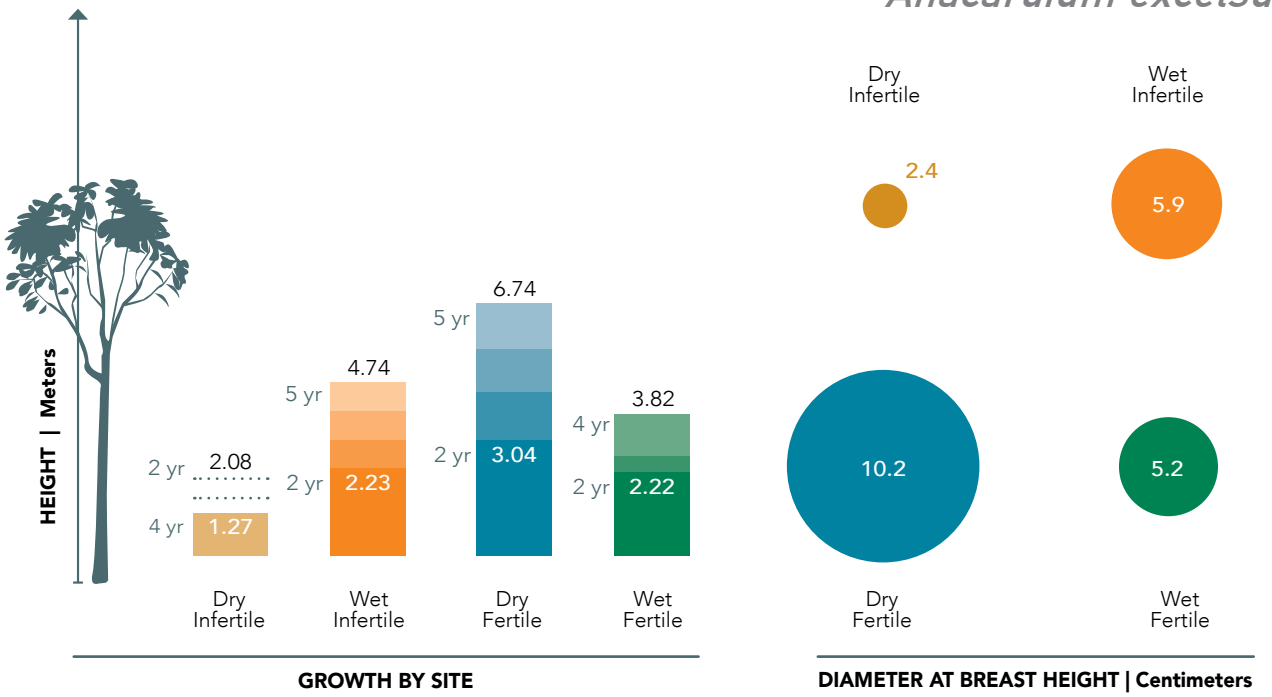
COMMON NAMES
Espavé, javillo, cornezuelo (Panama); espavel (Central America); caracolí (Venezuela, Colombia); marañón (Ecuador).

DESCRIPTION
*Anacardium excelsum* is an evergreen canopy species (20 to 40 meters) found in low- to mid-elevations from Honduras to Ecuador. In drier areas it is more common along streams and rivers. It is more broadly distributed in moist to wet forests. It can grow well in full sunlight and had high survivorship in the PRORENA species selection trials. However, in both the PRORENA trials and the Agua Salud plantations it exhibited marked within-site variability, presumably linked to soil moisture or nutrient status. In the PRORENA trials, its best overall growth was at the dry fertile site, which gets abundant rainfall in the wet season, followed by a long dry season. Four-year height growth was well above average at the wet infertile and dry fertile sites but below average at the other two sites. On good sites it tended to form a broad crown within the first years of development, casting shade on the understory. On less favorable sites, it did not branch in the first years, instead growing leaves directly off the stem almost vertically. Two-year crown widths were close to averages at all sites. Four-year carbon indices were above averages at the wet infertile and dry fertile sites and equivalent to the site average at the dry infertile site.

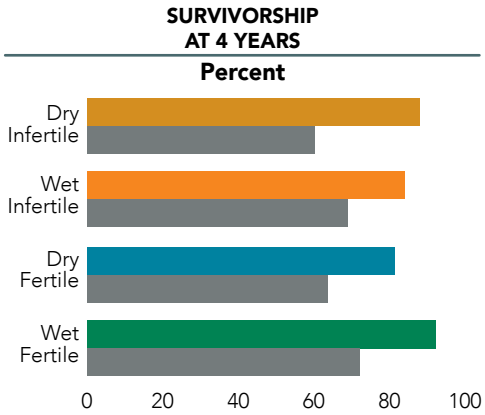
RECOMMENDATIONS
This species is well suited as a component of restoration and reforestation treatments in moist to wet sites, as well as adjacent to streams in moderately dry sites. Its high within-site variability in growth, particularly on wet and infertile sites like Agua Salud, suggest that it is not appropriate for high density plantings in dry and exceedingly infertile sites. Its carbon index values indicate that it is not recommended for upland sites in dry areas. Given its natural distribution along streams, it is probably particularly well suited for streamside restoration.

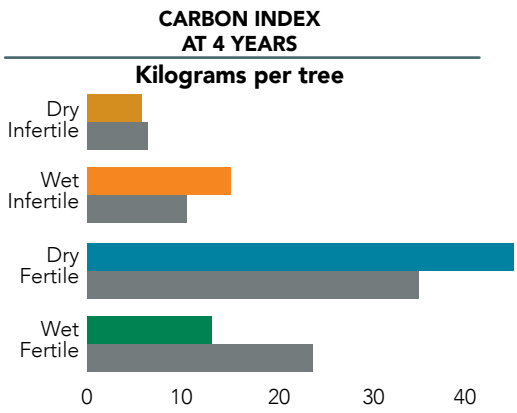
SELECTED USES
Canoes (dugout), construction, furniture, human consumption (toasted seeds), paddles, particle board, ornamental tree, canopy structure in reforestation, streambank restoration and protection.

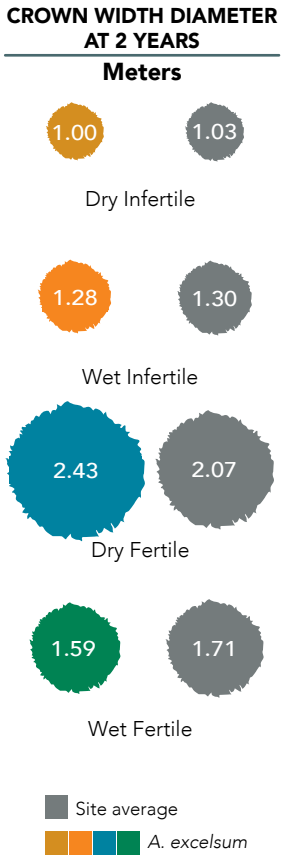
# *Anacardium excelsum*




Diameter at breast height taken in the last year of height growth measurement




SPACING

Two-year crown diameters suggest that this species can be grown at three-meter spacing or less at most sites, depending upon the crown architecture of neighbors.



SCIENTIFIC NAME

# *Anacardium occidentale*

FAMILY

Anacardiaceae

COMMON NAMES

Marañón (Panama, Central America, Ecuador, Colombia, Peru); cajú (Brazil); caujil, merey (Venezuela); cashew tree (North America).

DESCRIPTION

*Anacardium occidentale* is a small (5 to 12 meters), evergreen tree found in dry to moist, low- to mid-elevations from Mexico to Bolivia. This species exhibited high to very high survivorship across the PRORENA species selection trials, always surviving far above site averages. It exhibited its best height and diameter growth at the wet infertile and dry fertile sites. Four-year height growth was above average at the infertile sites but well below average at the fertile sites. This species tended to form a broad, short crown, and exhibited two-year crown diameters that exceeded averages at all sites, particularly the infertile ones. Its four-year carbon index far exceeded average at the infertile sites and was slightly below average for the fertile sites.

RECOMMENDATIONS

Cashew fruits and seeds are produced in large quantities for human consumption and the silviculture of this species is relatively well understood. Data from the PRORENA trials suggest it can be an important component of reforestation and restoration treatments, particularly on infertile sites. In Panama it is often encountered in living fences. Its crowns are broad but relatively thin, thus allowing light to get to the understory. It may help give understory structure to reforestation and restoration treatments, particularly as it approaches maximum height and is passed by canopy species. Its fruits and seeds provide valuable forage for animals. It produces oils that have medicinal properties, but can be toxic to some humans.

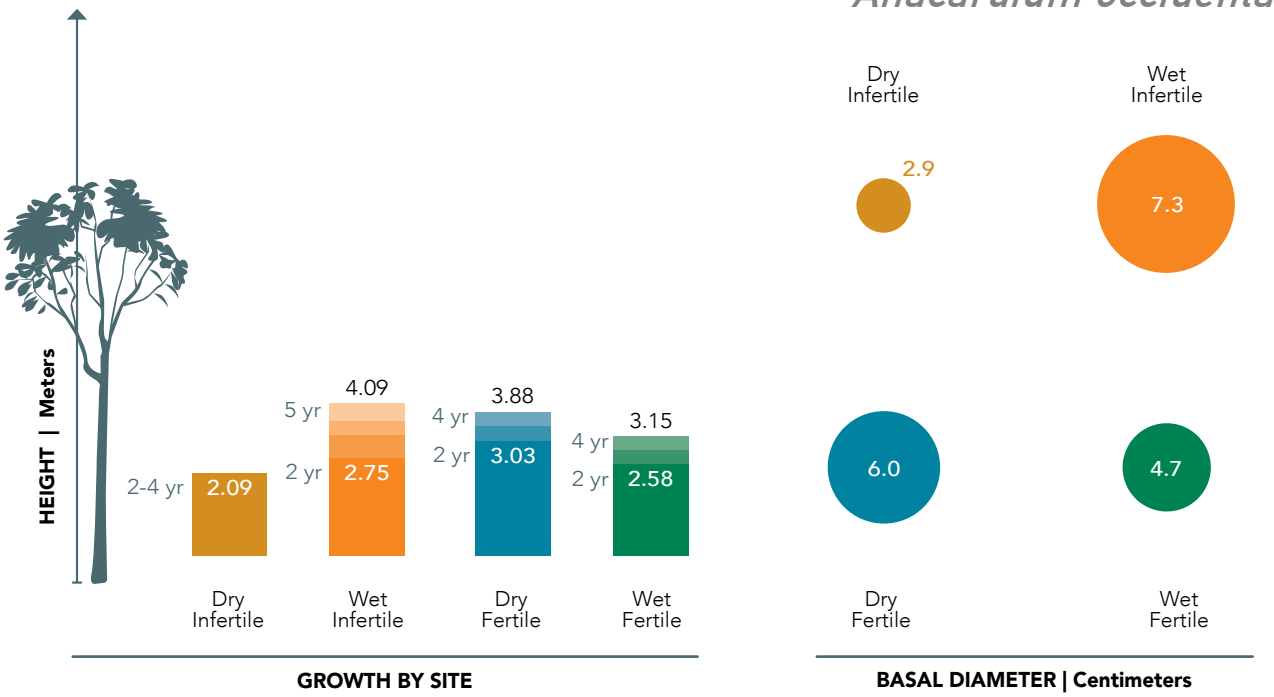
SPACING

In reforestation treatments, this species can be planted in moderate densities to help give understory structure. Two-year crown widths suggest that this species can be planted at three-meter spacing, but it will likely be overtopped by faster growing species.

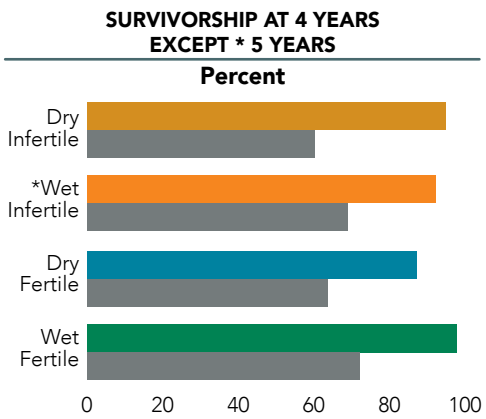
SELECTED USES

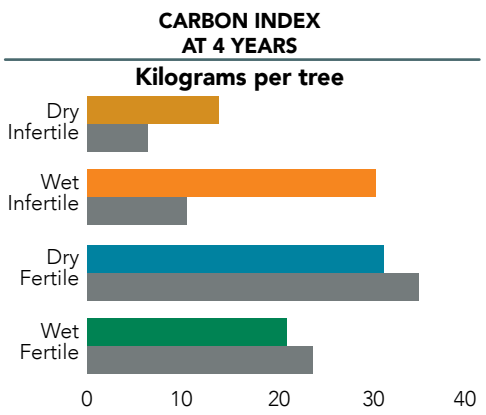
Construction, human consumption (fruits, seeds), fence posts, firewood, fodder (fruits, seeds), furniture, industrial oil (oil from nut), ink (resin), living fences, medicines (seeds, bark), poison (bark), attracting animals, understory structure in reforestation.

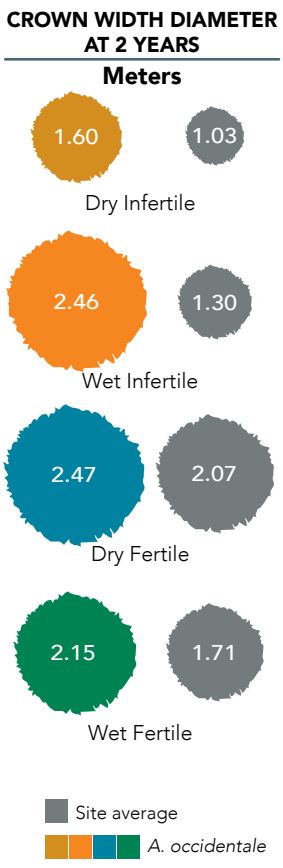
# *Anacardium occidentale*




Basal diameter taken at same age as maximum height





SCIENTIFIC NAME

# *Astronium graveolens*

FAMILY
Anacardiaceae

COMMON NAMES
Zorro, ron-ron, tigrillo, tolerante, cucaracho (Panama, Costa Rica); ciruello (Honduras, Guatemala); jovío (Mexico); gusanero (Colombia); aroeira, gonçalo (Brazil).

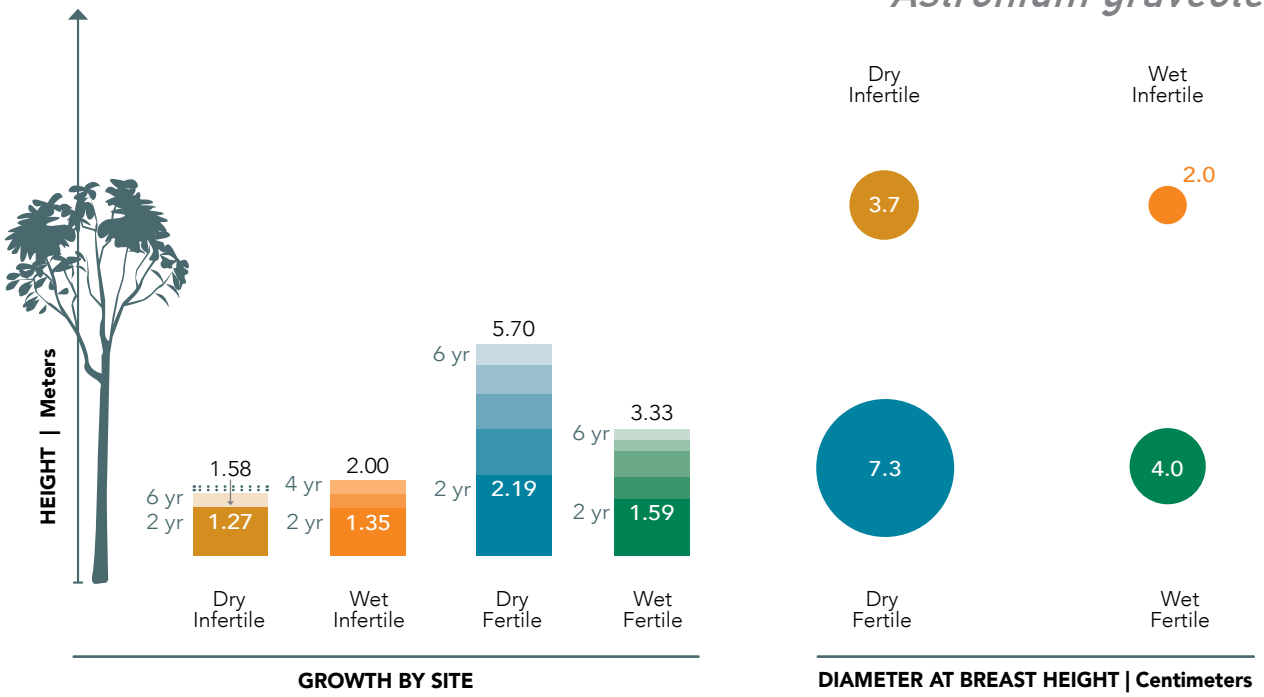
DESCRIPTION
*Astronium graveolens* is a medium to tall (10 to 30 meters), deciduous tree found in low- to mid-elevation, dry to moist forests from southern Mexico to Bolivia. It exhibited high to very high survivorship across the PRORENA species selection trials, with highest survival at the dry fertile site, and lowest at the dry infertile one. Its best height and diameter growth were at the dry fertile site, but height growth at the wet fertile site was also markedly higher than at the two infertile sites. Nevertheless, its four-year height growth was below average at all sites. It experienced dieback at the dry infertile site after two years. It formed narrow crowns, with two-year crown diameters far below averages at all sites.

Its four-year carbon indices were far below averages at all but the dry infertile site, where it was only slightly lower than average; however, the carbon indices did not take dieback into consideration, as the calculations were based on diameter only.

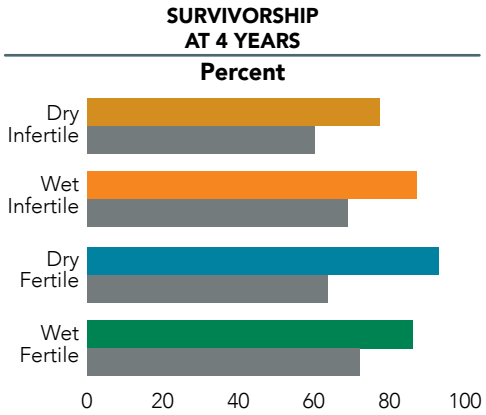
RECOMMENDATIONS
Although this species is regularly encountered in secondary forests at the dry fertile site, it did not grow as well in the PRORENA trials under similar soil conditions, suggesting that it may grow better in partial shade with surrounding pioneer species. Because it showed high survivorship and produces dense, high-value wood, it is likely to be a good candidate in restoration and reforestation treatments for carbon sequestration in the long term, particularly on dry fertile sites. It may also be used in mixed-species commercial plantations where its rotation length is longer than other species that are harvested at an earlier time in the mixture. Its narrow crown suggests it will not be useful in shading out grasses and competing vegetation, but its overall height and crown growth suggest it will be a useful component of the canopy.

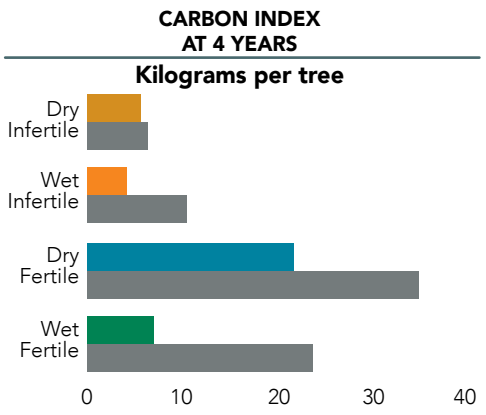
SELECTED USES
Carbon sequestration (long-term), carpentry, floorboards, furniture, handicrafts, tool handles, canopy structure in dry-forest site reforestation.

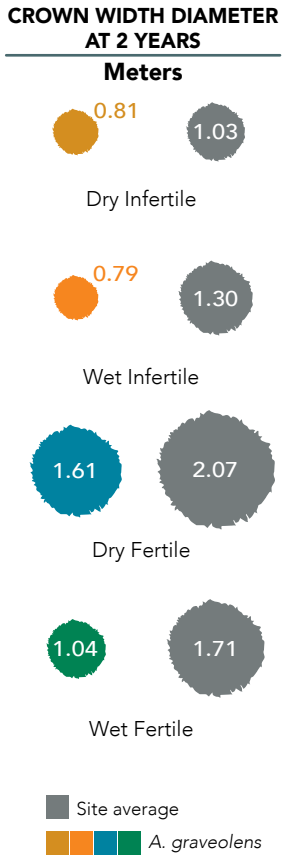
# *Astronium graveolens*




Diameter at breast height taken in the last year of height growth measurement




SPACING

Data from the literature and the PRORENA trials suggest that this species can initially be grown as close as two meters to neighbors. However, it may become overtopped by species with very high early growth.

SCIENTIFIC NAME

# *Brosimum alicastrum*

FAMILY

Moraceae

COMMON NAMES

Berbá, berba, cacique (Panama, Costa Rica); ramón (Mexico); charo (Venezuela); mashonaste (Peru).

DESCRIPTION

*Brosimum alicastrum* is a tall (20 to 40 meters), deciduous tree found in low- to mid-elevation, dry to moist forests from Mexico to Bolivia. In Panama it is common on the Pacific side of the mountains. It exhibited poor to very poor survivorship in the PRORENA species selection trials, with highest survival in the dry infertile site. It was not grown at the wet fertile site. Its growth was extremely low, with height growth decreasing at all sites between years two and four. At the dry fertile site, it only reached 1.3 meters (height at which diameter at breast height is measured) after four years. Four-year heights and two-year crown diameters were both well below averages at all sites. Its four-year carbon index barely registered. This species grows very well in the calcium-rich soils of the Yucatán, where it was frequently planted as a fruit tree by the Maya.

RECOMMENDATIONS

The full-sunlight conditions of the PRORENA trials resulted in very poor survival and growth of this species; however, in nursery settings, it grows more rapidly in shade conditions. This suggests that it may grow better in at least partial shade, and thus may do well if planted in the understory of plantations with a partially closed canopy. It should eventually become a component of the canopy in reforestation and restoration treatments.

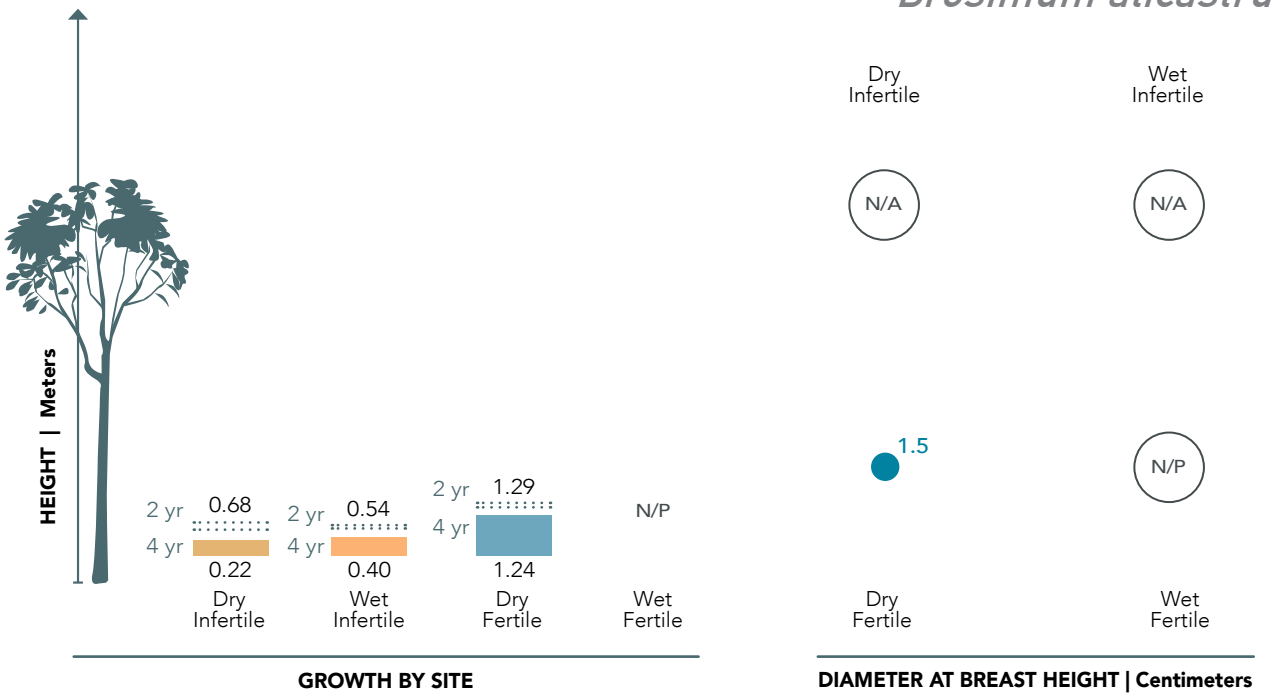
SPACING

Data from the literature and the PRORENA trials indicate that this species persists and grows in partial to deep shade, suggesting that it can be planted less than two meters apart from neighbors. In the long term, it will eventually become part of the forest canopy or sub-canopy.

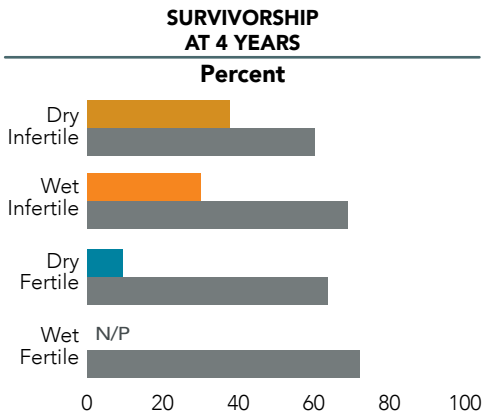
SELECTED USES

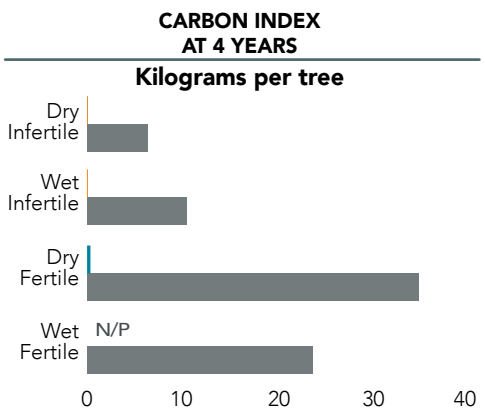
Carpentry, floorboards, fodder (leaves, tender stems), furniture, human consumption (cooked seeds, latex), tool handles, shade tree.

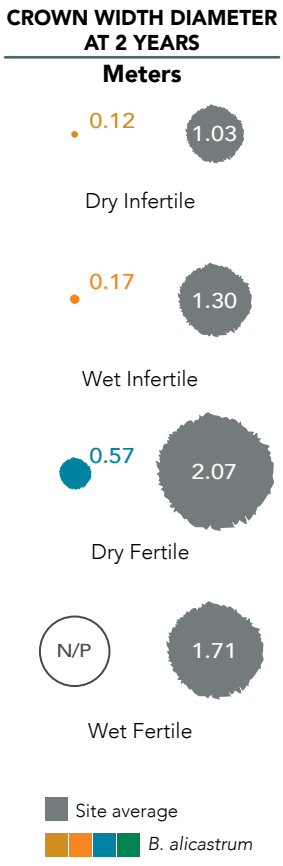
# *Brosimum alicastrum*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Brosimum utile*

FAMILY
Moraceae

COMMON NAMES
Sandé, mastate, palo de vaca (Panama, Costa Rica, Colombia, Venezuela, Ecuador); amapá, caucho macho (Brazil); panguana, leche caspi (Peru).

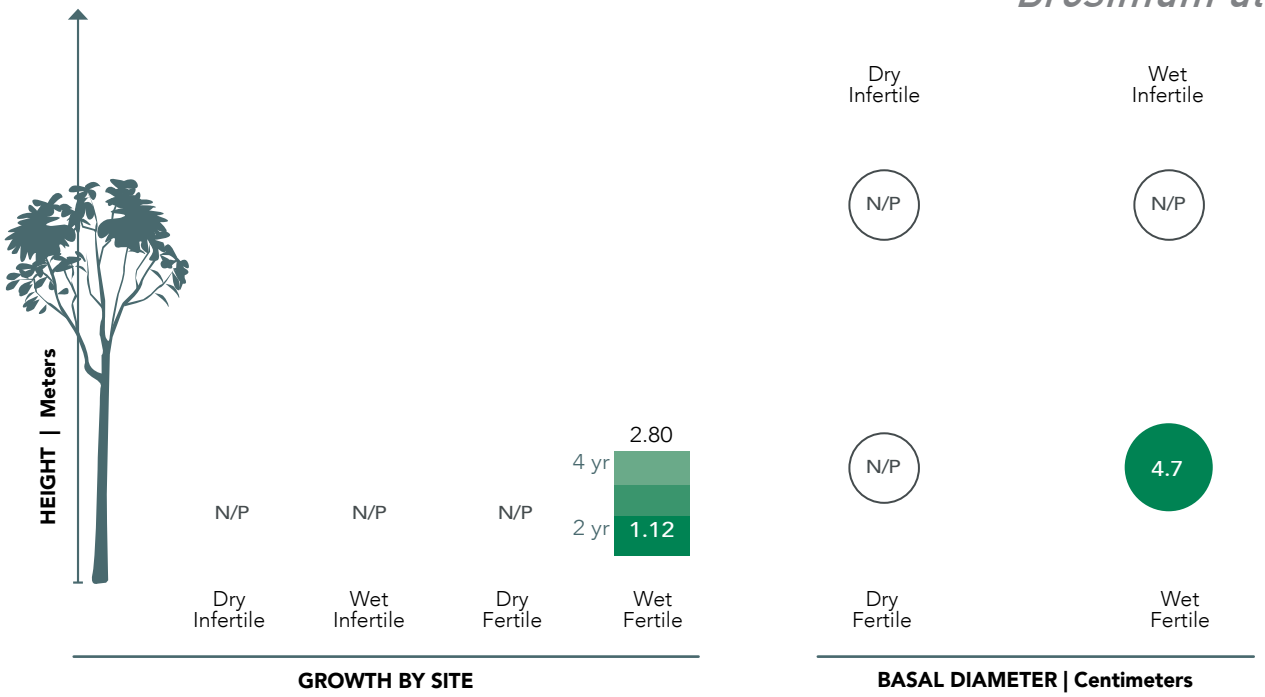
DESCRIPTION
*Brosimum utile* is a tall (20 to 40 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Honduras to Bolivia. In Panama it is common on the Caribbean side of the mountains. It was only planted in the wet fertile site of the PRORENA species selection trials, where survivorship was low. For surviving individuals, height and diameter growth were low, but showed sustained increase with time. Four-year height growth was far below the wet fertile site average. Two-year crown diameter was less than half that of the site average. Four-year carbon index was also very low compared to the site average.

RECOMMENDATIONS
The low survivorship and slow growth of this species at the wet fertile site suggest that it should not form a major component of restoration and reforestation treatments when grown in full sunlight. It required shade to grow well in nursery settings, suggesting that it may do better planted into the understory, where there is at least partial shade.

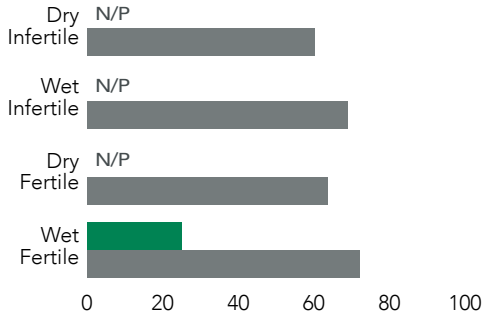
SPACING
Data from the literature and the PRORENA trials indicate that this species persists and grows in partial to deep shade, suggesting that it can be under-planted less than two meters apart from nurse tree neighbors. In the long term, it will eventually become part of the forest canopy.

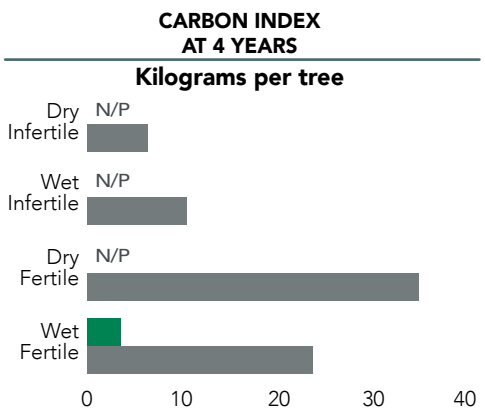
SELECTED USES
Boxes, carpentry, chipboard, human consumption (cooked seeds), medicines (resin), pulp for paper.

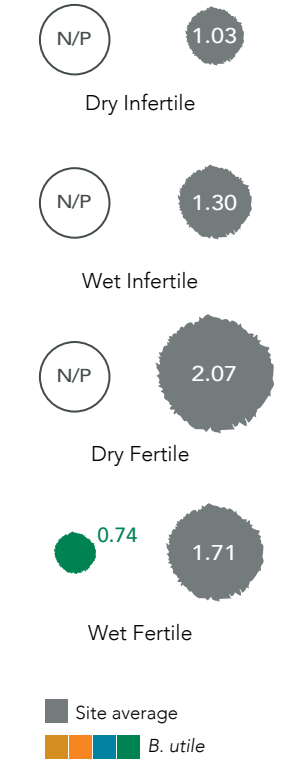
# *Brosimum utile*




Basal diameter taken at same age as maximum height



SCIENTIFIC NAME

# *Byrsonima crassifolia*

FAMILY

Malpighiaceae

COMMON NAMES

Nance (Panama, Costa Rica, Nicaragua, Mexico); tapal (Guatemala); murici (Brazil); chaparro (Colombia, Venezuela).

DESCRIPTION

*Byrsonima crassifolia* is a small tree (5 to 15 meters) found in low- to mid-elevation, dry to moist forests. It exhibited moderate to high survivorship in the PRORENA species selection trials, with highest survival at the infertile sites. It grew best at the wet infertile site, but surviving individuals at the dry fertile site were the second tallest. Four-year height growth far exceeded the average at infertile sites. It exhibited sustained height and diameter growth in the dry infertile site, and the average diameter was only slightly smaller than that of the wet fertile site. Two-year crown diameter far exceeded the averages at both infertile sites, and was also broader than average at the wet infertile site. Four-year carbon indices were below average at the fertile sites but twice the average at the dry infertile site and three times that of the wet infertile site.

RECOMMENDATIONS

Data from the PRORENA trials suggest that this species is best suited for restoration and reforestation treatments on infertile sites, where it can also contribute to rapid carbon sequestration. It can help rapidly cover the ground, and also give structure to young forests as taller species eventually overtop it. In Panama the fruits are a highly appreciated agricultural commodity. Given that it thrived at the infertile sites of the trials, it can also be considered for agricultural mixtures and home gardens on similarly infertile soils, or for wildlife habitat reforestation.

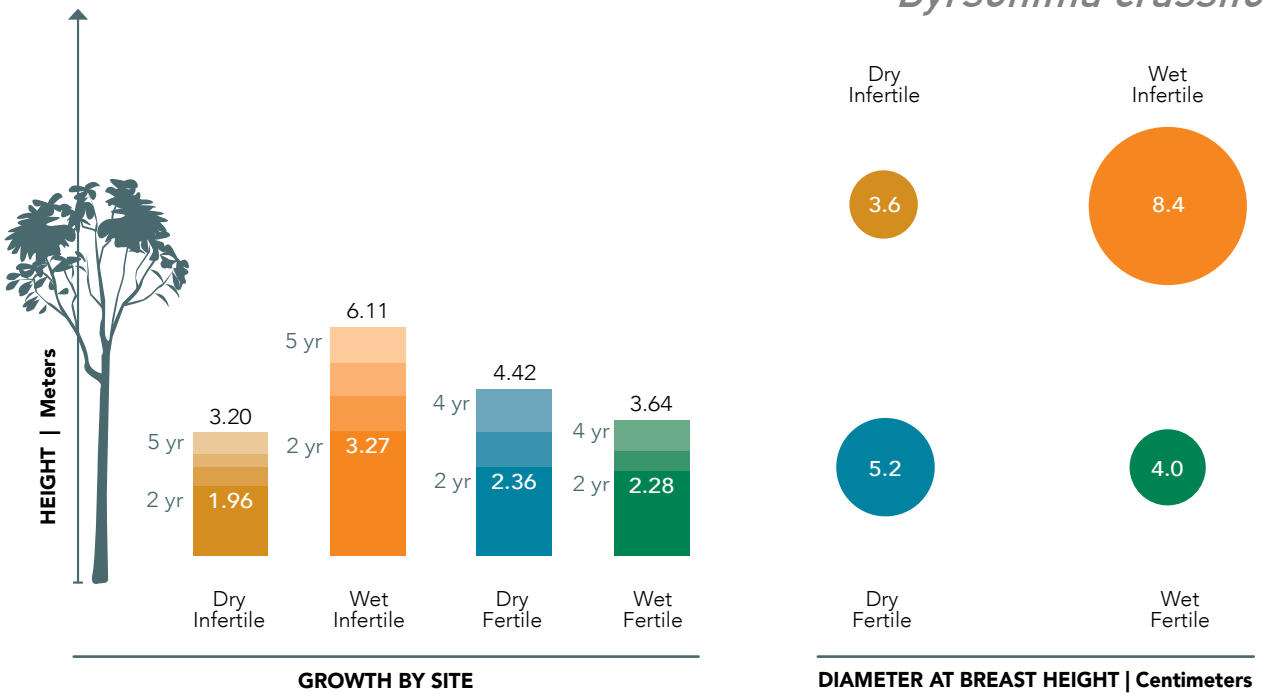
SPACING

This species can be grown at an initial spacing of three meters, and possibly less than that at dry infertile sites. The tree is a good structural and habitat component of stand understories for mixed plantings when planted beneath nurse trees or adjacent shade-tolerant canopy tree species.

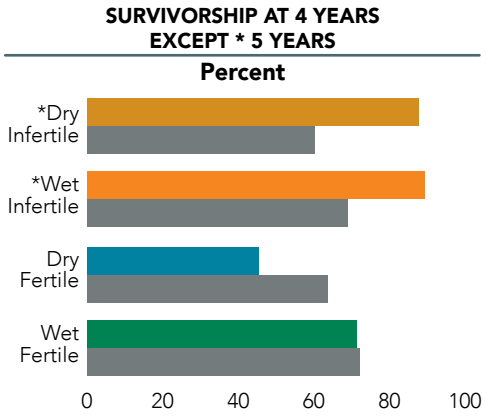
SELECTED USES

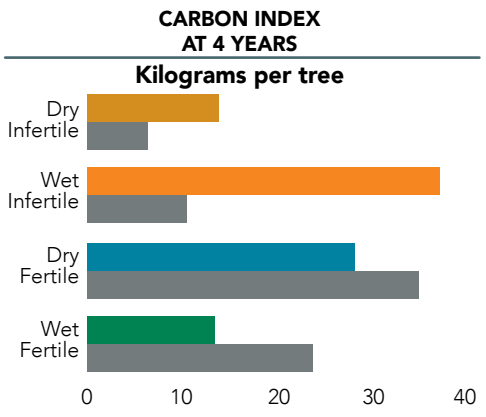
Carbon sequestration, carpentry, charcoal, firewood, flooring, furniture, human consumption (fruits), honey production, medicines (bark), ornamental tree, poison (for fishing, cut-up branches), tannery (bark), attracting animal diversity, early stand structure in reforestation, nurse tree for shade-tolerant species, shade tree (farms, gardens).

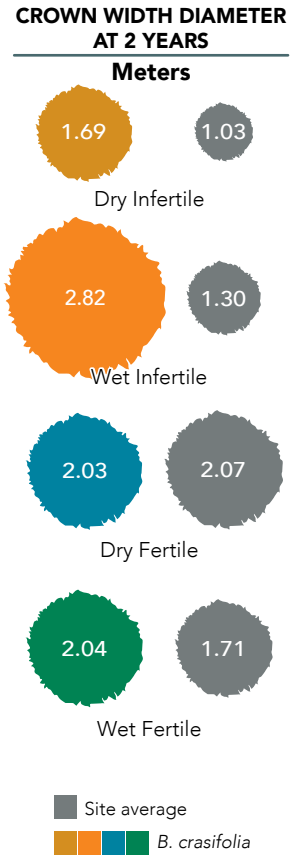
# *Byrsonima crassifolia*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Calophyllum brasiliense*

FAMILY

Clusiaceae (Recent molecular studies place this species in the Calophyllaceae)

COMMON NAMES

María (Panama, Central America); barí (Mexico); guanandi, jacareúba (Brazil, Argentina); aceite maría (Colombia); lagarto-caspi (Peru).

DESCRIPTION

*Calophyllum brasiliense* is a tall (10 to 35 meters), evergreen tree found in low-elevation, dry to moist forests from Mexico to Argentina. It is commonly found along stream or river banks and swampy areas. In the PRORENA species selection trials, it survived poorly on the dry sites; survival was equivalent to the site average on the wet fertile site. Height and diameter growth were well below average at all sites, with best performance at the wet sites. The species had very narrow crowns, with two-year crown diameters far less than half the averages at all sites except for the wet infertile one, where it was half the average. Its four-year carbon indices were all far below site averages, with the highest value at the wet infertile site, and the second highest at the wet fertile site.

RECOMMENDATIONS

Given its performance in the PRORENA trials, and that it is often associated with wet and inundated areas, this species is recommended for reforestation and restoration along streams, rivers, swamps, or areas with very high rainfall. Although only one in three trees survived at the wet infertile site, its sustained growth during the course of the trials suggests that it will continue growing in mixtures with other, faster growing species.

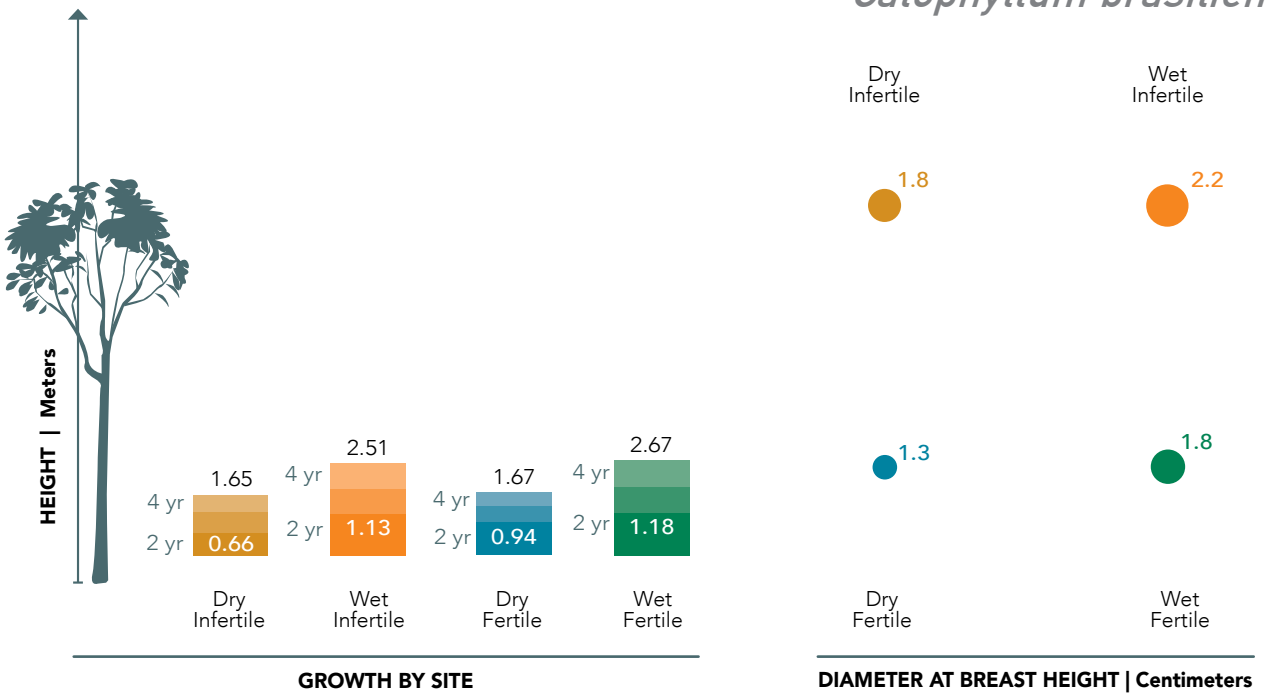
SPACING

PRORENA nursery and trials data suggest that this species can be planted in relatively close proximity to neighbors on wet or moist soils as a slow-growing, late-successional canopy timber tree.

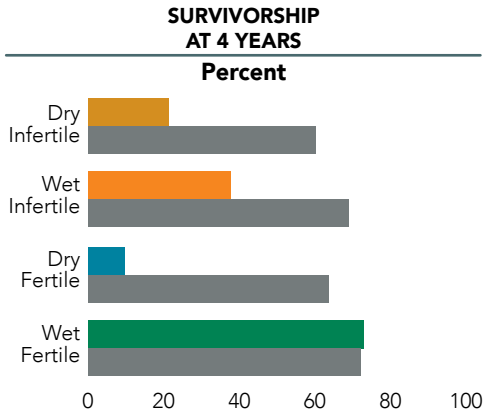
SELECTED USES

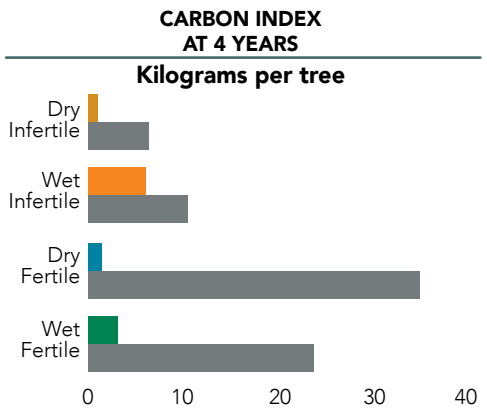
Carpentry, flooring, furniture (fine), medicines (resin), ornamental tree, posts, shade tree (coffee and cacao plantations), streambank restoration and protection.

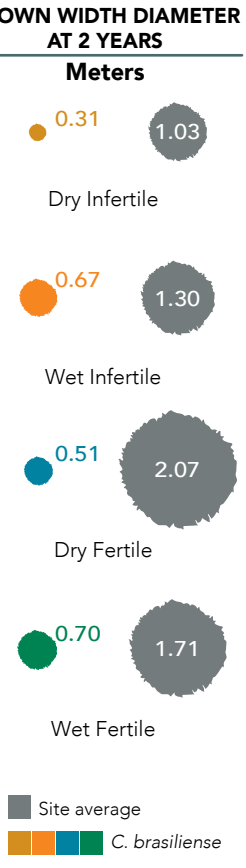
# *Calophyllum brasiliense*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Calophyllum longifolium*

FAMILY

Clusiaceae (Recent molecular studies place this species in the Calophyllaceae)

COMMON NAMES

María, santa maría, calaba (Panama, Costa Rica).

DESCRIPTION

*Calophyllum longifolium* is a tall (20 to 40 meters), evergreen tree that is native to Africa but introduced to Panama and the rest of Central America. In Panama it grows at low elevations, often close to the coast, in moist to wet forests. It is also found in the forest of Barro Colorado Island. It was grown in all but the dry infertile site of the PRORENA species selection trials. No individuals survived to five years at the dry fertile site. Survivorship was very poor at the wet infertile site and low at the wet fertile one. Height and diameter growth at the wet infertile site far exceeded that of the wet fertile one, with surviving individuals far exceeding the four-year height average. Two-year crown diameters were far below averages at the three sites where it was grown. Its four-year carbon index was far below average at the wet fertile site and just below average at the wet infertile site.

RECOMMENDATIONS

Although this species experienced near-complete mortality in the PRORENA trials, surviving individuals grew reasonably well at the wet infertile site, which receives far more rainfall than the wet fertile site. The species may survive better in lower densities than those of the PRORENA trials. Since its fruits are consumed by seed-dispersing animals, if planted in low densities, it may increase diversity and attract frugivores to restoration treatments in wet or very wet sites.

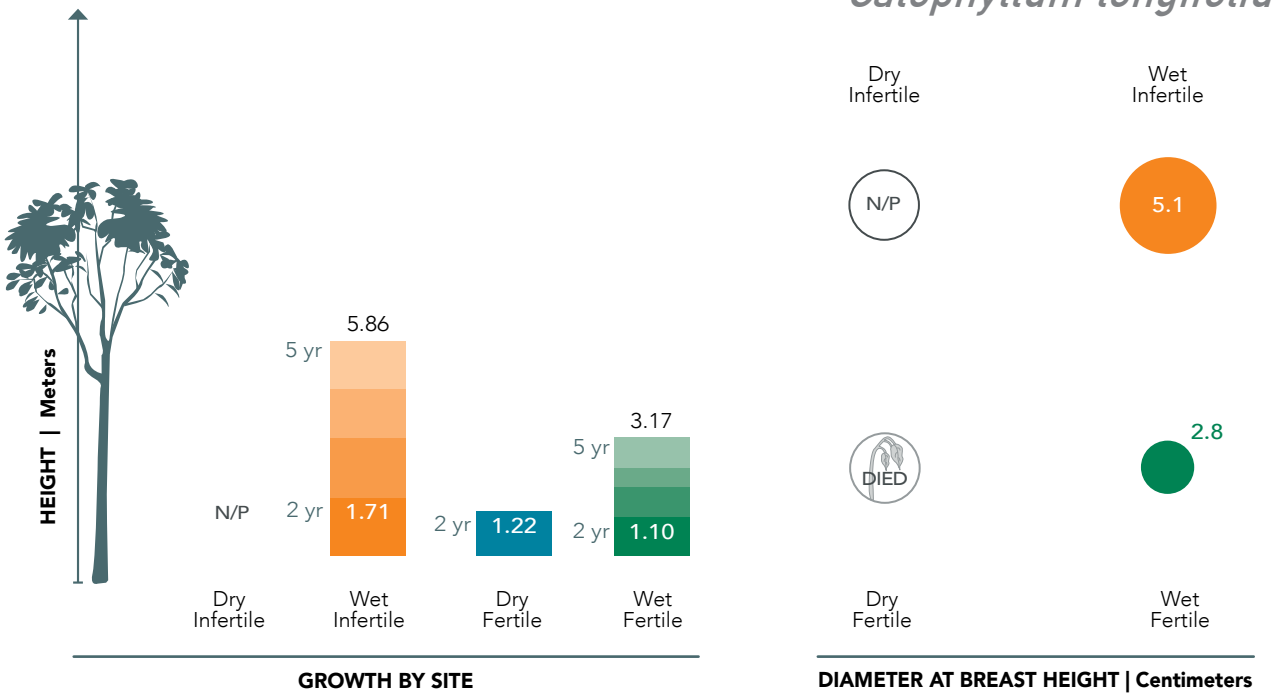
SPACING

Data from the literature and the PRORENA trials suggest this species can be grown less than two meters from neighbors, with partial to deep shade sustaining its survival and growth.

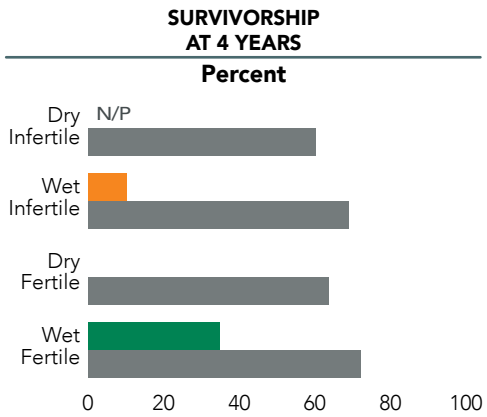
SELECTED USES

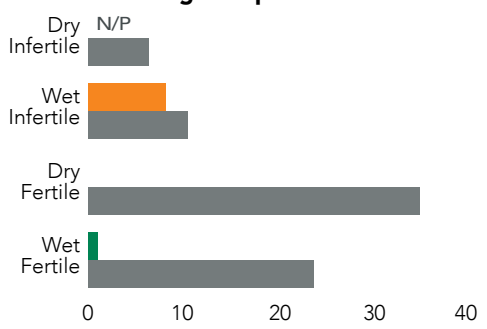
Carpentry, flooring, furniture, medicines (resin), plywood, railroad ties, tool handles, attracting animal diversity, canopy structure in reforestation.

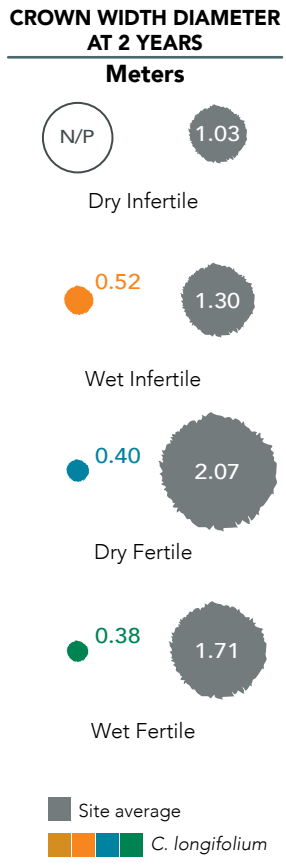
# *Calophyllum longifolium*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Calycophyllum candidissimum*

FAMILY
Rubiaceae

COMMON NAMES
Madroño, alazano, lluvia de plata, salamo (Panama, Costa Rica, Nicaragua); limoncillo, dégame, camarón, araguato, betún (Central America).

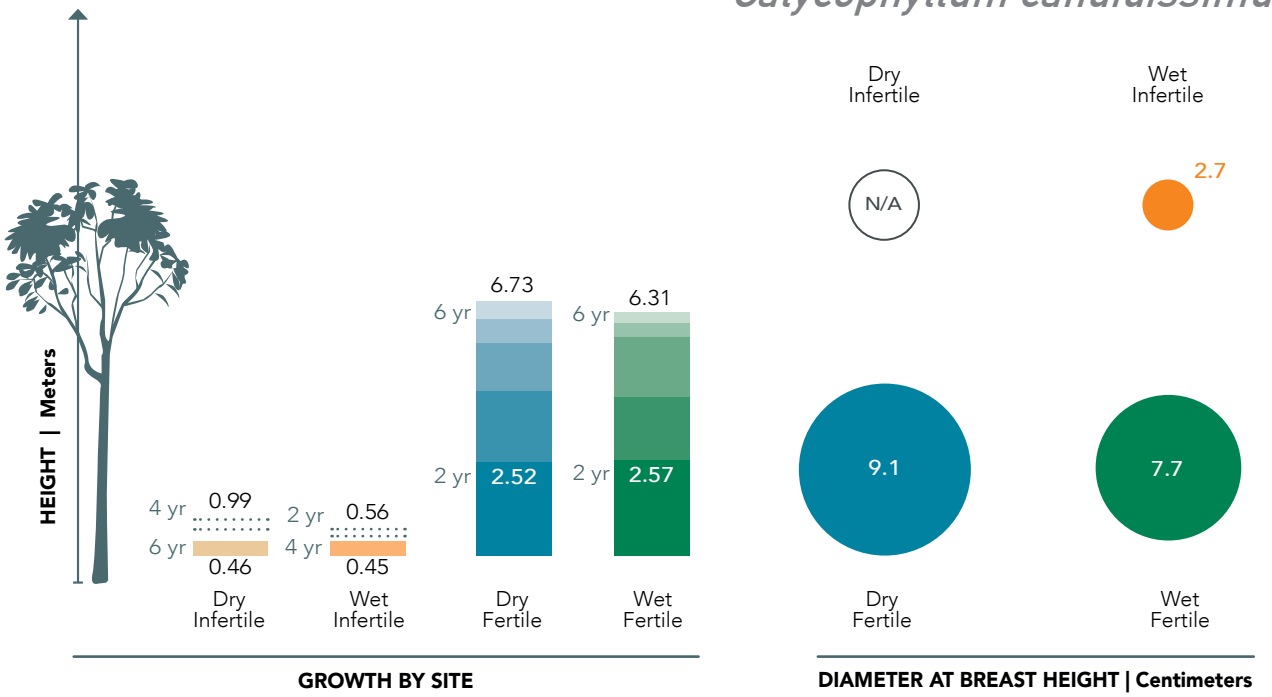
DESCRIPTION
*Calycophyllum candidissimum* is a tall (10 to 30 meters), deciduous tree found at low elevations in dry to moist forests from Guatemala to Panama. In the PRORENA species selection trials, it survived very well at the fertile sites, while survival at the infertile sites was close to 50 percent. Height and diameter growth were far better at the fertile sites. At the infertile sites, height growth declined after two years, with no individuals at the dry infertile site reaching the 1.3-meter breast height mark used for measuring diameters. This species formed narrow crowns, with two-year crown diameters at the fertile sites slightly below average and those of the infertile sites far below average. Four-year carbon indices were just below average at the fertile sites and well below average at the infertile sites.

RECOMMENDATIONS
Data suggest that this species is not suited for infertile sites but survives and grows better than most of the species in the PRORENA trials on fertile sites. It is recommended in restoration and reforestation treatments on relatively fertile soils as a future canopy species. Its relatively narrow crown suggests it will not provide deep shade. Its height growth slowed markedly between years four and six, possibly due to crown closure and competition, or some other unknown factor. Thus, it should probably be used in moderate to low densities in diversity treatments.

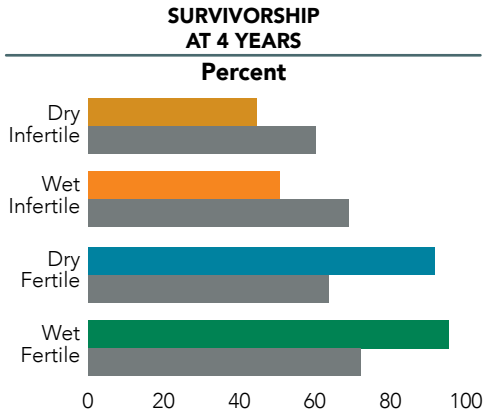
SPACING
This species can be spaced three meters apart from neighbors of the same or other species, or further apart if it risks being overtopped by faster growing trees.

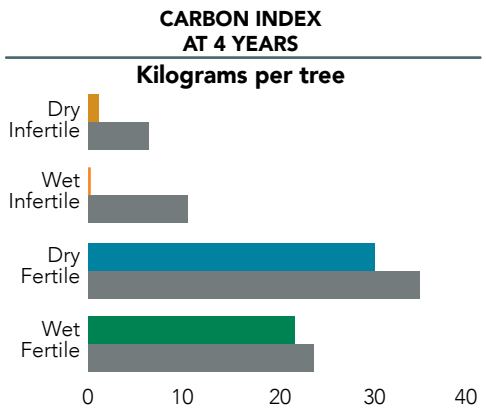
SELECTED USES
Construction (heavy), fence posts, flooring (fine), honey production, ornamental tree, tool handles, canopy structure in reforestation.

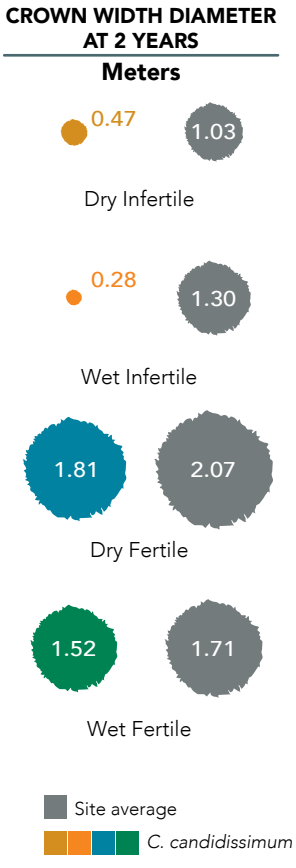
# *Calycophyllum candidissimum*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Carapa guianensis*

FAMILY
Meliaceae

COMMON NAMES
Tangaré, cedro bateo, bateo (Panama, Costa Rica); andiroba (Brazil, Paraguay, Peru); figueroa (Ecuador); güino, mazabalo (Colombia); carapa (French Guayana).

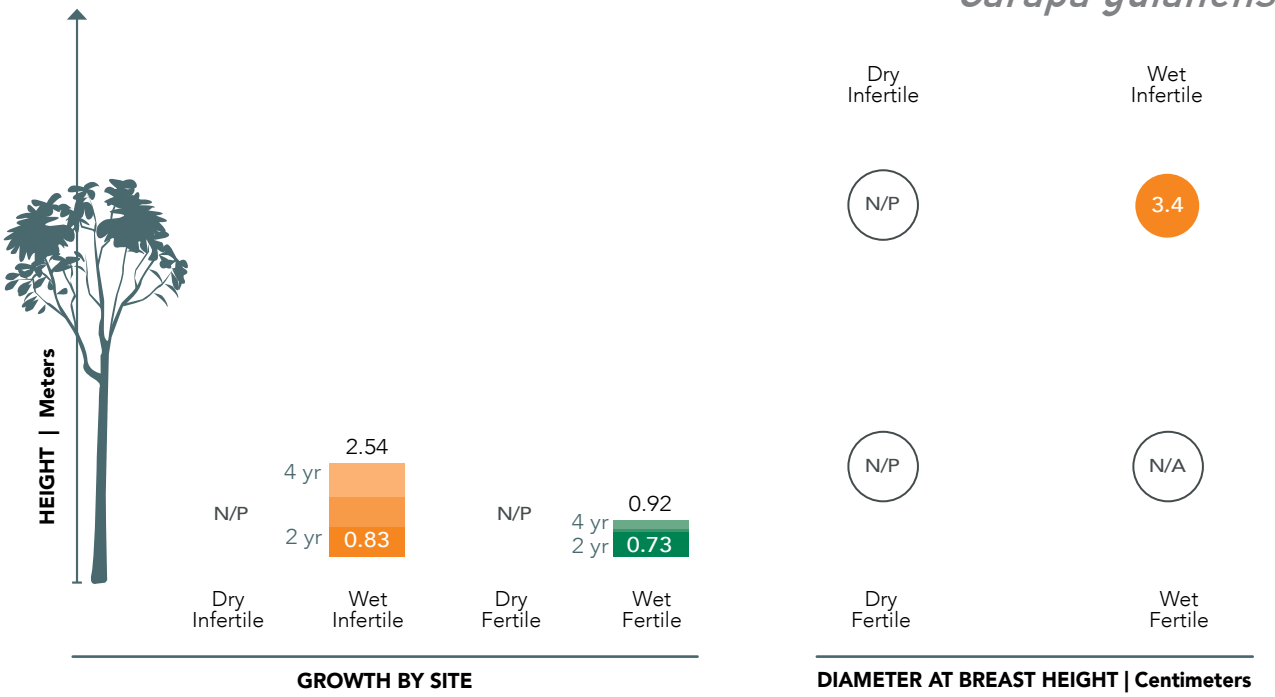
DESCRIPTION
*Carapa guianensis* is a medium to tall (20 to 40 meters), evergreen tree found at low- to mid-elevation, moist to wet forests from Guatemala to Peru. It is common in seasonally inundated forests, backwaters of floodplains, and brackish tidal estuarine systems. Of the four PRORENA species selection trials, it was only planted in the two wet sites, where it exhibited poor survivorship. Individuals that survived grew poorly, with four-year height growth well below site averages. At the wet fertile site, no trees reached the 1.3-meter marker for measuring diameter at breast height—average height was half that of the wet infertile site. Two-year crown diameters were less than half that of the two site averages. The four-year carbon index at the wet-infertile site was slightly more than half the site average.

RECOMMENDATIONS
This multiple-use species grew poorly in the PRORENA trials, with data suggesting that it is more sensitive to soil moisture than fertility, since it grew better at the wetter, infertile site. Despite relatively rapid nursery growth, subsequent survival in plantations was poor. Since it required shade to develop in the nursery, it might perform better when planted in at least partial shade. Until survival and growth barriers are better understood, it is not recommended in large-scale plantings in restoration and reforestation treatments. Nonetheless, it might be incorporated on a trial basis on wet or inundated riparian or floodplain sites, perhaps in gaps or adjacent to neighboring species with broad, thin crowns.

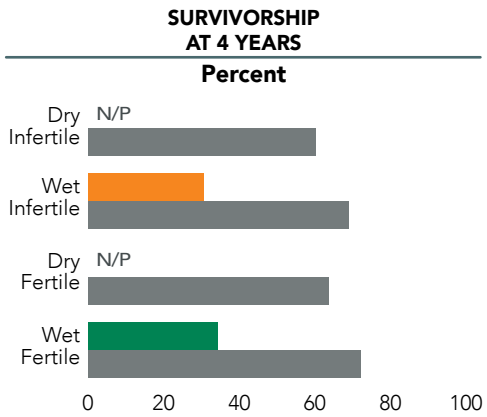
SPACING
With few surviving individuals in the PRORENA trials, two-year crown diameter data cannot be relied on to accurately derive spacing guidelines. The data suggest it can be planted very close to broader-crowned neighbors, but these species will quickly overtop it.

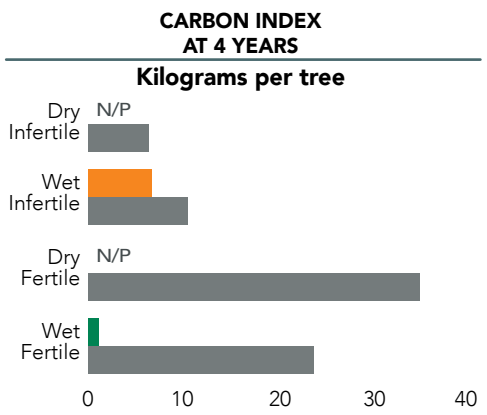
SELECTED USES
Cabinetry, carpentry, construction, flooring, medicines (bark), oil (seeds), ornamental tree, plywood, poison (seeds).

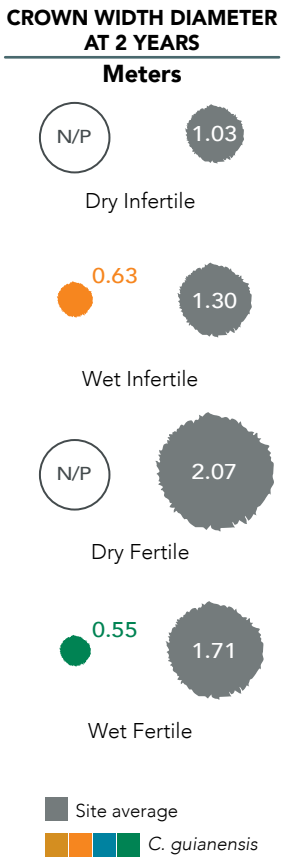
# *Carapa guianensis*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Cassia grandis*

FAMILY

Fabaceae-Caesalpinioideae

COMMON NAMES

Caña fístula (Panama, Colombia); carao (Nicaragua); bukut (Belize, Guatemala); carago (El Salvador, Honduras); cañandonga (Cuba); casia caballo (Peru); cássia-rosa, cássia-grande (Brazil).

DESCRIPTION

*Cassia grandis* is a medium-sized (15 to 25 meters), deciduous tree found at low elevations in dry to moist forests from Mexico to Bolivia. In Panama it is common in open areas and pastures. In the PRORENA species selection trials, it exhibited high survivorship in all but the dry infertile site, where it showed moderate survival. It grew best at the dry fertile site, with higher than average four-year height growth; all other sites had below average height growth. Wet fertile height and diameter values were only slightly better than those of the wet infertile site. Two-year crown diameter was markedly broader than average at the dry fertile site, but less than averages at all other sites. The four-year carbon index was slightly higher than average at the dry fertile site, but far below averages at all other sites.

RECOMMENDATIONS

This is a multiple-use species commonly found on farms. Data from the PRORENA trials suggest it survives well in all but the most moisture- and nutrient-stressed sites, and is thus recommended for restoration treatments at fertile sites in moderately dry areas, where it may form part of the mid-story or canopy.

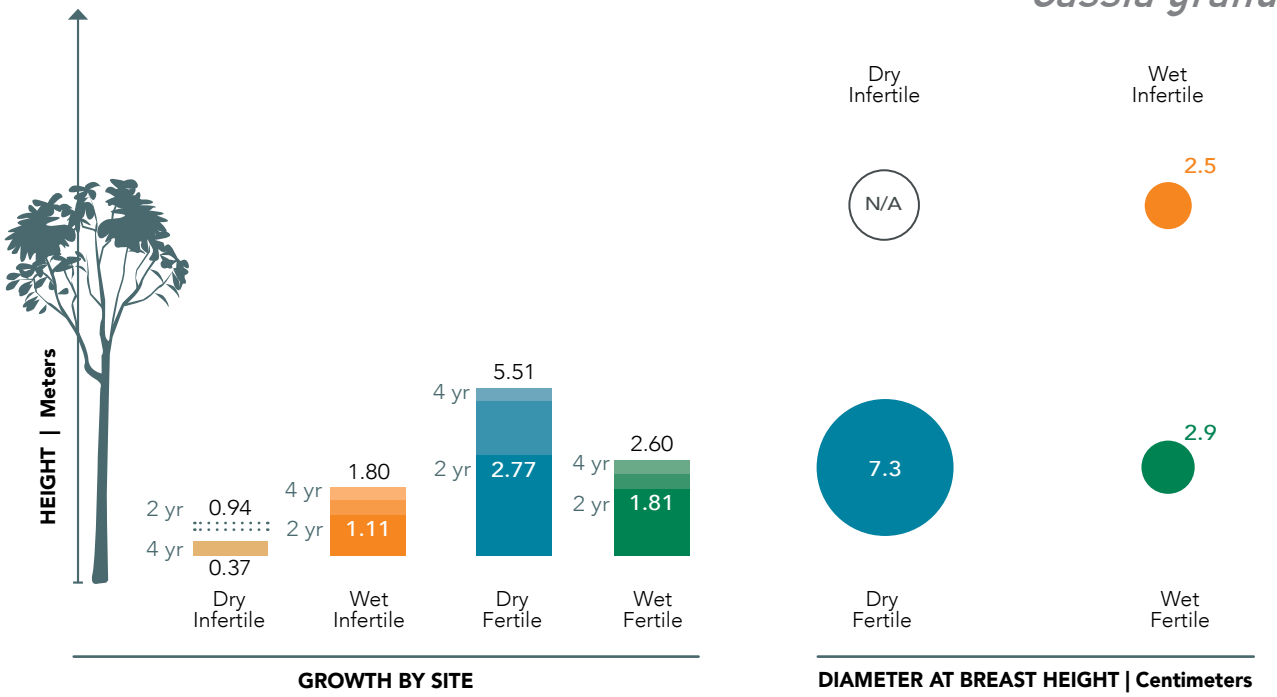
SPACING

Two-year crown diameter data suggest that spacing should be at least three meters on dry fertile sites, but can be less at other sites.

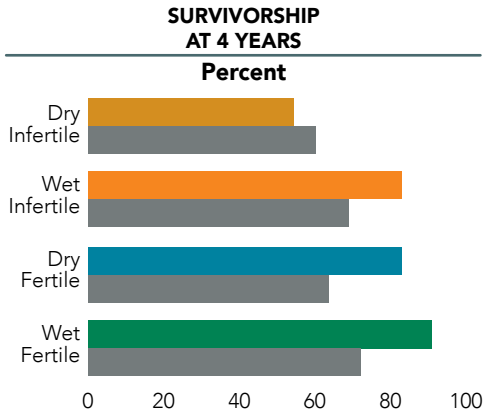
SELECTED USES

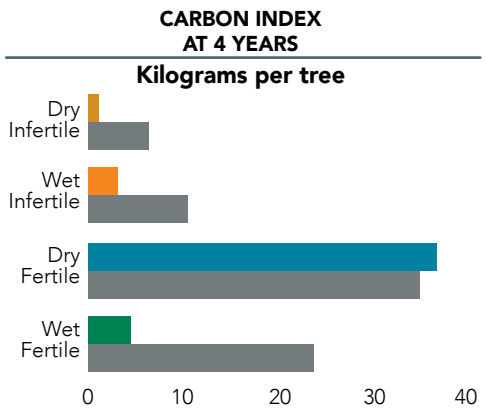
Carpentry, fence posts, firewood, fodder (fruits), human consumption (fruits, toasted seeds), medicines (leaves, fruits, seeds, bark), ornamental tree, dry-zone intercropping in agroforestry, mid-story or canopy in reforestation treatments.

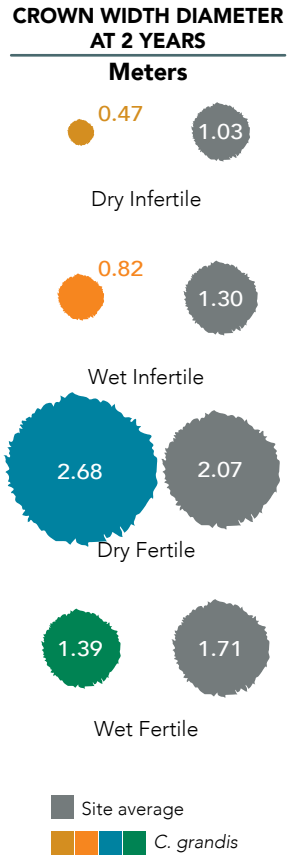
# *Cassia grandis*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Cassia moschata*

FAMILY

Fabaceae-Caesalpinioideae

COMMON NAMES

Casia amarilla, carao, caña fístula (Panama, Costa Rica).

DESCRIPTION

*Cassia moschata* is a small to medium (5 to 25 meters), deciduous tree found at low elevations in dry to moist forests from Mexico to Bolivia. In Panama it is common in dry secondary forests and along roadsides. In the PRORENA species selection trials it exhibited moderate survivorship, with highest survival at the wet infertile site. It grew best at the dry fertile and wet infertile sites. Four-year height growth was well above average at the wet infertile site, and equivalent to the average at the dry fertile one. Growth in the other two sites lagged far behind, with height growth well below average. With the exception of the wet fertile site, two-year crown diameters were far above the average, particularly at the wet infertile site. Its four-year carbon indices were below averages at all but the wet infertile site, where it was almost double the average.

RECOMMENDATIONS

Survival, growth, and carbon index values in the PRORENA trials suggest that this species can be used in moderate densities at wet infertile and perhaps dry fertile sites, where it can help provide relatively quick crown cover to shade the ground layer. It may also help create forest structure over time. It is unknown how the species will perform on particularly acidic soils.

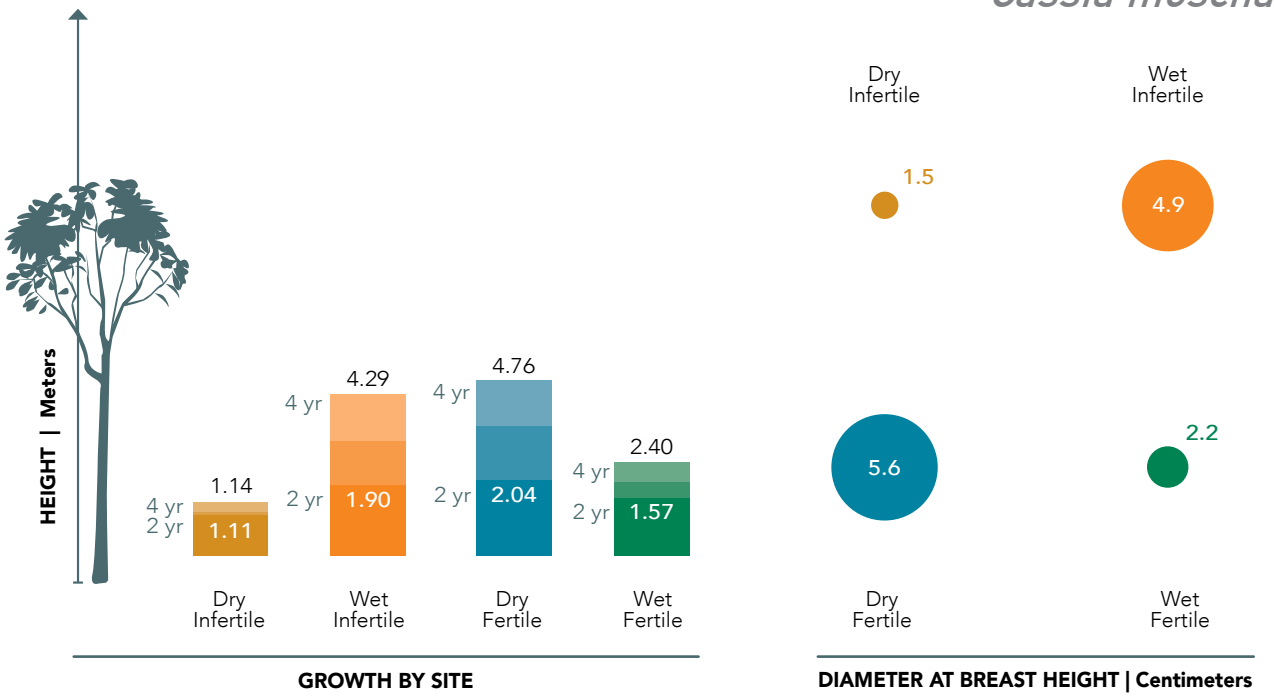
SPACING

Data suggest that at wet infertile sites and dry fertile sites this species can be planted three meters apart from neighbors. At other sites, spacing can be as close as two meters.

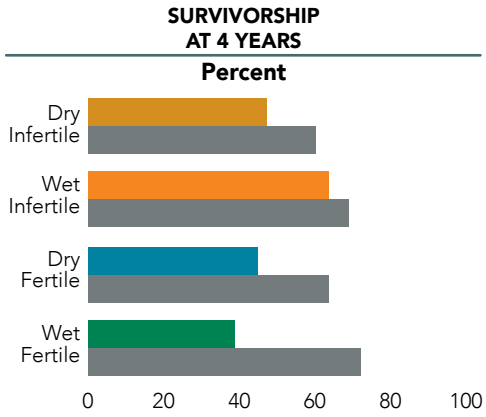
SELECTED USES

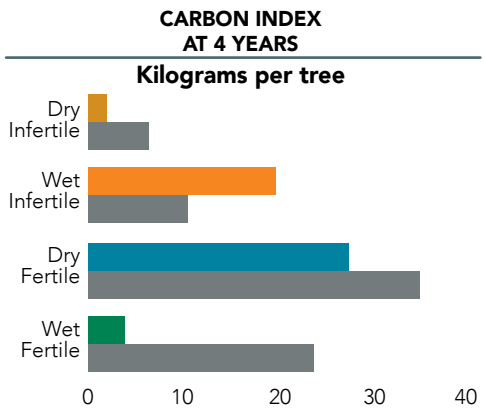
Fence posts, firewood, ornamental tree, early crown cover in reforestation, under- to mid-story structure in reforestation. It is believed to fix atmospheric nitrogen.

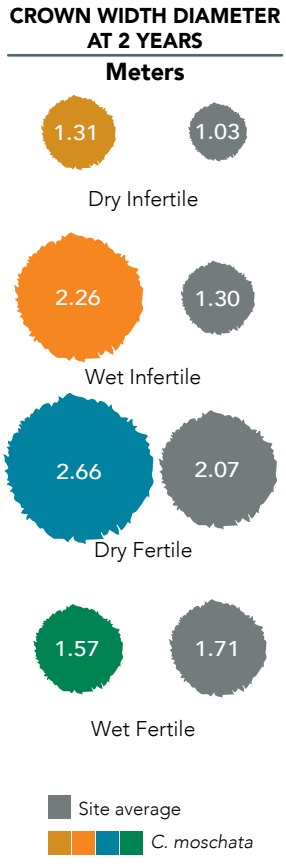
# *Cassia moschata*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Cedrela odorata*

FAMILY
Meliaceae

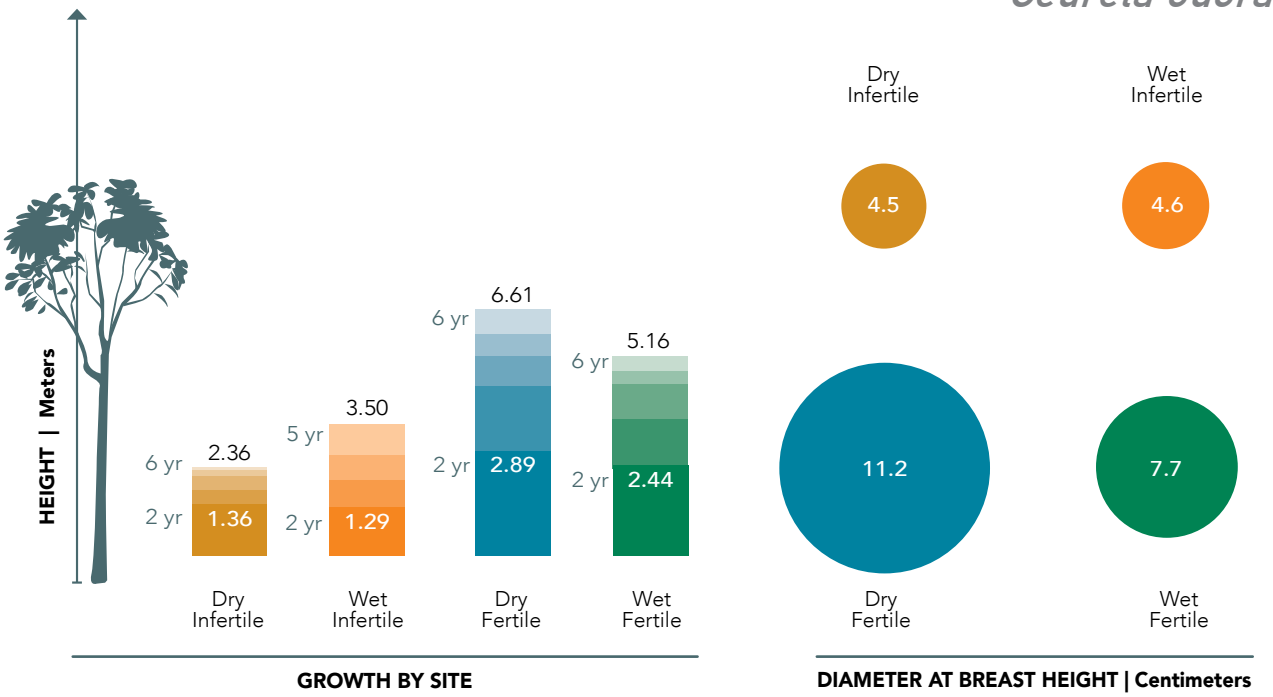
COMMON NAMES
Cedro, cedro amargo, cedro cebolla, cedro americano, cedro rojo (Panama, Central and South America).

DESCRIPTION
*Cedrela odorata* is a tall (25 to 35 meters), deciduous canopy tree found in dry to moist, lowland forests from Mexico to Argentina. In Panama it is common in dry forests on the Pacific coast. It survived best at the wet fertile site of the PRORENA species selection trials, and grew markedly better at fertile than infertile sites. Its best growth was at the dry fertile site. It tended to form very narrow crowns when very young, with a whirl or ball of compound leaves at the top, later followed by branching. Four-year height growth was well above average at the dry fertile site, and above average at the dry infertile and wet fertile sites. Two-year crown diameters were slightly higher than average at fertile sites, and slightly lower than average at infertile ones. Unless grown in very low densities, this species suffers from attacks by the shoot-boring caterpillars of the *Hypsipyla grandella* moth, even with regular insecticide treatment. The moth kills the leading shoot at the top of the tree, resulting in a crooked or wavy stem. The species' four-year carbon indices were slightly higher than averages at all but the wet fertile site, where it was lower than average.

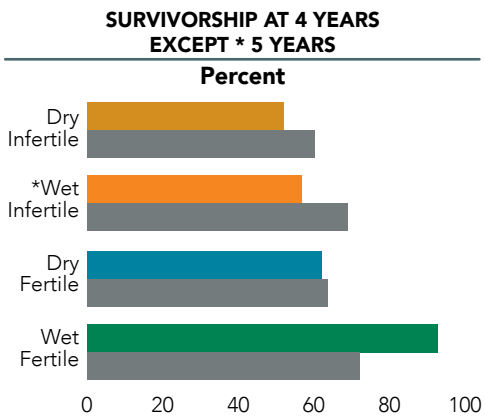
RECOMMENDATIONS
This species should always be grown at low densities, given its high susceptibility to attacks by *H. grandella*. Despite the species' high value on both local and international timber markets, it cannot be grown at high densities; however, regular pruning can help maintain a straight stem or bole for timber production. It can be grown on farms, and sometimes as a component of living fences. Despite its low four-year carbon indices, its medium wood density and relatively fast growth on appropriate sites suggest that it may still have carbon sequestration value in mixed-species reforestation treatments. It is useful in restoration and reforestation treatments as a future deciduous canopy species, and performs relatively well on dry sites, consistent with its natural distribution in dry forests. Other shade-tolerant tree species can exist beneath. It is compatible with slower growing evergreen species in intimate mixture.

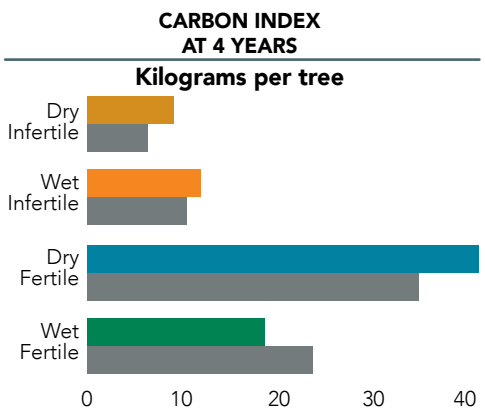
SELECTED USES
Canoes, construction, firewood, furniture (fine), handicrafts (fruits), living fences, medicines (roots, bark), musical instruments, ornamental tree, canopy structure in reforestation, carbon sequestration (long-term).

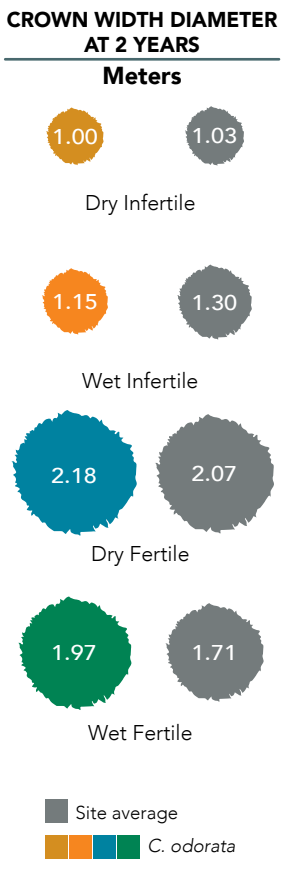
# *Cedrela odorata*




Diameter at breast height taken in the last year of height growth measurement




SPACING

To minimize the risk of insect attack and spread through a site, individuals of this species should be planted far apart from each other, as well as from related species. However, crown diameter data suggest that on fertile sites it can be spaced as close as two meters from neighbors of different species, and potentially closer on infertile sites, depending on the neighbors' growth rate.



SCIENTIFIC NAME

# *Cedrela tonduzii*

FAMILY
Meliaceae

COMMON NAMES
Cedro de montaña (Panama); cedro dulce (Costa Rica); cedro atlántico (Nicaragua).

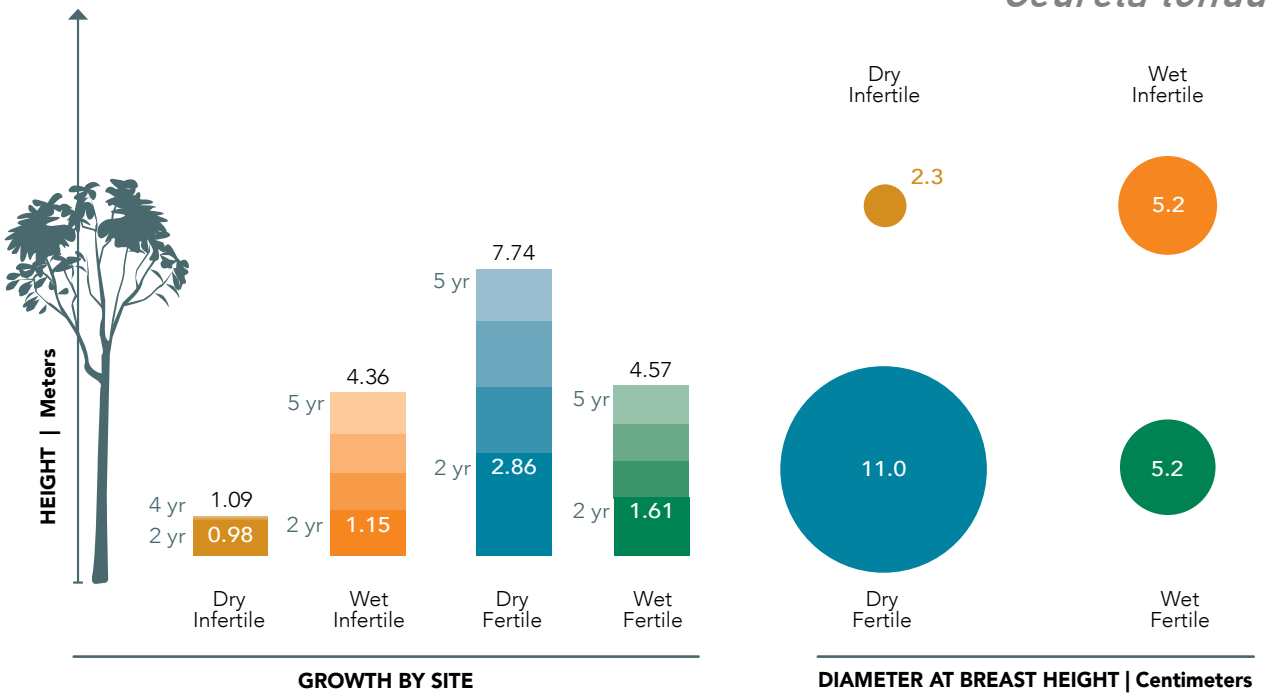
DESCRIPTION
*Cedrela tonduzii* is a tall (20 to 40 meters), deciduous tree found at mid- to high- elevations from Mexico to Panama. It is common in mature and secondary forests in the eastern part of Panama. It exhibited moderate to poor survivorship in the PRORENA species selection trials, with survival far below average at all sites. It grew best at the dry fertile site, and exhibited virtually equivalent height and diameter growth at the two wet sites. It formed narrow crowns early in life, with two-year crown widths far below average at all sites. Its four-year carbon indices were equivalent to the average at the wet infertile and dry fertile sites, and approximately half the average at the other two sites.

RECOMMENDATIONS
In the PRORENA trials, all sites were at low altitudes and apparently outside the tree's native range. Given its relatively good growth at the dry fertile site, and moderate carbon indices at this and the wet infertile site, it may be considered as part of reforestation treatments at similar sites. It may also be planted in low densities at wet fertile sites.

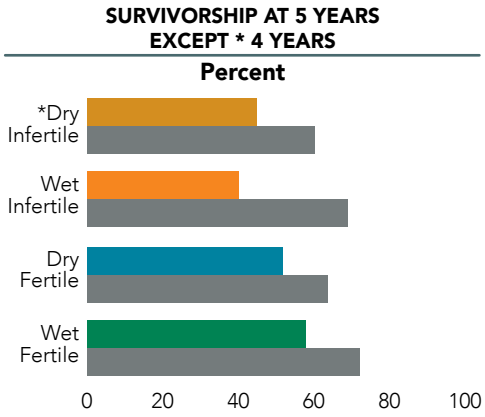
SPACING
Data from the PRORENA trials suggest this species should only be planted in low densities at low-altitude sites. It may do better at higher altitudes, where it might be planted at slightly higher densities. Like its relatives, this species suffers from attacks by the shoot borer moth, *Hypsipyla grandella*, and is thus best grown in intimate mixture with unrelated species. Like its relatives, it is a deciduous, shade-intolerant canopy tree that does well with subcanopy evergreen trees.

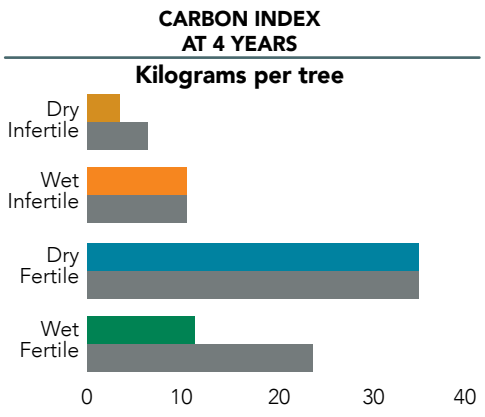
SELECTED USES
Construction, furniture (fine), musical instruments, carbon sequestration (long-term).

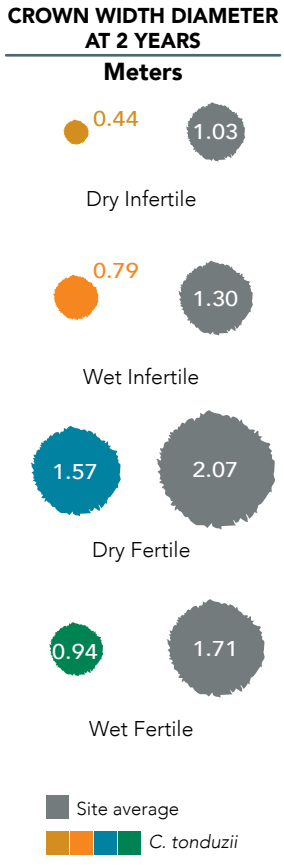
# *Cedrela tonduzii*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Chrysophyllum cainito*

FAMILY

Sapotaceae

COMMON NAMES

Caimito (Panama, Central America, Colombia, Peru); cainito (Brazil); canje (Ecuador); star-apple (Surinam, Curaçao, Trinidad and Tobago).

DESCRIPTION

*Chrysophyllum cainito* is a medium-sized (10 to 25 meters), evergreen tree found in low-elevation, dry to moist forests from Mexico to Argentina. In Panama it is common along rivers on the Pacific side of the mountains. It exhibited moderate to moderately high survivorship across all sites in the PRORENA species selection trials. It did best at the dry infertile site, with above-average survival. Height and diameter growth were far below averages at all sites, with best growth at the wet infertile one. This species had narrow crowns, with two-year crown diameters well below averages at all sites. Four-year carbon indices were lower than averages at all sites.

RECOMMENDATIONS

Despite its relatively high survivorship, the full-sunlight conditions of the PRORENA trials hampered this species' growth, in contrast with the rapid growth reported for nursery seedlings. The data suggest that it may do better as an under-planting in partial shade, and can be used as a component of reforestation and restoration treatments when conditions are similar to the wet infertile and dry fertile sites of the PRORENA trials. Its edible fruits may help attract animals.

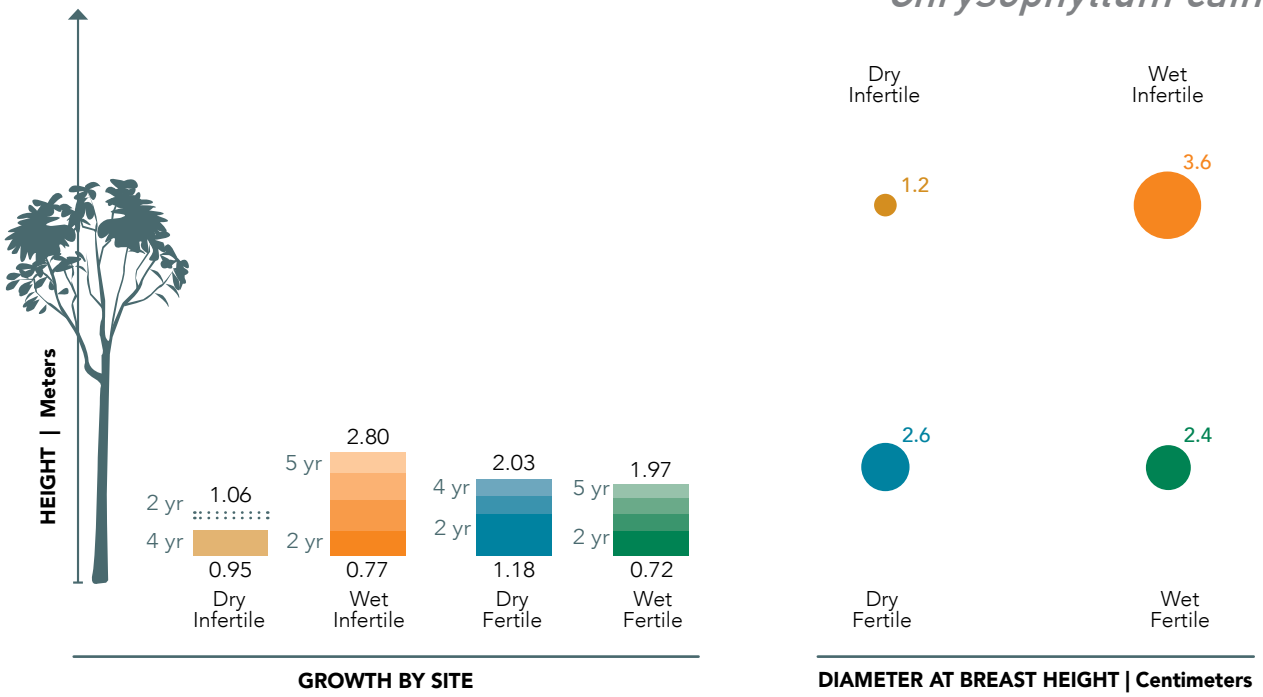
SPACING

Data from the literature and the PRORENA trials suggest good growth in partial shade, indicating that this species should be spaced within two meters of neighbors, and possibly closer when planted next to narrow, thin-crowned, or deciduous species.

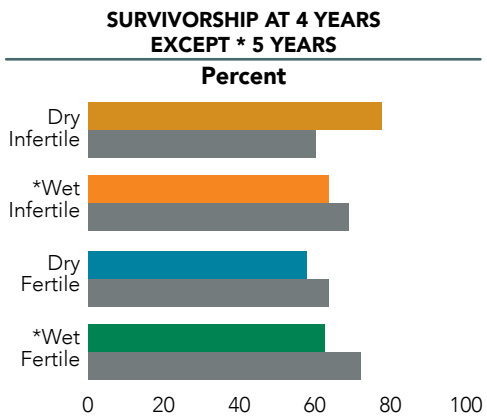
SELECTED USES

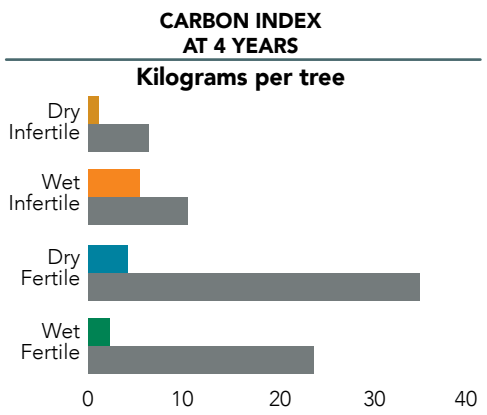
Furniture, human consumption (fruits), medicines (fruit), ornamental tree, posts, pulp for paper, tannery (bark), tool handles, attracting animal diversity, shade tree.

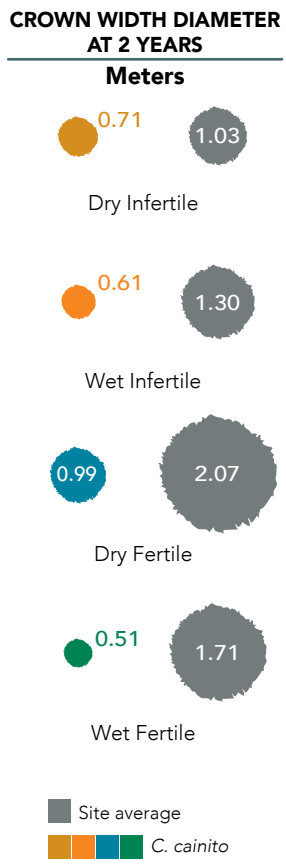
# *Chrysophyllum cainito*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Cinnamomum triplinerve*

FAMILY
Lauraceae

COMMON NAMES
Sigua, sigua blanca (Panama, Costa Rica); avispillo (Puerto Rico); aguacatillo, boniatillo (Cuba); laurel (Colombia); moena (Peru).

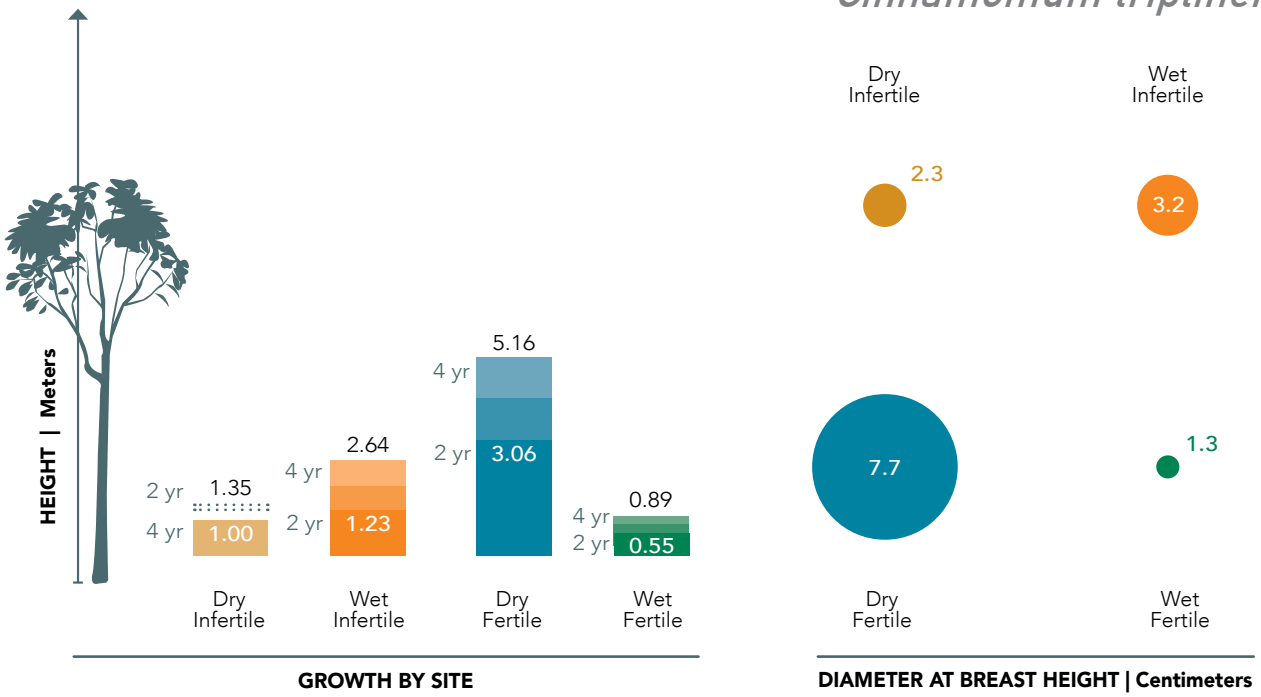
DESCRIPTION
*Cinnamomum triplinerve* is a medium to tall (10 to 30 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Guatemala to Paraguay. It exhibited poor to moderate survivorship in the PRORENA species selection trials, with lowest survival at the wet fertile site. Highest survival was still below average at the wet infertile site. Best height and diameter growth was at the dry fertile site, with height growth above average and vastly out-performing the species' growth at other sites. Second-best growth was at the wet infertile site. It formed narrow crowns, with two-year crown diameters far below averages at all sites. Its highest four-year carbon index, at the dry infertile site, was still below the site average.

RECOMMENDATIONS
Data from the PRORENA trials suggest that this species performs relatively better on dry fertile sites, where it might be incorporated into reforestation and restoration treatments in low densities, with the goal of becoming a part of the canopy community. As this species grew very slowly in the nursery and required shade for early development, it might do better in at least partial shade when planted out.

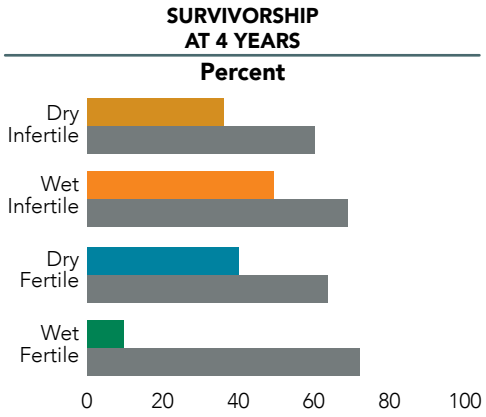
SPACING
Data from the literature and the PRORENA trials and nursery suggest that this species can be grown as close as one meter to neighbors so it can develop under shade. It will eventually become a canopy species.

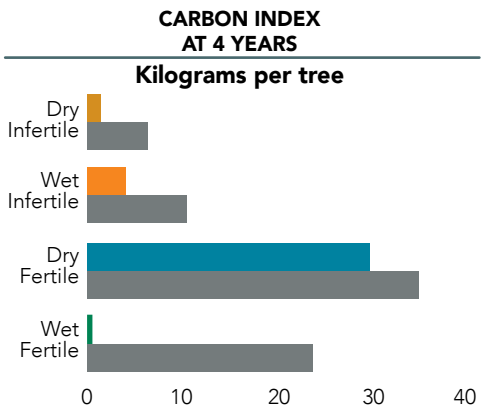
SELECTED USES
Bridges, construction, flooring, living fences, canopy structure in reforestation.

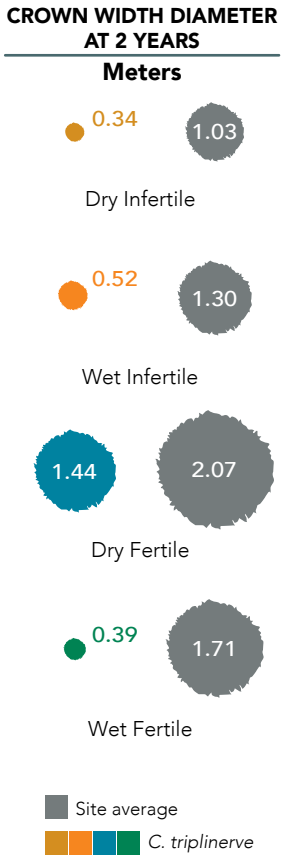
# *Cinnamomum triplinerve*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Colubrina glandulosa*

FAMILY
Rhamnaceae

COMMON NAMES
Carbonero, frio (Panama, Costa Rica); shaina (Peru); caçoca, falso-pau-brasil (Brazil).

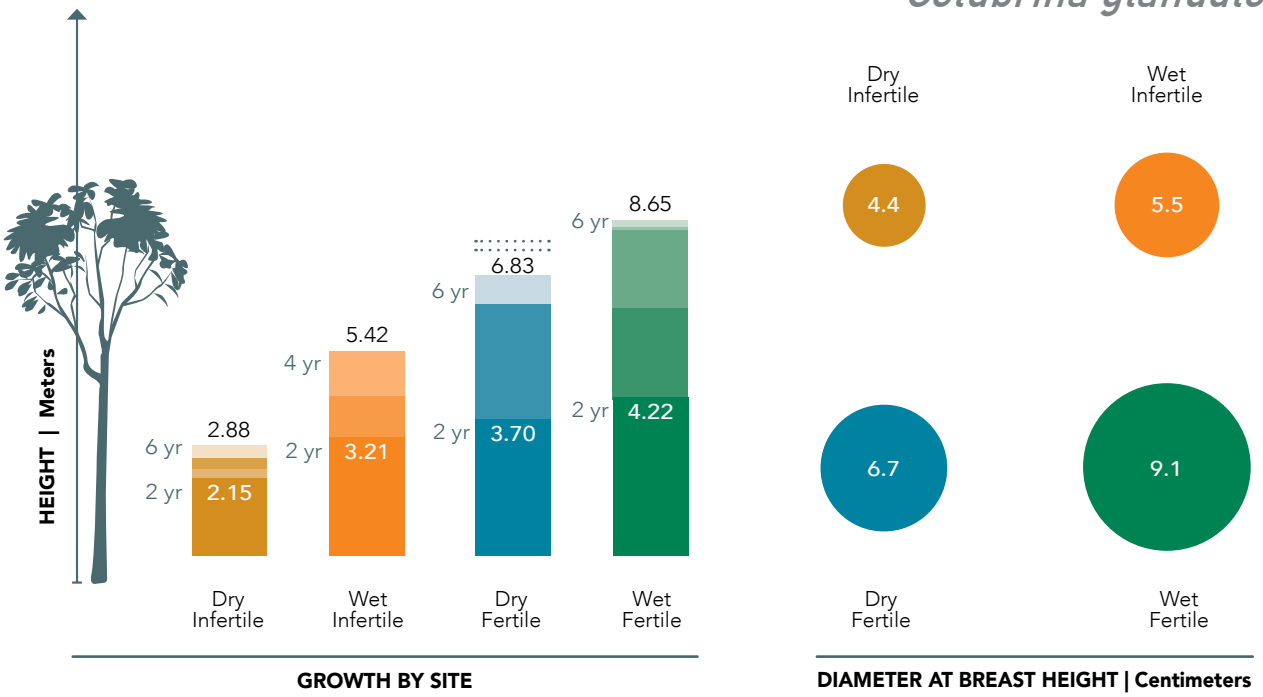
DESCRIPTION
*Colubrina glandulosa* is a medium-sized (10 to 25 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Panama to Bolivia. It exhibited above-average survivorship at all but the dry infertile site of the PRORENA species selection trials, with highest survival at wet sites. Its best height and diameter growth were at the wet fertile site, but height growth stagnated after four years, possibly due to intense competition from neighbors. Growth was also good at the wet infertile site. While it initially grew well at the dry fertile site, it experienced a decline in height growth after four years. Height was far above averages at all sites. This species had a broad crown. Two-year crown diameters were wider than averages at all sites. Notably, the crown diameters were double the averages at the wet sites. Four-year carbon indices exceeded averages at all but the dry infertile site, and was more than twice the average at the wet fertile site.

RECOMMENDATIONS
This species' broad two-year crowns suggest it can help provide shade relatively rapidly. Its high survivorship and growth, particularly in wet sites, suggest it can be an important component of reforestation and restoration treatments under similar conditions, contributing early to crown closure with relatively tall trees that will eventually be surpassed by other canopy trees.

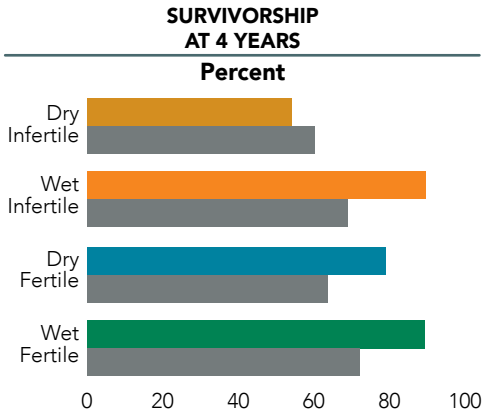
SPACING
Given its broad crowns, it should not be grown closer than six meters to trees of the same species or with similar crown characteristics. It can be spaced three meters apart from other species at moderate densities.

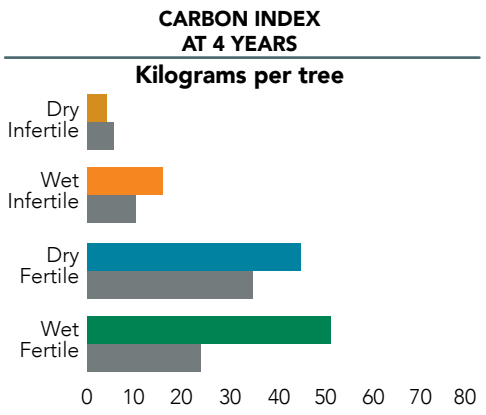
SELECTED USES
Bridges, construction, posts, shade tree, early crown cover in reforestation, mid-story structure in reforestation, nurse tree for shade-tolerant species.

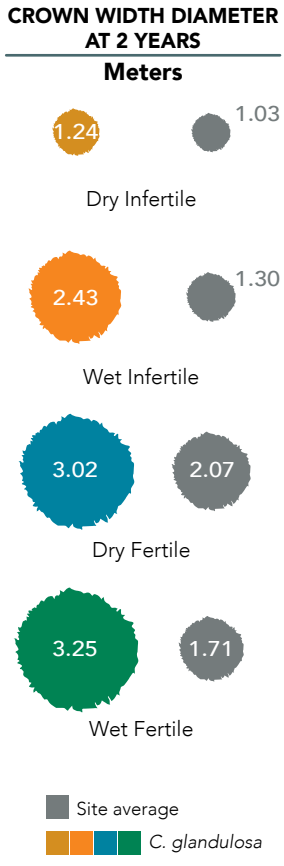
# *Colubrina glandulosa*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Copaifera aromatica*

FAMILY
Fabaceae-Caesalpinioideae

COMMON NAMES
Cabimo (Panama, Venezuela); camíbar (Costa Rica, Nicaragua).

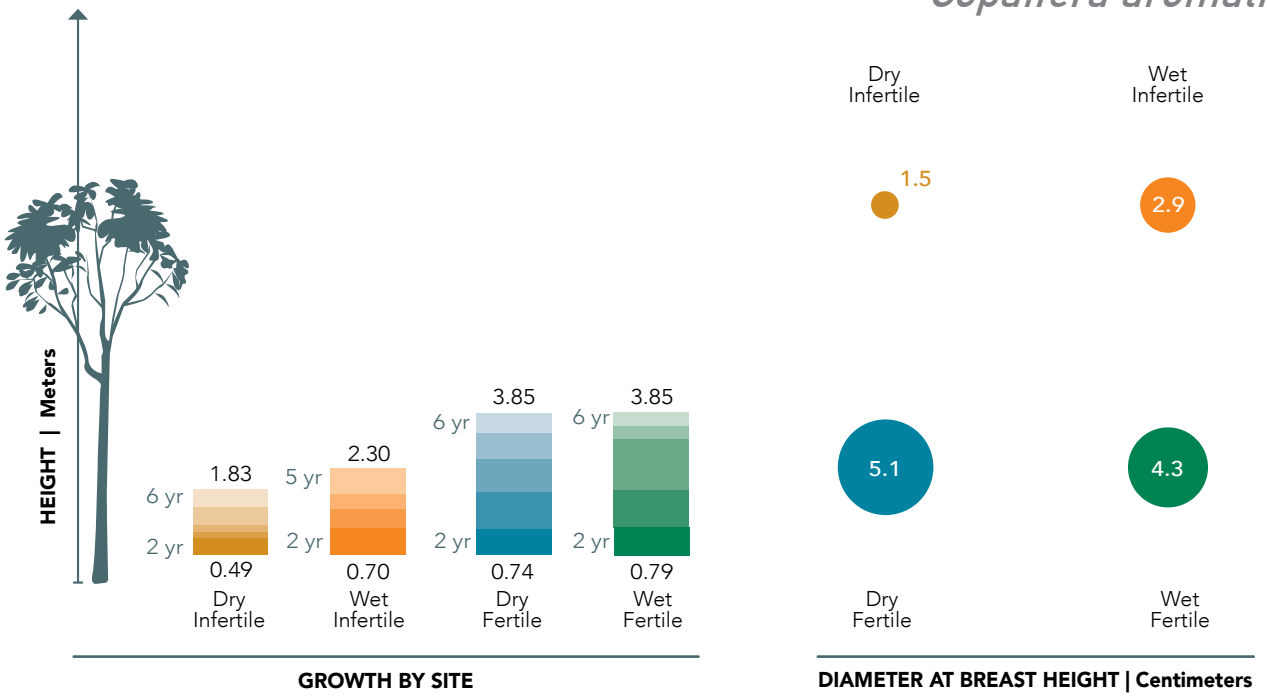
DESCRIPTION
*Copaifera aromatica* is a medium-sized (10 to 30 meters), evergreen tree found in low- to mid-elevation, dry to wet forests from Nicaragua to Venezuela. In Panama it is common along rivers and streams of the Pacific side of the mountains. It exhibited moderately low to moderately high survivorship in the PRORENA species selection trials, with highest survival at the wet infertile site. Height was below average at all sites, with best height and diameter growth at the fertile ones. It formed relatively narrow crowns, with two-year crown diameters far below averages at all sites. Four-year carbon indices were far below averages at all but the wet infertile site, which was only slightly below average.

RECOMMENDATIONS
As a future mid-canopy, late-successional evergreen tree, this species can be used in reforestation and restoration treatments at all sites except those that are dry infertile. It may be particularly useful in plantings at wet infertile sites similar to those of the PRORENA trials. Given its somewhat slower growth and narrow crown, it is not recommended to help create rapid forest cover at a site but for underplanting beneath a faster growing, light-shaded canopy.

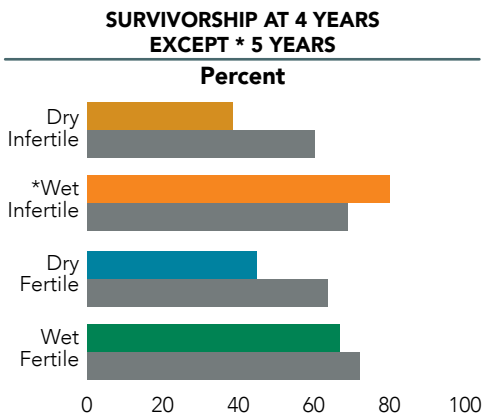
SPACING
This species can be grown as close as three meters to neighbors of the same or other species, but it will be overtopped by fast-growing trees with broad crowns.

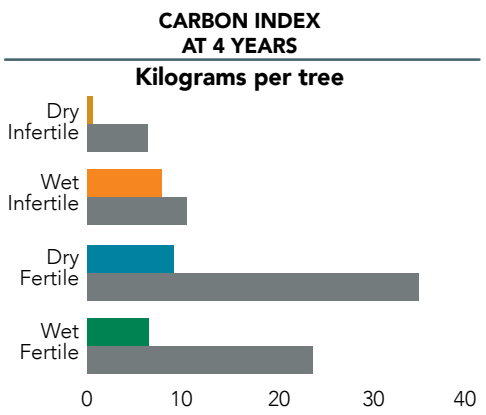
SELECTED USES
Bridges, cabinetry, carpentry, construction (heavy), floorboards, medicines (resin), mid-story structure in reforestation.

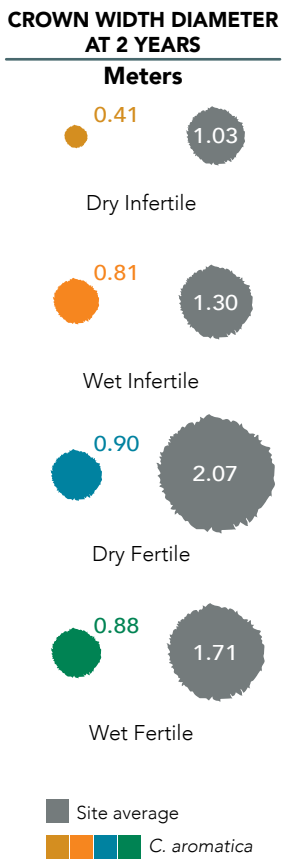
# *Copaifera aromatica*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Cordia alliodora*

FAMILY

Boraginaceae

COMMON NAMES

Laurel, laurel negro, muñeco (Panama); bojón (Mexico); vara de humo (Colombia); laurel blanco (Venezuela); louro (Brazil); picana (Bolivia); peterebi (Argentina).

DESCRIPTION

*Cordia alliodora* is a small- to medium-sized (5 to 25 meters), deciduous tree found in low- and mid-elevation, dry to wet forests from Mexico to Argentina. In Panama it is common in secondary forests on the Pacific side of the mountains. It exhibited moderate to moderately high survivorship in the PRORENA species selection trials. It performed best at the dry fertile site, with highest survival as well as nearly double the height and diameter growth values of the next-best performing site. Its four-year height was far above average at the dry fertile site, and slightly above average at the wet infertile site. It has relatively narrow crowns, with two-year crown diameters close to average at all sites. Its four-year carbon indices were below averages at all sites.

RECOMMENDATIONS

The data suggest that this species will perform best in restoration and reforestation treatments where conditions are similar to those of the PRORENA trials' dry fertile site. It may also be incorporated into treatments on wet sites. Despite its moderate survivorship at the dry fertile site, its steady decline in height growth suggests that it would not be useful in moisture- and nutrient-stressed sites in the long term. Given its crown width, it would not be useful in high densities when obtaining early crown closure is a management objective. Although its carbon indices were below averages, its sustained growth nevertheless makes it worth considering in mixture plantings with the goal of carbon sequestration in the first decades of forest development.

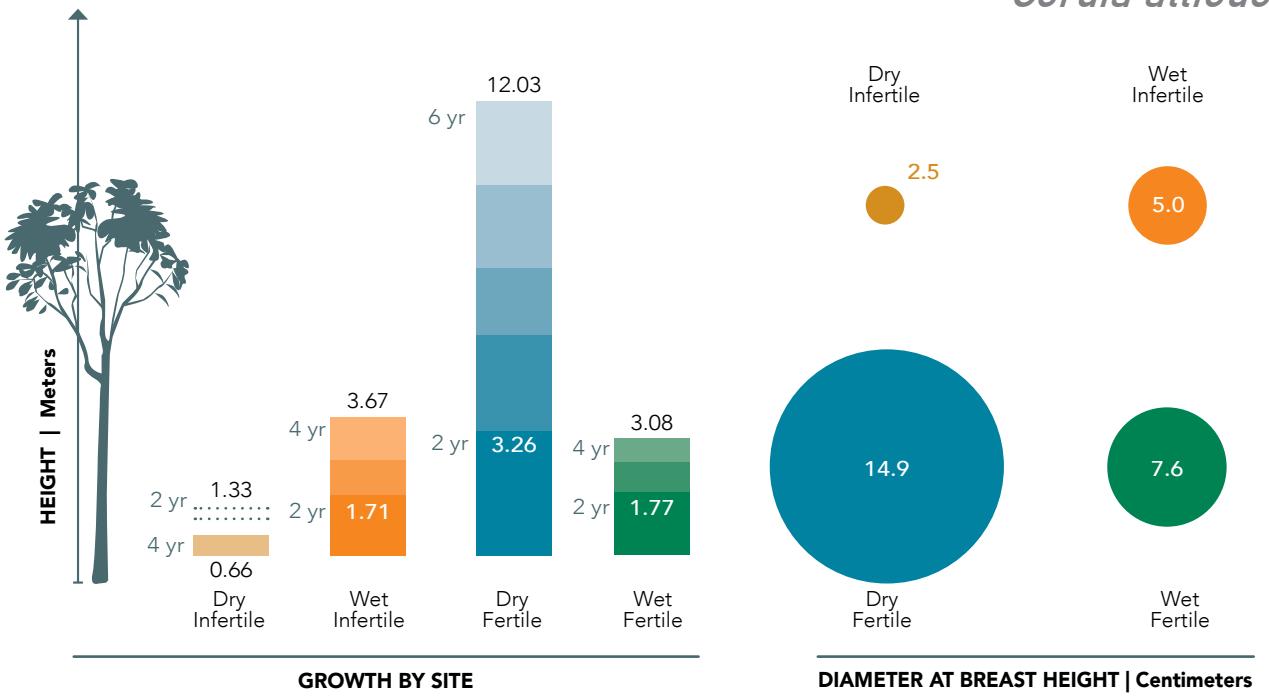
SPACING

Data from the literature and the PRORENA trials suggest that this species can be planted as close as two meters to neighbors. On sites where it grows exceptionally well, neighboring species should be shade-tolerant.

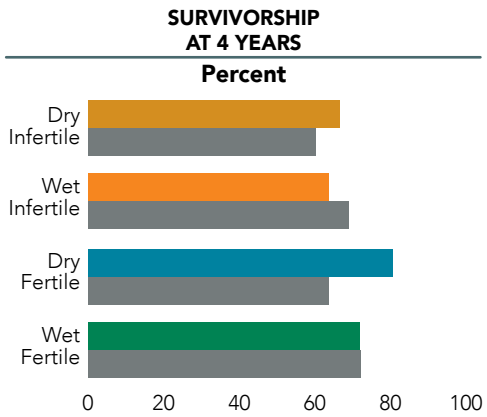
SELECTED USES

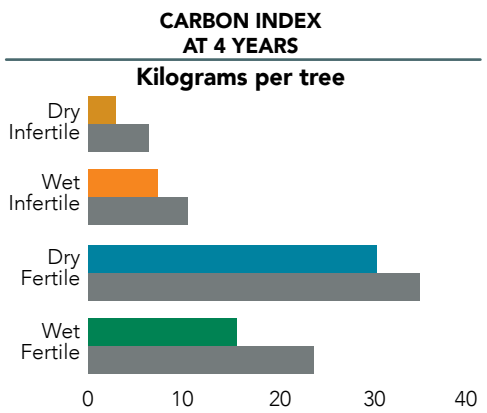
Fence posts, flooring, furniture, medicines (leaves), veneer, carbon sequestration (long-term), shade tree (coffee or cacao plantations).

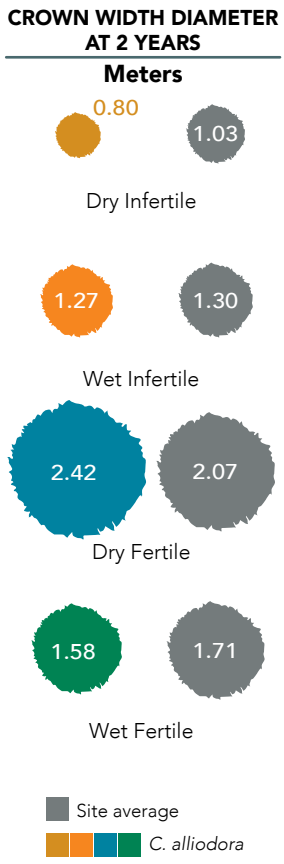
# *Cordia alliodora*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Dalbergia retusa*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Cocobolo (Panama, Costa Rica); funera (El Salvador); granadillo, rosul (Guatemala); granadillo negro, palo negro (Honduras); guacibán (Mexico).

DESCRIPTION

*Dalbergia retusa* is a medium-sized (10 to 20 meters), deciduous species found in the canopy of low-elevation, dry to wet forests from Mexico to Colombia. In Panama it is common in dry forests. It exhibited high survivorship across all sites in the PRORENA species selection trials. It grows relatively well on most well-drained sites, with remarkably little variation between most locations in the PRORENA trials. In the Agua Salud plantation it grew relatively well even in the most nutrient-stressed plots, showing no growth difference between monocultures and mixtures at five years. Four-year heights exceeded averages at all sites in the PRORENA trials, with differences particularly pronounced at the infertile sites. In plantations it formed multiple stems from the base, tending to look more like a shrub than a potential canopy tree in its early years. The resulting broad crown far exceeded two-year crown diameter averages at all sites. Its deciduousness and thin crown allow abundant light to reach the understory, allowing grasses and weeds to persist when planted in pastures. Owing in part to its high wood density, its four-year carbon indices far exceeded the averages at all but the wet fertile site, which still had an above-average value for the index. The species fixes nitrogen, and is very water-use efficient.

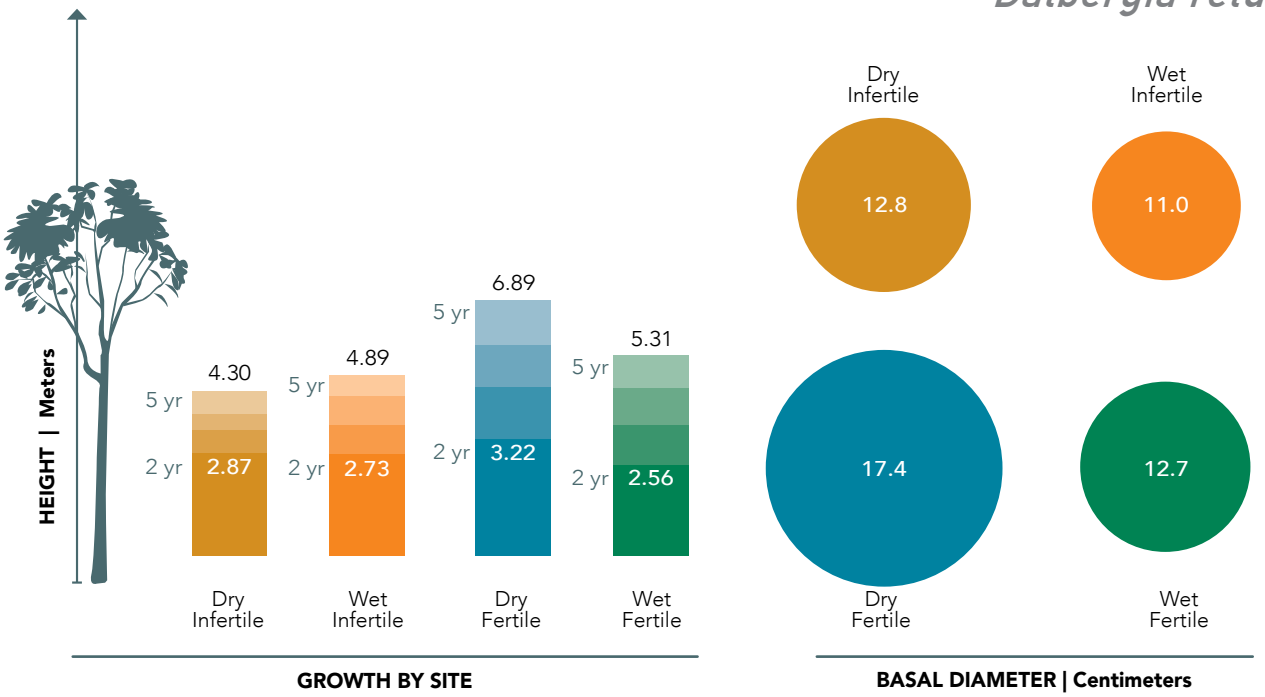
RECOMMENDATIONS

This is an exceedingly valuable timber species when harvested in mature forests. Current markets also seem to accept small stems and poor form, as it is also a highly desired craft wood. Pruning can have a positive effect on the tree's form in plantations, and planting with fast-growing species with broad crowns might likewise help reduce the number of stems it forms. Given its ability to grow well on drought- and nutrient-stressed sites, it is well suited for use in mixtures aimed at restoring such areas. It is a nitrogen-fixing species and thus may enhance nutrient cycling.

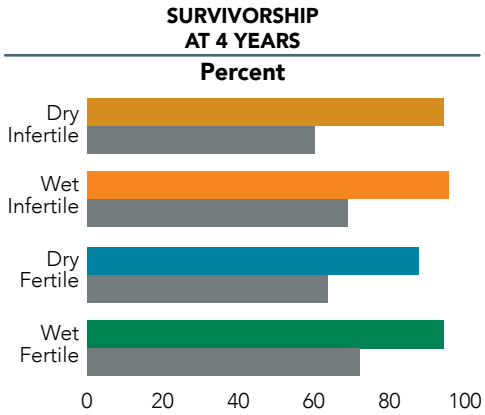
SELECTED USES

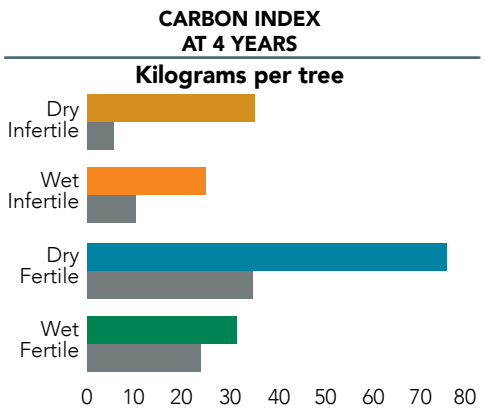
Furniture (fine), handicrafts (fine), nurse tree for shade-tolerant species, carbon sequestration, potential soil improvement through nitrogen fixation and use as green manure.

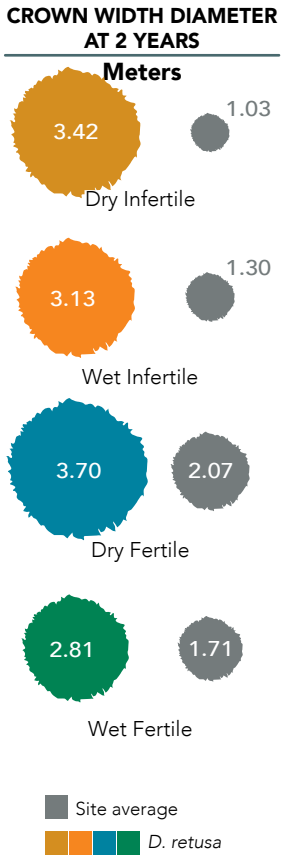
# *Dalbergia retusa*




Basal diameter taken at same age as maximum height




It can also contribute to carbon sequestration. This combination of uses suggests it can provide multiple benefits in agroforestry systems.

## SPACING

This species can be grown three meters apart from all but the fastest growing, broad-crowned species, unless the objective is to improve form. In such instances it can be planted within two meters or less, as long as managers are prepared to thin its neighbors over time. It may also be grown close to species requiring partial shade, as its thin crowns allow light to penetrate the understory.



SCIENTIFIC NAME

# *Diphysa americana*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Macano, cacique (Panama); guachipelín (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua).

DESCRIPTION

*Diphysa americana* is a small (5 to 15 meters), deciduous tree found at low elevations in dry to moist forests from Mexico to Panama. It exhibited high to very high survivorship across all sites of the PRORENA species selection trials, with virtually no mortality at the dry fertile site. Its best height and diameter growth were at the fertile sites, but with apparent height-growth stagnation in the wet fertile site at four years. Growth at the dry infertile site was good, but it did experience dieback there. Four-year height growth was far above averages at all but the wet infertile site. It formed broad crowns, with two-year crown width more than double the averages at all but the wet infertile site, where it was still higher than average. Four-year carbon indices far exceeded averages at all but the wet infertile site, and more than doubled the averages at the wet fertile and dry infertile sites.

RECOMMENDATIONS

High survivorship at all sites in the PRORENA trials suggests that this species is an excellent candidate for a broad range of reforestation and restoration projects. Its rapid height and crown growth suggest that it will help provide early shade and vertical stratification at sites. It may not do well on particularly acidic soils on wet sites, and should be tested in such conditions before attempting high-density plantings. Its very high carbon indices on all but the wet infertile site suggest that it could help sequester carbon early in reforestation treatments where this is a management objective. Since it can also fix atmospheric nitrogen, it may help improve ecosystem nitrogen status on sites where this limits forest growth.

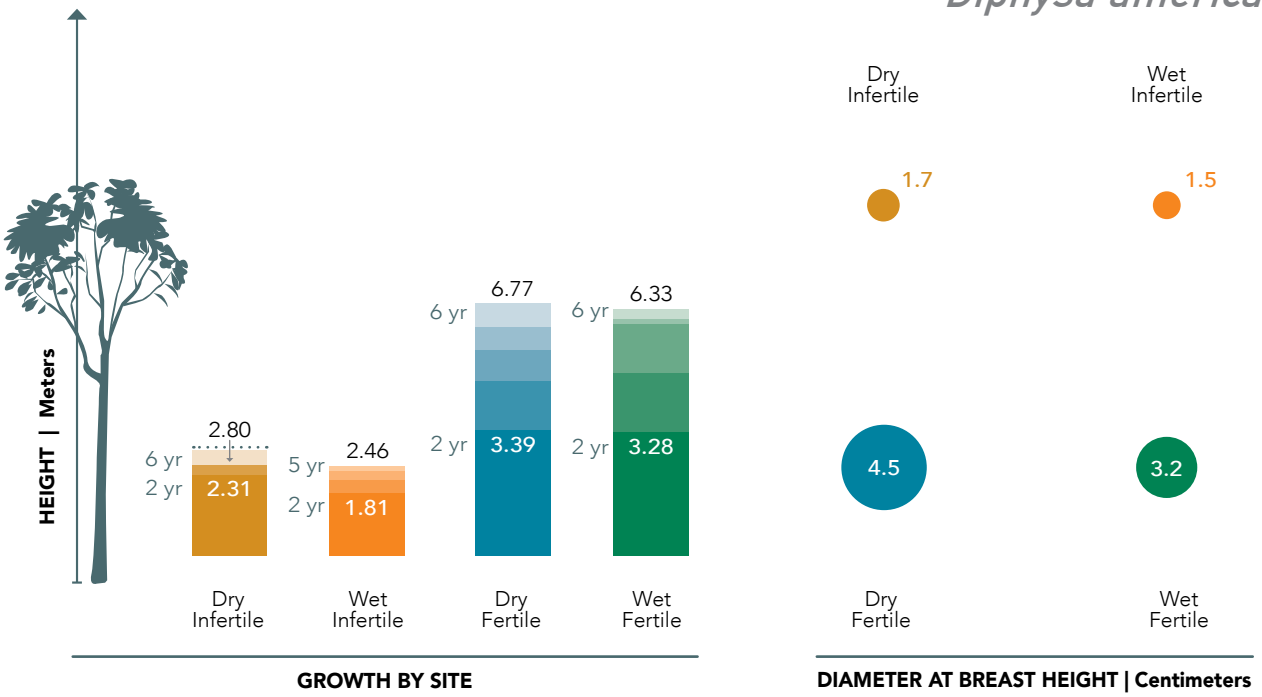
SPACING

This species has broad crowns and so should not be grown closer than three meters to neighbors, unless they are shade-tolerant species.

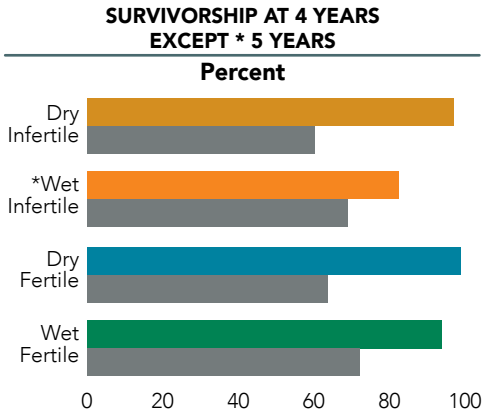
SELECTED USES

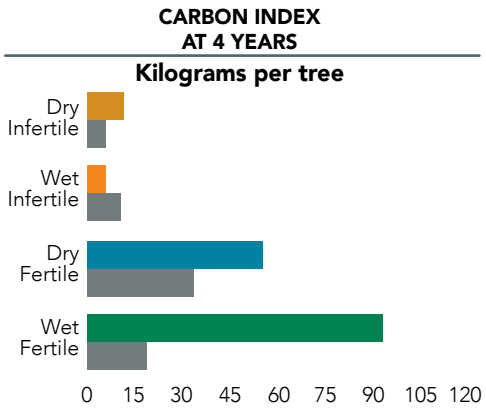
Cabinetry, carpentry, construction (rural), fence posts, ornamental tree, tool handles, pillars, carbon sequestration (early), early crown cover in reforestation, early stand structure in reforestation, potential soil improvement through nitrogen fixation and use as green manure.

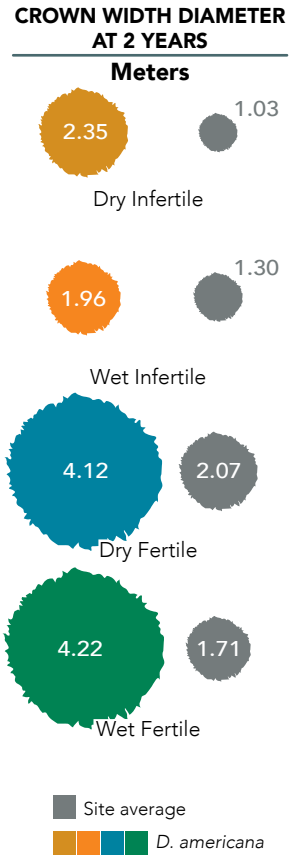
# *Diphysa americana*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Dipteryx oleifera*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Almendro, almendro de montaña (Panama, Costa Rica, Nicaragua); choibá (Colombia).

DESCRIPTION

*Dipteryx oleifera* is a tall (20 to 40 meters), deciduous tree found in low- to mid-elevation, moist and wet forests from Nicaragua to Panama. It exhibited moderate to very poor survivorship in the PRORENA species selection trials, with the highest survival at the wet sites. Height and diameter growth were slightly better in the dry fertile site, but less than 45 percent of the individuals survived to four years there. Height and diameter growth were slightly better at the wet fertile site than the wet infertile one. Four-year height growth was close to or slightly higher than averages at all but the dry infertile site. It tended to form narrow crowns early in growth, with two-year crown diameters well below averages at all sites. Its four-year carbon indices were well below averages at all but the wet infertile site, where it was slightly below average. This species has been grown successfully in enrichment plantings and may do better with partial shade than in the full-sunlight conditions of the PRORENA trials.

RECOMMENDATIONS

This is a very high-value timber species that appears to fare better at wet sites. It is very long-lived and may grow better in moderate shade than in full sunlight. Its narrow crown suggests it is not a good choice to plant in high densities when there is a need to overcome tall grasses in reforestation treatments. However, its height and long lifespan suggest that it can be an important component of the canopy. Its fruits are eaten by large frugivores, such as macaws and tapirs, and may help attract these species back to a restored forest.

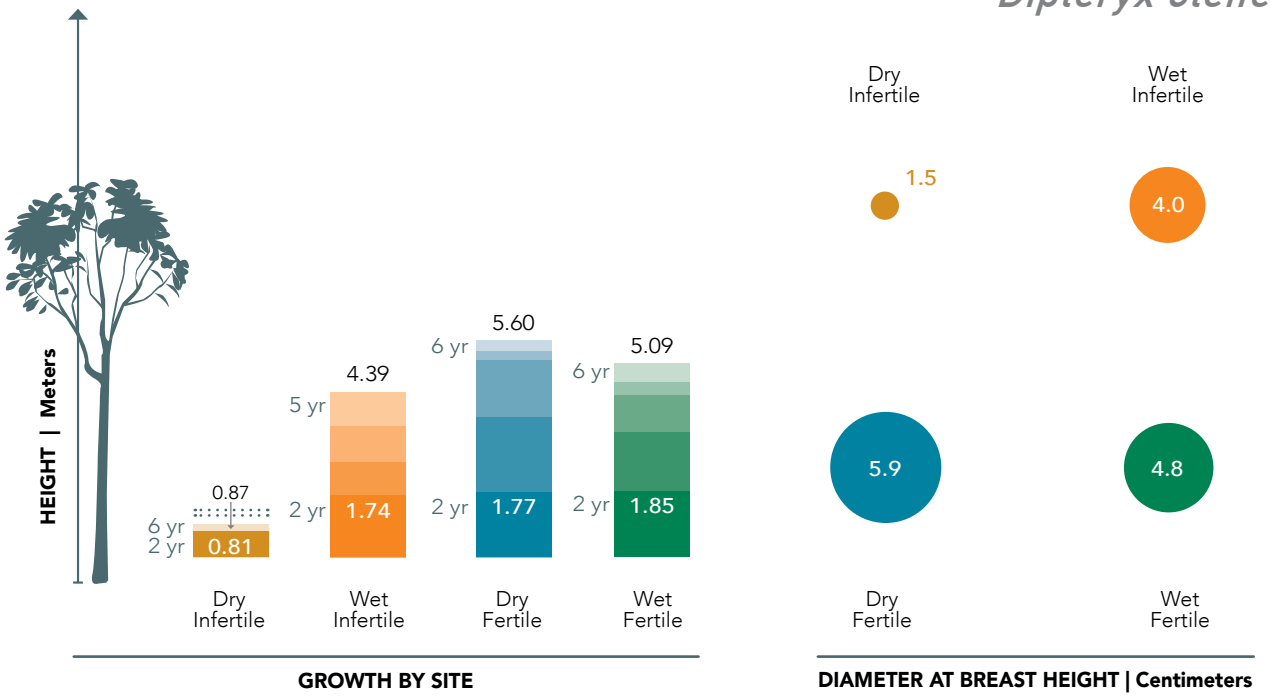
SPACING

Data from the literature and the PRORENA trials suggest that this species can be planted two meters apart from neighbors. However, since seeds are hard to acquire and germinate, it is better to grow individuals at least nine meters apart to avoid the need to thin aggressively over time.

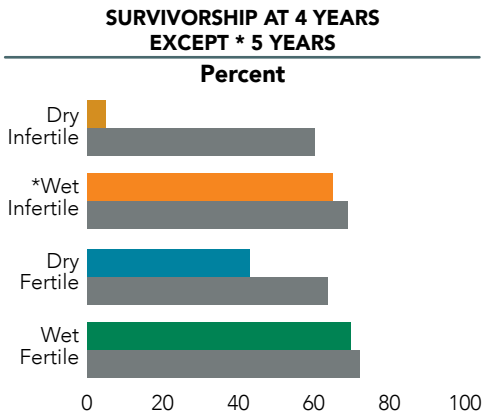
SELECTED USES

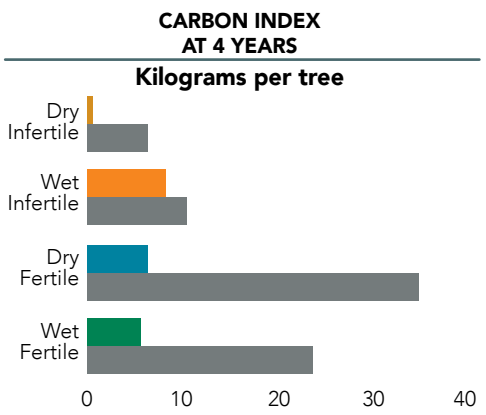
Bridges, construction (naval), flooring, framing structures in tunnels and mines, handicrafts, human consumption (toasted seeds), railroad ties, tool handles, attracting animal diversity, canopy structure in reforestation. It is believed to be a nitrogen-fixing species and thus may help improve ecosystem nitrogen status.

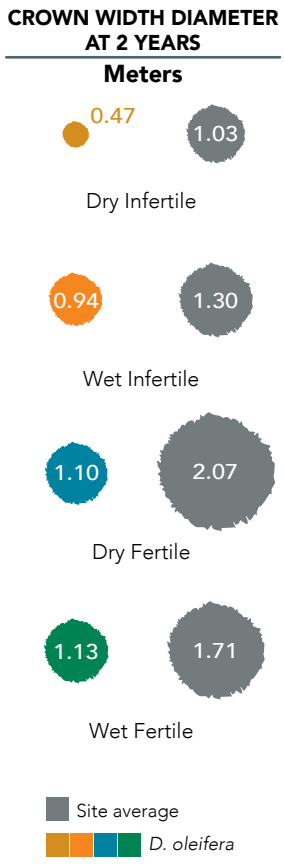
# *Dipteryx oleifera*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Enterolobium cyclocarpum*

FAMILY

Fabaceae-Mimosoideae

COMMON NAMES

Corotú (Panama); guanacaste (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Mexico); carocaro (Venezuela).

DESCRIPTION

*Enterolobium cyclocarpum* is a tall (20 to 35 meters), deciduous tree found in low-altitude, dry to moist forests from Mexico to Venezuela. It exhibited low to very high survivorship across the PRORENA species selection trials, with poor survival at the dry infertile site and high to very high survival at the fertile sites. It grew far better at the fertile sites than the infertile ones. Height and diameter growth were better at the dry fertile site than the wet fertile one. Its four-year height growth was above averages at the fertile sites, and roughly equivalent to the average at the wet infertile site. Despite above-average height growth, it experienced dieback at the dry infertile site. It formed broad, deep crowns when grown in the open, with two-year crown diameters exceeding averages at all sites. Four-year carbon indices were far higher than averages at all but the wet infertile site, where it was approximately two-thirds the site average.

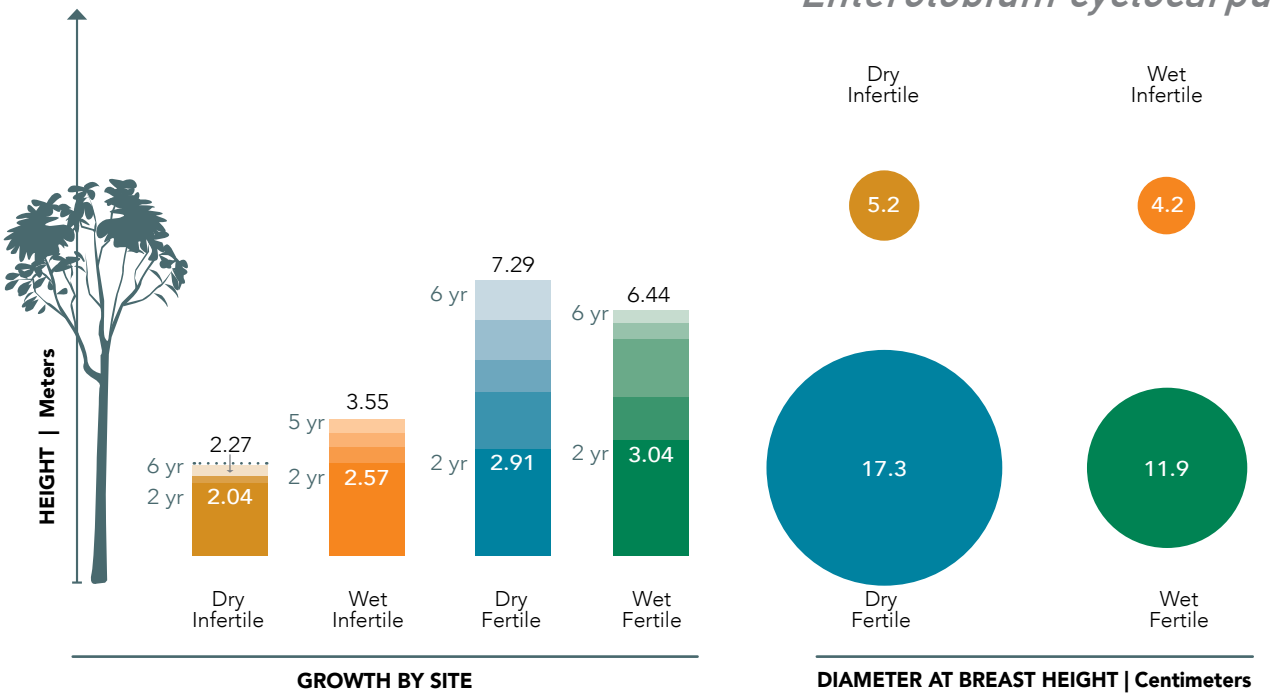
RECOMMENDATIONS

This is a multi-use species that serves as a forage and shade tree in pastures, where it develops a broad, spreading crown at maturity. Data from the PRORENA trials suggests it is well suited for restoration and reforestation treatments on fertile sites, where its nitrogen-fixing ability may also help improve soil quality. Its high carbon indices on the fertile as well as dry infertile sites suggest that it would be a useful species for early carbon capture on sites with similar conditions. However, low survivorship on the dry infertile site suggests that it should only be planted in low densities to lower the risk of mortality under such conditions. It is not recommended for wet infertile sites, where it reportedly suffers high mortality and poor growth due to moist, acidic, and infertile conditions. Its broad crown at two years indicates that it can help create early crown closure at all sites.

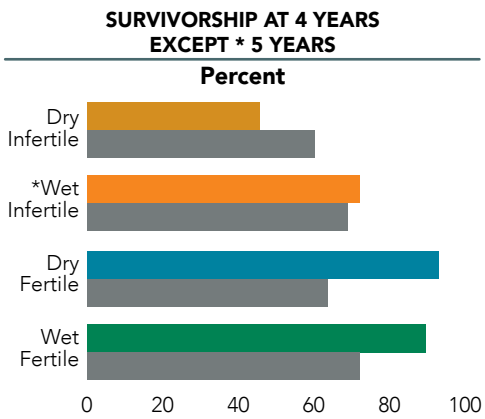
SELECTED USES

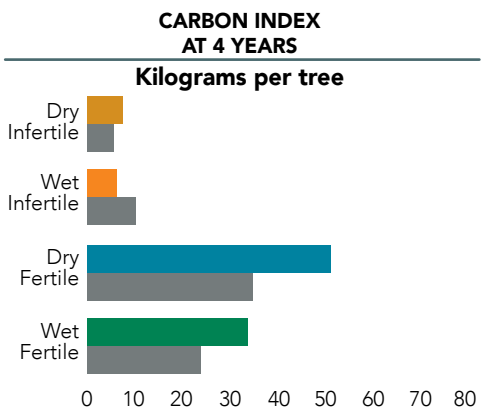
Boxes, boat construction, cabinetry, carpentry, fence posts, firewood, fodder (fruits), handicrafts (seeds), human consumption (toasted seeds), medicines (resin), ornamental tree, pulp for paper, carbon sequestration (early), early crown cover in reforestation, nurse tree for shade-tolerant species, shade tree (in pastures), potential soil improvement through nitrogen fixation and use as green manure.

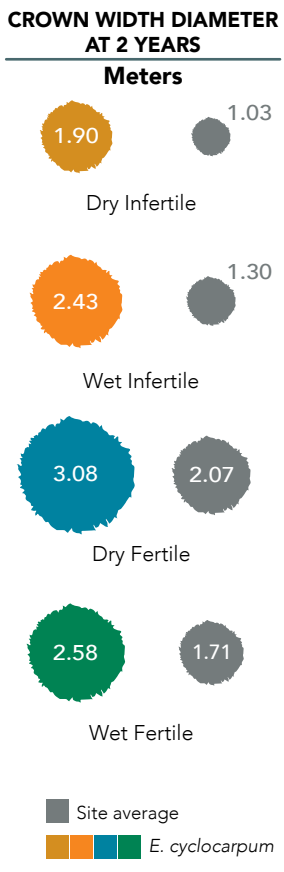
# *Enterolobium cyclocarpum*




Diameter at breast height taken in the last year of height growth measurement




SPACING

Due to its exceedingly broad crown, this species should not be planted in high densities in reforestation and restoration treatments, and no closer than 15 meters to individuals of the same species. However, it can be grown at three-meter spacing with narrow-crowned species, and closer to shade-tolerant species.



SCIENTIFIC NAME

# *Erythrina fusca*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Palo de bobo, palo santo, pito, gallito (Panama); poró (Costa Rica); búcaro (Nicaragua, Colombia); ahuijote (El Salvador); amasisa (Peru), palo prieto (Ecuador).

DESCRIPTION

*Erythrina fusca* is a medium-sized (10 to 20 meters), deciduous tree found in lowland, dry to moist forests from Guatemala and Belize to Bolivia. In Panama it is found in open and marshy areas and along riverbanks and streams. It exhibited high to very high survivorship in fertile sites of the PRORENA species selection trials and survivorship well above 50 percent in both infertile sites. It had markedly lower growth on infertile sites compared to the fertile ones. In the Agua Salud plantations, as well as the wetter, low-nutrient, slightly acidic soils of the PRORENA wet infertile site, it grew significantly poorer. Four-year height growth was far above averages at the fertile sites. It was close to average at the dry infertile site and below average at the wet infertile one. Crown widths were above average at all sites, but especially so at the fertile sites. It had a very high carbon sequestration index over the first four years of growth at the fertile sites, almost three times the site averages. In contrast, this value was slightly above average at the dry infertile site and below average at the wet infertile site. Given that it is a relatively short-lived pioneer, and grew to within the range of its potential mature height at the dry fertile site, the rate of carbon index increase is not likely to continue.

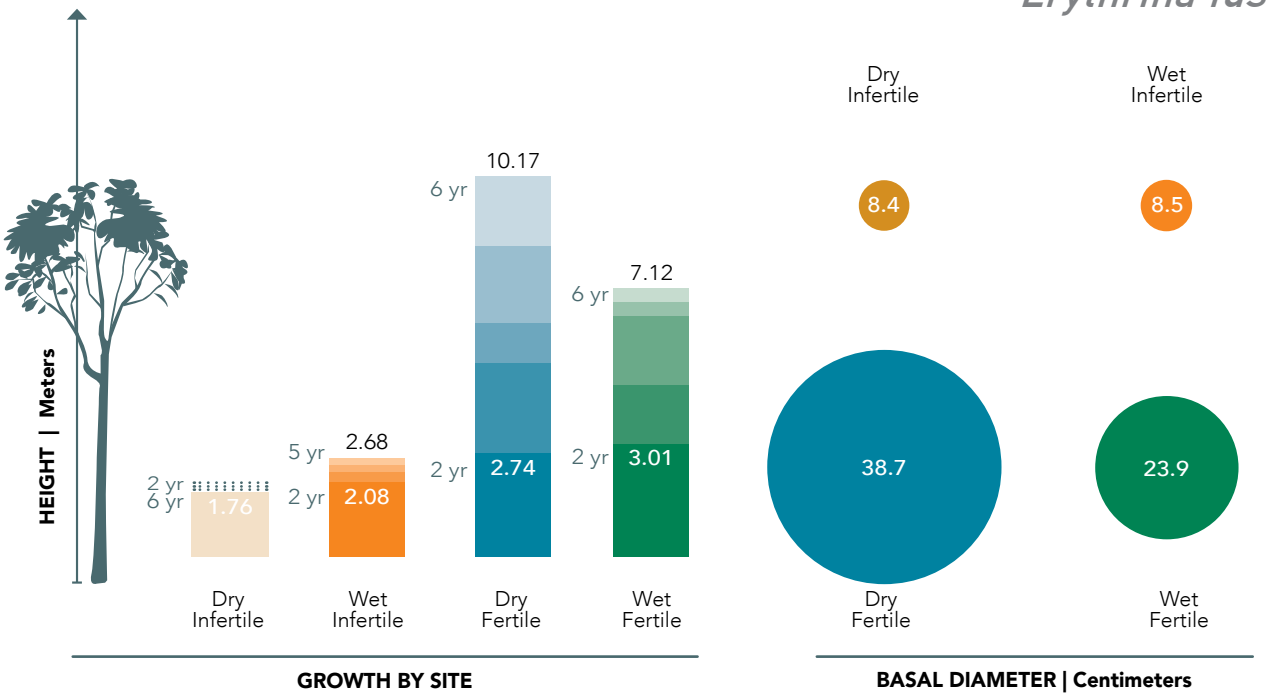
RECOMMENDATIONS

This species is often found in cattle pastures and in living fences around pastures. The leaves are fodder and can also serve as green manure. It can be incorporated into restoration and reforestation treatments as a nitrogen-fixing species, in alley cropping and shade tree agroforestry systems, and as living fences, with very good growth at fertile sites with less acidic soils. It is not well suited for acidic and extremely infertile soils. It had high carbon index values on sites where it grew best, suggesting it can be used to sequester carbon early in reforestation treatments.

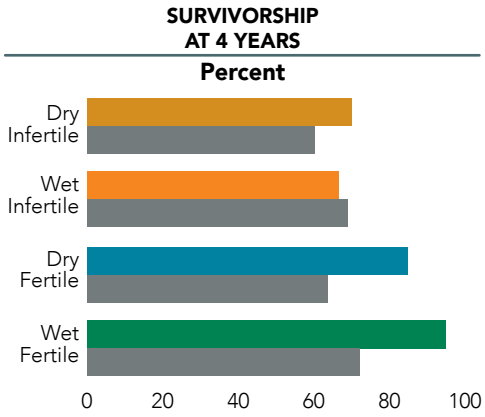
SELECTED USES

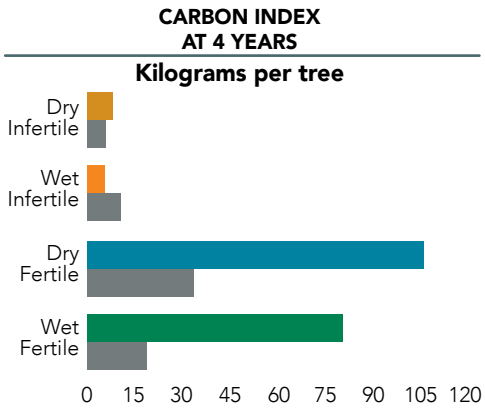
Fishing (resin-based poison), fodder (leaves), living fences, medicines (bark), mid-story structure in reforestation, nurse tree for shade-tolerant species, ornamental tree, shade tree (in pastures), carbon sequestration (early), potential soil improvement through nitrogen fixation and use as green manure.

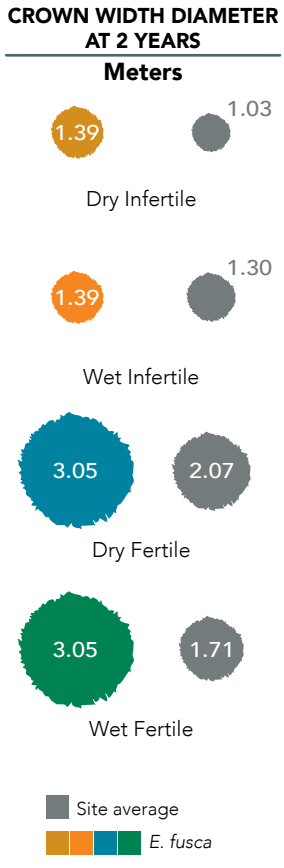
# *Erythrina fusca*




Basal diameter taken at same age as maximum height




SPACING

Given its tendency to form broad, relatively low crowns, it is best to intersperse this species with other species, including those that will form the canopy in forest restoration treatments. It should not be planted closer than three meters to neighbors at fertile sites unless a shade benefit is desired.



SCIENTIFIC NAME

# *Gliricidia sepium*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Balo, bala, mata ratón, madero negro (Panama, Costa Rica); cocoíte (Mexico); cacaguanancé (Guatemala); madreado (Honduras); madrecacao (El Salvador, Venezuela).

DESCRIPTION

*Gliricidia sepium* is a small- to medium-sized (5 to 15 meters), deciduous tree found in dry to wet areas. Its native range is from Mexico to northern South America. It is one of the most commonly planted nitrogen-fixing species for agroforestry in the tropics. It exhibited very high survivorship across all sites in the PRORENA species selection trials and grew particularly well on relatively fertile soils. It had markedly lower growth at infertile sites as compared to fertile sites. It also had significantly lower growth on the wetter, more acidic, and lower-nutrient wet infertile PRORENA site, as well as in the Agua Salud plantations. Its four-year height growth far exceeded averages at the fertile sites and the dry infertile site. It tended to form a broad, thin-spreading crown from multiple stems when grown unpruned in plantations, allowing some light to get to the understory. Two-year crown diameters were more than twice the average for all but the wet infertile site, which still was higher than average. It exhibited an exceptionally high ability to sequester carbon in all but the wet infertile site. Indeed, its four-year carbon index was the highest of all the native species screened in the dry fertile site, where it approached its maximum height.

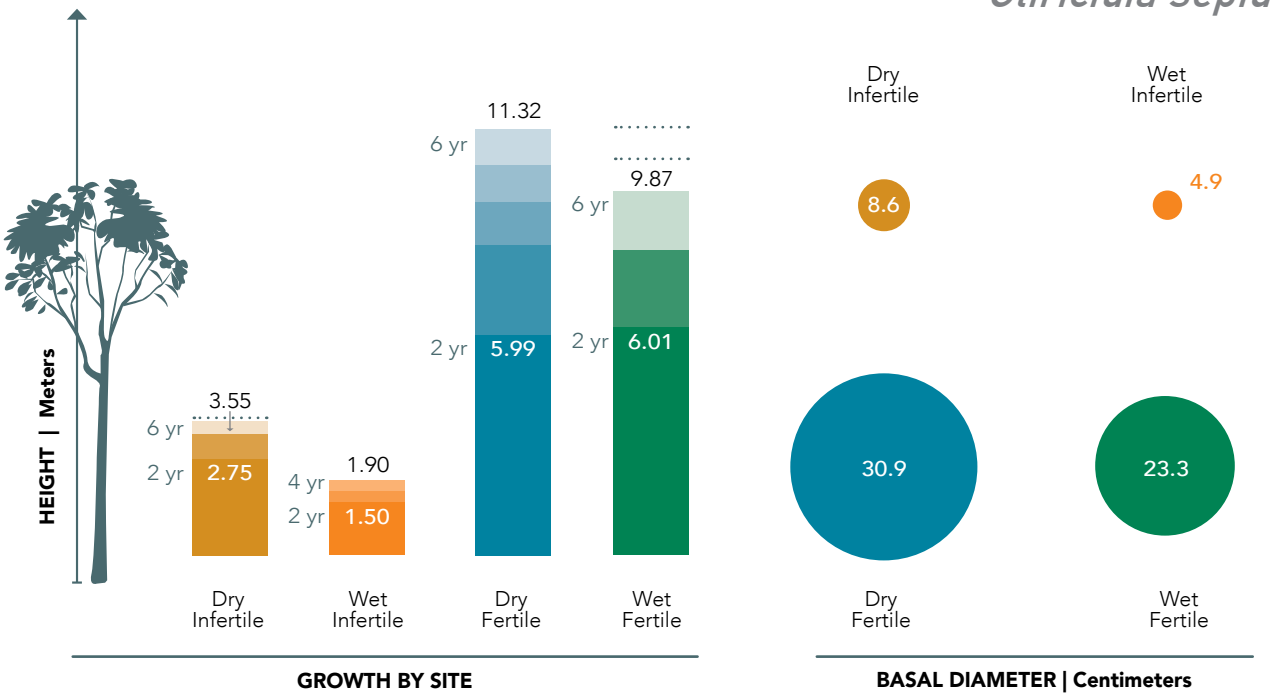
RECOMMENDATIONS

This species is commonly used in agroforestry, where branches are cut and leaves are allowed to decompose and release nutrients into the soil in both alley cropping and shade tree systems. PRORENA data suggest that it is well suited for use as a nurse in reforestation treatments on sites with moderately acidic to neutral soils, and soil fertility at least comparable to that of the dry infertile site. It is well suited for living fences and firewood production on similar sites. Due to its thin crown, it should not be used to create conditions of deep shade to eliminate aggressive grasses. However, its crown form may allow for the recruitment of shade-tolerant species, and will help create

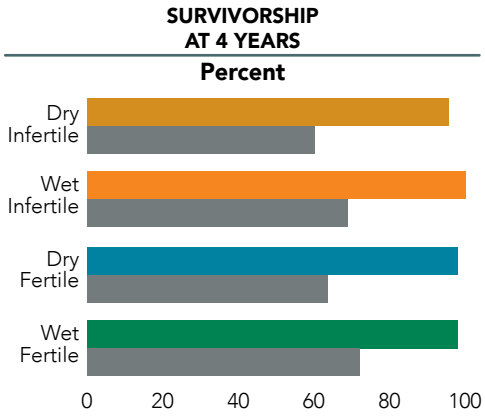
SELECTED USES

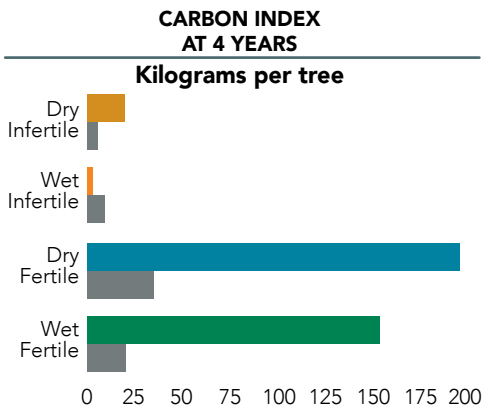
Firewood, fodder, furniture, living fences, rat poison (crushed bark and seeds), honey production, human consumption (fried flowers), tool handles, shade tree (in pastures), carbon sequestration (early), early forest structure in reforestation, nurse tree for shade-tolerant species, potential soil improvement through nitrogen fixation and use as green manure.

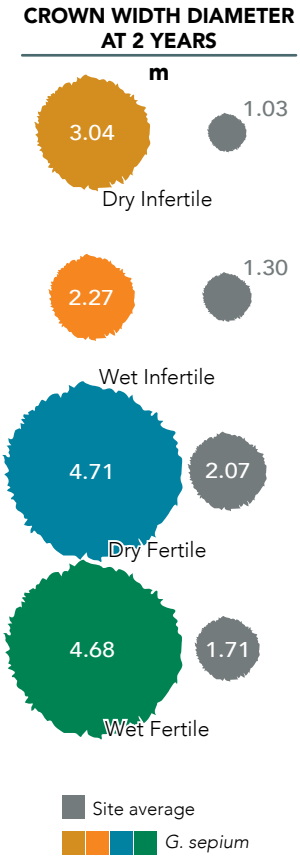
# *Gliricidia sepium*




Basal diameter taken at same age as maximum height




forest structure over time in restoration and reforestation treatments, particularly as canopy species pass it. Once overtopped it quickly dies. It shows high carbon index values on sites where it grows best, suggesting it can be used to sequester carbon early in reforestation treatments.

SPACING

Given its tendency to form broad, relatively low crowns, it is best to intersperse it with other species, including those that will form the canopy in forest restoration treatments. It can be planted three meters apart from shade-tolerant or narrow-crowned neighbors on fertile sites.



SCIENTIFIC NAME

# *Guazuma ulmifolia*

FAMILY
Malvaceae

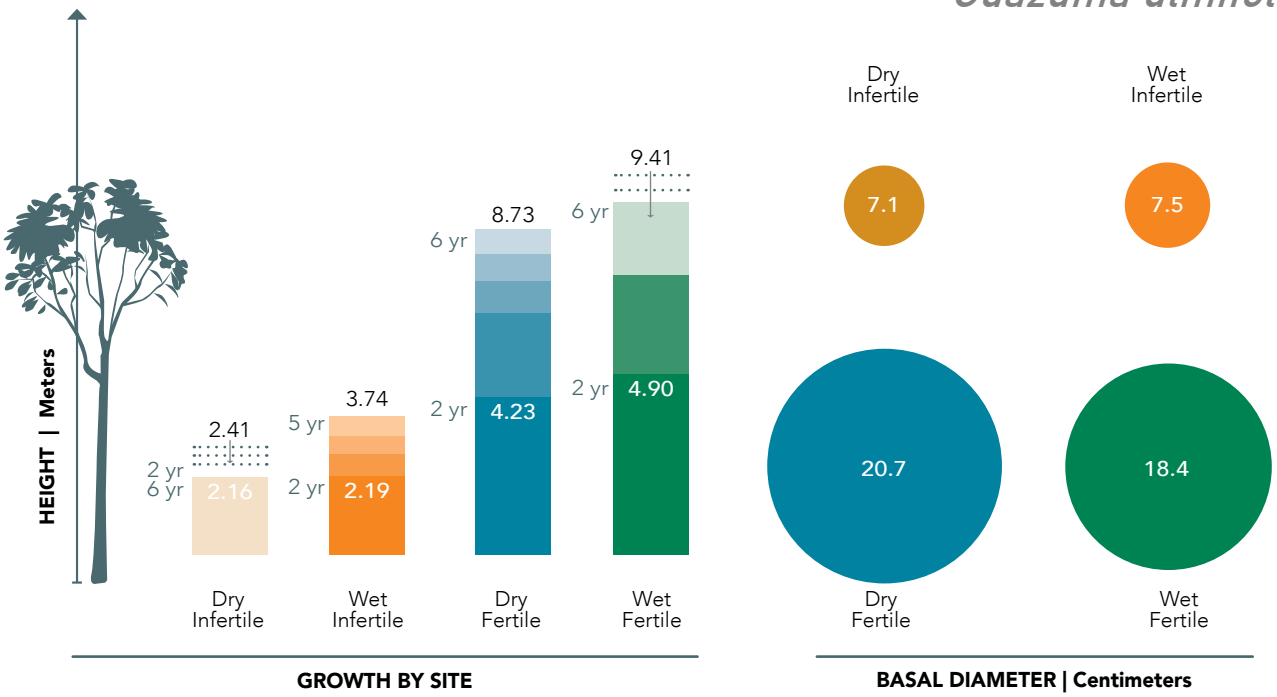
COMMON NAMES
Guácimo (Panama, Costa Rica, El Salvador, Honduras, Nicaragua, Mexico); cabeza de negrito (Panama); caulote, tapaculo (Guatemala); bolaina negra (Peru); coco (Bolivia).

DESCRIPTION
*Guazuma ulmifolia* is a medium-sized (10 to 25 meters), deciduous tree found in low- to mid-elevation, dry to moist forests from Mexico to Paraguay. It exhibited moderately high to exceptional survivorship in the PRORENA species selection trials, with no mortality at the fertile sites. Height and diameter growth at the fertile sites far exceeded that of the infertile sites. However, height did decline at the wet fertile site between years four and six, probably due to intense competition. The species exhibited steady height growth at the wet infertile site, and a considerable decline in height after year four at the dry infertile site. Four-year height growth far exceeded averages at all but the wet infertile site, where it was roughly equivalent to the site average. Two-year crown diameters far exceeded averages at all sites. Four-year carbon indices exceeded averages at all sites, with the index more than double the average at the wet fertile site.

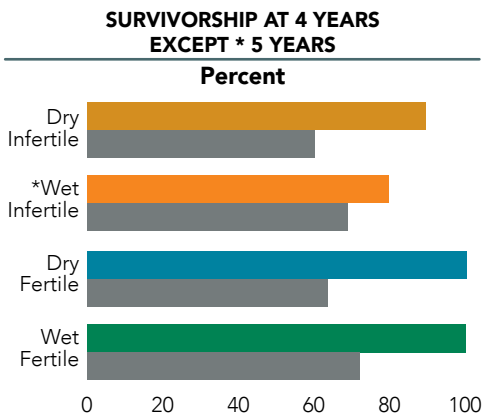
RECOMMENDATIONS
This species' decline in height growth at the wet fertile site is probably due to competition. However, the dieback at the dry infertile site should give pause when considering in restoration or other reforestation activities at sites with similar properties. Given its multipurpose uses and high survivorship, it is a good candidate for reforestation efforts in areas where rural people will continue to use the land. Four-year carbon indices, particularly at the fertile sites, suggest it is a good candidate for mixtures where early carbon sequestration is desired. It is a good candidate to help provide vertical structure in early reforestation treatments. Its broad crown suggests it is useful in helping gain crown closure early in reforestation treatments but also suggests that individuals of the same species should not be grown close together.

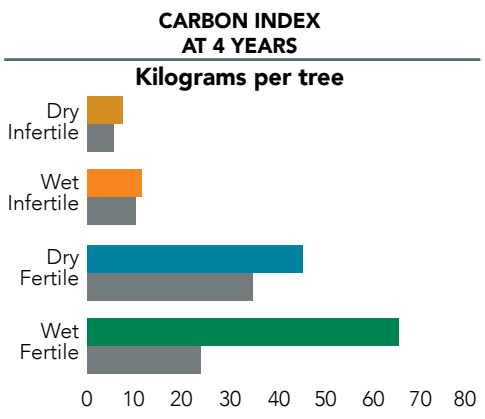
SELECTED USES
Construction (rural), fence posts, firewood, fodder (leaves, fruits), honey production, human consumption (seeds), medicines (bark, leaves, flowers, fruits), rope or twine (fiber), carbon sequestration (early), early crown closure in reforestation, early stand structure in reforestation, nurse tree for shade-tolerant species, shade tree (in pastures).

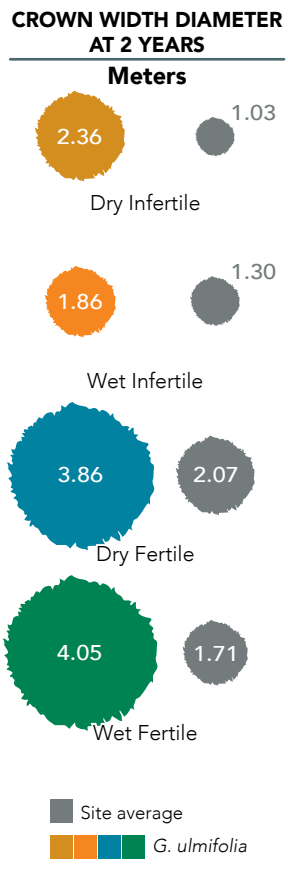
# *Guazuma ulmifolia*




Basal diameter taken at same age as maximum height




SPACING

Individuals of this species should not be planted within 12 to 15 meters of one another when the objective is to obtain a mixed stratified forest over time without thinning. A spacing of three meters is appropriate for shade-tolerant neighbors, or relatively fast-growing species with narrow crowns.

SCIENTIFIC NAME

# *Gustavia superba*

FAMILY
Lecythidaceae

COMMON NAMES
Membrillo (Panama, Colombia); paco, chupo (Colombia).

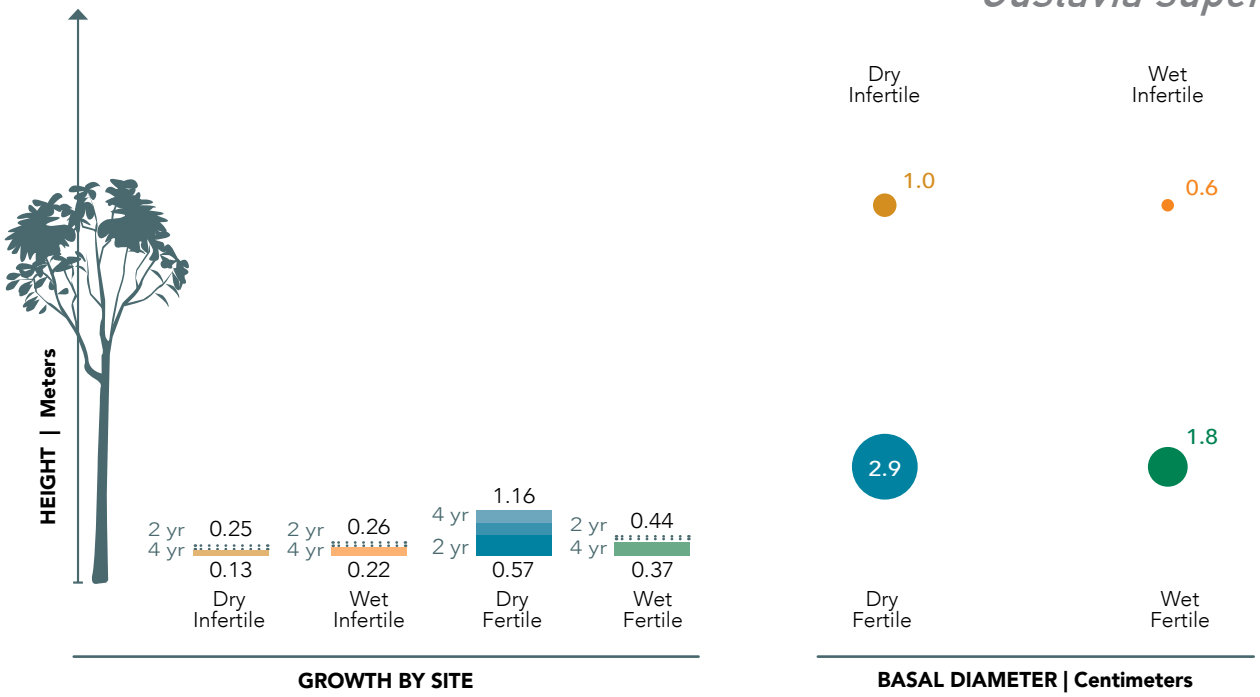
DESCRIPTION
*Gustavia superba* is a small- to medium-sized (5 to 20 meters), evergreen tree found at low- to mid-elevation, moist to wet forests from Panama to Colombia. In Panama it is common in secondary forests. It exhibited low to very low survivorship in the PRORENA species selection trials. At four years, height and diameter growth were very low, with no trees reaching the 1.3-meter marker for measuring diameter at breast height at any site. The species exhibited sustained height growth at only the dry fertile site. Two-year crown diameters were far below averages at all sites, as were four year carbon indices.

RECOMMENDATIONS
This species performed very poorly in the PRORENA trials, despite its rapid growth in the nursery in full-sunlight conditions. It persists and grows in partial shade in the mature forest of Barro Colorado Island. Its poor growth in the PRORENA trials may be due to excessive attack by pathogens or insects in monoculture stands. It is possible it will do better when planted in low densities within intimate mixtures of other tree species in restoration or reforestation treatments.

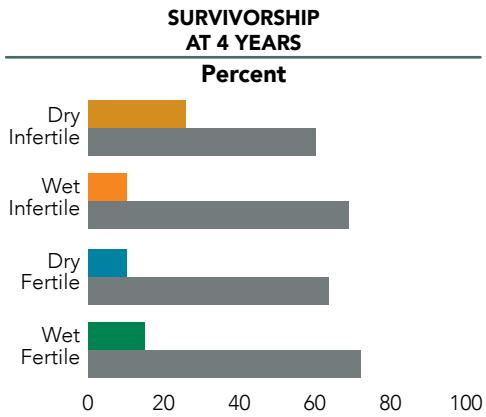
SPACING
Given the literature and the PRORENA growth trial data, this species can be planted at low densities, two meters or closer to neighbors.

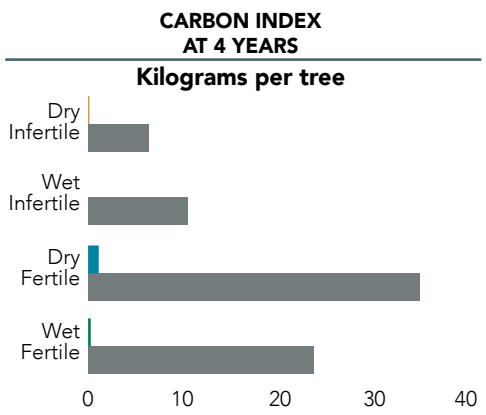
SELECTED USES
Honey production, human consumption (fruits), medicines (leaves).

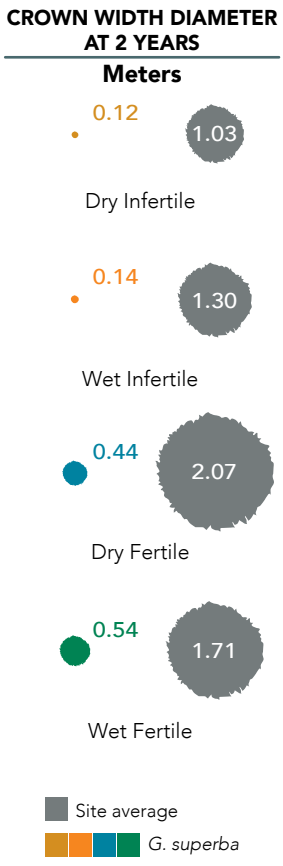
# *Gustavia superba*




Basal diameter taken at same age as maximum height



SCIENTIFIC NAME

# *Hieronyma alchorneoides*

FAMILY
Phyllanthaceae

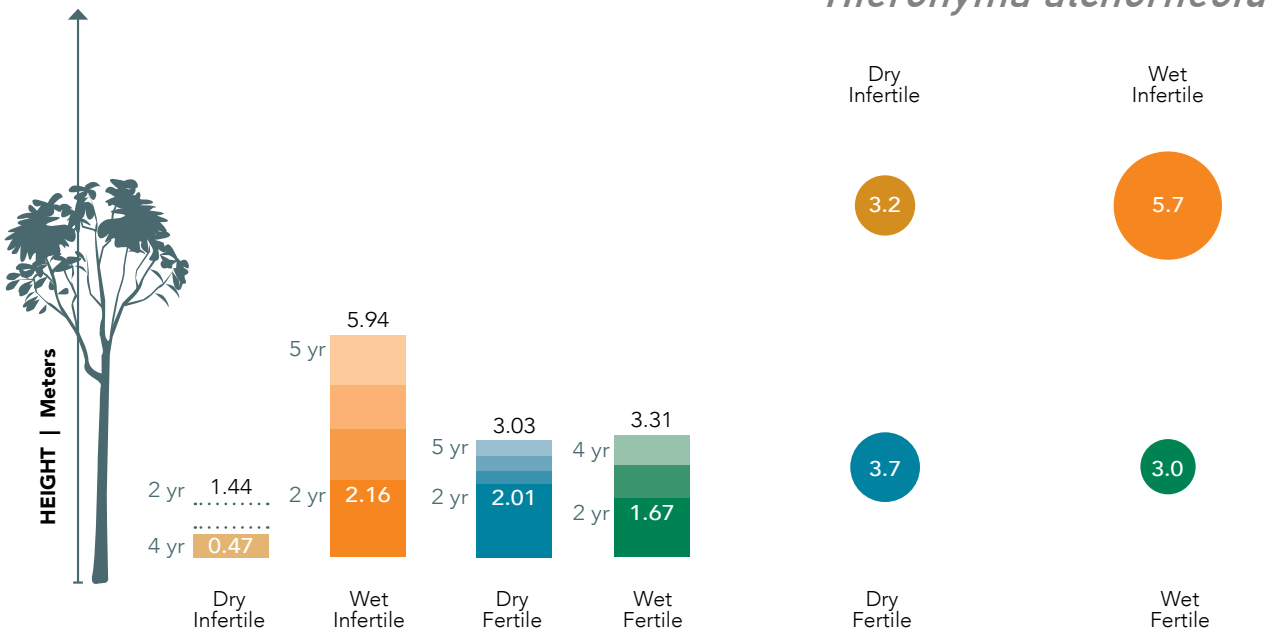
COMMON NAMES
Zapatero, pilón, palo chancho, piedro, pantano (Panama); llorón colorado, nancitón (Costa Rica); carneasada (Venezuela); mascarey (Ecuador); suradan (Surinam).

DESCRIPTION
*Hieronyma alchorneoides* is a tall (20 to 35 meters), semi-deciduous tree found in low- to mid-elevation wet forests from Mexico to Bolivia. In Panama it is common in wet forests and wetlands on the Caribbean side of the mountains. It exhibited very low to high survivorship in the PRORENA species selection trials, with highest survival at wet sites and lowest at the dry fertile site. Best height and diameter growth were at the wet sites, with values at the wet infertile site markedly higher than those of the wet fertile site. Four-year height growth far exceeded the average at the wet infertile site. It tended to form narrow crowns early in life, with two-year crown diameters below average at all sites, and particularly narrow when compared to the average at the fertile sites. Four-year carbon indices were below average at all but the wet infertile site, where it was nearly double that of the site average.

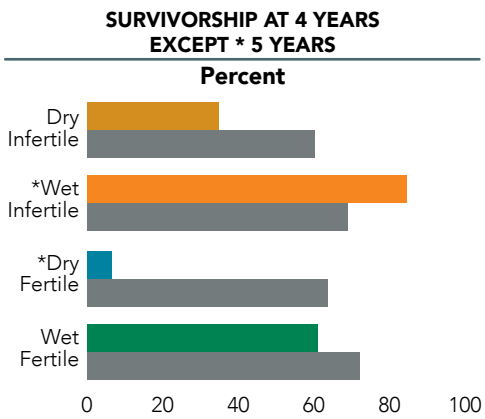
RECOMMENDATIONS
Its survivorship, growth, and carbon indices suggest that it is well suited for reforestation and restoration treatments in wet sites, doing particularly well at the wet infertile site. It is not recommended for dry sites. Its height growth suggests it will help form an early stratified canopy that will persist with forest development. Its narrow crowns suggest it can be planted relatively close to neighbors of the same or other species, including those with broader crowns. It can be very effective planted at close spacing in shading out the understory vegetation in plantations by accelerating stands into the stem exclusion phase of forest dynamics. In restoration treatments on wet sites where a goal is to provide a stratified forest structure, it may do particularly well in combination with smaller, broad-crowned trees.

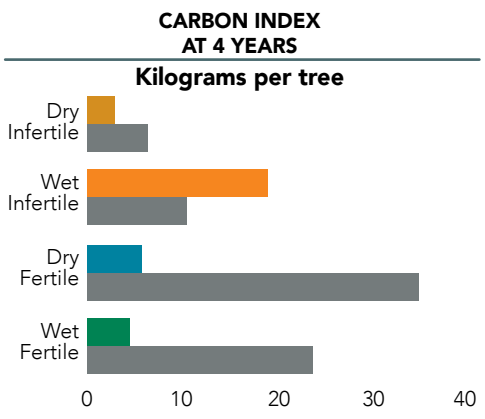
SELECTED USES
Barrels, bridges, construction (naval), fence posts, medicines (seeds), tannery (bark), railroad ties, wagon bottoms, carbon sequestration, early canopy structure in reforestation.

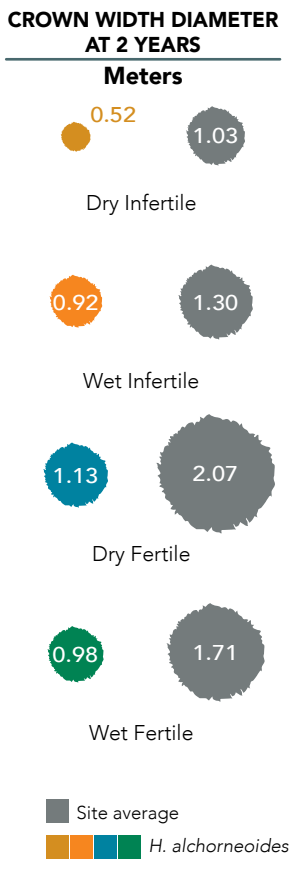
# *Hieronyma alchorneoides*




Diameter at breast height taken in the last year of height growth measurement




SPACING

This species can be grown within three meters of neighbors with narrow or broad crowns on wet sites.



SCIENTIFIC NAME

# *Hura crepitans*

FAMILY

Euphorbiaceae

COMMON NAMES

Tronador, nuno, havillo, ceibo (Panama, Costa Rica); ochoó (Bolivia); catahua (Peru); jabillo (Venezuela); salvadera (Cuba); ceibo amarillo (Colombia); assacú (Brazil).

DESCRIPTION

*Hura crepitans* is a tall (20 to 40 meters), semi-deciduous tree found in low-elevation, dry to moist forests from Honduras to Bolivia. In Panama it is common along rivers and streams, particularly in the Canal watershed. It exhibited moderate to very high survivorship in the PRORENA species selection trials. Height and diameter growth were best at the fertile sites. Growth was particularly good relative to other species at the dry fertile site, where four-year height growth was above average. Two-year crown diameters were greater than averages at all but the wet infertile site, with broadest crowns relative to averages at the dry sites. Four-year carbon indices were above averages at all sites and more than double the average at the dry fertile site.

RECOMMENDATIONS

This species survived and grew best at fertile sites but also did particularly well relative to other species at the dry infertile site, suggesting that it can be widely used in restoration and reforestation treatments. Although crown widths were not particularly broad at wet sites, dry-site crown growth suggests it will help provide early canopy closure in similar sites and is effective at shading out competition. Its height growth suggests it will keep pace with other species—not falling behind to become over-topped—when grown with all but the fastest growing species with broadest crowns. Its four-year carbon indices indicate it will help sequester carbon early during reforestation treatments.

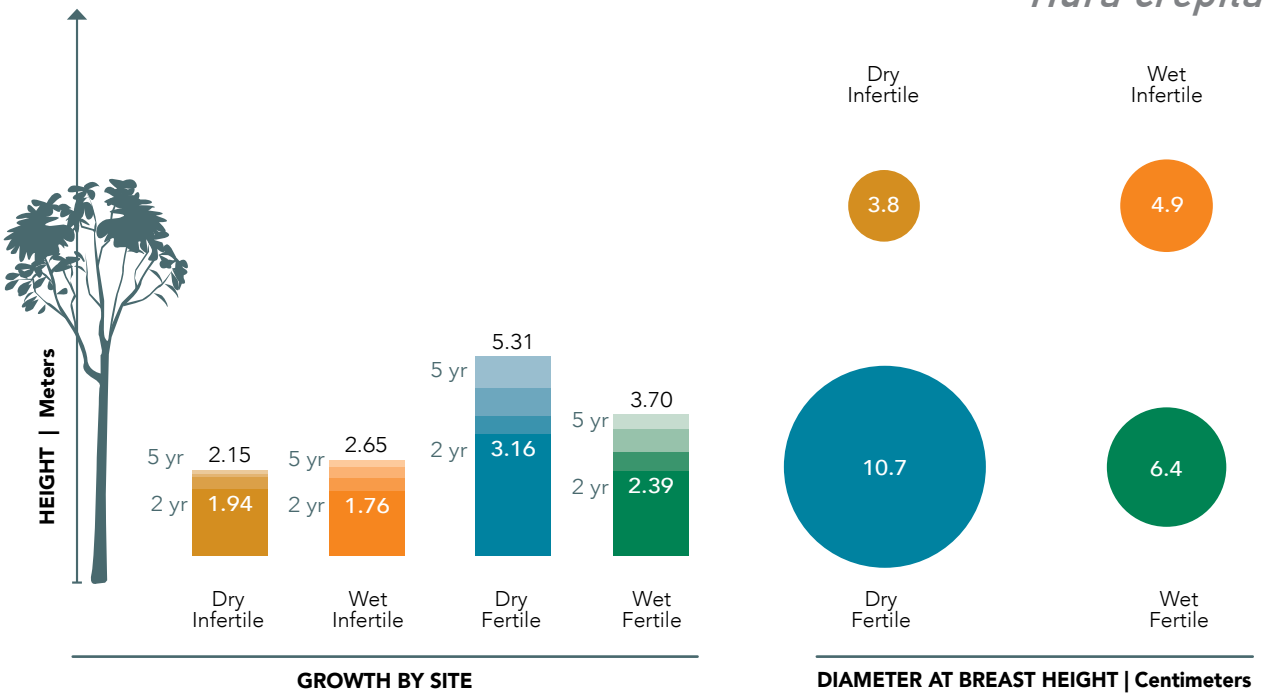
SPACING

Given the literature and the PRORENA data, this species can be spaced as close as two meters to neighbors at all sites.

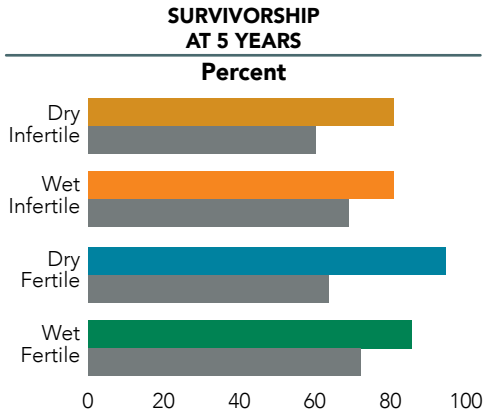
SELECTED USES

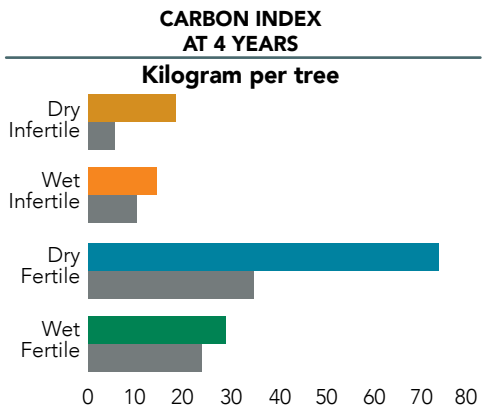
Boat construction, carpentry, charcoal, firewood, fishing (resin-based poison), handicrafts (fruits), medicines (seeds, resin), plywood, carbon sequestration (early), early canopy structure in reforestation, streambank restoration.

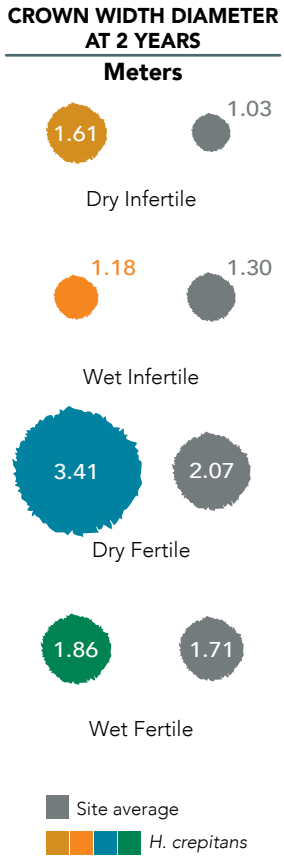
# *Hura crepitans*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Hymenaea courbaril*

FAMILY

Fabaceae-Caesalpinioideae

COMMON NAMES

Algarrobo, algarroba (Panama); guapinol (Central America, Mexico); locust (Belize, Guyana); curbaril (Cuba); corobore (Venezuela); copal (Ecuador); jatobá (Brazil); paquió (Bolivia).

DESCRIPTION

*Hymenaea courbaril* is a medium to tall (10 to 30 meters), semi-deciduous tree found in low-elevation, dry to moist forests from Mexico to Paraguay. It exhibited moderate to very high survivorship in the PRORENA species selection trials, with highest survival at the wet infertile site and lowest at the dry fertile one. Its best height and diameter growth were at the wet infertile and dry fertile sites, but four-year heights were far below average at all sites. It formed relatively narrow crowns. Two-year crown diameters were below average at all sites, but close to average at the wet infertile site. Four-year carbon indices were below average at all sites.

RECOMMENDATIONS

Although survivorship was generally high, this species did not grow particularly well in the PRORENA trials. Since its best growth was at the wet infertile site, it could be used as a component of restoration and reforestation initiatives at similar sites. It may also perform well on particularly acidic soils. Its narrow crowns suggest that it can be planted relatively close to other species, but it may be overtopped by fast-growing neighbors. Given its poor growth, it is not recommended in high-density plantings, but because of its shade-tolerance it can be under-planted as a late-successional tree that attains the canopy after harvesting or overtopping faster growing pioneers.

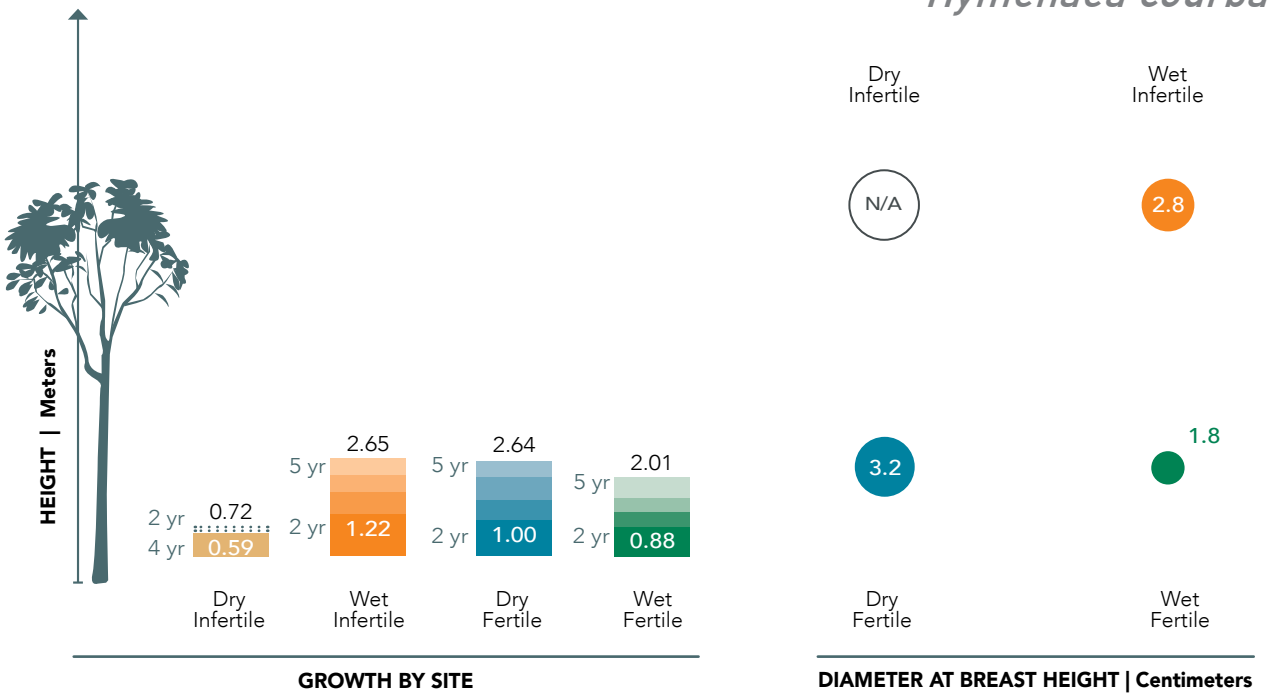
SPACING

This species can be spaced two to three meters apart from neighbors.

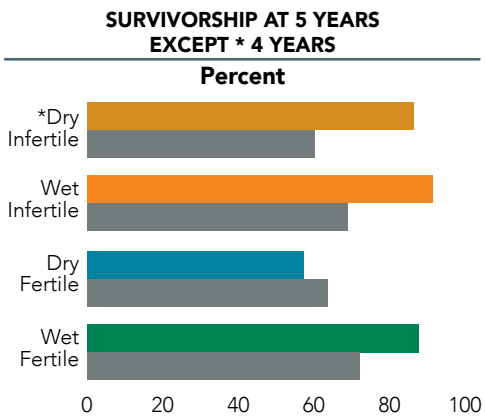
SELECTED USES

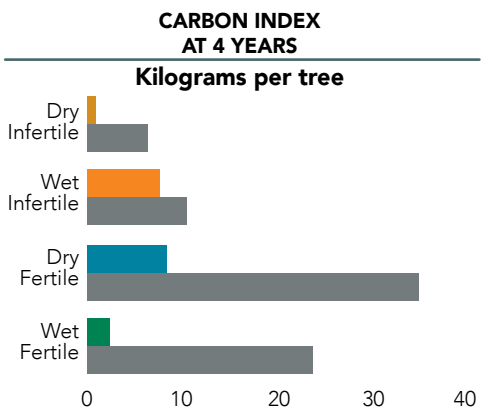
Bridges, cabinetry, carpentry, construction (heavy), floorboards, honey production, human consumption (fruits), medicines (resin, bark), ornamental tree, varnish and glue (resin), mid-story structure in reforestation.

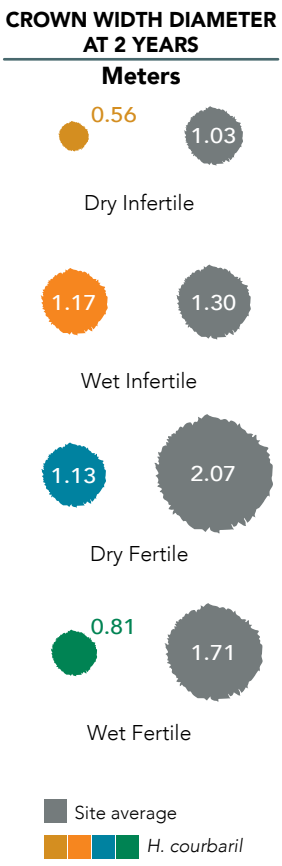
# *Hymenaea courbaril*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Inga laurina*

FAMILY
Fabaceae-Mimosoideae

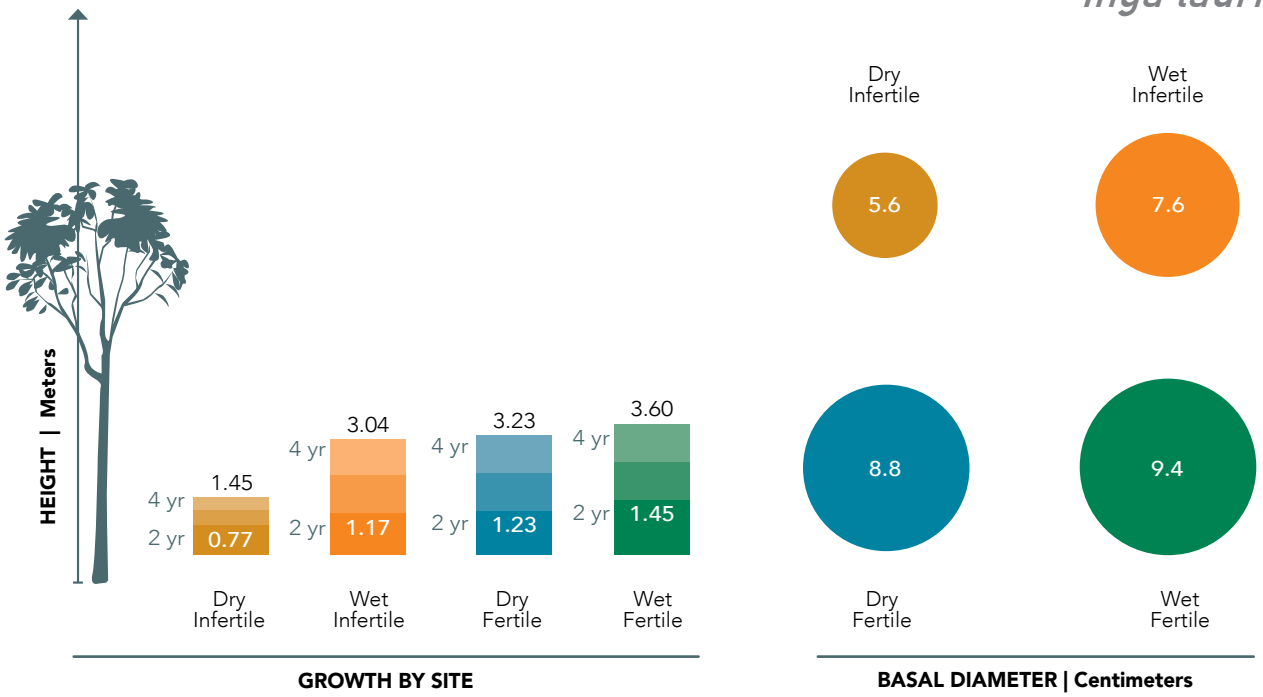
COMMON NAMES
Guabo, guaba, guaba de mono, guabito cansa boca (Panama).

DESCRIPTION
*Inga laurina* is a medium to tall (15 to 30 meters), evergreen tree found in low- to mid-elevation, dry to wet forests. In Panama it is common in the forests of the Panama Canal watershed. Four-year survivorship exceeded or was equivalent to site averages in the PRORENA species selection trials. Height and diameter growth were roughly equivalent between the wet infertile and two fertile sites. Four-year height growth was below averages at all but the wet infertile site, where it was similar to the site average. Two-year crown diameters were below average at all sites. Four-year carbon indices were roughly equivalent to the averages at the infertile sites.

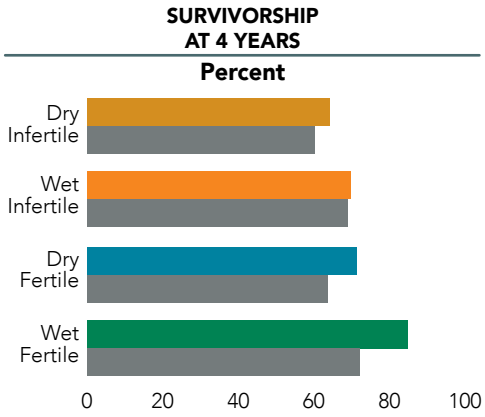
RECOMMENDATIONS
This species exhibited moderate survival in the PRORENA trials, growing particularly well at the wet infertile site, but also sufficiently well enough at other sites to be considered for reforestation and restoration treatments at similar sites. Its ability to fix atmospheric nitrogen makes it a useful component of treatments designed to improve soil fertility, particularly in alley cropping and shade-tree agroforestry systems. Its two-year crown diameters suggest it would not be ideal for use in treatments designed to rapidly shade out grasses and weeds. The trees produce fruits early; these are, in turn, eaten by birds that act to promote natural regeneration beneath. However, its four-year carbon indices indicate it would be a useful component of a multispecies treatment that has carbon sequestration as a goal in infertile sites.

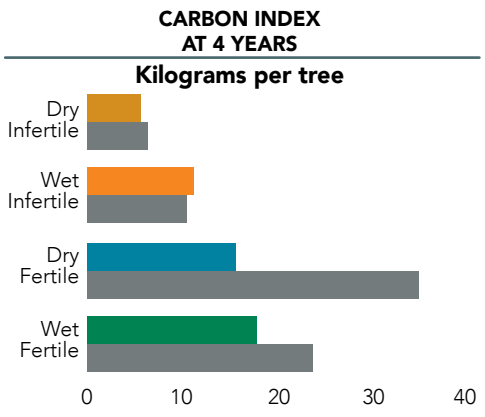
SELECTED USES
Boxes, firewood, human consumption (seeds), attracting animal diversity, carbon sequestration (infertile sites), potential soil improvement through nitrogen fixation and use as green manure.

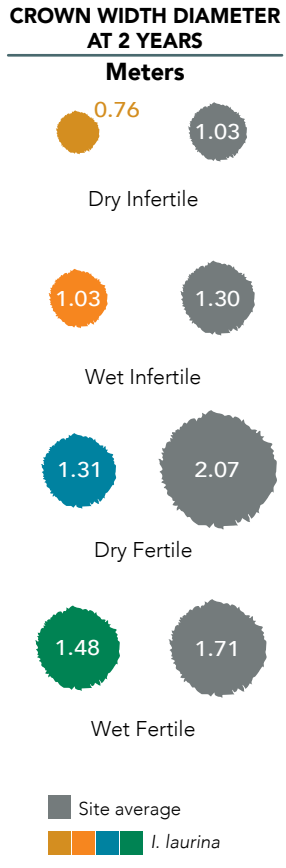
# *Inga laurina*




Basal diameter taken at same age as maximum height




SPACING

Data from the literature as well as the PRORENA trials suggest that this species persists and grows even in deep shade, suggesting it can be planted as close as one meter to neighbors at infertile sites. At fertile sites it can be spaced at two meters or less.



SCIENTIFIC NAME

# *Inga punctata*

FAMILY

Fabaceae-Mimosoideae

COMMON NAMES

Guabo, guaba, guaba de mono, guabito cansa boca (Panama); cuajinicuil (Costa Rica, Guatemala); guamo (Honduras); bitz (Mexico); guabo machetero (Ecuador).

DESCRIPTION

*Inga punctata* is a small- to medium-sized (5 to 15 meters), evergreen tree found in dry to wet forests from Mexico to Bolivia. In Panama it is common in secondary forests and along streams and roads. It is a nitrogen-fixing species that has been found to fix abundant nitrogen at the wet fertile site of the PRORENA species selection trials. Survivorship was below averages at all but the wet fertile site, where it was reasonably high. Four-year height growth exceeded averages, particularly the wet fertile site. At the Agua Salud sites, it grew poorly on the most acidic soils. When grown in the open, the species had a shrub-like structure composed of multiple stems with a broad, thick crown. Height growth stagnation at the wet fertile site is probably due to crowding by its neighbors. Two-year crown diameters were close to averages at all but the wet fertile site, where it was almost twice the average. Its four-year carbon index was higher than averages at all sites, and almost three times the average at the wet fertile site.

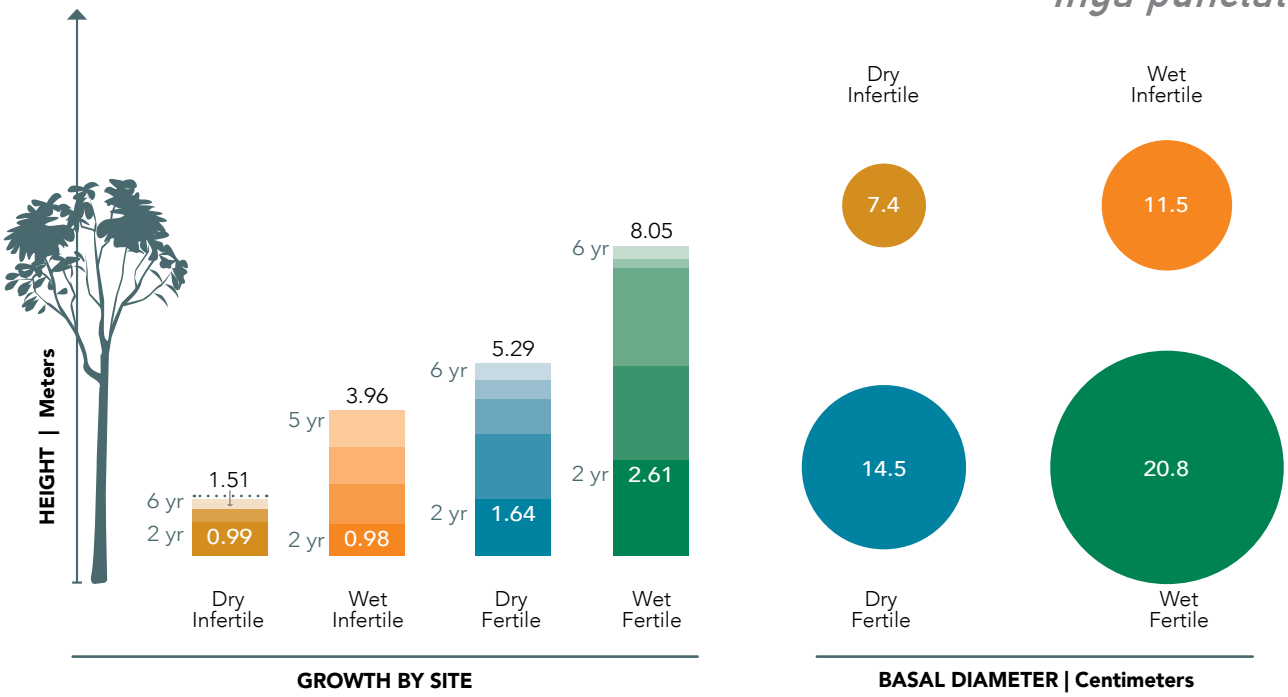
RECOMMENDATIONS

This species has high potential for agroforestry systems and restoration treatments on fertile to relatively fertile sites of moderate acidity. Its growth and survivorship at the dry infertile site suggest that it may not be suitable for drought-stressed sites. Its ability to fix nitrogen in the PRORENA wet fertile and Agua Salud sites suggest that it should assist in nutrient cycling, particularly of nitrogen. Its fruits will attract birds and mammals, adding an additional component to restoration treatments by promoting natural regeneration beneath. Its relatively low stature, coupled with height growth stagnation in the wet fertile site and observations of crown closure and competition, suggest that individuals should be widely spaced in reforestation treatments. In agroforestry treatments, it will require pruning. On fertile sites it will help provide early crown closure, and later add forest structure as faster growing canopy species overtop it.

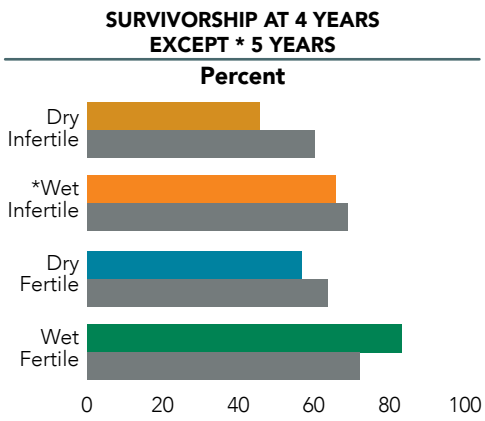
SELECTED USES

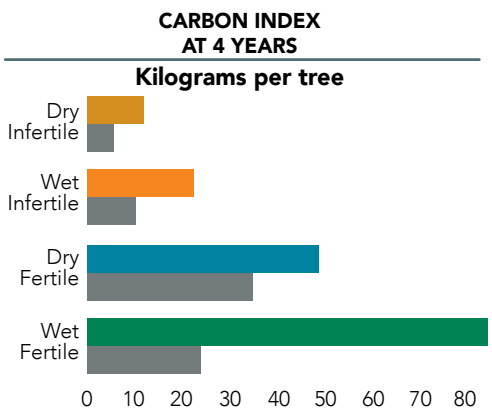
Boxes, firewood, floorboards, human consumption (fruits), attracting animal diversity, early crown cover in reforestation, mid-story forest structure in reforestation, potential soil improvement through nitrogen fixation and use as green manure.

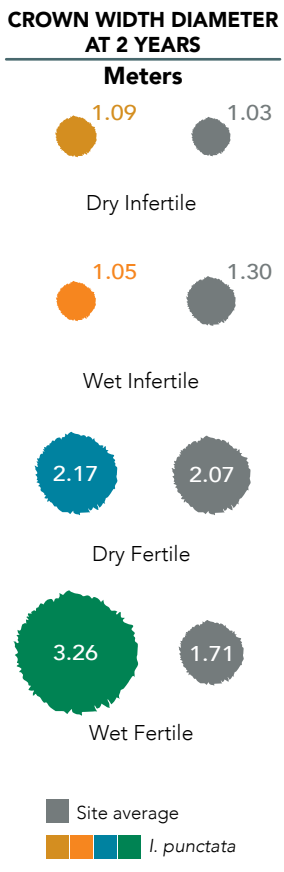
# *Inga punctata*




Basal diameter taken at same age as maximum height




SPACING

This species should be planted at least three meters distant from all but the most shade-tolerant species at fertile sites, with best success when grown with fast-growing, narrow-crowned species.

SCIENTIFIC NAME

# *Lacmellea panamensis*

FAMILY
Apocynaceae

COMMON NAMES
Lagarto negro, palo perezoso (Panama); cerillo, espinudo (Costa Rica); lechudo (Colombia).

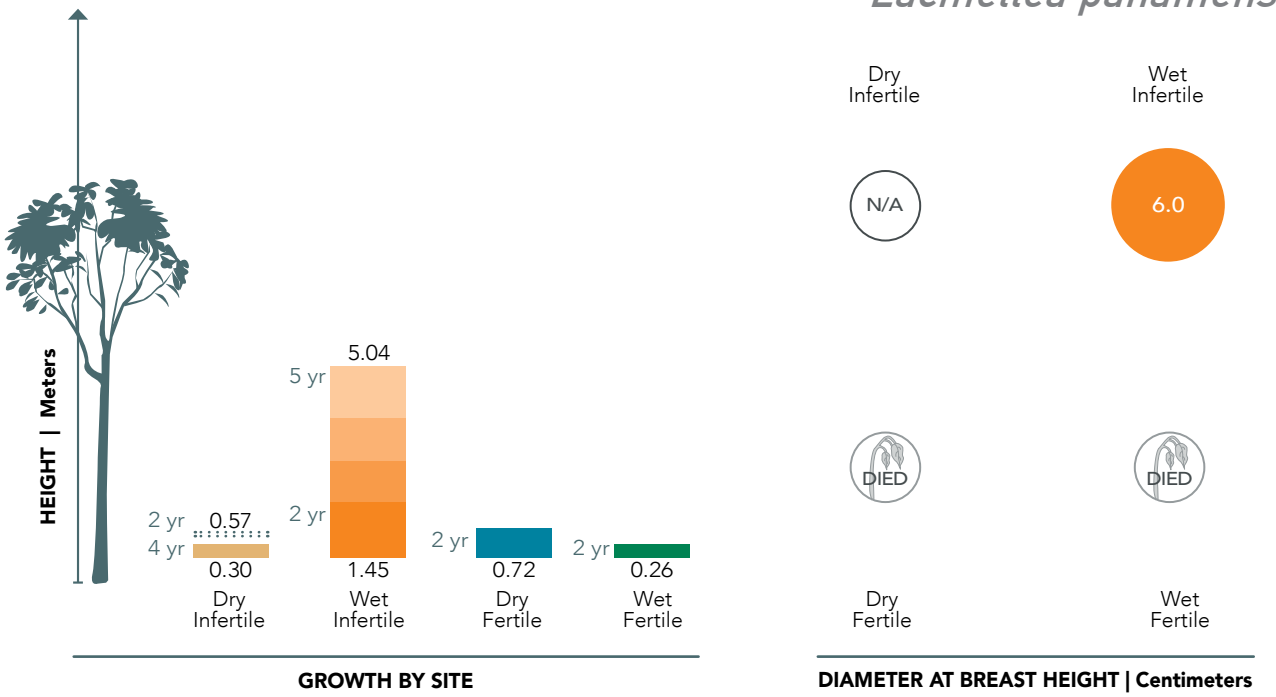
DESCRIPTION
*Lacmellea panamensis* is a medium-sized (10 to 20 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Belize to Ecuador. In Panama it is common on the Caribbean side of the mountains. It exhibited poor to very poor survivorship in the PRORENA species selection trials, with best survival at the wet infertile site and virtually no survival at the dry and wet fertile sites, respectively. Surviving individuals grew relatively well at the wet infertile site, exceeding the four-year height site average. It forms narrow crowns, with two-year crown diameters far below averages at all sites. Its four-year carbon index was close to average at the wet infertile site.

RECOMMENDATIONS
Data from the PRORENA trials suggest that although this species' survival might be a concern, it can be used as part of reforestation and restoration initiatives in wet infertile sites, consistent with its natural distribution. The tree can be useful wildlife habitat because the fruits attract birds.

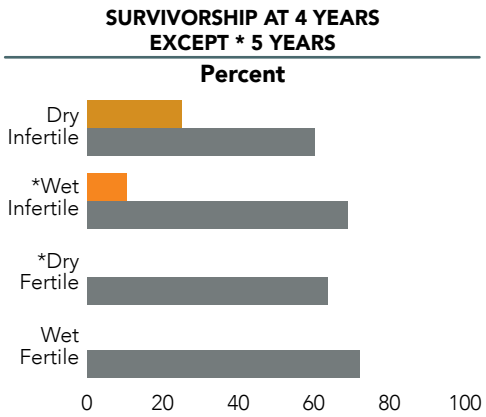
SPACING
Data from the literature and the PRORENA trials suggest that this species can be planted at two meters or less to neighbors.

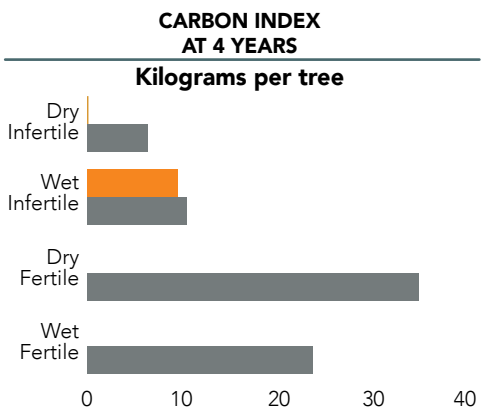
SELECTED USES
Boxes, boards, chipboard, human consumption (fruits, resin), tool handles, attracting animal diversity.

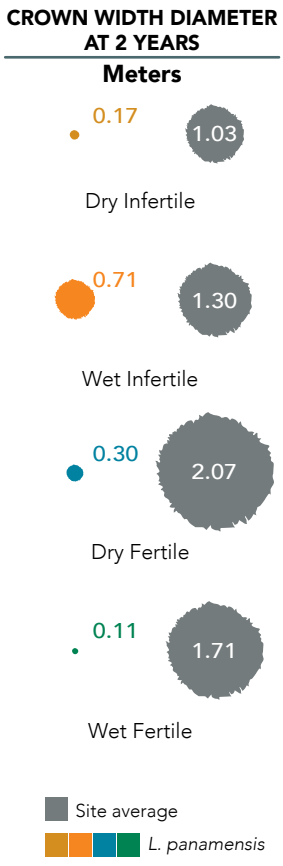
# *Lacmellea panamensis*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Luehea seemannii*

FAMILY

Tiliaceae (Recent molecular studies consider this species to be in the Malvaceae)

COMMON NAMES

Guácimo colorado, guácimo molenillo, guácimo pacheco (Panama); guácimo macho (Nicaragua); cotonrón, yayo (Guatemala).

DESCRIPTION

*Luehea seemannii* is a medium to tall (10 to 30 meters), deciduous tree found in low- to mid-elevation, dry to moist forests from Mexico to Colombia. It is a common secondary forest species in Panama. It exhibited high to very high survivorship across the PRORENA species selection trials, but survived poorest where it grew best—at the dry fertile site. It grew markedly better at fertile sites, with slightly better height and diameter growth on the dry site compared to the wet. At Agua Salud, it showed poor growth on soils that were infertile, clayey and relatively acidic. Four-year height growth far exceeded averages at all but the wet infertile site, where it was roughly equivalent. Despite its growth, it experienced significant dieback at the dry infertile site. When grown in the open, it tended to form a narrow crown. Two-year crown width was higher than average at all sites. It is thought to produce abundant leaf litter that may increase soil organic matter. Its four-year carbon indices were well above averages at all but the wet infertile site, where it was average.

RECOMMENDATIONS

Data from the PRORENA trials suggest that this fast-growing pioneer is well suited for multispecies reforestation and restoration initiatives in relatively fertile soils, but that it is not suitable on highly acidic soils. It will help create forest cover and standing biomass relatively quickly, and also increase organic matter in soil.

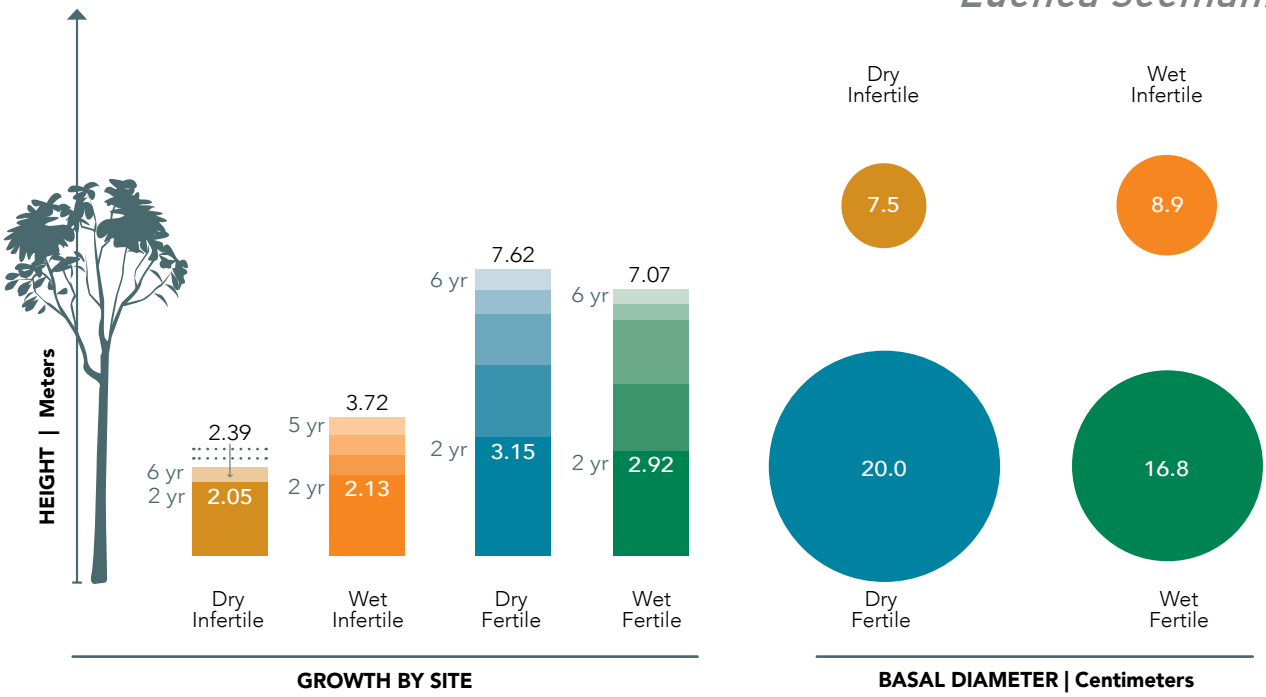
SPACING

Data from the literature and the PRORENA trials suggest that this species can be planted as close as two meters to neighbors.

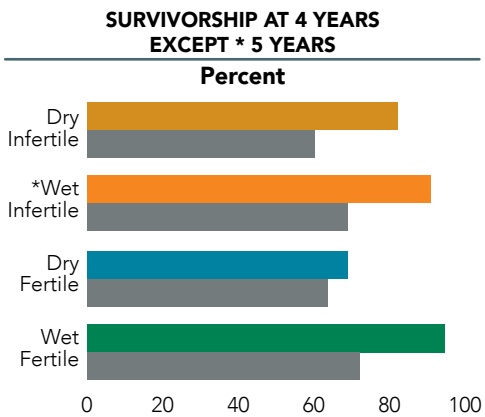
SELECTED USES

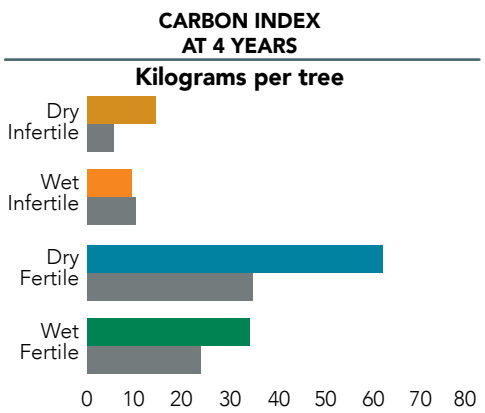
Boards, boxes, chipboard, firewood, honey production, mooring rope (bark), pulp for paper, carbon sequestration (early), early crown cover in reforestation, soil organic matter through litter production.

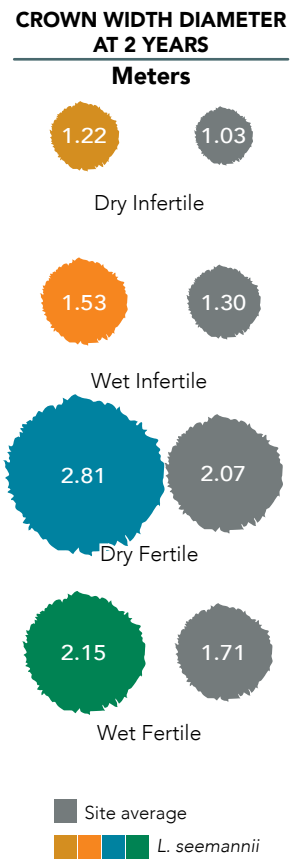
# *Luehea seemannii*




Basal diameter taken at same age as maximum height





SCIENTIFIC NAME

# *Manilkara zapota*

FAMILY

Sapotaceae

COMMON NAMES

Níspero (Panama, Costa Rica, Nicaragua, El Salvador); zapote, chicozapote, chicle (Mexico).

DESCRIPTION

*Manilkara zapota* is a medium to tall (10 to 30 meters), evergreen tree found in low to medium elevations in dry to moist forests from Mexico throughout Central America. In Panama it is common in farms on the Pacific side of the mountains. Survivorship ranged from poor to very high in the PRORENA species selection trials, with lowest survival at the dry fertile site and highest at the wet infertile one. Although its best height and diameter growth were at the wet infertile site, this was still below the site average. It exhibited dieback at the dry infertile site. At all sites, this species formed very narrow crowns, with two-year crown diameters far below average. Four-year carbon indices were very low across all sites.

RECOMMENDATIONS

Data from the PRORENA trials suggest that this species is suitable as a shade-tolerant, late-successional tree, and can be under-planted or planted in intimate mixtures as an evergreen with faster growing, deciduous trees.The tree is commonly found on farms in Panama. Its fruits are highly appreciated. Its best use may be in riparian areas and as isolated trees for fruit production.

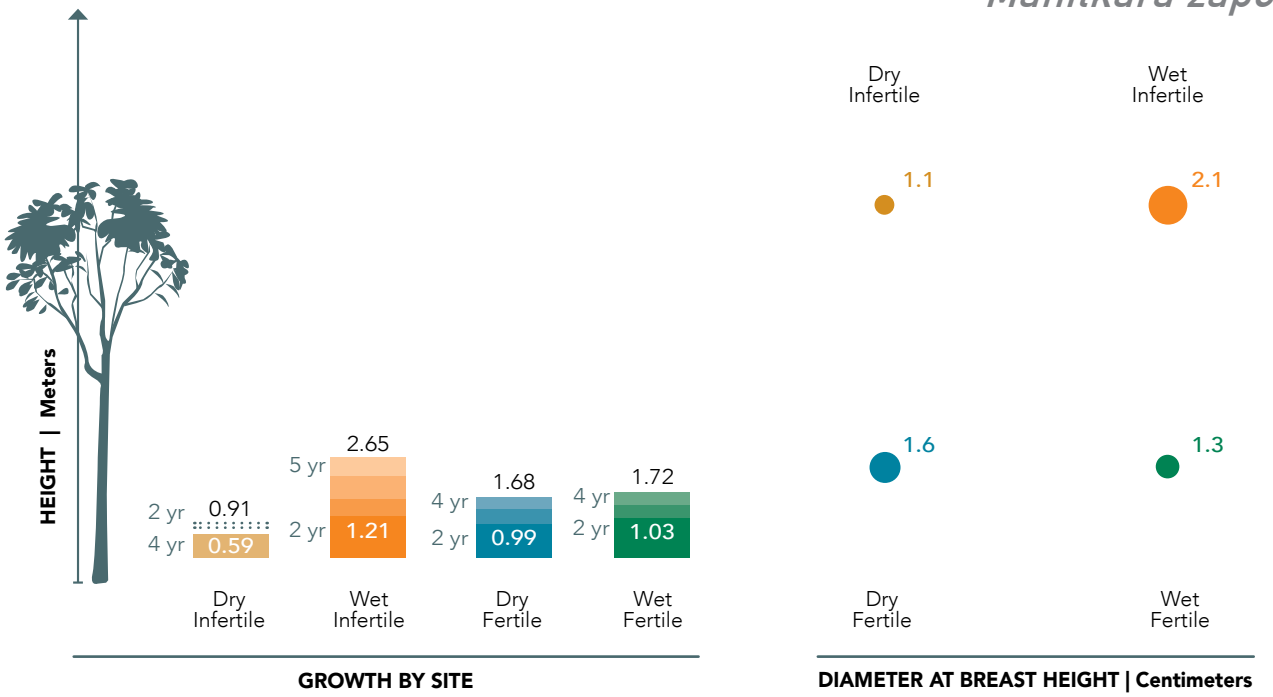
SPACING

Its narrow crowns suggest that it can be planted relatively close to neighbors, but it may suffer due to shading when overtopped by faster growing evergreens.  Spacing between other *Manilkara* trees should be wide, to accommodate for its stature when it eventually becomes an emergent.

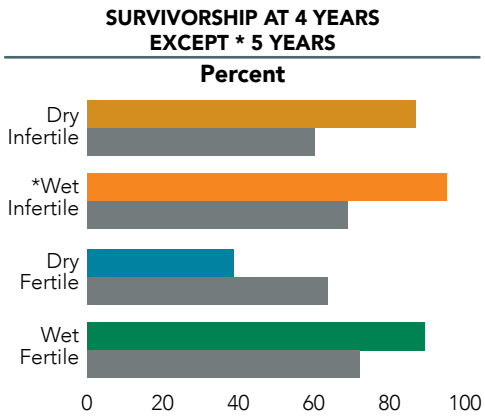
SELECTED USES

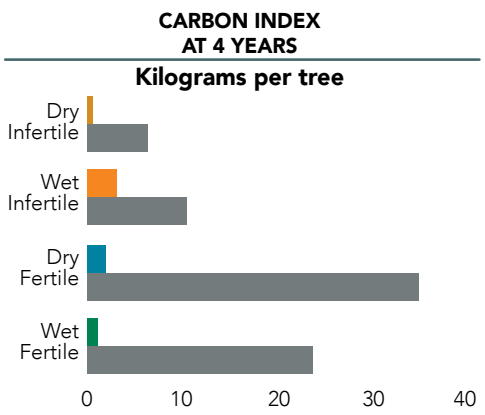
Boards, construction (naval), fence posts, honey production, human consumption (fruits, resin), living fences, ornamental tree, railroad ties, tannery (bark), tool handles.

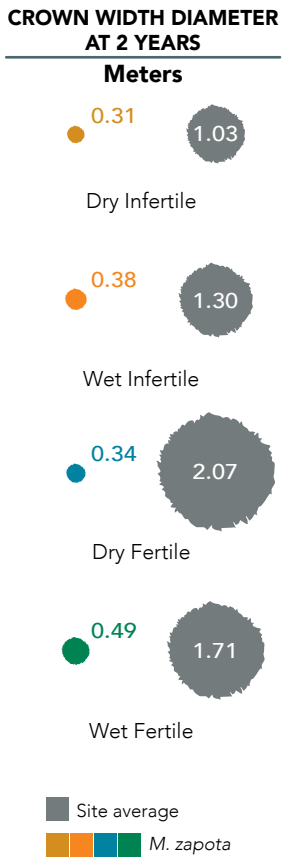
# *Manilkara zapota*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Muntingia calabura*

FAMILY

Tiliaceae (Recent molecular studies put this species in the family of Mutingiaceae)

COMMON NAMES

Periquito, pacito, majaguillo (Panama); capulín (Mexico, Central America); chitató (Colombia); nigüito (Ecuador); yumanaza (Peru); calabura, pau de seda (Brazil).

DESCRIPTION

*Muntingia calabura* is a small (3 to 10 meters), deciduous tree with a native range from Mexico to Argentina, where it is found in low- to mid-elevation, dry to wet forests. In the PRORENA species selection trials it exhibited high to very high survivorship in all but the wet infertile site, where it completely disappeared despite having greater than 50 percent survival at two years. Its height and diameter growth at the dry fertile site was nearly double that of the wet fertile and dry infertile sites. At the dry infertile site it also exhibited a precipitous decline in height growth due to dieback between years two and four. Four-year height growth far exceeded the average at the dry fertile site and was equivalent to the average at the wet fertile site. When grown unpruned in plantations, the species tended to form a broad, thin, spreading crown from multiple stems, allowing light to get to the understory. Two-year crown diameters were above averages, and more than double that of the dry site averages. Four-year carbon index nearly doubled averages at the dry sites and was below average at the wet fertile site. The species has bright red fruits that attract birds, resulting in abundant regeneration of other bird-dispersed plant species below it.

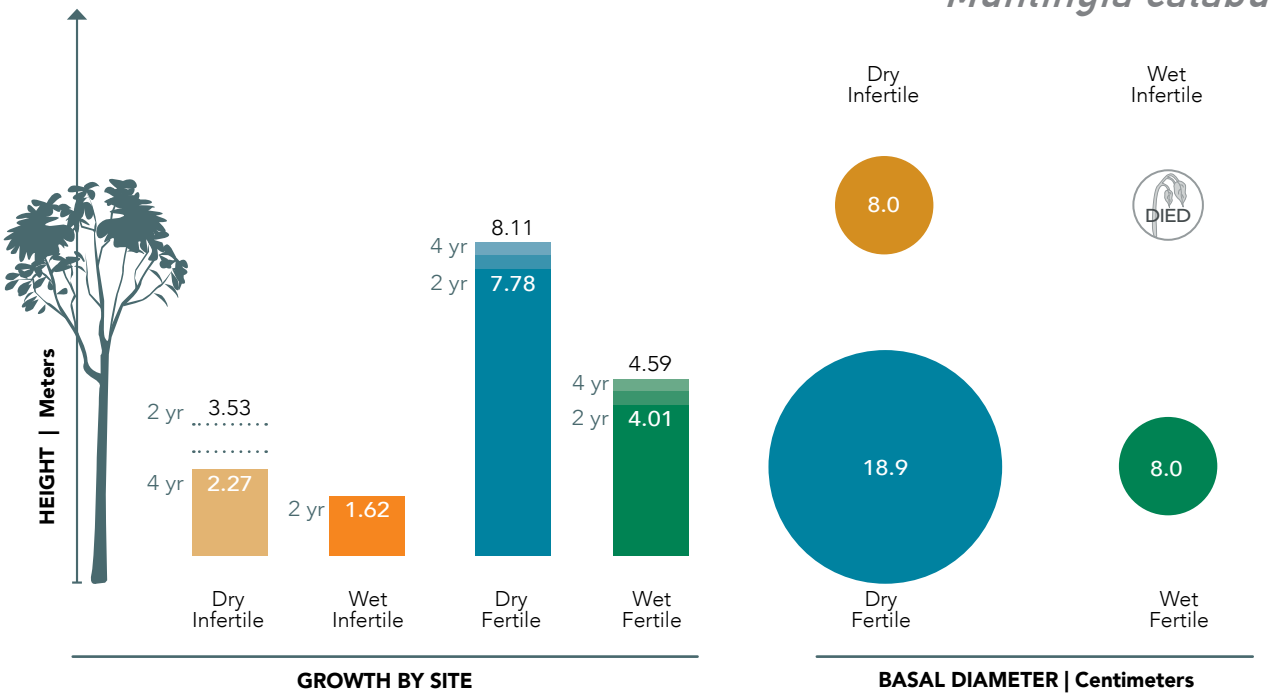
RECOMMENDATIONS

This species has shown great potential for reforestation and restoration. Its fast growth and above-average two-year crown diameters suggests its value in helping quickly recover forest cover at different sites. Its four-year carbon index also suggests its ability to help recover carbon sequestration values when used in combination with other, more long-lived species. Its disappearance from the wet infertile sites between years two and four—as well as its marked dieback at the dry infertile site—suggest that it will be an ephemeral component of these forests.

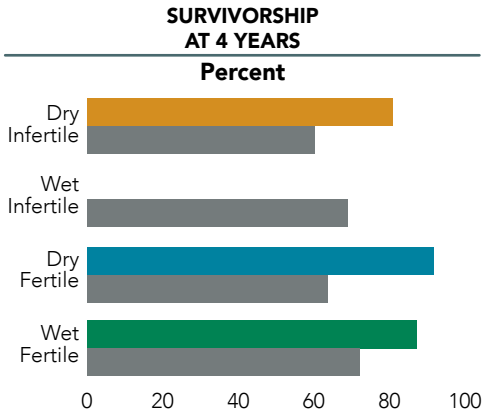
SELECTED USES

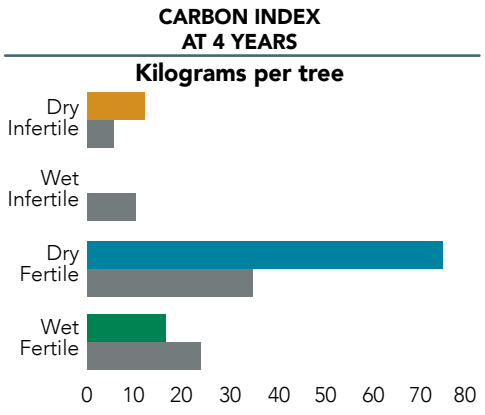
Charcoal, fence posts, firewood, honey production, human consumption (fruits), living fences, medicines (all plant parts), mooring rope and basketry fibers (bark), attracting animal and plant diversity, carbon sequestration (early), early crown cover in reforestation, nurse tree for shade-tolerant species, understory structure in reforestation.

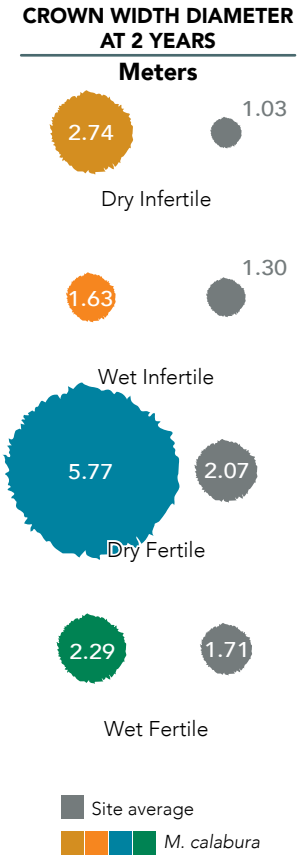
# *Muntingia calabura*




Basal diameter taken at same age as maximum height




Nevertheless, it has value even at these sites because its fruits attract seed-dispersing birds that can foster plant diversity and regeneration. Its short stature as a pioneer can provide structure to young forests by creating a shrubby tree layer for below-canopy, late-successional species.

SPACING

This species can be grown uniformly at three-meter spacing and wider in all but the dry fertile site conditions. At closer spacing, it can serve as a nurse tree for species requiring partial shade. It facilitates establishment of natural regeneration beneath because of seed dispersal from birds.



SCIENTIFIC NAME

# *Ochroma pyramidale*

FAMILY

Bombacaceae (Recent molecular studies put this species in the family of Malvaceae)

COMMON NAMES

Balso, balsa, lano (Panama, Central America); algodón (El Salvador); gatillo (Nicaragua); lanero (Cuba); corcho (Mexico); túcumo (Colombia); topa (Peru); tami (Bolivia); pau de balsa (Brazil).

DESCRIPTION

*Ochroma pyramidale* is a medium to tall (10 to 30 meters), deciduous pioneer tree found in low- to mid-elevation, dry to wet forests from southern Mexico to Bolivia and Brazil. It is very common in secondary forests and along roads and streams. It exhibited high, above-average survivorship at all sites of the PRORENA species selection trials. Height and diameter growth were markedly higher at fertile sites, but were still relatively high at the infertile sites. Four-year height growth was exceptional, at least twice the averages at all sites. Growth was lower but still relatively good in the microsites at Agua Salud, where soils are more acidic. Its two-year crown widths were well above averages at all sites, and double the averages at the fertile sites. While it has very large leaves and a broad crown, it is still rather thin and lets abundant light into the understory. Although it may live a decade or more, it is a very short-lived pioneer species, often completing its life cycle in four or five years. Its four-year carbon indices were higher than averages at all sites, and two or more times the averages at the fertile sites. Nevertheless, these indices were lower than might be suggested by the size (height and diameter) of the trees, since the wood itself is of very low density.

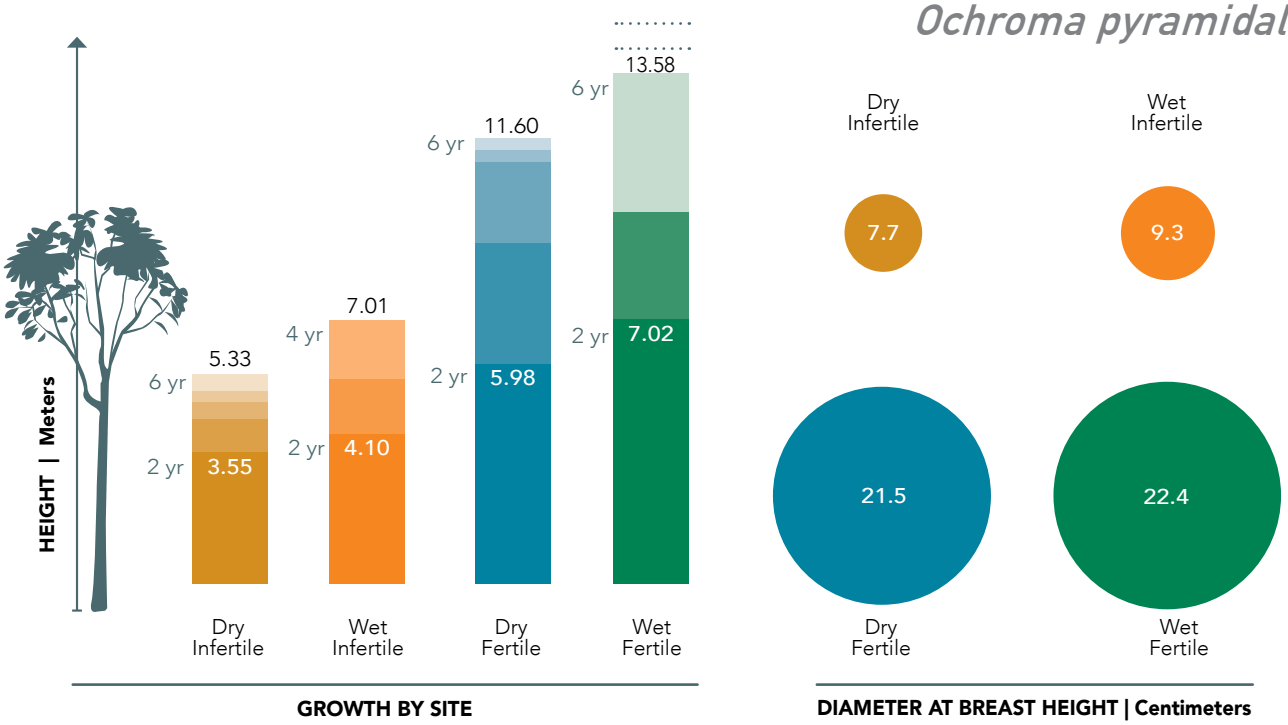
RECOMMENDATIONS

This species is recommended for restoration and reforestation treatments where it is important to quickly cover the site with trees and provide some forest structure. It does best on fertile sites, but also grows quite well compared to other species on moisture- or nutrient-stressed sites. Its large leaves, deciduous nature, and fast growth may help enhance nutrient cycling on a site. Its short life span may help jumpstart succession by providing moderate shade for more shade-tolerant and slower growing species early in their life cycles.

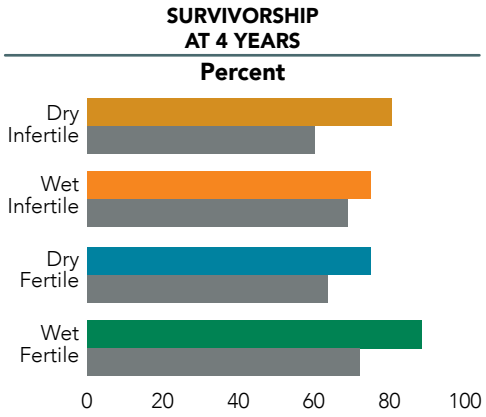
SELECTED USES

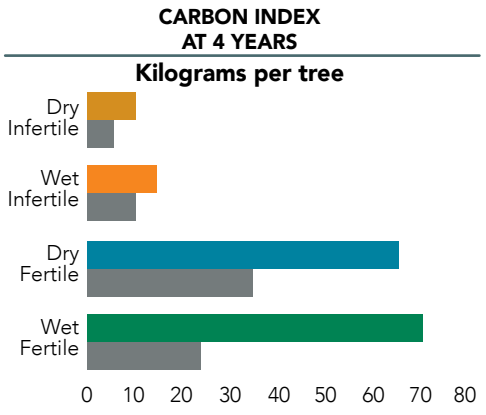
Buoys, insulation, mattress and pillow stuffing (fibers from fruits), models, musical instruments (vibrating properties), ornamental tree, packaging, rafts, carbon sequestration (early), early crown cover in reforestation, early stand structure in reforestation, nurse tree for shade-tolerant species, soil organic matter through litter production.

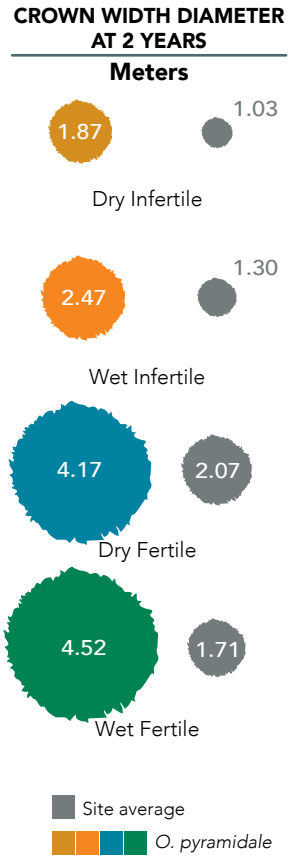
# *Ochroma pyramidale*




Diameter at breast height taken in the last year of height growth measurement




SPACING

This species can be grown three meters apart from neighbors, or placed closer if used as a shade-providing nurse tree for other species.



SCIENTIFIC NAME

# *Ormosia macrocalyx*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Alcornoque, coralillo, peronil, cabresto, palo de collar, janeiro, nené, conejito colorado (Panama); chocho grande (Colombia); huairuro (Peru, Bolivia); tento (Brazil).

DESCRIPTION

*Ormosia macrocalyx* is a medium to tall (10 to 30 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Mexico to Bolivia and Brazil. In Panama it is a common ornamental tree. It exhibited moderately high to very high survivorship in the PRORENA species selection trials, with the highest survival at the wet fertile site. It had sustained growth at all sites, but showed best height and diameter growth at the wet fertile site. Four-year height growth far exceeded the average at the dry infertile site, but heights were well below averages at all other sites. It formed relatively narrow crowns, with two-year crown diameters far below averages at all sites. Its four-year carbon index was higher than average at the dry infertile site and indices were slightly below averages at the wet infertile and wet fertile sites.

RECOMMENDATIONS

This species is known to fix nitrogen and thus is recommended in reforestation and restoration treatments to increase ecosystem nitrogen. Its narrow crown suggests that it can be grown close to neighbors, but since it exhibited moderate growth at best, it will get overtopped; however, its shade tolerance allows it to be used as a soil nurse for nitrogen enrichment (rather than for creating partial shade).

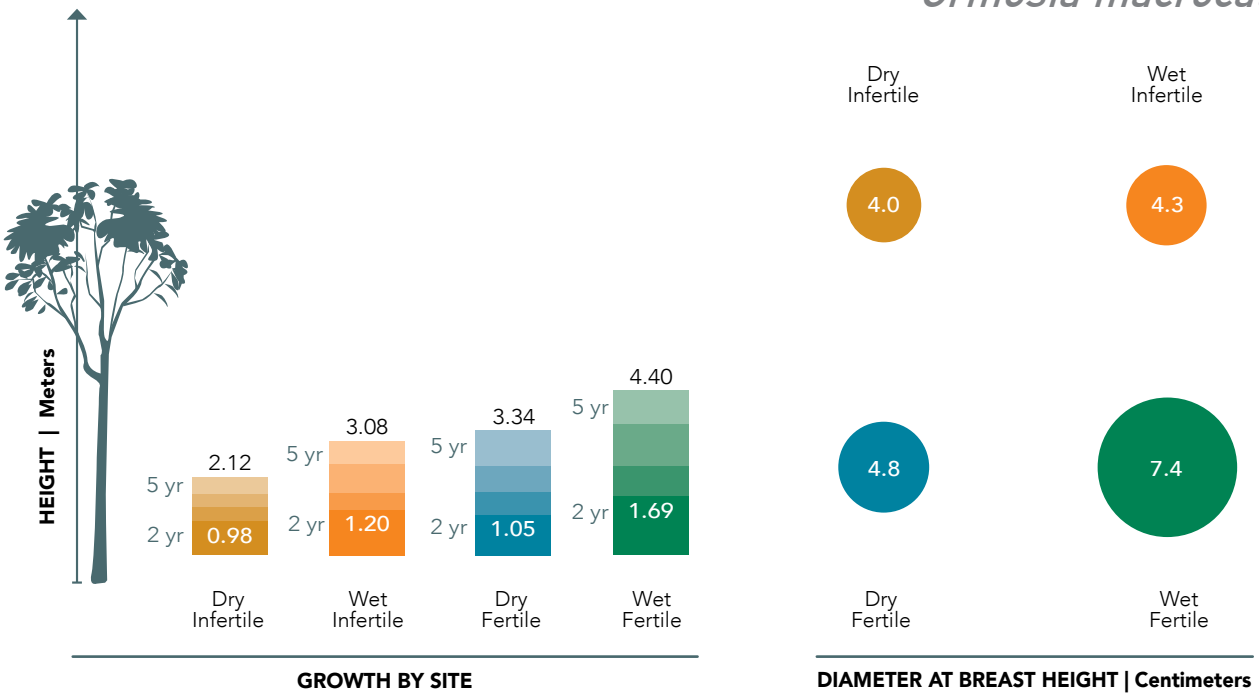
SPACING

Data from the literature and the PRORENA trials suggest that this species can be grown less than two meters apart from faster growing species with broad crowns. It should not be spaced further than three meters if early crown closure is a management objective.

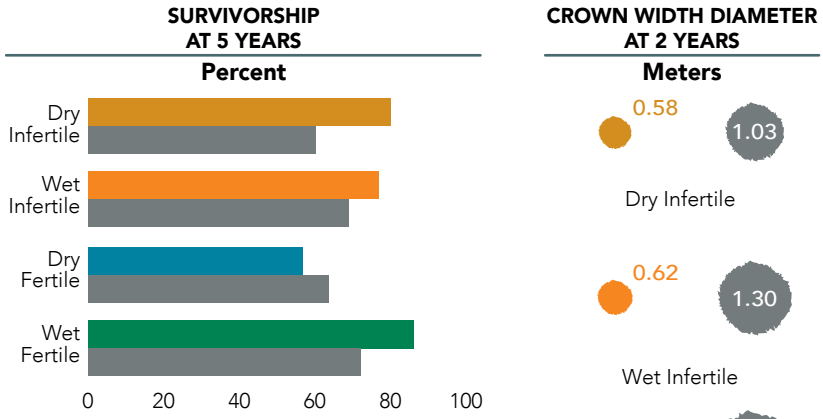
SELECTED USES

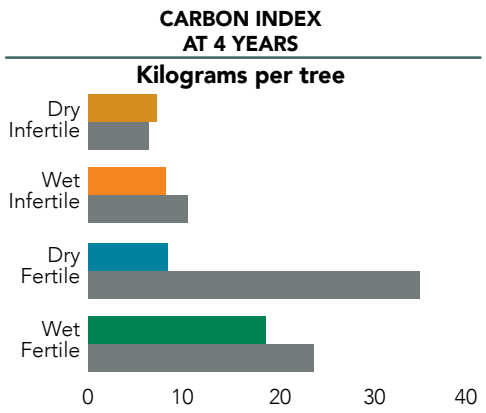
Bridges, cabinetry, carpentry, furniture, handicrafts (seeds), ornamental tree, railroad ties, potential soil improvement through nitrogen fixation and use as green manure.

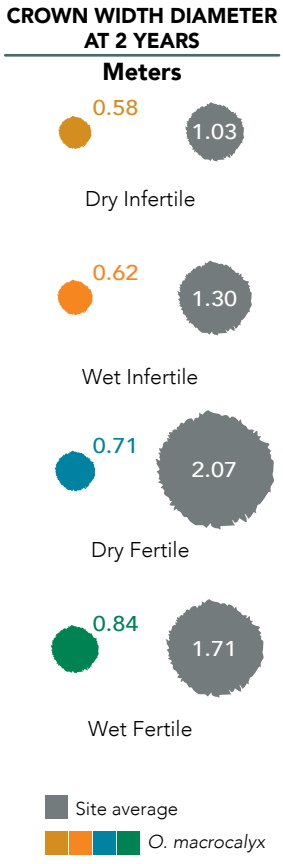
# *Ormosia macrocalyx*

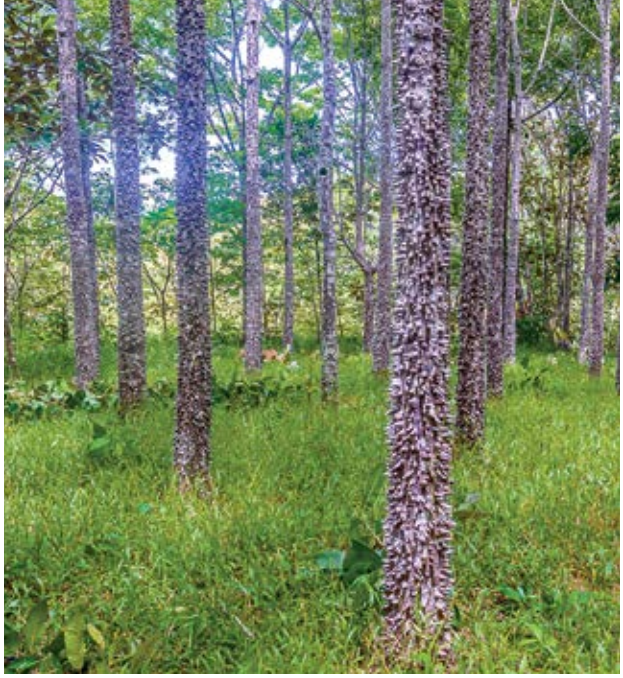



Diameter at breast height taken in the last year of height growth measurement




SCIENTIFIC NAME

# *Pachira quinata*

FAMILY

Bombacaceae (Recent molecular studies place this species in the Malvaceae)

COMMON NAMES

Cedro espino, cedro espinoso (Panama, Honduras, Colombia); pochote (Costa Rica, Nicaragua); saquisaqui, jaris, masguara (Venezuela).

DESCRIPTION

*Pachira quinata* is a tall (20 to 40 meters), deciduous canopy species found in dry to moist, lowland forests from Nicaragua to Colombia and Venezuela. In Panama it is common in dry areas and on calcareous soils. It showed very high survivorship and growth on fertile sites in the PRORENA species selection trials, with far better growth on the dry fertile site. Growth was very poor on infertile soils. Four-year height growth far exceeded site average at all but the wet infertile site. At the Agua Salud plantations, this species grew better in mixtures than monocultures for un-thinned stands. It formed a straight stem, but tended to allocate growth to diameter rather than height, often resulting in short, stout trees. It formed broad, deep crowns. Two-year crown diameters exceeded averages at all but the wet infertile site. Moisture stress does not appear to trigger its seasonal leaf fall. Leaf fall benefits competing vegetation below the crown as long as soil moisture conditions allow. However, dieback results in understory vegetation during the dry season that can leave abundant fuel on the ground, creating a fire risk. Fires can cause immediate mortality to this species and also leave it susceptible to insect attack and disease. Despite low wood density, the species' four-year carbon indices exceeded site averages, with those for fertile sites being exceptional.

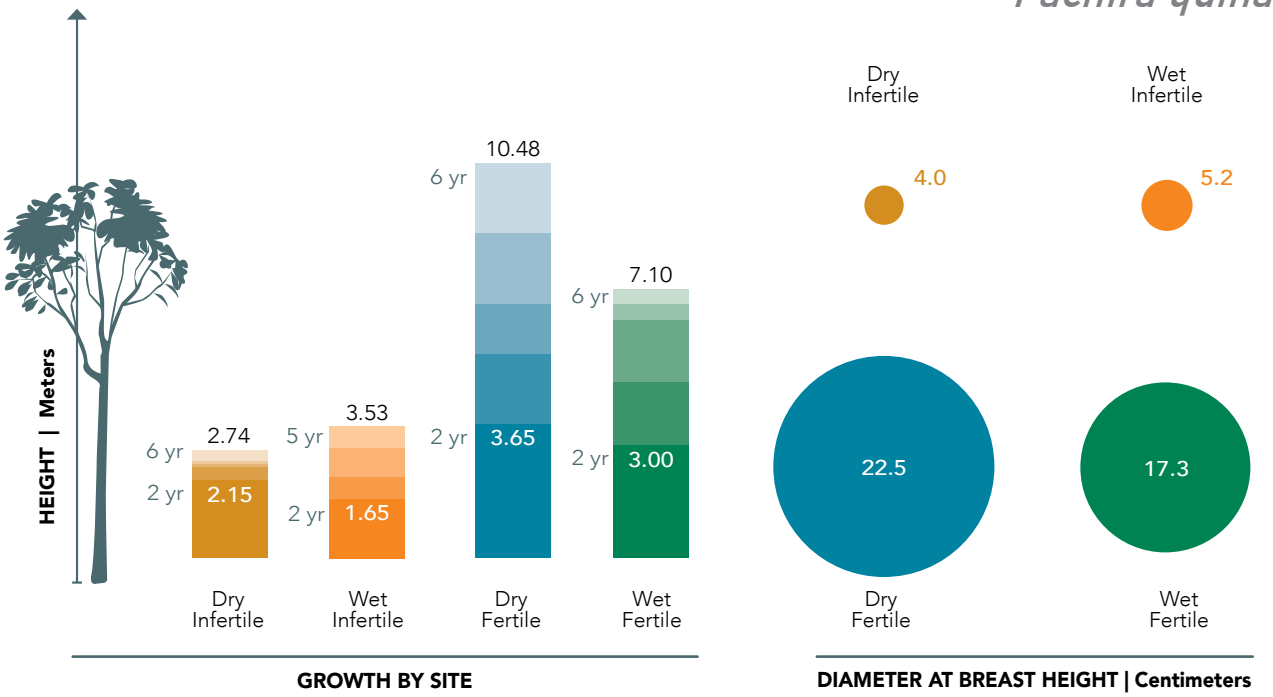
RECOMMENDATIONS

This species forms abundant juvenile wood and can require decades for the formation of heartwood, the desirable wood from a timber perspective. Indeed, it reportedly requires 50-year or longer rotations in timber plantations. It has been widely planted in small landholder plantations throughout Panama, often on suboptimal sites. While these stands can be aesthetically pleasing, they are unlikely to be profitable from a timber income perspective. For reforestation purposes, it can be used in combination with other species as a canopy tree on fertile sites. Despite its high content of juvenile

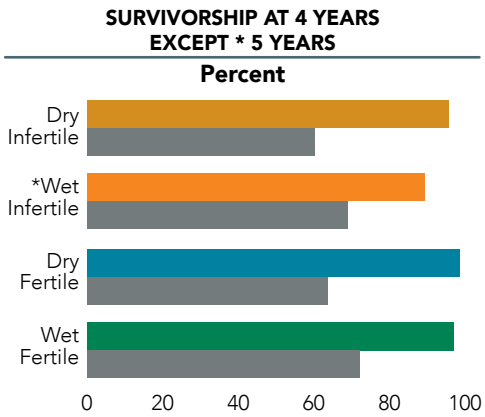
SELECTED USES

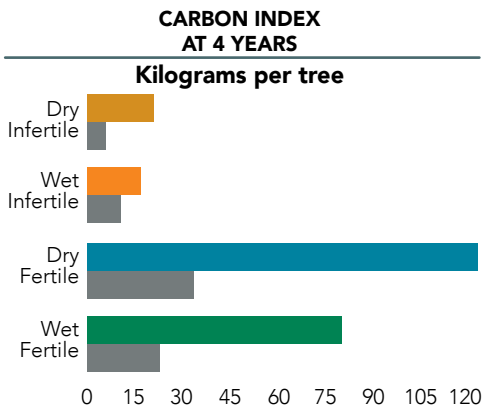
Boards, boxes, canoes, doors, furniture (fine), mattress and pillow stuffing (fibers from fruits), medicines (flowers), particle board, window framing, carbon sequestration, nurse tree for shade-tolerant species, soil moisture retention through seasonal leaf fall.

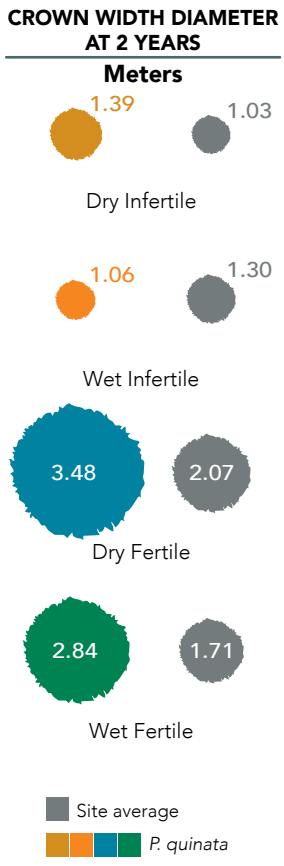
# *Pachira quinata*




Diameter at breast height taken in the last year of height growth measurement




wood, its high growth on dry fertile sites suggests potential for use in carbon sequestration on similar sites. Given its deciduous habit and tendency to foster growth of understory weeds and shrubs, caution should be taken when planting it in high densities in reforestation or restoration schemes that do not receive adequate fire protection. However, its tendency to lose leaves before the onset of the dry season suggests it may be appropriate for planting where dry season soil moisture retention is desired.

## SPACING

This species can be grown at an initial spacing of three meters. It can be grown at less than two meter spacing if the intention is to provide partial or seasonal shade to neighbors.

SCIENTIFIC NAME

# *Peltogyne purpurea*

FAMILY

Fabaceae-Caesalpinioideae

COMMON NAMES

Nazareno (Panama, Costa Rica, Colombia); cananeo, tananeo (Colombia); purpleheart (North America).

DESCRIPTION

*Peltogyne purpurea* is a tall to very tall (30 to 50 meters), late-successional, semi-deciduous tree found in low-elevation, moist forests from Costa Rica to Colombia. It exhibited poor to very poor survivorship in the PRORENA species selection trials, with highest survivorship at the wet infertile site. Growth was poor across all sites, with trees not reaching the 1.3-meter mark for measuring breast height diameter even after four years. Two-year crown diameters were far below site averages. Four-year carbon indices barely registered.

RECOMMENDATIONS

This species survived poorly and grew exceptionally slowly in the PRORENA species selection trials. This may be due to its reported slow-growing late successional habit. Studies show it does better when grown in partial shade.

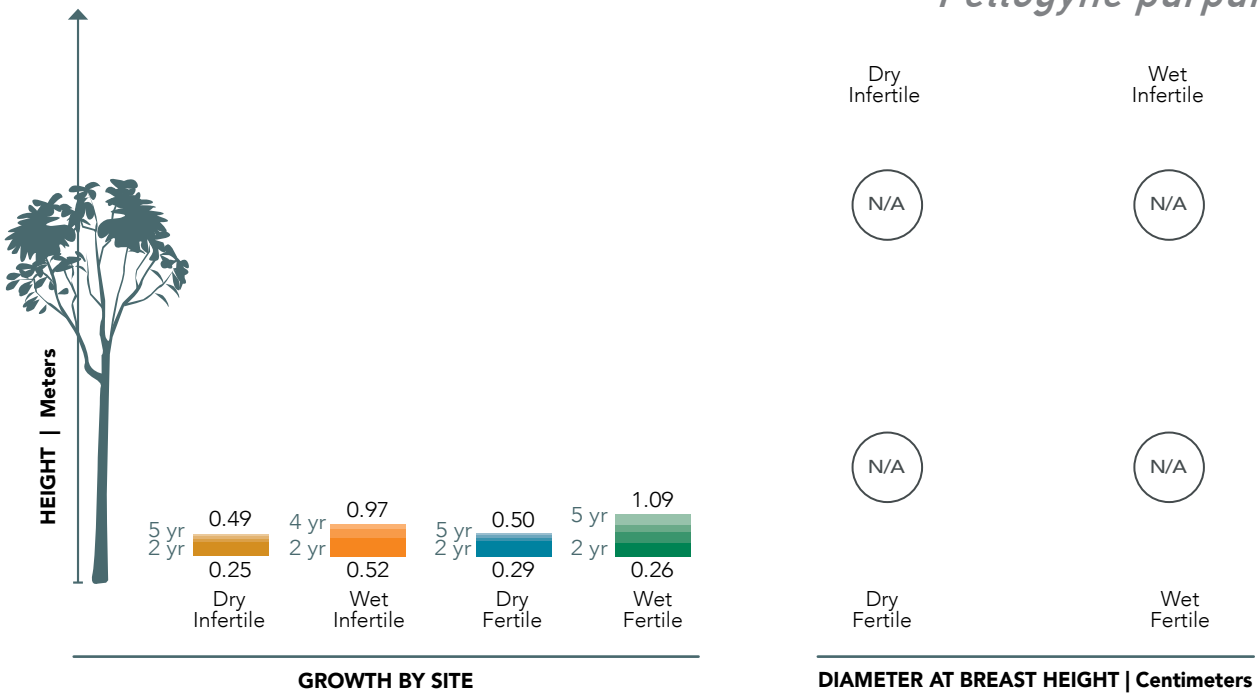
SPACING

If used in restoration or reforestation treatments, it should be planted in close proximity to neighbors so that it will benefit from shade; it is best under-planted on moist soils. The tree should be expected to take a long time to mature to any harvestable size (60 years plus) and can be integrated within conservation plantings or successional mixed plantings that ultimately are intended to end with a late-successional forest type.

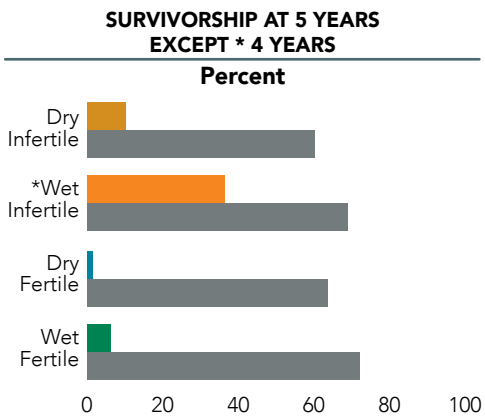
SELECTED USES

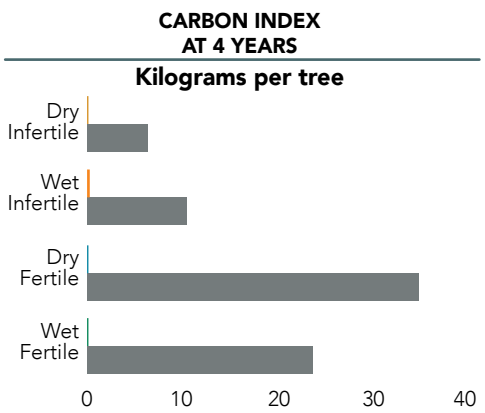
Cabinetry, flooring, handicrafts, veneer, canopy species in reforestation. This is an extremely valuable timber species, producing heavy, purple-colored heartwood.

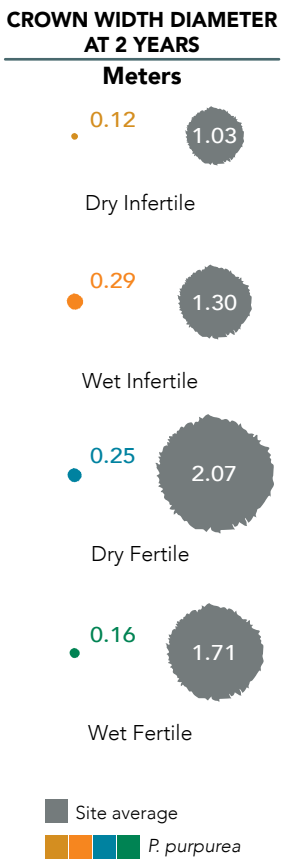
# *Peltogyne purpurea*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Pentaclethra macroloba*

FAMILY

Fabaceae-Mimosoideae

COMMON NAMES

Gavilán (Panama, Costa Rica, Nicaragua); koorooballí (Guyana, Surinam); dormilón (Colombia); mulato, carbonero (Venezuela); panará-cachy, pracaxy (Brazil).

DESCRIPTION

*Pentaclethra macroloba* is a medium to tall (10 to 35 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Nicaragua to Brazil. In Panama it is found along rivers and swamps on the Caribbean side of the mountains. It was grown at only the wet infertile site of the PRORENA species selection trials. It exhibited moderately poor survivorship, with height and diameter growth below site averages. It exhibited narrow crown growth, with two-year crown diameter less than half the site average. Its four-year carbon index was approximately half the site average.

RECOMMENDATIONS

In restoration and reforestation treatments on wet infertile sites similar those of the PRORENA trials, this species can be used to increase diversity and help fix atmospheric nitrogen. However, its slow growth and low survivorship in the PRORENA trials suggests that it would rapidly be overtopped by most species used in such endeavors. It has been reported to grow better on fertile moist sites or under conditions of partial shade.

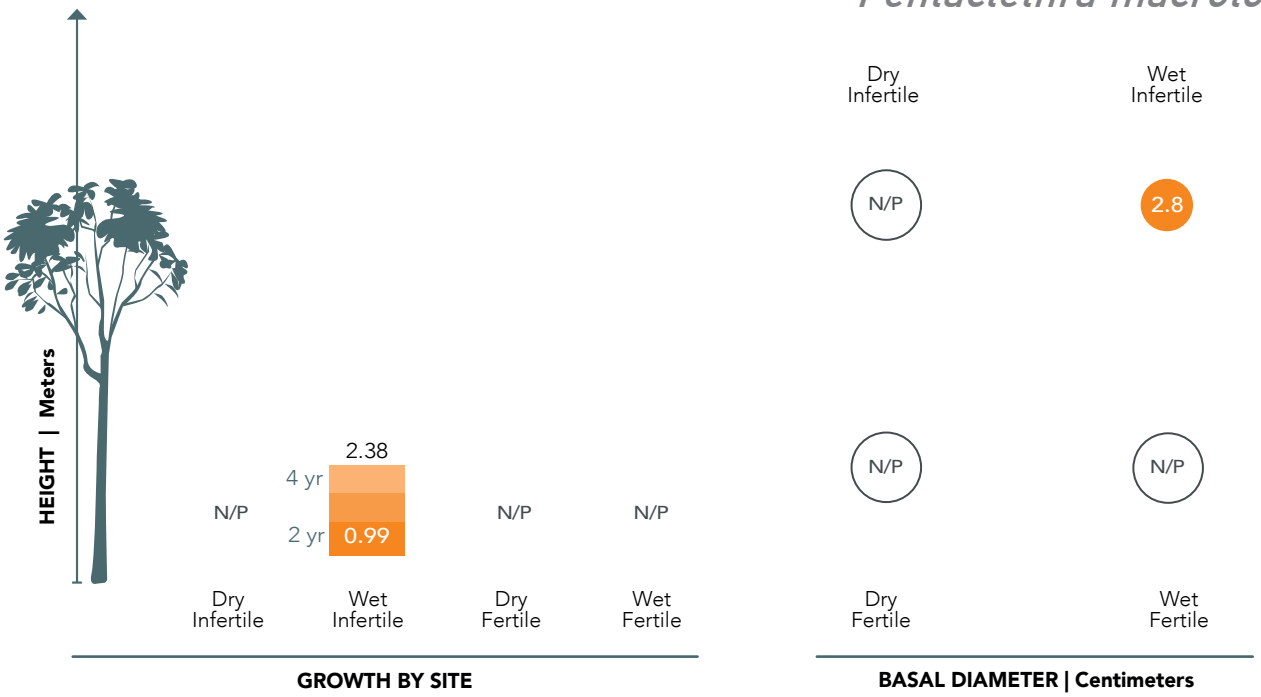
SPACING

This species can be planted within two meters of neighbors but will be quickly overtopped. A release and thinning regime will be required to move this species into the canopy; it can be intimately mixed with a fast-growing, deciduous canopy tree that provides partial shade.

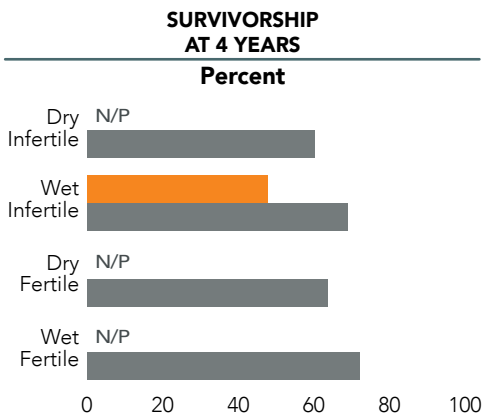
SELECTED USES

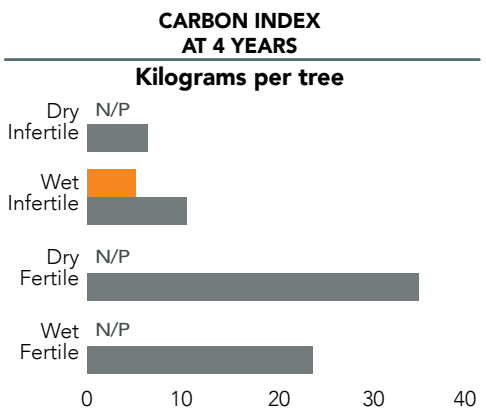
Boards, cooking oil (seeds), construction (heavy), firewood, human consumption (seeds), medicines (seeds, fruits), mid-story structure in reforestation, potential soil improvement through nitrogen fixation and use as green manure.

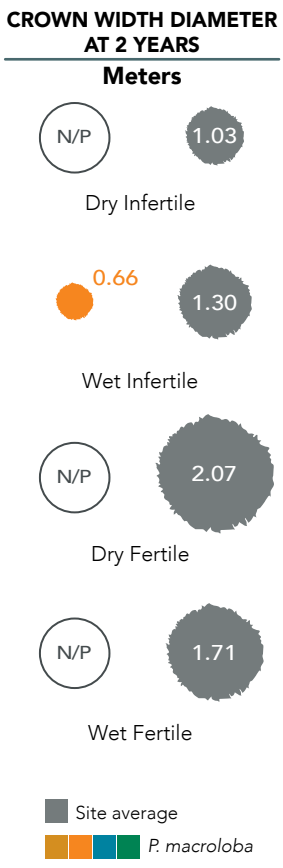
# *Pentaclethra macroloba*




Basal diameter taken at same age as maximum height





SCIENTIFIC NAME

# *Platymiscium pinnatum*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Quira, quirá (Panama); cachimbo, cristóbal (Costa Rica); coyote (Nicaragua); granadillo (Mexico); roble, tasajo (Venezuela).

DESCRIPTION

*Platymiscium pinnatum* is a medium to tall (10 to 35 meters), semi-deciduous tree found in low- to mid-elevation, dry to moist forests from Mexico to Venezuela. It exhibited high to exceptionally high survivorship in the PRORENA species selection trials, with its highest survivorship at the wet fertile site. There was little differentiation in height and diameter growth between sites. Four-year height growth was markedly higher and equivalent to averages at the dry infertile and wet infertile sites. Height growth was below average at the fertile sites. Two-year crown diameters were close to averages at all but the dry fertile site, where it was markedly below average. Four-year carbon indices were markedly below average.

RECOMMENDATIONS

This species showed good survivorship and growth at all PRORENA sites, including those that were nutrient- and moisture-stressed. It is thus recommended for reforestation and restoration treatments, particularly on sites with similar nutrient status to the infertile sites. Its narrow crown allows it to be grown in relative close proximity to neighbors of the same or other species. Its ability to fix atmospheric nitrogen also makes it an appealing component of restoration and reforestation treatments.

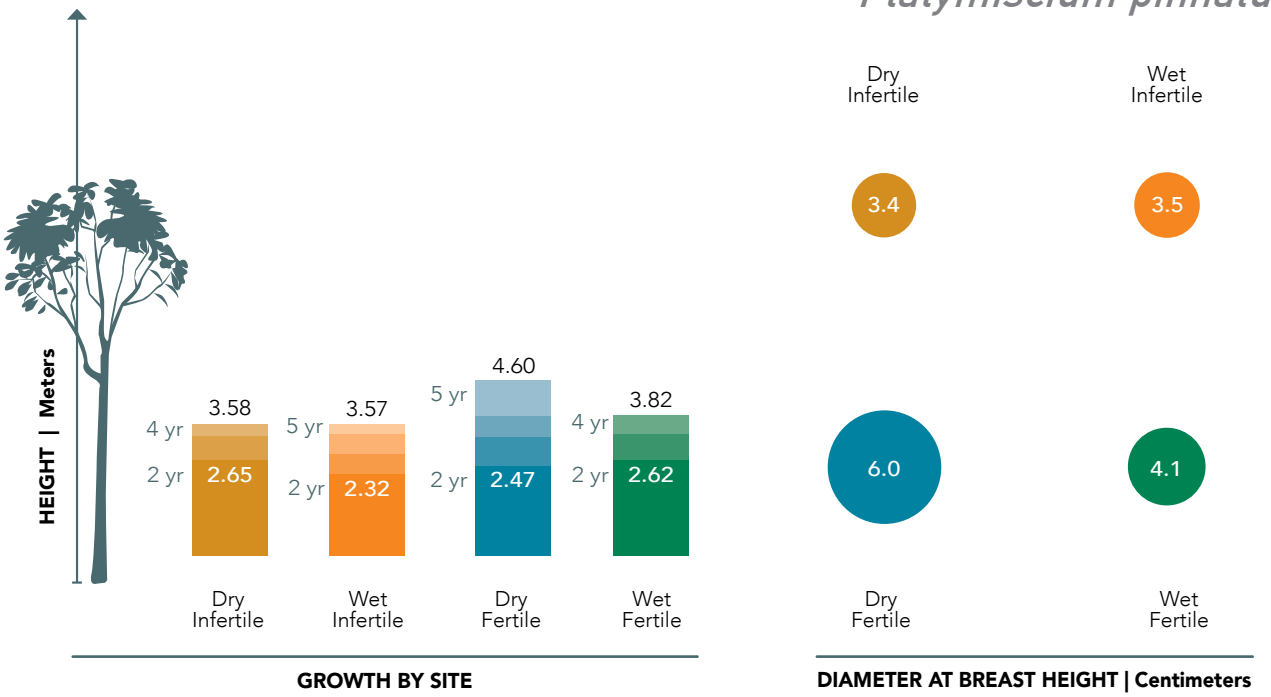
SPACING

Data from the literature as well as the PRORENA trials indicate that this tree can persist and grow in partial to deep shade. This suggests that the species can be spaced at two meters or less to its neighbors, making it a useful tree in promoting stem exclusion and upward growth in forest stand stature.

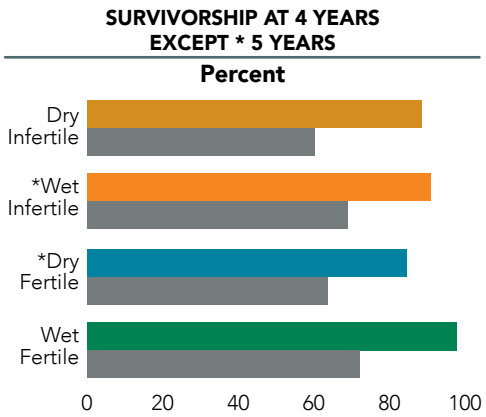
SELECTED USES

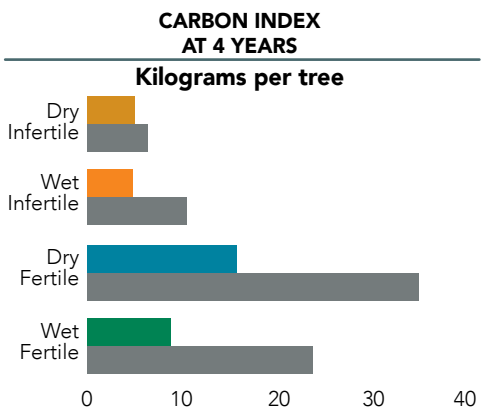
Boat keels, cabinetry, carpentry, fine wood turning, musical instruments, mid-story structure in reforestation, potential soil improvement through nitrogen fixation and use as green manure.

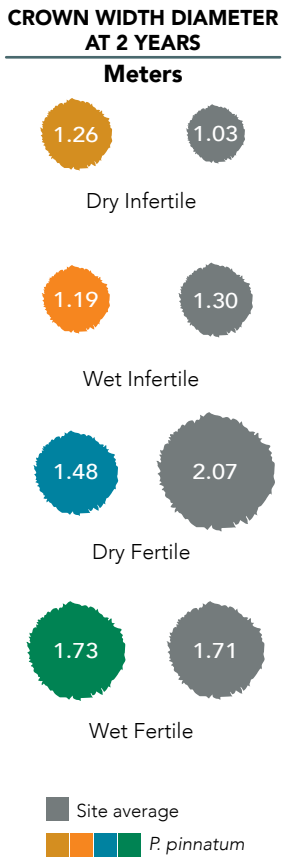
# *Platymiscium pinnatum*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Protium tenuifolium*

FAMILY
Burseraceae

COMMON NAMES
Copal, copá, chutra (Panama); anime (Colombia); breu-preto (Brazil).

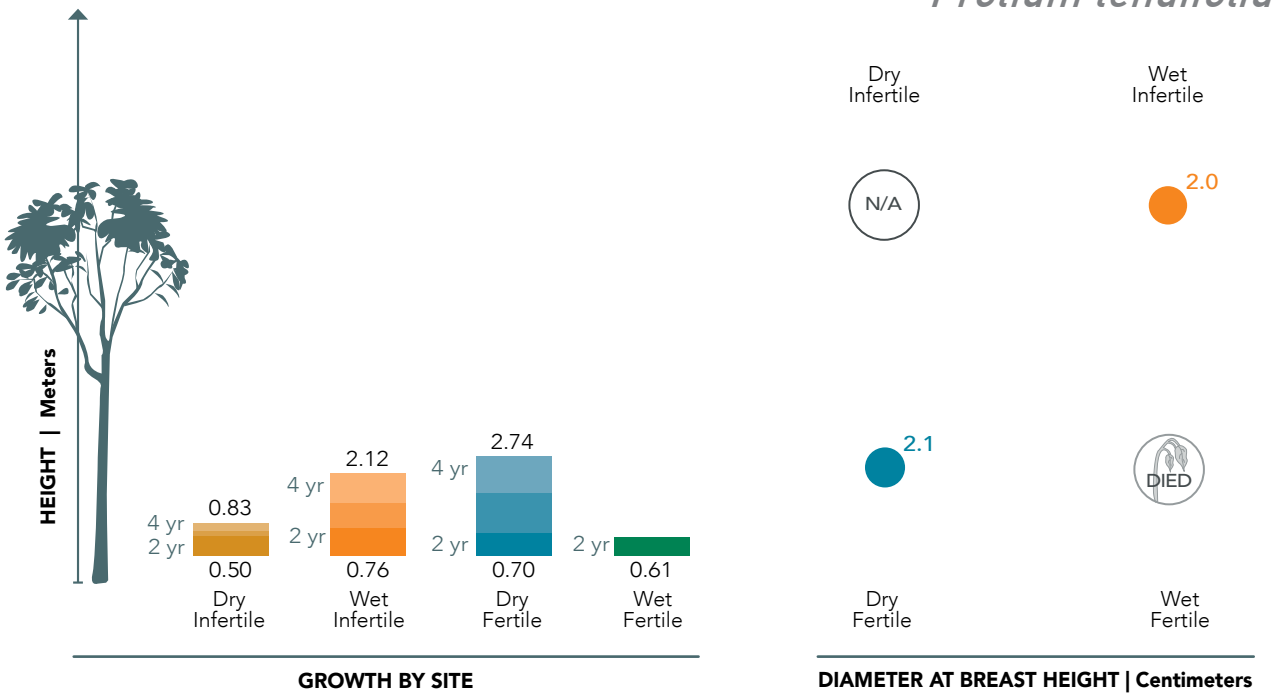
DESCRIPTION
*Protium tenuifolium* is a medium-sized (10 to 25 meters), evergreen tree found in low- to mid-elevation, moist to wet forests from Panama to Bolivia. It exhibited poor to very poor survivorship in the PRORENA species selection trials, with highest survivorship at the wet infertile site and no individuals surviving at the wet fertile site at four years. Height and diameter growth for surviving individuals was well below site averages at all sites, with similar growth at the wet infertile and dry fertile sites. It formed very narrow crowns at two years, with crown diameters far below site averages at all sites. Four-year carbon indices were very low across all sites.

RECOMMENDATIONS
Survivorship and growth data suggest that this species does not do well in full-sunlight conditions, but it grows better in the understory. Low seed germination rates and slow growth indicate many challenges in managing this species at large scales. Its narrow crown suggests it can be grown in close proximity to neighbors but also may reflect its overall poor growth.

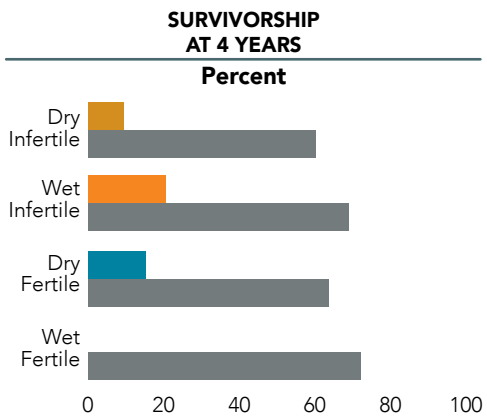
SPACING
Given the literature and data from the PRORENA trials, this species does best on relatively nutrient-poor soils, and is best under-planted within existing plantations in wet regions. Irrespective of site, however, the species has a low chance of survival without careful tending.

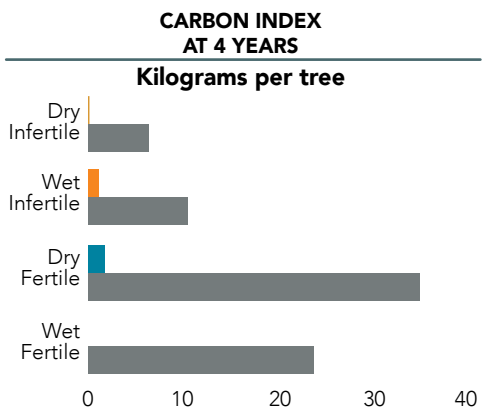
SELECTED USES
Cabinetry, carpentry, construction, domestic utensils, flooring, furniture, medicines (resin).

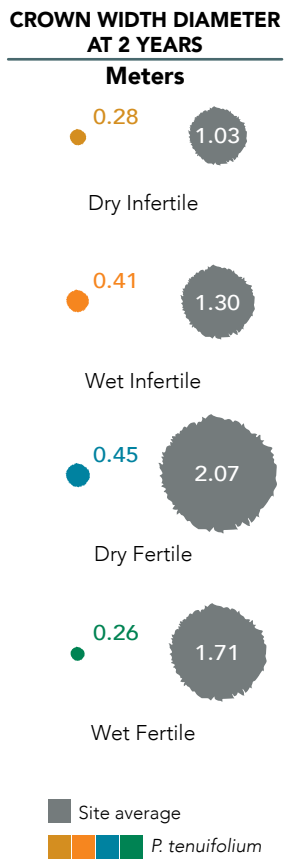
# *Protium tenuifolium*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Pterocarpus officinalis*

FAMILY

Fabaceae-Papilionoideae

COMMON NAMES

Sangre de gallo, cricamola, suela (Panama); chajada amarilla (Costa Rica); cahué (Guatemala); sangreado (Nicaragua, Honduras); palo de pollo (Puerto Rico).

DESCRIPTION

*Pterocarpus officinalis* is a medium to tall tree (15 to 35 meters) found in low-elevation, moist to wet forests from Belize and Guatemala to Ecuador. In Panama it is common in flooded forests, particularly on the Caribbean side of the Isthmus. It exhibited moderate to poor survivorship in the PRORENA species selection trials, as would be expected given its site preference. Highest survivorship was at the infertile sites, but well below site averages. It exhibited best height growth at the wet sites but best diameter growth at the infertile sites. Four-year height and diameter growth were far below site averages for all sites, except for height growth equivalent to the site average at the dry infertile site. Two-year crown width and four-year carbon index values were far below site averages for this species.

RECOMMENDATIONS

Given that almost all its performance attributes were below site averages, it would be risky to plant the species in full sunlight at sites with soil fertility similar to the PRORENA trials. The species may do better than other species at inundated sites and riparian or floodplain restoration sites. However, trials should be completed before planting out large numbers of individuals. It can be planted in low densities at infertile sites but may be quickly overtopped by some neighbors.

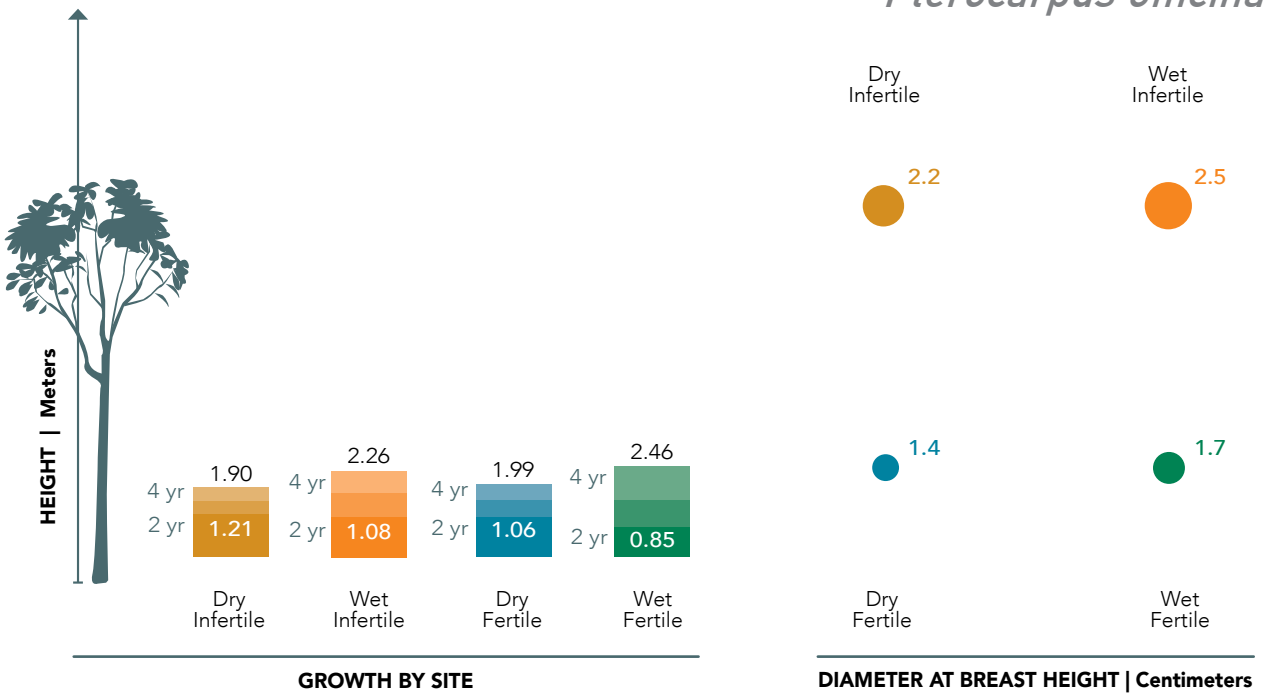
SPACING

The PRORENA trials do not provide data on this species' shade tolerance. Its extremely small crowns at two years may have resulted from full-sunlight conditions at the sites. Crown diameters indicate that it can be grown in close proximity to individuals of species with moderate to slow growth and crown development.

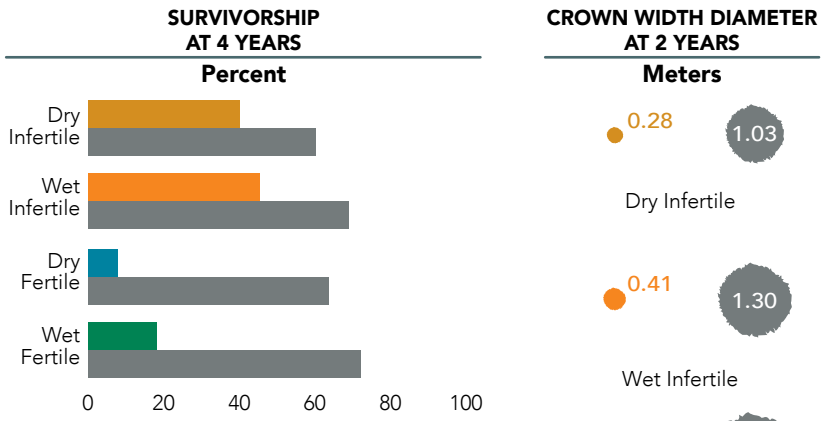
SELECTED USES

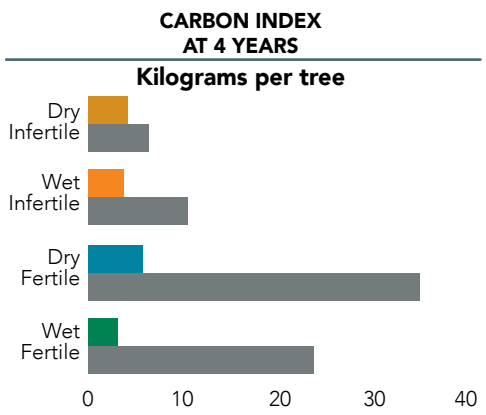
Boxes, carpentry, charcoal, construction, firewood, medicines (resin), potential soil improvement through nitrogen fixation and use as green manure.

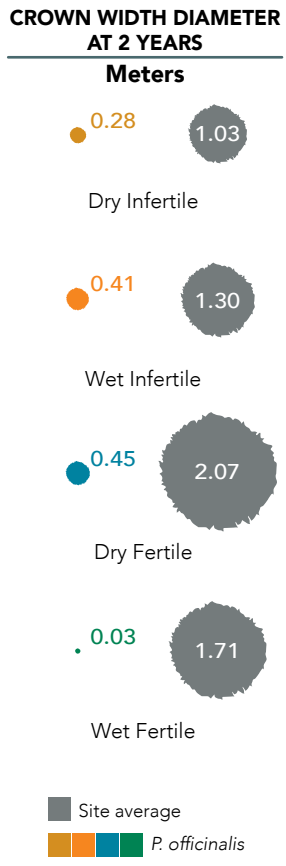
# *Pterocarpus officinalis*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Pterocarpus rohrii*

FAMILY
Fabaceae-Papilionoideae

COMMON NAMES
Sangre de gallo, sangre, cricamola, suela (Panama); sangrillo, sangreado (Costa Rica); sangre (Honduras); bollo blanco (Colombia); charapa caspi (Peru).

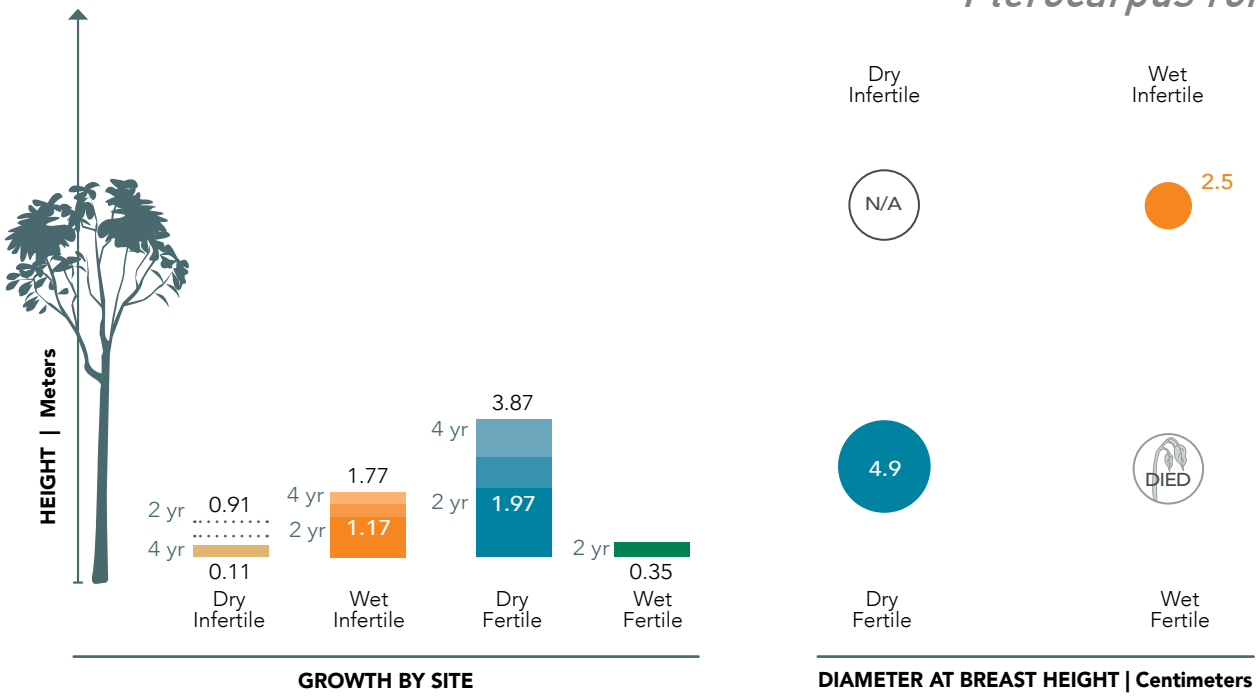
DESCRIPTION
*Pterocarpus rohrii* is a medium to tall tree (15 to 35 meters) found in low-elevation, moist to wet forests from Mexico to Peru and Bolivia. In Panama it is common on the Caribbean side of the Isthmus. It exhibited moderately high, above average survivorship at the wet infertile site of the PRORENA species selection trials, but low to very poor survivorship at the dry fertile and dry infertile sites respectively. All individuals died by four years at the wet fertile site. Best height and diameter growth were at the dry fertile site; however, as with the other sites, this was still well below the site average. Two-year crown width for this species was well below site averages, with broadest crowns at the dry fertile site. Four-year carbon index values were well below site averages.

RECOMMENDATIONS
Data from the PRORENA trials suggest this species can be planted in full sunlight at sites similar to the dry fertile site, though in low densities to reduce the risk of reforestation failure due its inability to successfully establish.

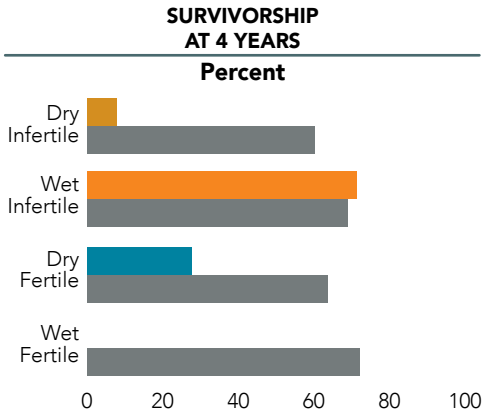
SPACING
Data from the literature as well as the PRORENA trials indicate that this species can persist and grow in moderate to deep shade, suggesting that it can be planted less than two meters apart from neighbors, or that it can be under-planted with species that exhibit superior growth to create greater stratification within a young plantation.

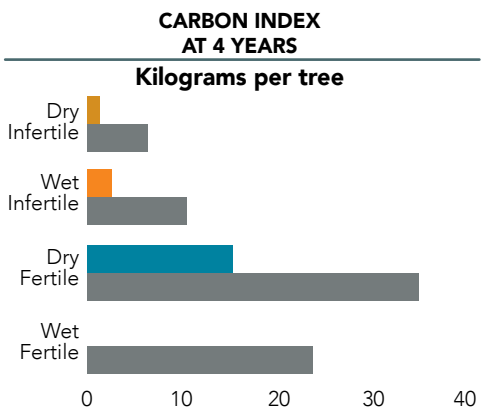
SELECTED USES
Boards, carpentry, furniture, ladders.

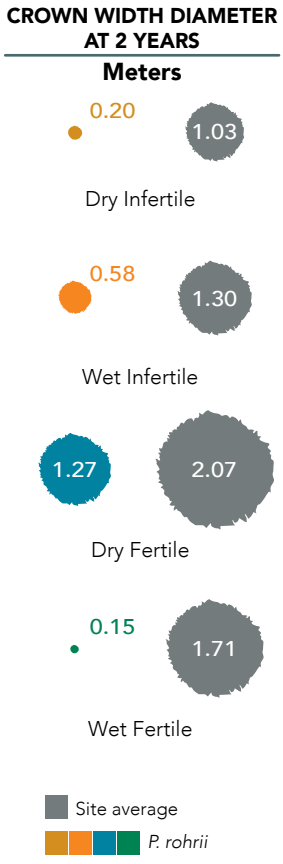
# *Pterocarpus rohrii*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Sapindus saponaria*

FAMILY

Sapindaceae

COMMON NAMES

Jaboncillo (Panama, Costa Rica, Nicaragua, Guatemala, Mexico); soap tree (Belize); pacón (Honduras); chumbino (Colombia); boliche (Peru); saboeiro (Brazil); palo-jabón (Argentina).

DESCRIPTION

*Sapindus saponaria* is a medium-sized (10 to 25 meters), deciduous tree found in low-elevation, dry to moist forests from Mexico to Argentina and Paraguay. In Panama it is common in pastures and dry forests on the Pacific side of the Isthmus. It exhibited moderate to high survivorship in the PRORENA species selection trials, with highest survival at the dry fertile site. At the wet fertile site, survival was approximately average. Best height and diameter growth was at the dry fertile site, followed by the wet infertile site. Four-year height growth was still below averages at all sites. This species formed narrow crowns, with two-year crown diameters about half the averages at most sites. Four-year carbon indices were far below averages at all sites.

RECOMMENDATIONS

Data suggests this species can be used in all but dry infertile sites. However, as even the best growth was below site averages in the PRORENA trials, it should be used in moderate densities in restoration and reforestation treatments. It is not useful for shading out grasses and competing vegetation, but its growth nevertheless suggests it will help give early structural complexity to reforestation treatments when combined with faster growing species. It is highly prized by birds and is a useful edge tree along open riparian plantings. It can also be planted in clusters in openings or around larger tree islands to facilitate nucleation of natural regeneration on open old fields.

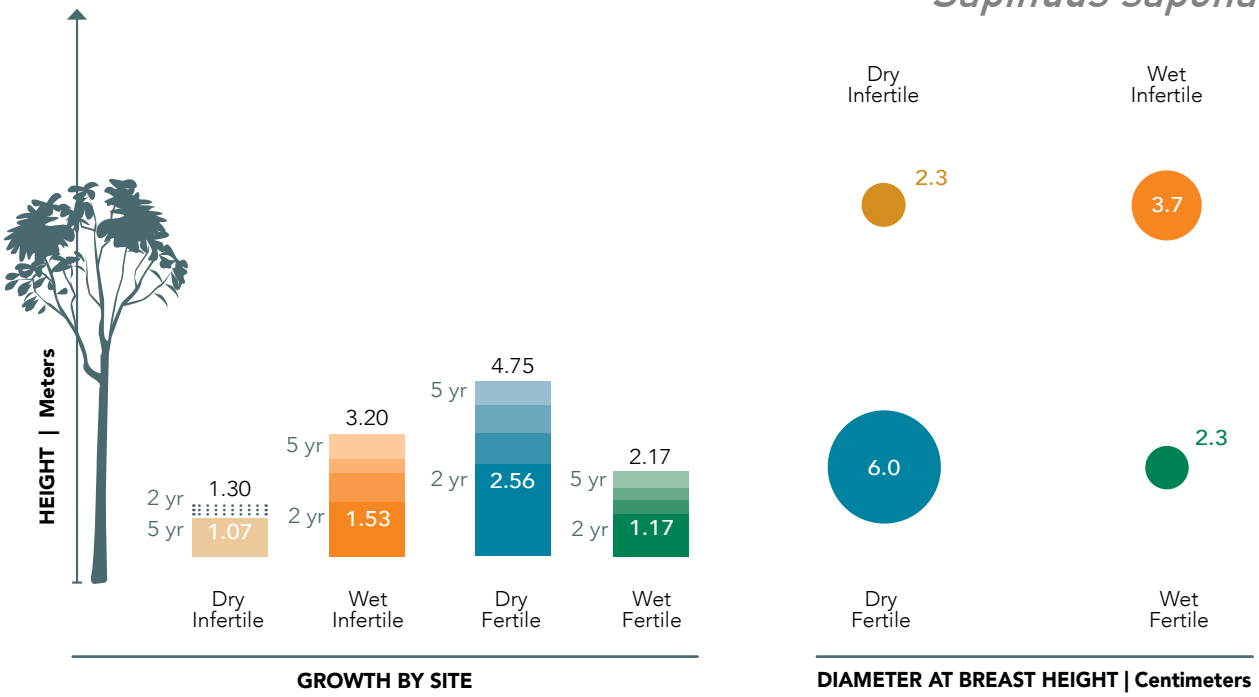
SPACING

This species can be grown at two meter spacing among species with moderate growth rates but would be quickly overtopped by species with better growth rates at the different PRORENA sites.

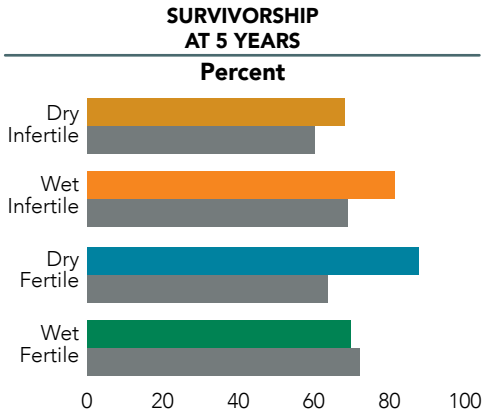
SELECTED USES

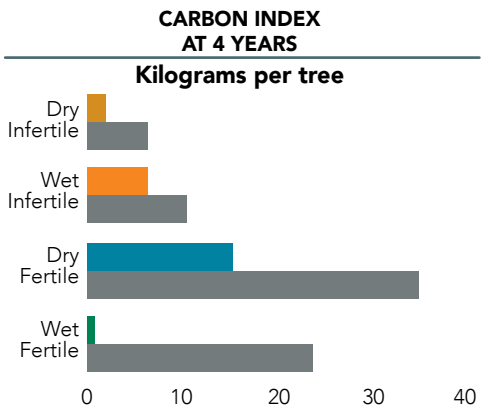
Fence posts, firewood, handicrafts (seeds), ornamental tree, honey production, medicines (tea from leaves, fruits), pitchforks, soap (fruits), tool handles, attracting animal diversity, early stand structure in reforestation.

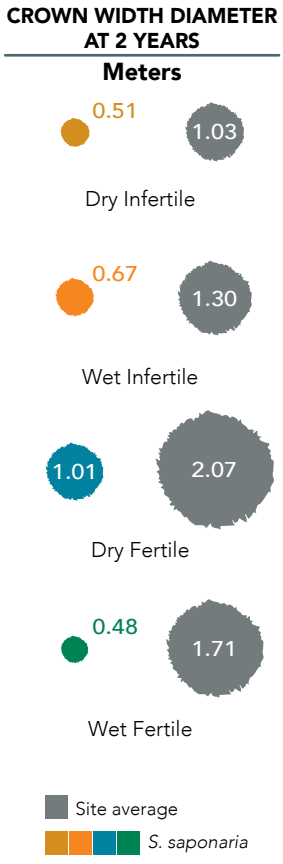
# *Sapindus saponaria*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Sapium glandulosum*

FAMILY

Euphorbiaceae

COMMON NAMES

Olivo (Panama); yos (Costa Rica); pau-leiteiro, pau-de-leite (Brazil); curupí, árbol de la leche (Argentina, Uruguay); shiringa rana (Peru).

DESCRIPTION

*Sapium glandulosum* is medium-sized (10 to 25 meters), deciduous tree found in low- to mid-elevation, dry to wet forests from Mexico to Bolivia. In Panama it is common in secondary forests or mature forest gaps. In the PRORENA species selection trials, it exhibited below-average but moderate survivorship at all but the dry infertile site, where survival was low. Its best height and diameter growth were at the fertile sites. Four-year height growth far exceeded averages at the fertile site and was also above average at the wet infertile site. Two-year crown width for this species far exceeded the average at the dry fertile site, but was close to or below averages at the other sites. Its four-year carbon index far exceeded average at the dry fertile site, and was roughly equivalent to averages at the wet fertile and dry infertile sites.

RECOMMENDATIONS

The tree has a capacity to spread and coppice. The fruit is bird-dispersed. Crown width data suggest that it can be used to help shade out competing grasses in reforestation and restoration treatments. Four-year carbon indices suggest it can be used in treatments where carbon sequestration is an objective, particularly on dry fertile sites. It is a useful tree to plant along open edges of conservation plantings and riparian zones.

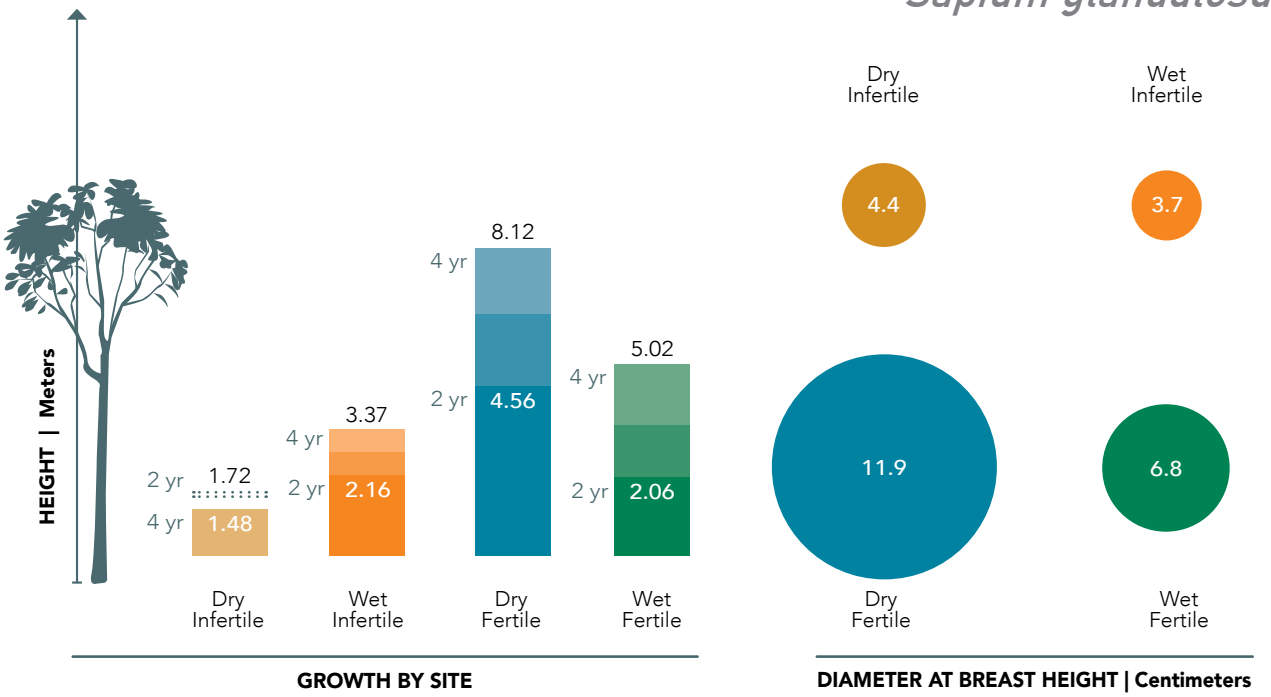
SPACING

This species' height growth suggests that it will not be overtopped by most species with which it might be grown, except at dry infertile sites. Crown diameters suggest that an initial spacing of two or more meters would be appropriate at wet sites, and three meters at dry fertile sites.

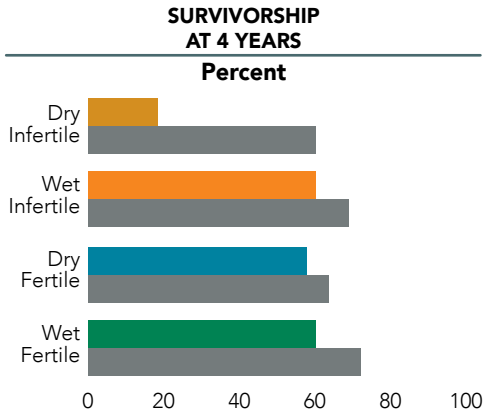
SELECTED USES

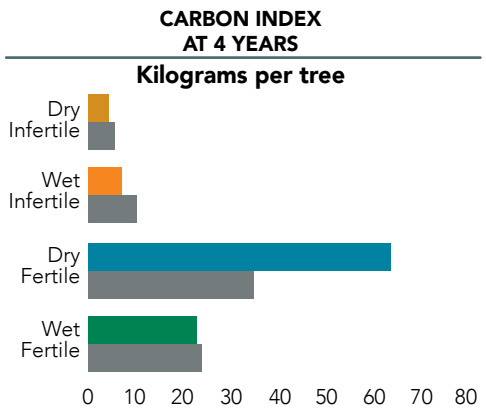
Boxes, carpentry, copious milky sap once used to make rubber, living fences, oil (resin), plywood, attracting animal diversity, carbon sequestration, mid-story structure in reforestation, shade tree (eliminating weeds and grasses).

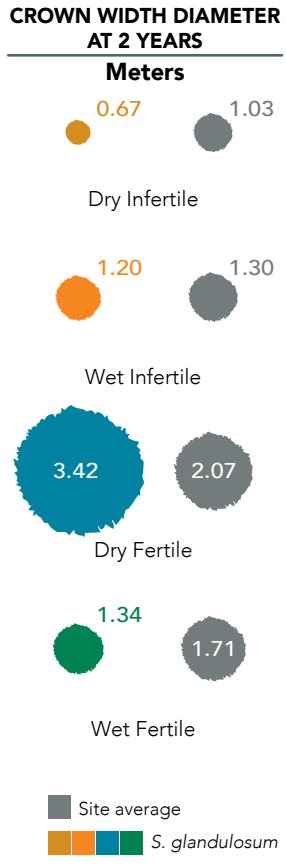
# *Sapium glandulosum*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Schizolobium parahyba*

FAMILY

Fabaceae-Caesalpinioideae

COMMON NAMES

Gallinazo, indio, tinecú, cigarrillo, cucharo (Panama); gallinazo (Costa Rica); falso guanacaste (Mexico); frijolito (Colombia); serebó (Bolivia); pashaco (Peru); guapurúvu (Brazil).

DESCRIPTION

*Schizolobium parahyba* is a tall (20 to 35 meters), deciduous tree species found in low- and mid-elevation, dry to moist forests from Mexico to Bolivia. In Panama it is common in secondary forests. It exhibited high, above-average survivorship at all but the dry infertile site of the PRORENA species selection trials, where very few individuals survived to four years. Height growth was exceptional at the dry fertile site, exceeding two and half times the average. It also grew far taller than average at the wet infertile site, and was equivalent to the average at the wet fertile site. Diameter growth was highest at the dry fertile site, but equivalent to the site average. Diameter growth exceeded the average at the wet infertile site, but was far below averages at the wet fertile and dry infertile sites.

Two-year crown diameters far exceeded averages at the three sites where survivorship was high. Its four-year carbon index was above average at the dry fertile site, and only slightly below average at the wet infertile site.

RECOMMENDATIONS

This species can be used in high densities at sites similar to the dry fertile and wet infertile sites of the PRORENA trials. It will allow for rapid vertical stratification in intimate mixed plantings. It will also aid in carbon sequestration at such sites. Its broad crowns are not dense, allowing relatively high amounts of light into the understory. It is not recommended at particularly dry and infertile sites.

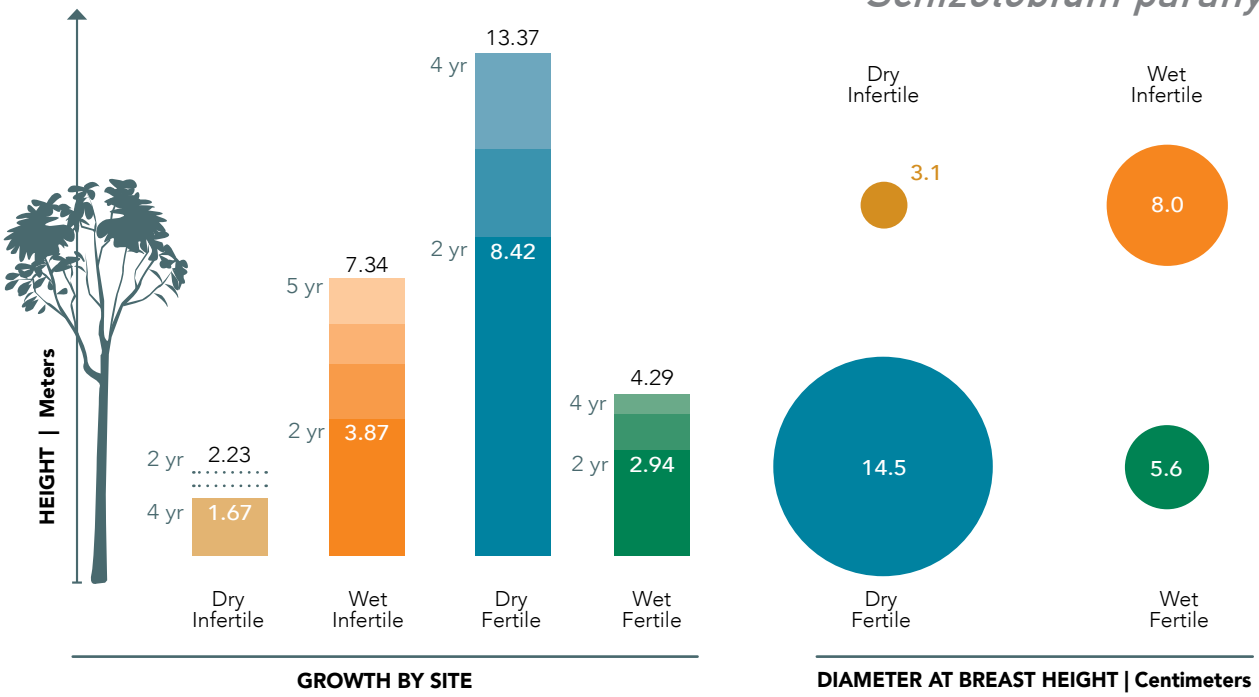
SPACING

This species can be planted within two to three meters of neighbors at sites similar to the dry fertile, wet infertile, and wet fertile sites of the PRORENA trials. It may serve as a nurse tree for shade-tolerant species.

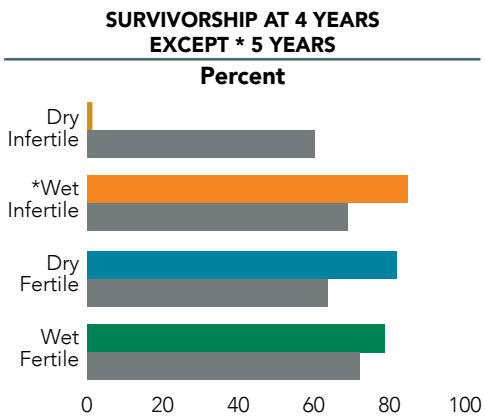
SELECTED USES

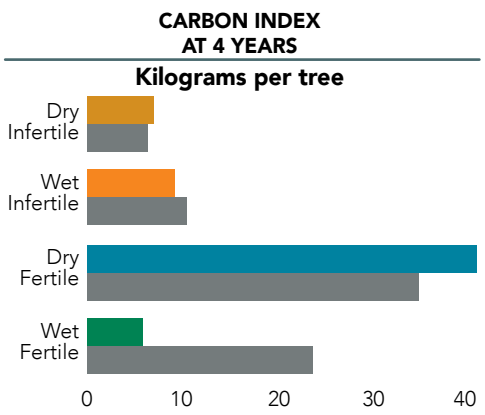
Boards, boxes, door frames, furniture, honey production, ornamental tree, canopy structure in reforestation, carbon sequestration, early stand structure in reforestation, nurse tree for shade-tolerant species.

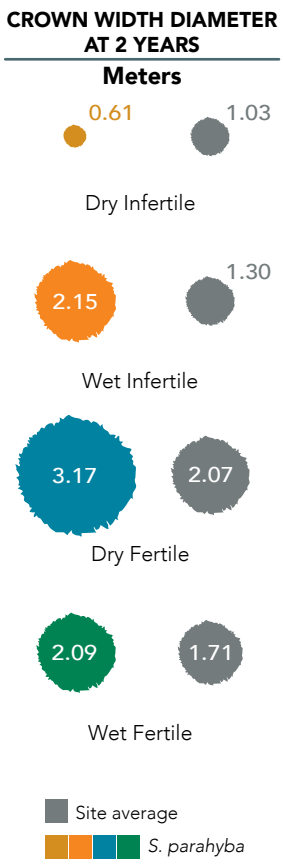
# *Schizolobium parahyba*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Spondias mombin*

FAMILY

Anacardiaceae

COMMON NAMES

Jobo, jobo amarillo (Panama, Central America); ciruela amarilla (Cuba, Ecuador); jobo blanco (Colombia); cuajo (Venezuela); ubos (Peru); cajá (Brazil); sucá (Bolivia).

DESCRIPTION

*Spondias mombin* is a medium to tall (10 to 35 meters), deciduous species found in low- to mid-elevation, dry to moist forests from Mexico to Bolivia. In Panama it is common in secondary forests and pastures. It exhibited high to exceptionally high survivorship in the PRORENA species selection trials, exceeding averages at all sites. It grew far better at the fertile sites than the infertile ones. Height growth was approximately double the averages at the fertile sites, and slightly higher than average at the wet infertile one. At the dry infertile site it experienced significant dieback by year six. It grew broad crowns at the fertile sites, with two-year diameters markedly larger than site averages. Four-year carbon index was more than twice the average at the dry fertile site, and almost twice the average at the wet fertile site. Its four-year carbon index also exceeded the average at the wet infertile site.

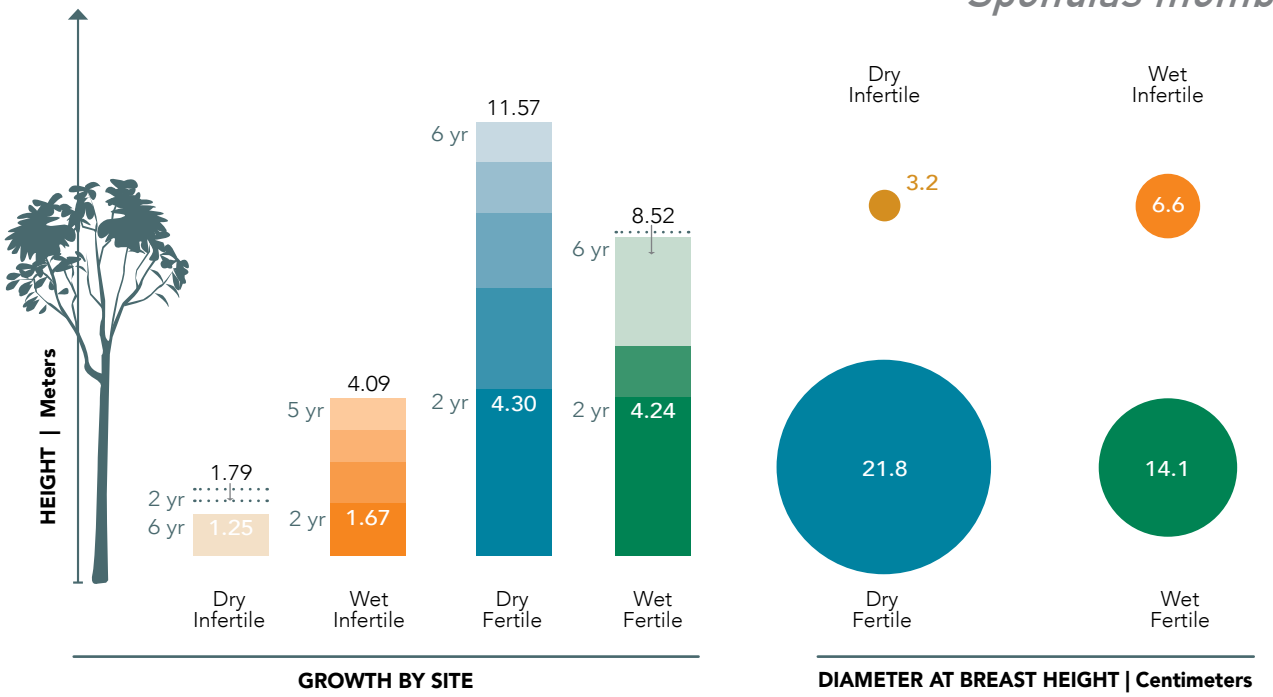
RECOMMENDATIONS

This species survived well across all PRORENA sites. Data from the trials suggest this species can be an important component of restoration and reforestation treatments at fertile sites. Its performance at the wet infertile site suggests it can be useful in areas with similar conditions. It is a major component of living fences near the dry fertile site of the PRORENA trials, and its fruits attract birds and primates. It is also recommended in restoration treatments for conservation plantings. Given the extreme growth difference between fertile and infertile sites, it should only be used with caution at extremely infertile sites, and is not recommended on highly nutrient- and water-stressed sites. Its broad crowns may be useful in shading out grasses and competing vegetation at fertile sites, and its exceedingly high carbon index at such sites suggests it can be useful in plantings where early carbon sequestration is desirable. It is a useful tree to facilitate natural regeneration in nucleation plantings of open areas; as living fences and in agroforestry tree gardens.

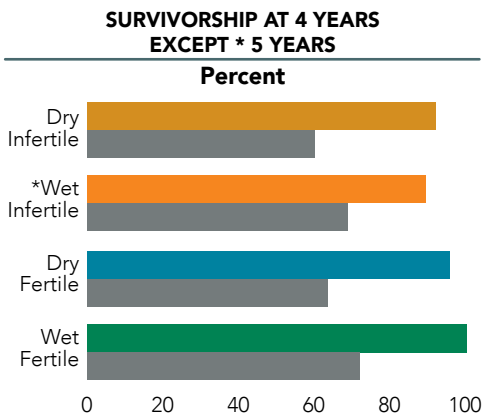
SELECTED USES

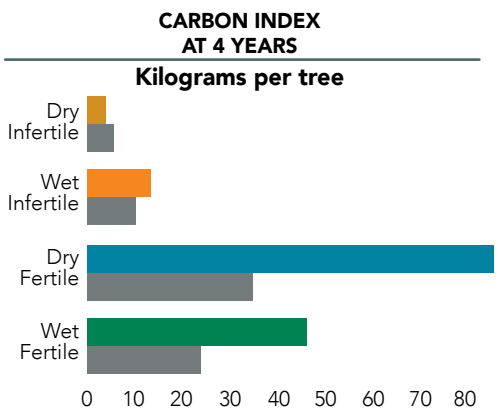
Boxes, carpentry, construction (light), fodder (fruits, leaves), honey production, human consumption (fruits), living fences, medicines (bark, leaves, roots), plywood, pulp for paper, attracting animal diversity, carbon sequestration (early), nurse tree for shade-tolerant species, shade tree (eliminating weeds and grasses).

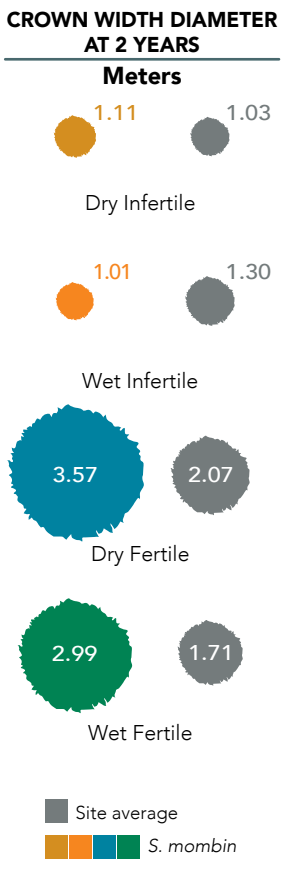
# *Spondias mombin*




Diameter at breast height taken in the last year of height growth measurement




SPACING

Given its height and crown growth on fertile sites, this species should not be planted closer than three meters to other trees of the same or other species at similar sites, except where partial shade is needed to facilitate growth of a neighbor. A spacing of two meters would be appropriate for wet fertile sites similar those of the PRORENA trials.



SCIENTIFIC NAME

# *Sterculia apetala*

FAMILY

Sterculiaceae (Recent molecular studies consider this species to be in the Malvaceae)

COMMON NAMES

Panamá, árbol panamá (Panama); bellota (Guatemala, Mexico); castaño (El Salvador, Honduras); camajurú (Colombia); camoruco (Venezuela); xixá (Brazil); huarmi-caspi (Peru); sujo (Bolivia).

DESCRIPTION

*Sterculia apetala* is a medium to tall (10 to 35 meters), deciduous tree species found in low-elevation, dry to moist forests from Mexico to Bolivia and Brazil. In Panama it is found in pastures and dry forests on the Pacific side of the Isthmus. This species exhibited high to moderately high survivorship across the PRORENA species selection trials, with four-year survivorship exceeding averages at all but the wet fertile site. Four-year height and diameter growth was best at the dry fertile site but below averages, as with all other sites. Two-year crown diameters were far below averages at all sites, as were four-year carbon indices.

RECOMMENDATIONS

The data suggest this species can be a component of reforestation and restoration efforts at most sites, but it will be most successful under conditions similar to the dry fertile and wet infertile sites of the PRORENA trials. Dieback at the dry infertile site suggests it should not be planted at sites with similar conditions. If shading out the understory grasses is an objective, it should not be a major component of a mixed-species treatment unless planted at very high densities or in close proximity to neighbors. It will make a relatively small contribution to early carbon sequestration in reforestation treatments.

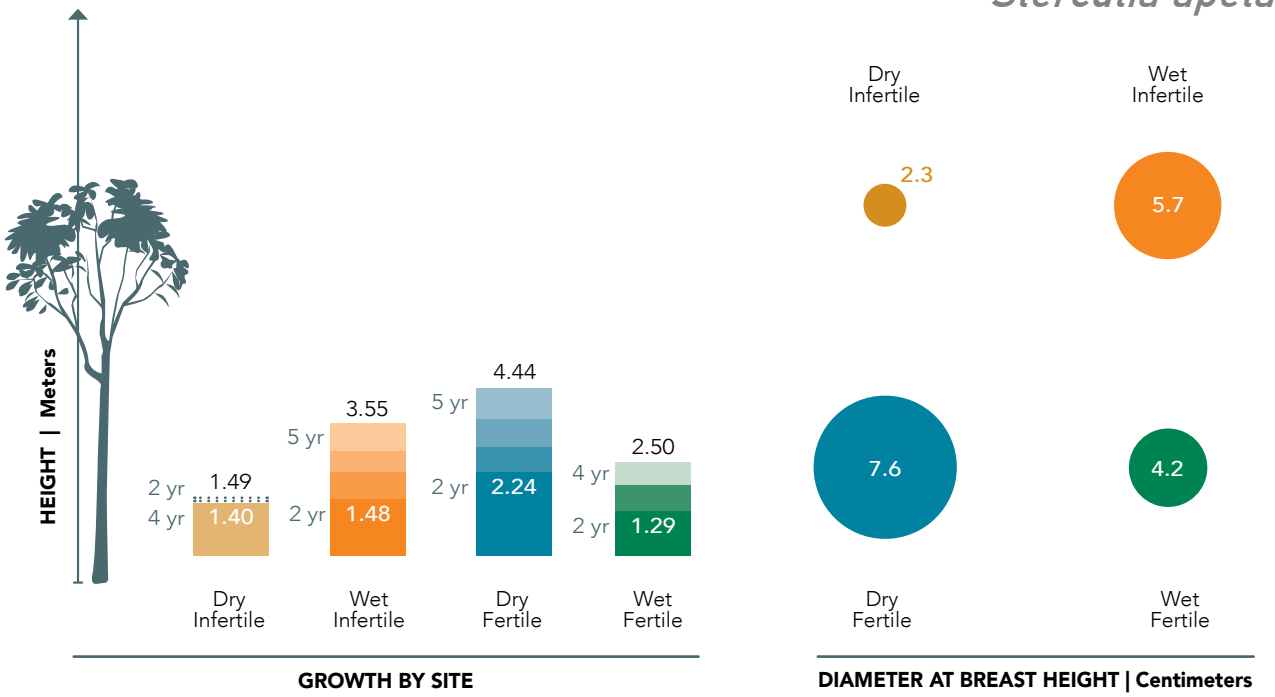
SPACING

Data from the literature and the PRORENA trials show that this species persists and grows well in shade, suggesting it can be spaced at two meters or less at fertile sites and as close as one meter at wet infertile sites.

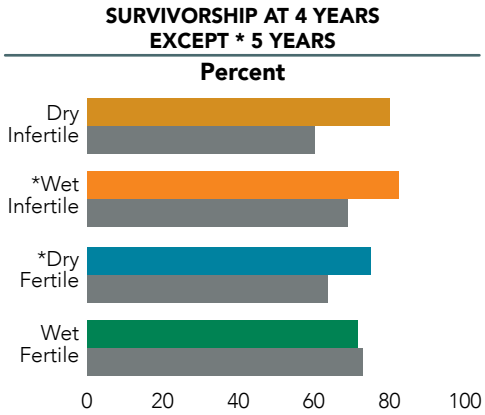
SELECTED USES

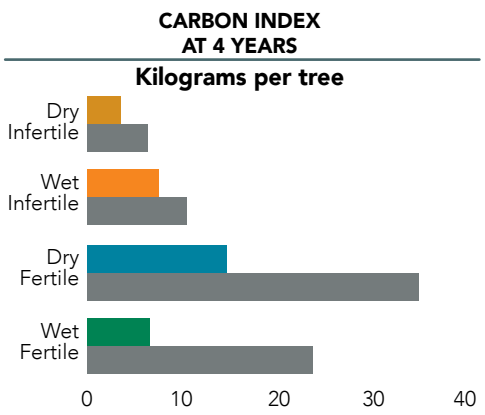
Boxes, construction (light), fence posts, honey production, human consumption (boiled or roasted seeds), matchsticks, medicines (bark), ornamental tree, plywood.

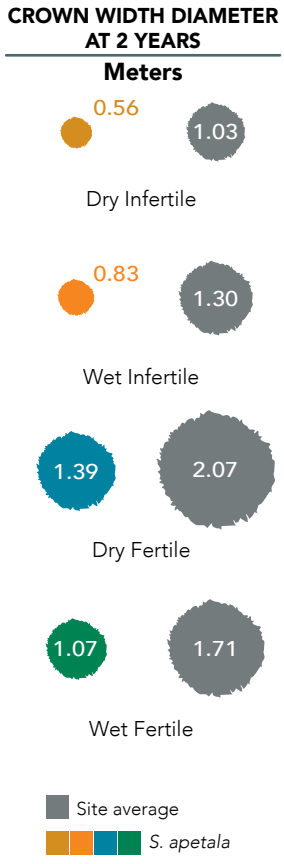
# *Sterculia apetala*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Swietenia macrophylla*

FAMILY
Meliaceae

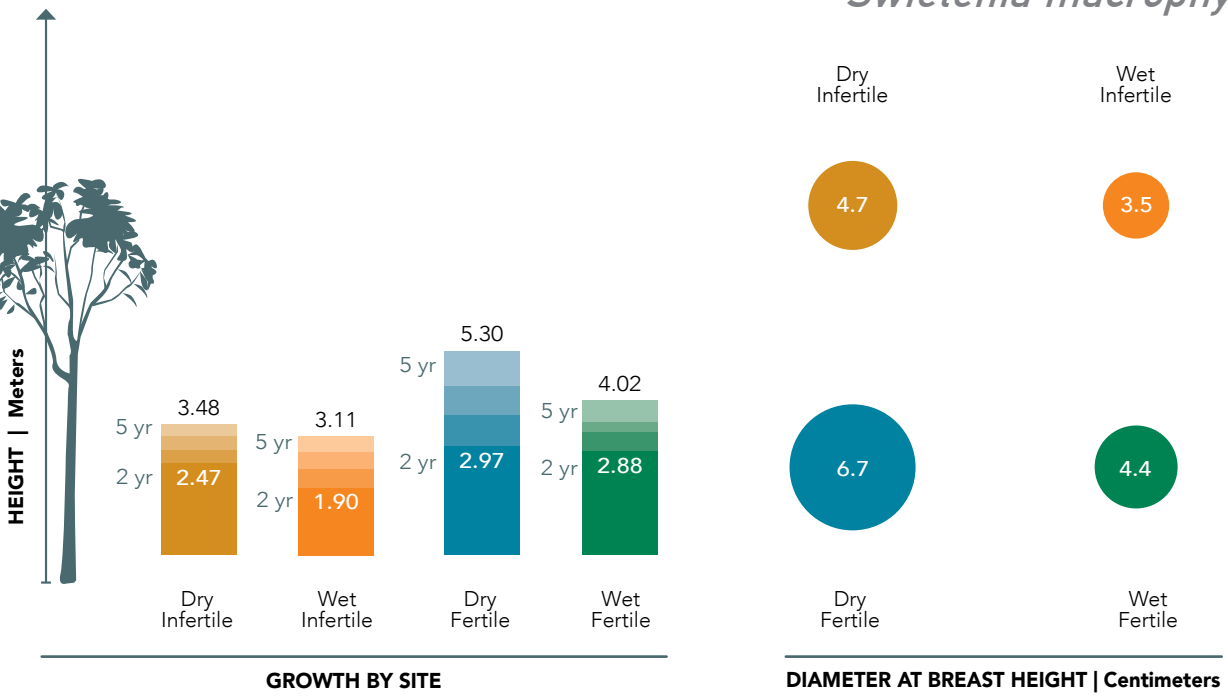
COMMON NAMES
Caoba (Panama, Latin America); mahogany (Belize); mogno (Brazil); aguano (Peru); mara (Bolivia).

DESCRIPTION
*Swietenia macrophylla* is a tall (20 to 40 meters), canopy to emergent, deciduous tree found in lowland, dry to moist forests from Mexico to Bolivia, Peru, and Brazil. It exhibited high to very high survivorship across all sites in the PRORENA species selection trials. This species is known to respond well to soil fertility and its best height and diameter growth were in the dry fertile site. Four-year height growth was above average at the dry sites. It tended to form relatively narrow crowns early in life. Crown diameters were well below average at most sites. This species suffers from attack by shoot borer caterpillars of the *Hypsipyla grandella* moth, which attack its terminal shoot. Insect attacks and relatively slower growth compared to other species account for this species' lower-than-average carbon index values on all but the dry infertile site. Here, above-average growth was probably because of relatively fertile microsites.

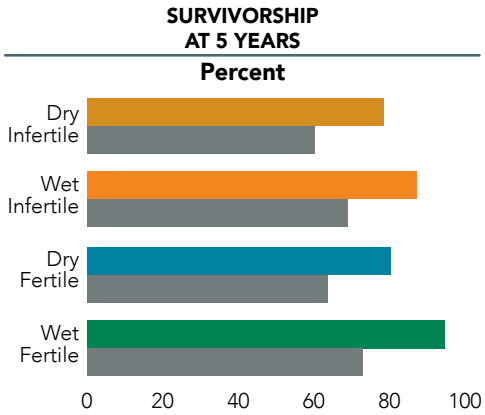
RECOMMENDATIONS
This is an extremely valuable timber species that has been harvested to such an extent from natural forests that it is protected under the Convention on International Trade in Endangered Species (CITES), restricting its export. It is a large tree that grows well on relatively dry and fertile microsites and emerges from the canopy. It can thus play an important role in restoration and reforestation treatments by providing structure to the future forest. Because it suffers from attack by shoot borers it should only be planted in low densities unless very intensive management is planned. Regular pruning of dead terminal shoots may help preserve a relatively straight stem in plantations. Its broad crown provides abundant shade and is thus often encountered in gardens and along streets.

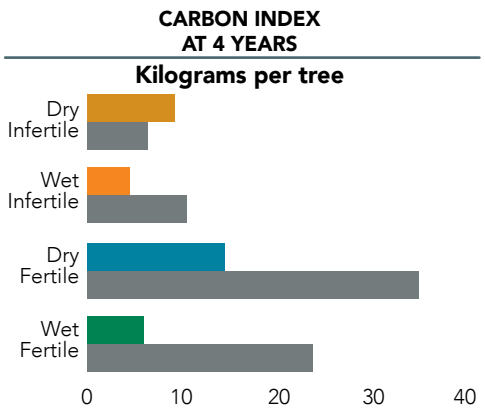
SELECTED USES
Cabinetry, carpentry (decorative, moldings), furniture (fine), medicines (bark), musical instruments, ornamental trees, shade tree (streets), tannery (bark), canopy structure in reforestation.

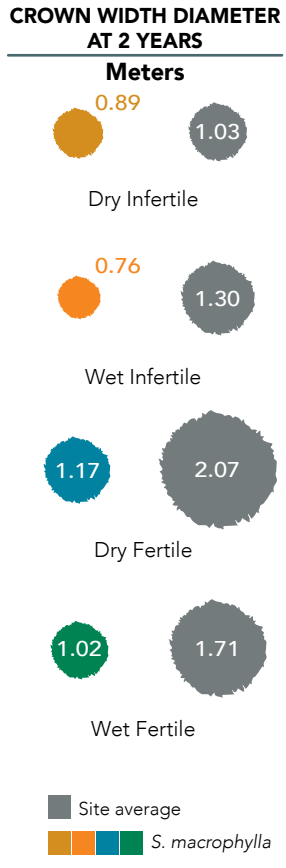
# *Swietenia macrophylla*




Diameter at breast height taken in the last year of height growth measurement




SPACING

To avoid attack by the shoot borer, this species should be planted in low densities in intimate mixture with short-lived, small-leaved deciduous pioneers and slower-growing, shade-tolerant evergreen species. Initial spacing with neighbors of other species can be at two meters or less, but thinning may be necessary over time.

SCIENTIFIC NAME

# *Tabebuia guayacan*

FAMILY
Bignoniaceae

COMMON NAMES
Guayacán (Panama, Mexico); corteza (Costa Rica, Honduras, Nicaragua); flor amarilla (Venezuela); madera negra (Ecuador); tahuarí (Peru); ipê (Brazil).

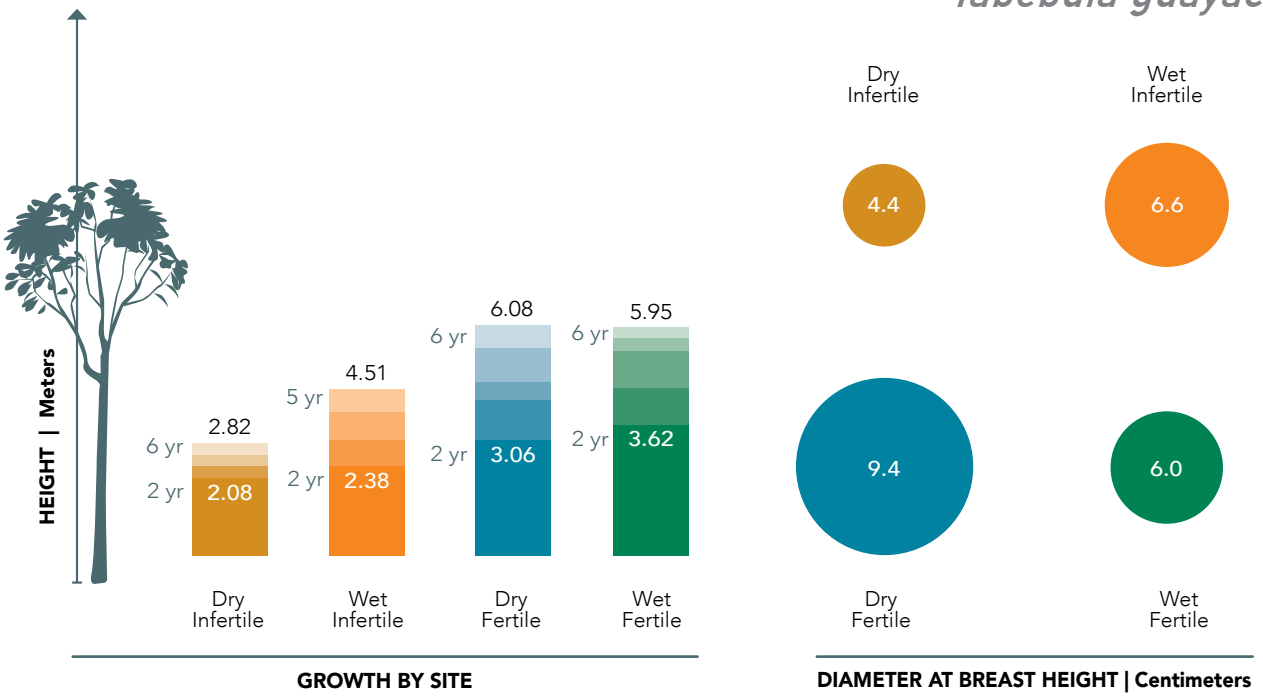
DESCRIPTION
*Tabebuia guayacan* is a medium to tall (20 to 40 meters), deciduous tree found in the canopy of low- to mid-elevation, dry to wet forests from Mexico to Peru and Brazil. It exhibited high survivorship in all but the dry infertile site in the PRORENA species selection trials. Its best height growth was in the fertile sites. It also had good height growth at the wet infertile site, where its diameter growth exceeded that of the wet but not dry fertile site. Four-year height growth exceeded averages at the infertile sites, but not the fertile ones. It tended to form a narrow crown in early years, with two-year crown diameters equivalent to site averages in all but the dry fertile site, where it was far below average. Crowns were not deep and thus allowed significant light to pass through. At all sites, its four-year carbon indices were higher than site averages.

RECOMMENDATIONS
Although this species was somewhat shorter in stature than others in the PRORENA trials, its carbon indices were higher than averages at all sites. This indicates high potential for use in restoration or reforestation at all but perhaps dry infertile sites, where survivorship is likely to be low and below average. Indeed, it can be an important component of the future canopy. With big, showy yellow flowers, the species is a common ornamental in parks and along streets, providing a spectacular show for a few days each year.

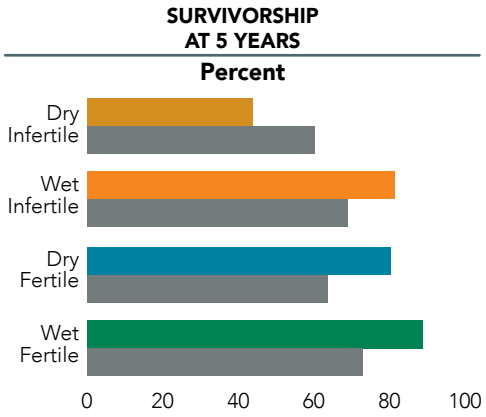
SPACING
Data from the literature and the PRORENA trials indicate this species' persistence and growth in moderate to deep shade, suggesting it can be grown at a spacing of two meters or less with neighbors. Like the related species *T. rosea*, it may suffer from intense herbivory and thus may not be warranted in very high densities; it does better in mixed plantings.

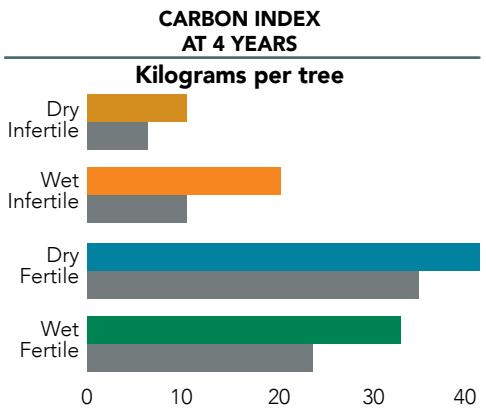
SELECTED USES
Bridges, carriages, construction (naval), ornamental tree, railroad ties, tool handles, canopy structure in reforestation, carbon sequestration (long-term).

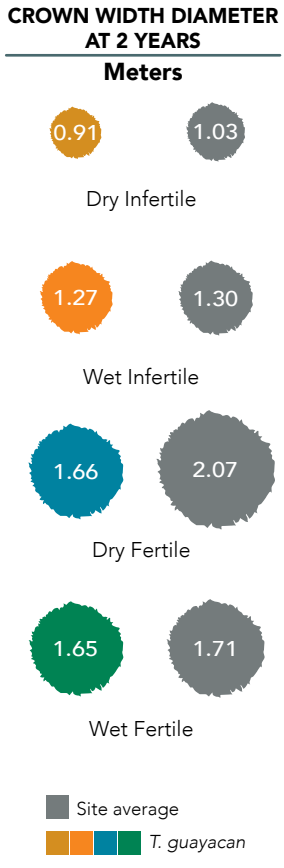
# *Tabebuia guayacan*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Tabebuia impetiginosa*

FAMILY
Bignoniaceae

COMMON NAMES
Cortez negro, ipé (Costa Rica, Panama); lapacho negro (Mexico); ipé-roxo, pau d'arco (Brazil); tajibo morado (Bolivia); puy (Venezuela); lapacho rosado (Argentina, Paraguay).

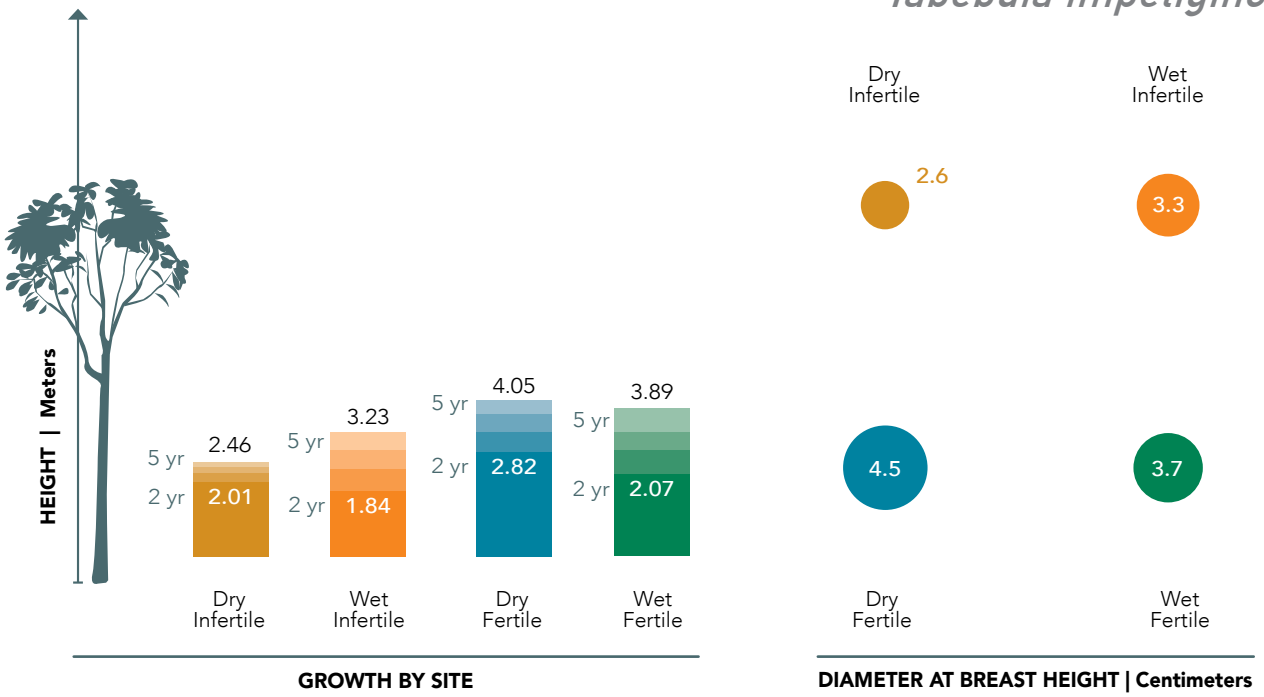
DESCRIPTION
*Tabebuia impetiginosa* is a medium-sized (10 to 30 meters), deciduous species found in low-elevation, dry to moist forests from Mexico to Argentina. In Panama it is common on the Pacific side. It exhibited high to very high survivorship in the PRORENA species selection trials, with the highest survival in the wet fertile site. Its best height and diameter growth were at the fertile sites, but trees in the wet infertile site were only slightly smaller. Trees of this species were much smaller in the PRORENA trials than those of the related species *T. guayacan* and *T. rosea*, but did not show any growth stagnation. Four-year height growth exceeded the averages for the infertile sites but not fertile sites. Two-year crown widths were approximately equivalent to site averages at the wet fertile and dry fertile sites. The crown width at the dry infertile site was broader than average, while that of the wet fertile site was below average. Unlike its close relatives, its four-year carbon index was well below site averages.

RECOMMENDATIONS
This species had high survivorship, indicating that it should do well in restoration and reforestation treatments. It appears relatively well suited for sites similar to the infertile sites of the PRORENA trials. Its small stature and carbon index value suggest that it would not be the best choice to plant in very high densities when quick ground cover is needed. It may be used as an ornamental tree for its showy, yellow flowers. Like its close relatives, its abundant production of wind-borne seeds may help in reforesting open sites with exposed mineral soil. It can be incorporated into mixed-species treatments and will become a mid-story or canopy co-dominant over time.

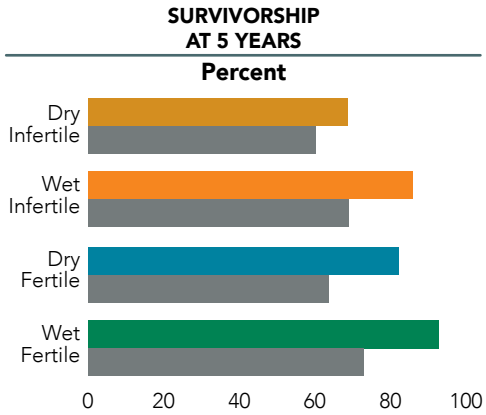
SPACING
This species can be grown two to three meters from neighbors.

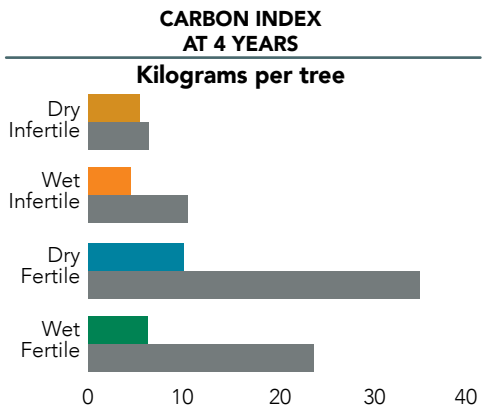
SELECTED USES
Construction, furniture, medicines (bark), ornamental tree, mid-story structure in reforestation.

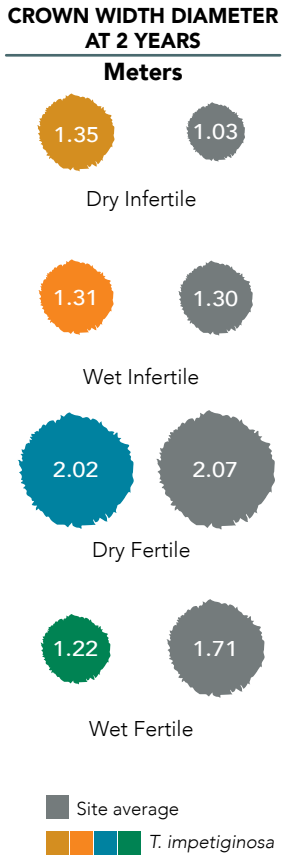
# *Tabebuia impetiginosa*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Tabebuia rosea*

FAMILY

Bignoniaceae

COMMON NAMES

Roble, roble de sabana (Panama, Costa Rica, Nicaragua, Honduras); maculís (Guatemala, Mexico); maquilishuat (El Salvador); roble morado (Colombia).

DESCRIPTION

*Tabebuia rosea* is a medium to tall (20 to 40 meters), deciduous tree found in lowland and mid-elevation forests from Mexico to Ecuador. It is common in secondary forests and urban areas in Panama. It grew well in full sunlight in the PRORENA species selection trials, with high survivorship and best growth on fertile sites. Four-year height growth was above averages at all sites. The observed stagnation in growth at the wet fertile site is most likely due to insect attack, as leaves resembled fish nets due to herbivory. In PRORENA monoculture plots with farmers, the trees also exhibited witches' broom, where crown branches are swollen with multiple protrusions of small stems. In the Agua Salud plantations, the species had poor overall growth, likely due to infertile, acidic soils. It formed a straight stem with a very thin crown in the first years of development. It is a popular ornamental and street tree, due to its abundant, showy pink flowers.

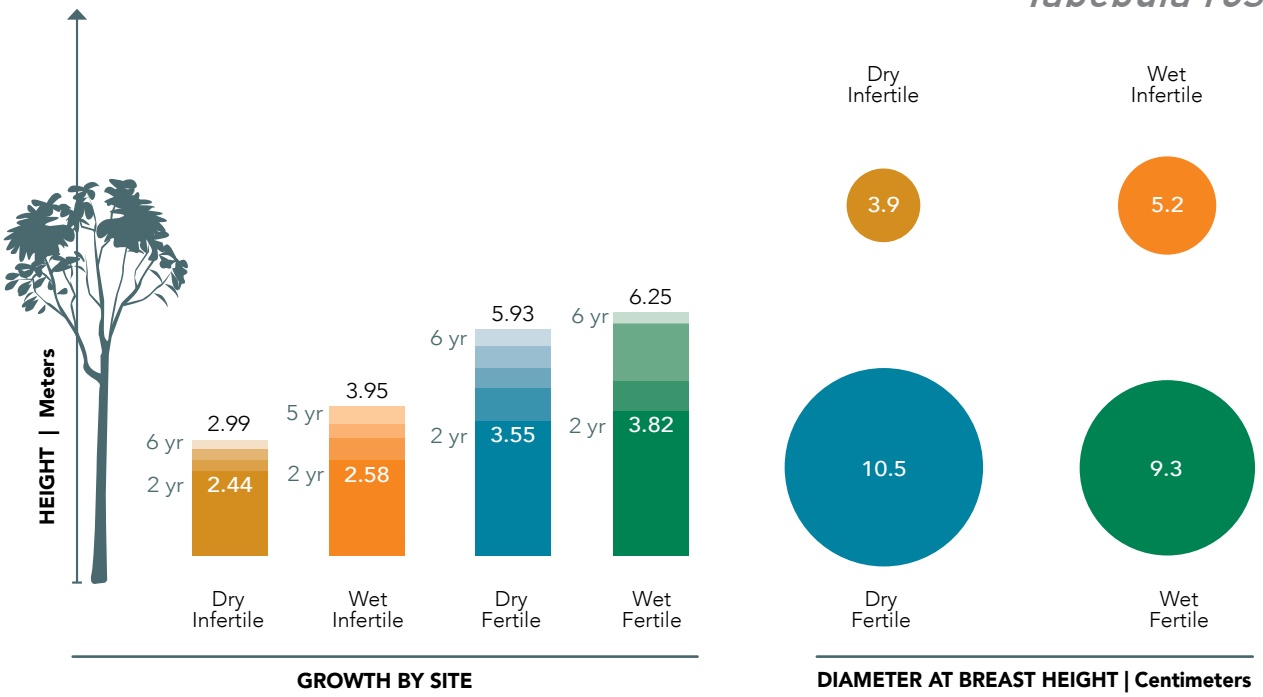
RECOMMENDATIONS

This species has valuable wood and may be considered as part of mixed-species plantations on good sites. Despite having low carbon index values in early years, its moderate wood density and overall size at maturity suggest it may also be considered for long-term carbon sequestration purposes on such sites. It has been successfully included in restoration or reforestation plantings on fertile sites, where its relatively fast growth allows it to maintain a place in the canopy. It is not recommended for plantings in monocultures or at high densities due to potentially high rates of insect damage and disease. Its tendency to form only a few leaves at the top of a long stem early in development makes it unsuitable for high-density plantings where eliminating grasses is an objective. It is often found in pastures, living fences, and urban plantings.

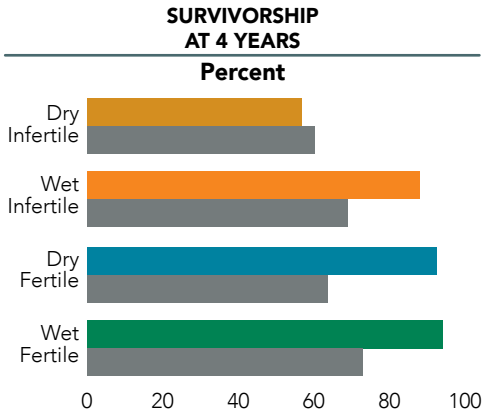
SELECTED USES

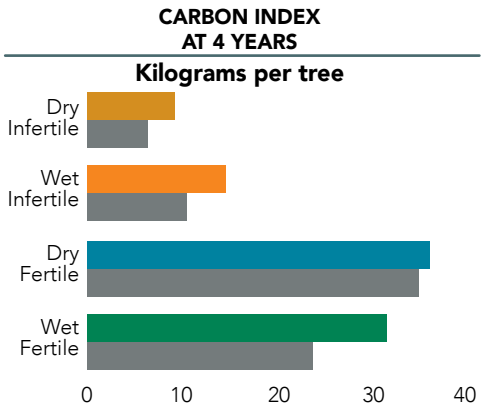
Boards (decorative), boat construction, cabinetry, flooring, furniture (fine), handicrafts, medicines (bark, leaves), ornamental tree, packaging, canopy structure in reforestation, carbon sequestration (long-term).

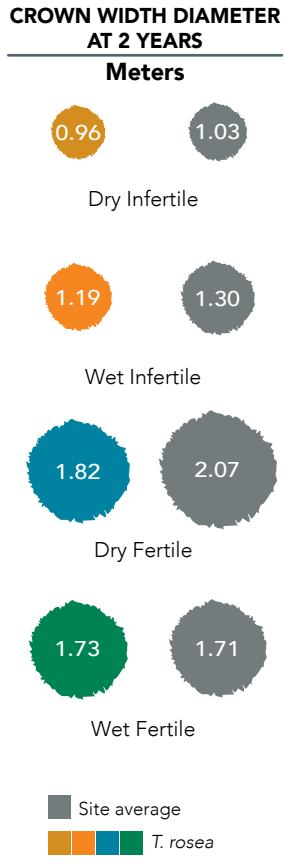
# *Tabebuia rosea*




Diameter at breast height taken in the last year of height growth measurement




SPACING

Data from the literature and the PRORENA trials indicate this species can persist and grow in shade, suggesting it can be planted within two meters of neighbors.

SCIENTIFIC NAME

# *Terminalia amazonia*

FAMILY

Combretaceae

COMMON NAMES

Amarillo, roble amarillo, amarillo carabazuelo (Panama); amarillón, roble coral (Costa Rica); canshán (Guatemala, Mexico); guayabo (Colombia); tanimbuca (Brazil).

DESCRIPTION

*Terminalia amazonia* is a tall (20 to 40 meters), canopy to emergent, evergreen species found in low- to mid-elevation, moist to wet forests from Mexico to Bolivia and Brazil. In Panama it is common in forests near the Panama Canal. It grows well in moist to wet sites in full sunlight, with very high survivorship and growth on these sites in the PRORENA species selection trials. Four-year height and diameter were approximately twice that of the site average at the wet infertile site. Values for these measures were similar to those of the wet fertile site. The species performs particularly well compared to other species on low-nutrient, clay to loamy-clay soils of moderate to high acidity. The observed growth stagnation on the wet fertile site is likely due to competition between trees for light and other resources; similar stagnation has also been observed in monoculture stands of the Agua Salud plantations. Four-year height growth was also above site averages at dry sites. The species formed a straight stem, rapidly growing broad and deep crowns, with two-year crown widths far exceeding averages on wet sites. It tended to form deep shade below the crown, with relatively deep and persistent leaf litter on the soil. Thus, there is relatively little regeneration of any species below monoculture stands, or even below isolated trees that have not been pruned in pastures. Four-year carbon indices far exceeded averages on wet sites but were well below averages on dry sites.

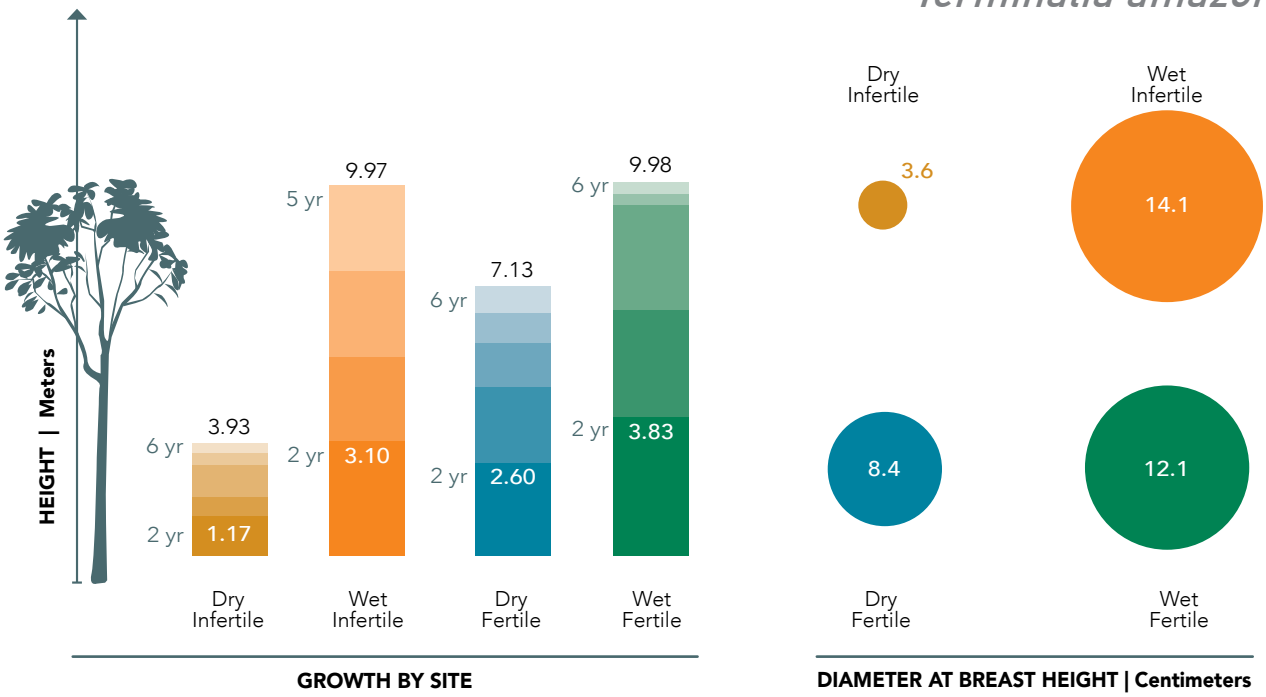
RECOMMENDATIONS

It has high potential as a commercial plantation species, as it can be grown in 20-year rotations and performs well on poor-quality, wet soils when compared to high-value species like teak. Because of its high water use throughout the year it is not recommended for dry sites. It may help quickly establish forest cover on sites with low soil fertility and either abundant, year-round rainfall or a short dry season. Its dense wood makes it desirable for carbon sequestration projects on moist to wet sites, and its deep crown helps shade out grasses, thus reducing weed-clearing costs. It can play an important role as a canopy species in restoration treatments, particularly

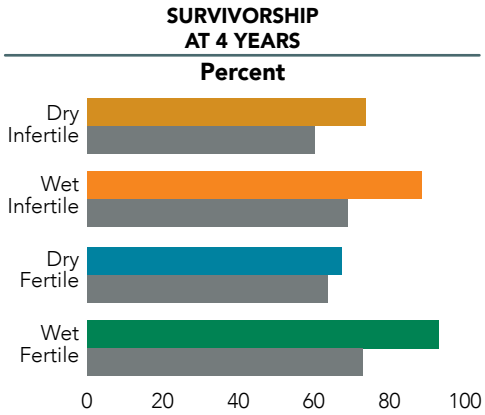
SELECTED USES

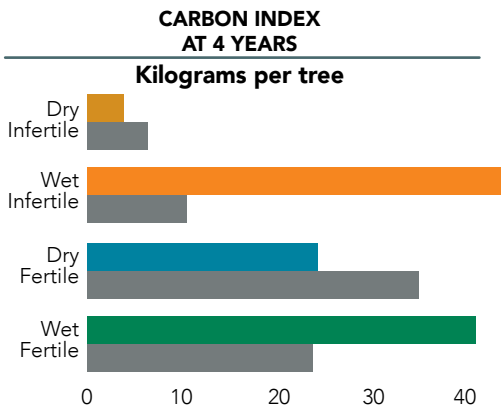
Bridges, construction (naval), flooring, furniture, ornamental tree, railroad ties, tannery (bark), tool handles, carbon sequestration, canopy structure in reforestation, early crown cover in reforestation, nurse tree for shade-tolerant species, shade tree (eliminating weeds and grasses).

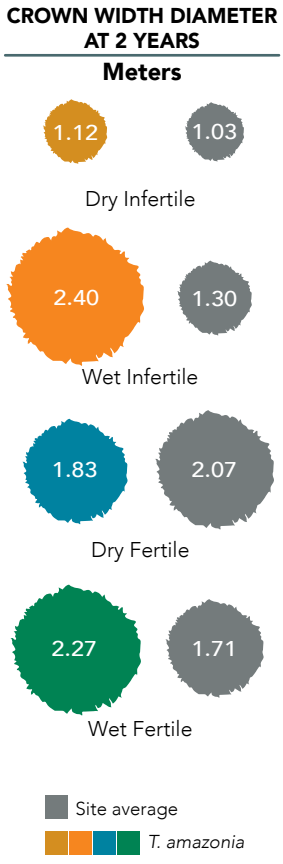
# *Terminalia amazonia*




Diameter at breast height taken in the last year of height growth measurement




for riparian restoration of stream cover. It can also serve as a nurse species for shade-tolerant species. It may have potential in agroforestry systems where the objective is to increase revenue through timber harvest rather than enhanced growth of crops or pasture.

SPACING

This species can be grown at three-meter spacing on moist to wet sites in plantations if thinning is planned between three to five years. Otherwise, individuals should be placed six meters or more apart. It will shade out slower growing species planted within three meters in a matter of years.



SCIENTIFIC NAME

# *Trichilia hirta*

FAMILY

Meliaceae

COMMON NAMES

Conejo colorado, mata piojo (Panama); cedrillo (Costa Rica, El Salvador, Guatemala); cabo de hacha (Puerto Rico); hobo macho (Colombia); gajigua (Ecuador).

DESCRIPTION

*Trichilia hirta* is a medium-sized (10 to 20 meters), deciduous tree species found in low-elevation, dry to moist forests from Mexico to Bolivia. In Panama it is common in pastures and secondary forests on the Pacific side. Its survivorship was highly variable between sites in the PRORENA species selection trials, with highest survival at the fertile sites and very low survivorship at the dry infertile site. Height and diameter growth were best in the dry fertile site but, similar to the other sites, these values were well below averages at four years. Two-year crown widths for this species were markedly below average at all sites except for the dry fertile one, where it was close to average. Its four-year carbon index values were well below averages for all sites.

RECOMMENDATIONS

This species had high survivorship but below-average growth at the fertile sites of the PRORENA trials, indicating that it may be used in restoration and reforestation treatments at similar sites, though preferably at low densities. It may also require targeted release through understory clearing to combat weed competition. Data indicate that it is not recommended for crown closure and understory shading within two years if planted at high densities. In dry zones, it may do better as part of riparian restoration within pastures rather than for forest plantations. It may do well on edges given no competition from over-topping effects.

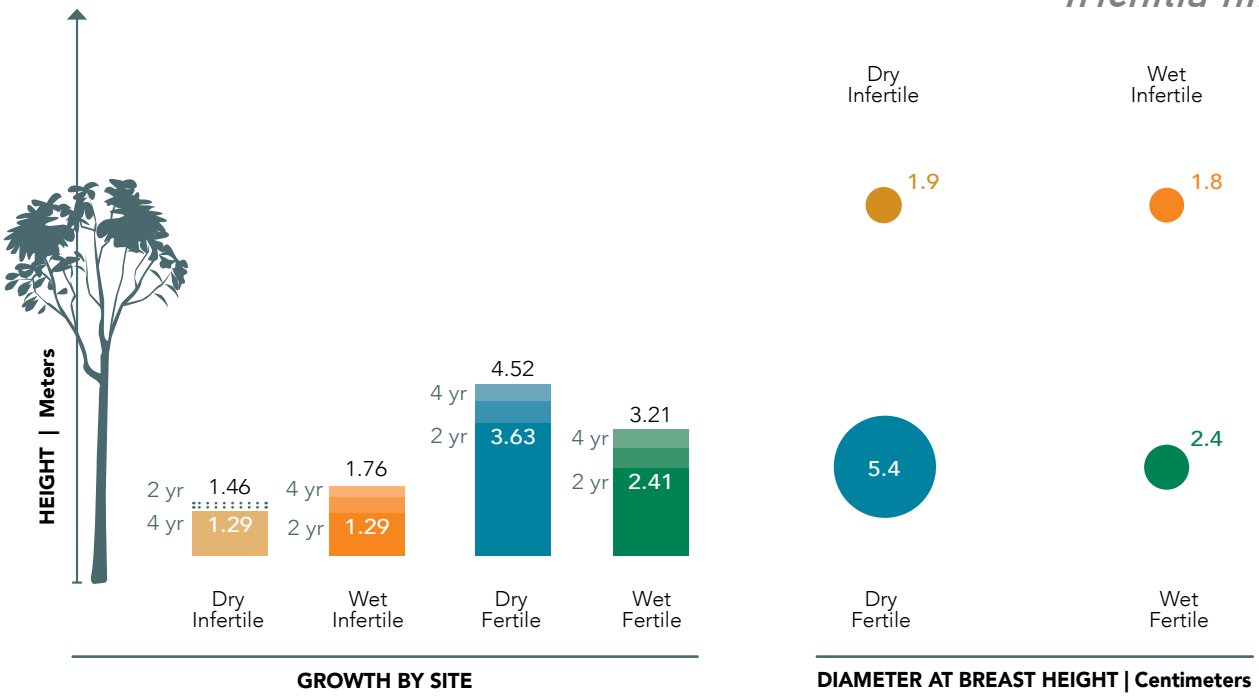
SPACING

This species does not rapidly form broad crowns and so can be planted within two to three meters of neighbors, except for faster growing, broad-crowned species. Its slow growth suggests that it may get overtopped by most species in the PRORENA trials.

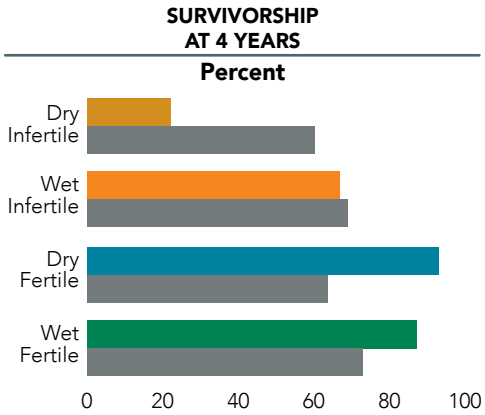
SELECTED USES

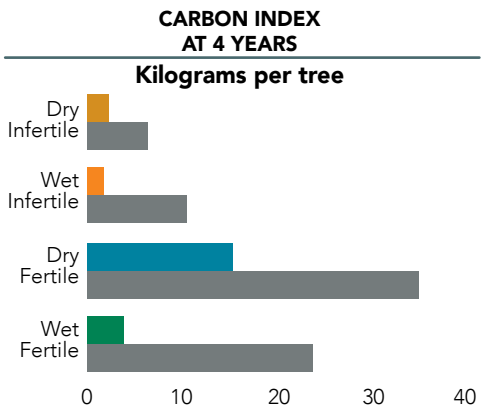
Carpentry, cosmetics (seeds), fence posts, ornamental tree, streambank restoration and conservation.

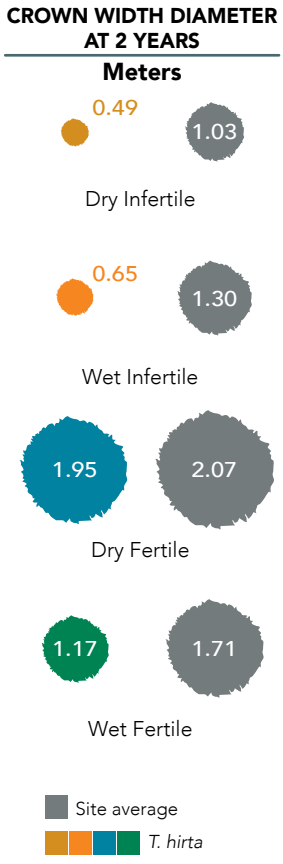
# *Trichilia hirta*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Vitex cooperi*

FAMILY
Lamiaceae

COMMON NAMES
Cuajado, flor azul (Panama); cuajada, manú plátano (Costa Rica); bimbayán (Nicaragua); flor azul, cenizo, barrabas (Honduras).

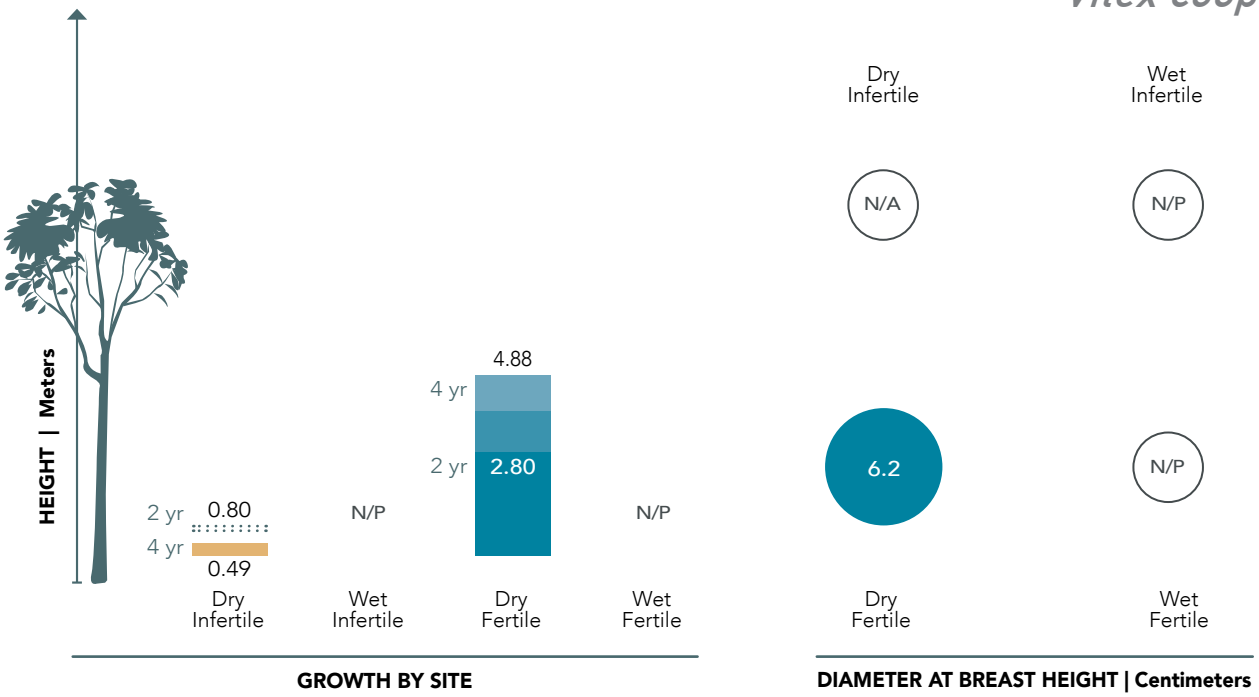
DESCRIPTION
*Vitex cooperi* is a medium-sized (10 to 30 meters), semi-deciduous species found in low- to mid-elevation, moist to wet forests from Guatemala to Panama. In Panama it is common on the Pacific side and in the Canal area. In the PRORENA species selection trials, it exhibited high survivorship at the dry fertile site and above-average survivorship at the dry infertile one. Its best growth was at the dry fertile site, with four-year height equivalent to the site average. It experienced dieback at the dry infertile site, with heights and four-year diameter growth well below the site average. Two-year crown width was above average at the dry fertile site but only half that of the dry infertile site average. Four-year carbon indices were somewhat below the dry fertile site average and exceedingly below that of the dry infertile site.

RECOMMENDATIONS
This species was not planted at the wet sites of the PRORENA trials, but given its natural distribution, it is expected to grow best at such sites. It is not recommended on very dry infertile sites. However, since it did exhibit high survivorship and reasonable growth at the dry fertile site, it can be used sparingly in restoration and reforestation treatments in similar sites. It can be used as a component of living fences.

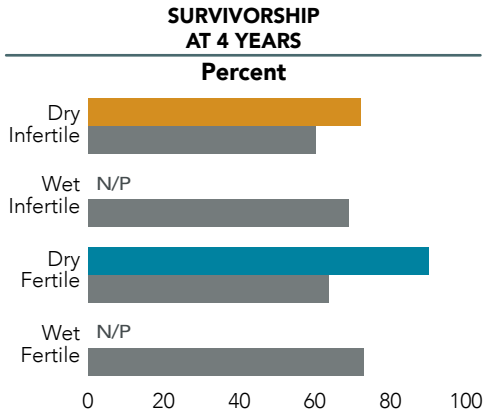
SPACING
Given its two-year crown and height growth at the dry fertile site, this species should not be planted any closer than three meters from its neighbors to avoid it being prematurely overtopped. It can be planted closer to slower growing, shade-tolerant species.

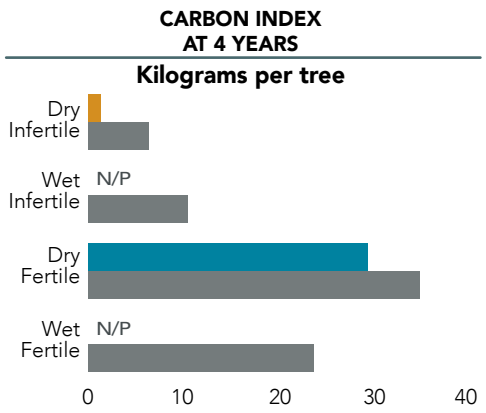
SELECTED USES
Construction, fence posts, firewood, tool handles, ornamental tree, nurse tree for shade-tolerant species.

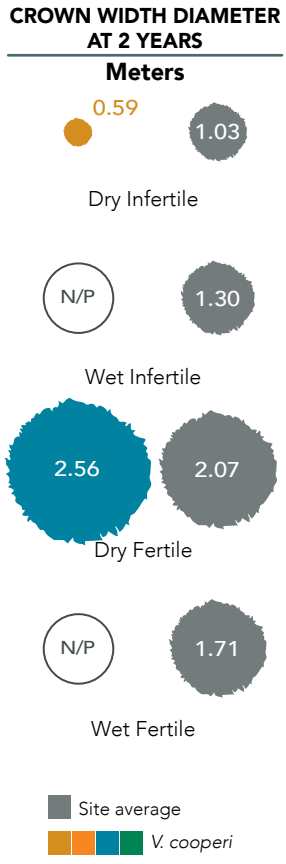
# *Vitex cooperi*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Vochysia ferruginea*

FAMILY
Vochysiaceae

COMMON NAMES
Flor de mayo, botarrama, tecla, mayo (Panama); areno colorado (Costa Rica); barbachele (Nicaragua); sorogá (Ecuador); pese (Venezuela); quaruba (Brazil).

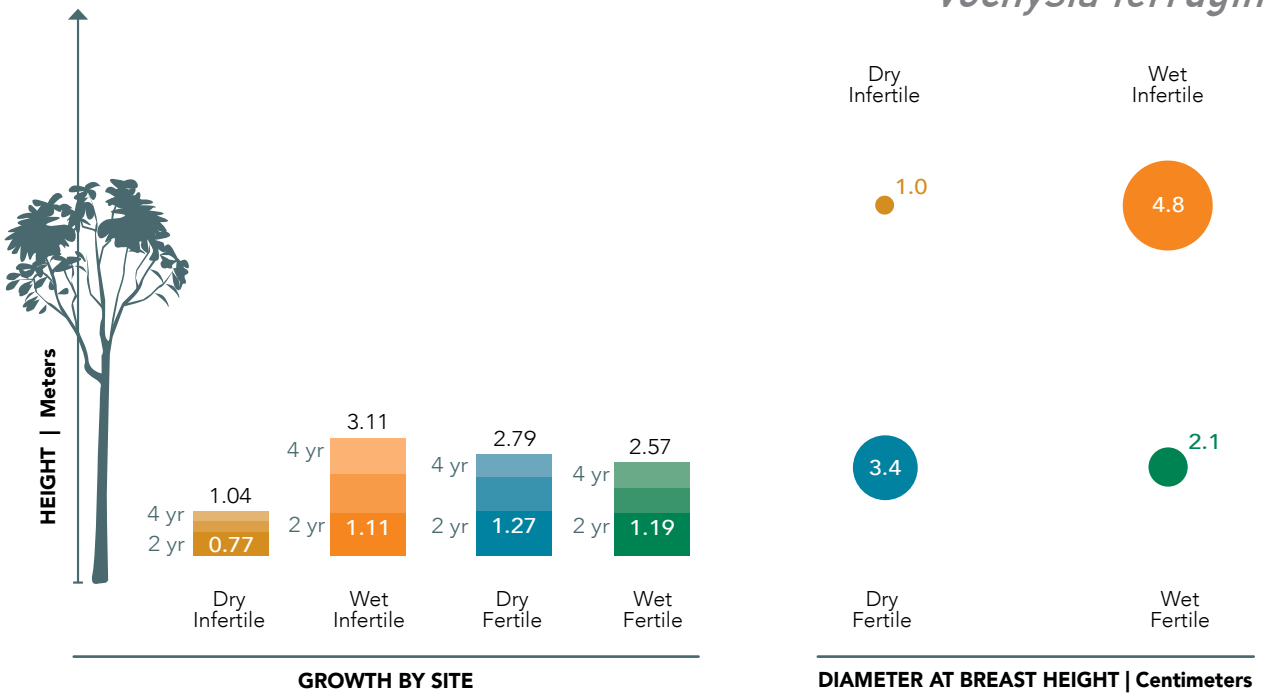
DESCRIPTION
*Vochysia ferruginea* is a medium to tall (10 to 30 meters), evergreen species found in mid-elevation, moist to wet forests from Honduras to Bolivia. Although this species has been grown successfully at moist and wet sites in plantations in neighboring Costa Rica, four-year survivorship in the PRORENA species selection trials was unexpectedly low, particularly at the wet sites. Four-year height growth was equivalent to the site average at the wet infertile site but well below averages at the other sites. Two-year crown widths were all well below site averages. Four-year carbon index was above average at the wet infertile site, but well below site averages at other sites.

RECOMMENDATIONS
This species has been grown successfully on plantations in Costa Rica, particularly on moist to wet, acidic, infertile soils, suggesting that it can be an important component of restoration and reforestation treatments on similar sites. However, data from the PRORENA trials indicate that establishment and growth of this species may be a challenge.

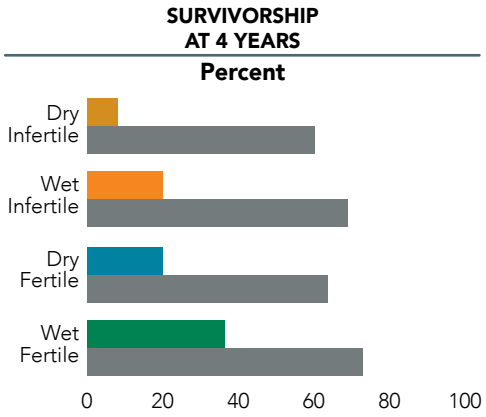
SPACING
The PRORENA trials data indicate that this species can be grown at an initial spacing of two to three meters.

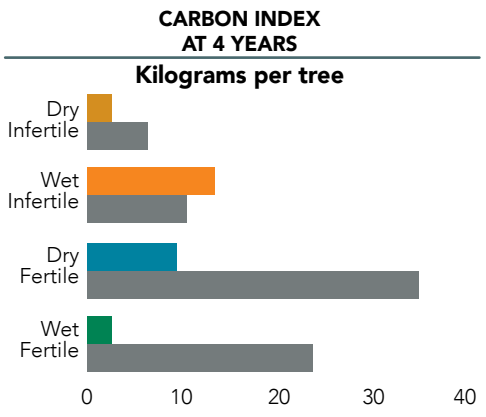
SELECTED USES
Boxes, carpentry, construction (indoor), fence posts, honey production, matchsticks, medicines (bark), ornamental tree, pulp for paper, carbon sequestration.

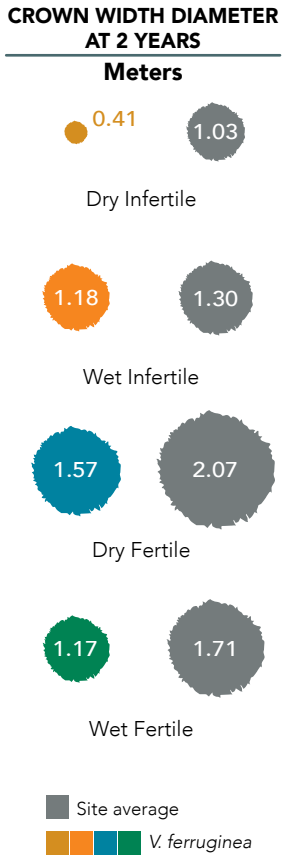
# *Vochysia ferruginea*




Diameter at breast height taken in the last year of height growth measurement



SCIENTIFIC NAME

# *Vochysia guatemalensis*

FAMILY

Vochysiaceae

COMMON NAMES

Flor de mayo, mayo blanco (Panama); cebo, chancho (Costa Rica); barbachele, palo de agua (Nicaragua); san juan (Belize, Guatemala, Honduras).

DESCRIPTION

*Vochysia guatemalensis* is a medium to tall (10 to 40 meters), semi-deciduous species found in low- to mid-elevation, moist to wet forests from Mexico to Panama. In Panama it is common in the provinces of Bocas del Toro and Chiriqui. Four-year survivorship exceeded the average at the wet fertile site of the PRORENA species selection trials. Survivorship was particularly low at the dry sites. Four-year height and diameter growth exceeded averages at the wet infertile site. Four-year height growth also exceeded average at the dry infertile site. Two-year crown widths were below averages at all sites. Four-year carbon index was well above average at the wet infertile site, but either well below or slightly below averages at the other sites.

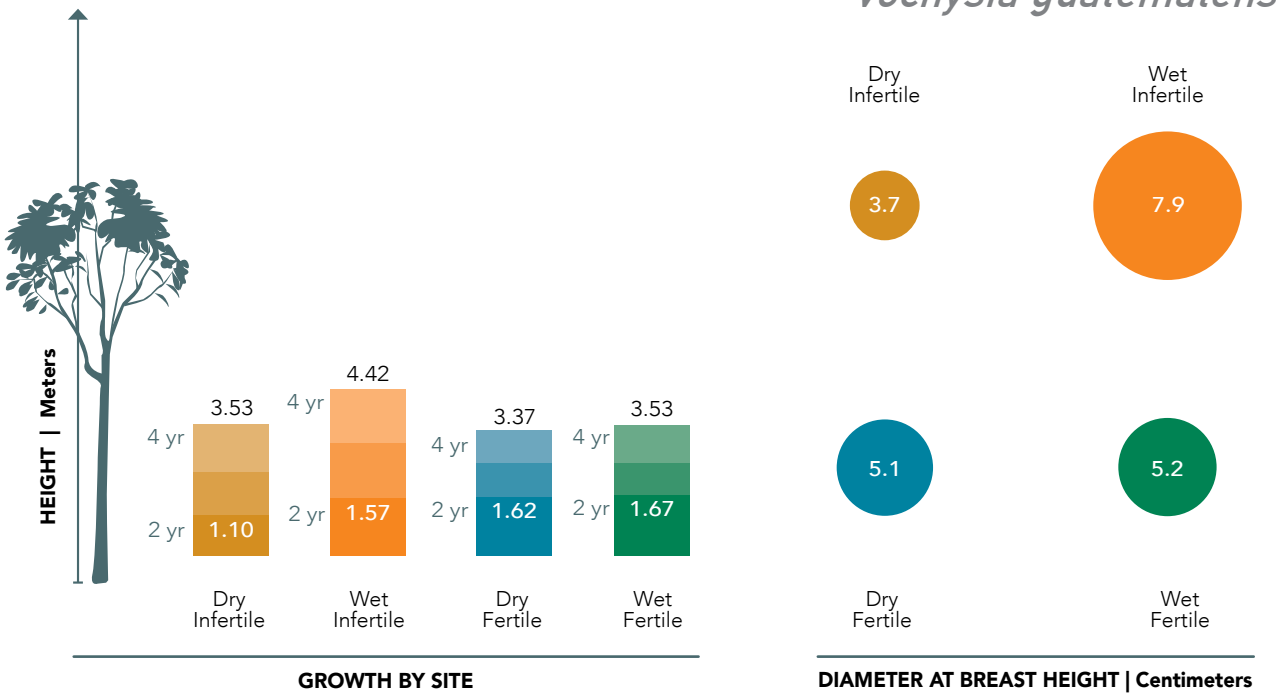
RECOMMENDATIONS

This species did not survive particularly well at the wet infertile site of the PRORENA growth trials but exhibited well above site average height and above site average diameter at this site. The few surviving stems at the dry infertile site markedly exceeded the site height average but, given the extremely high mortality, it is not recommended for similar sites. It has been shown to survive and grow extremely well in plantations in neighboring Costa Rica at moist to wet sites on infertile, acidic soils, such that it is recommended for these sites. As its two-year crown diameters were all below site averages, it is not the first choice to plant if rapid shade is desired to suppress undergrowth of weeds. It is a good species choice on wet infertile sites, where it can form a significant component of planting stock, with rapid carbon accumulation. It can also be planted, though perhaps as a minor component, on wet fertile sites.

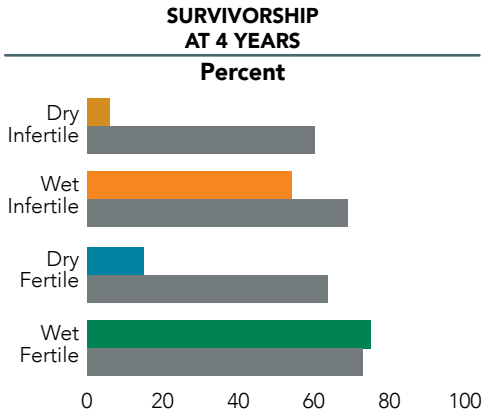
SELECTED USES

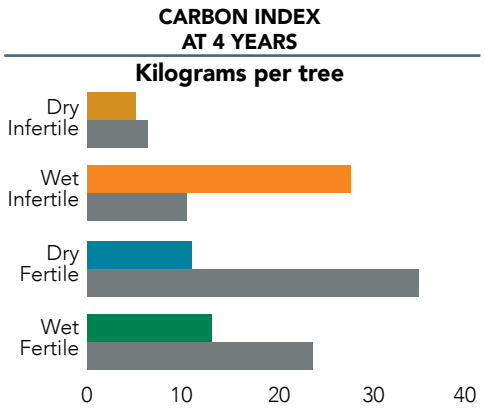
Boxes, carbon sequestration, carpentry, construction (indoor), fence posts, matchsticks, pulp for paper, restoration on wet and infertile soils.

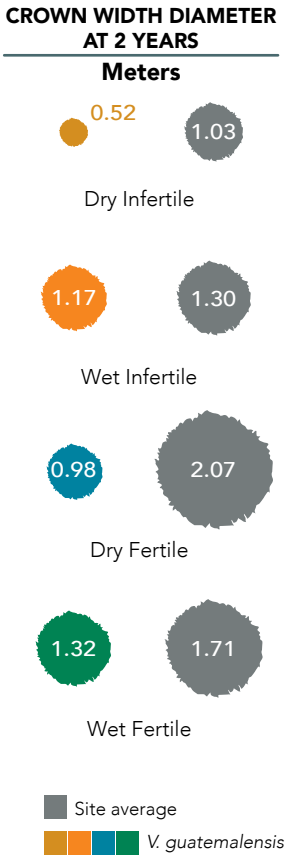
# *Vochysia guatemalensis*




Diameter at breast height taken in the last year of height growth measurement




SPACING

This species can be initially spaced at three to four meters in single-species plantations where the crowns close quickly and can self-prune, but at closer spacing it will require release cleanings. In mixed plantations it can be planted in intimate mixture with slower growing, late-successional evergreen species at a closer spacing (two meters).



SCIENTIFIC NAME

# *Xylopia frutescens*

FAMILY

Annonaceae

COMMON NAMES

Malagueto, malagueto macho (Panama, Central America, Colombia); majagua (Costa Rica); espintana (Peru); peraquina colorada (Bolivia).

DESCRIPTION

*Xylopia frutescens* is a small (5 to 10 meters), tree species found in low-elevation, dry to moist forests from Mexico to Bolivia. It exhibited slightly lower than average survival in wet sites, and extremely low survival in dry sites of the PRORENA species selection trials. Its best growth was at the wet infertile site, with four-year height growth above average and diameter growth below the site average. At all other sites, height and diameter growth were below averages. Two-year crown diameter and four-year carbon index values were below averages at all but the wet infertile site, where these values were respectively above and equivalent to the average.

RECOMMENDATIONS

Given its survival and growth on the wet infertile site of the PRORENA trials—where it obtained roughly a third of its total maximum height in four years—this species can help provide structural complexity in restoration and reforestation treatments at similar sites. It will also make an important contribution to early carbon accumulation at such sites. It may also be planted in wet fertile sites.

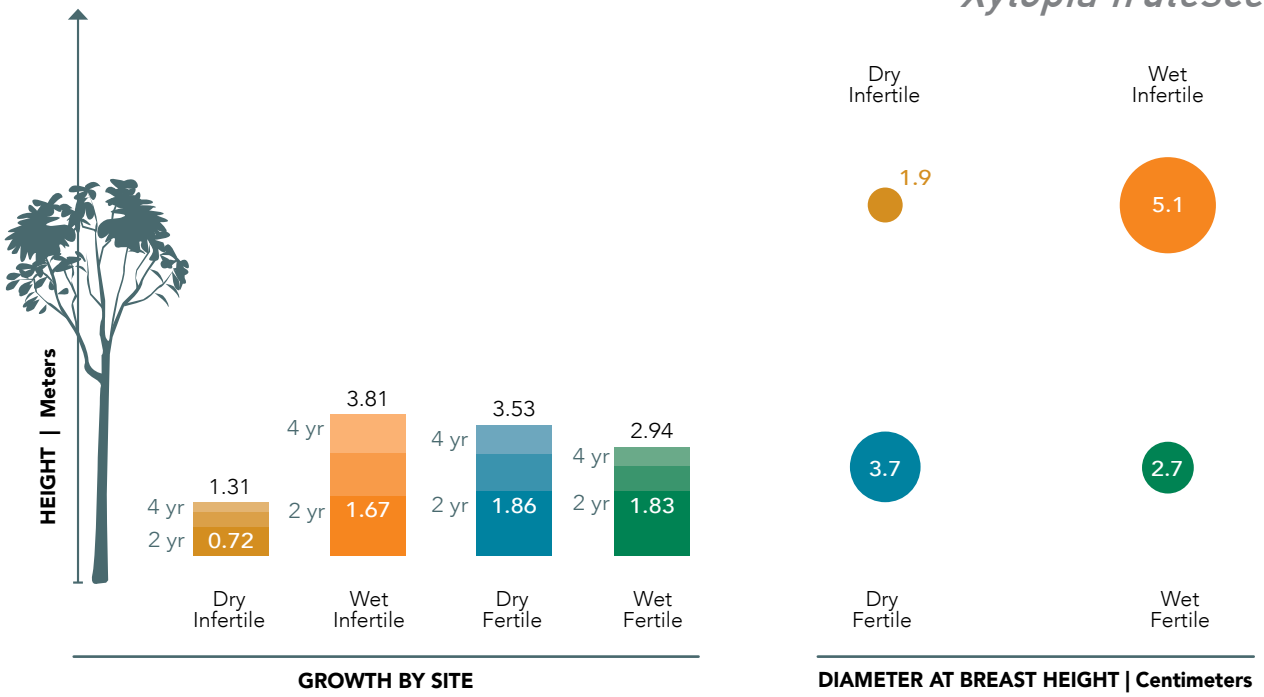
SPACING

This species can be grown as close as two meters to neighbors of the same or other species.

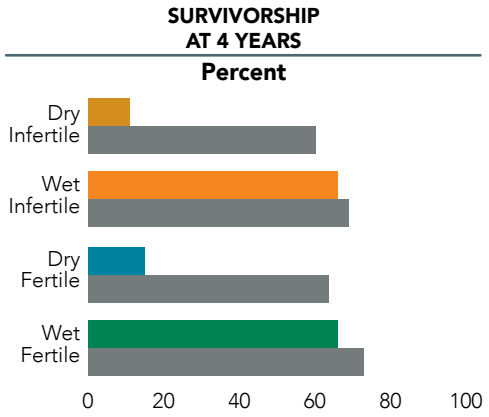
SELECTED USES

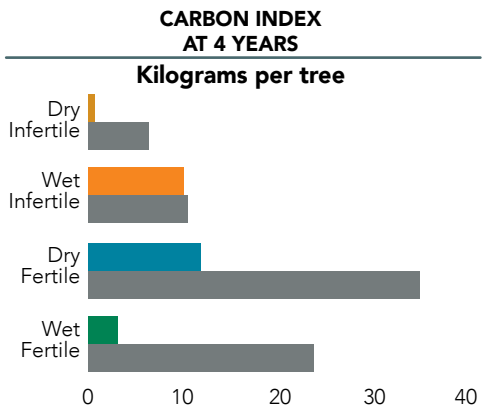
Fence posts, firewood, human consumption (fruits), mooring rope (bark), rat poison (seeds), carbon sequestration (early), early stand structure in reforestation.

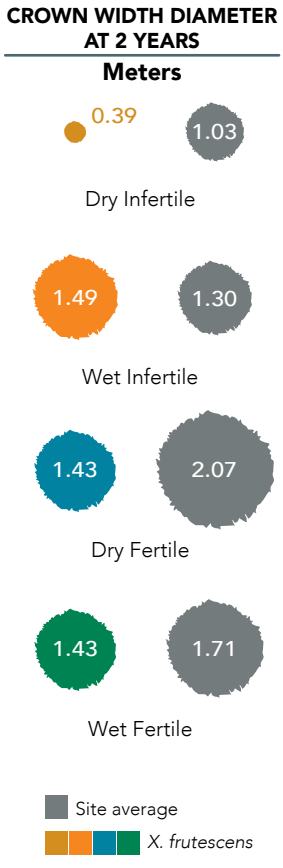
# *Xylopia frutescens*




Diameter at breast height taken in the last year of height growth measurement





SCIENTIFIC NAME

# *Zygia longifolia*

FAMILY

Fabaceae-Mimosoideae

COMMON NAMES

Guabito de río, guabito cansa boca, pichindé (Panama); azote-caballo, sotacaballo (Costa Rica, Nicaragua); amé, barbasquillo, suribio (Colombia); bushica (Peru).

DESCRIPTION

*Zygia longifolia* is a small (5 to 15 meters), evergreen species found in low- to mid-elevation, dry to wet forests from Mexico to Bolivia. In Panama it is common along the rivers and streams within the Panama Canal watershed. Four-year survivorship exceeded averages at all but the dry fertile site of the PRORENA species selection trials, with best survival at the wet sites. Its best height and diameter growth were in the wet fertile site, but with relatively little variation between growth at this site and both the dry fertile and wet infertile sites. Four-year height growth was slightly above average at the wet infertile site and either similar to or below averages at the other sites. The two-year crown widths were above averages at the infertile sites, and equivalent to that of the wet fertile site. Four-year carbon index exceeded the average at the infertile sites and was equivalent to the average at the wet fertile site.

RECOMMENDATIONS

The species survived sufficiently well to be considered for use in reforestation and restoration treatments at all but the dry fertile site of the PRORENA trials. Its height and diameter growth suggest that it can be used at a wide variety of sites. Given its ability to fix nitrogen, it may be particularly useful in restoring degraded sites. Crown widths were close to site averages, suggesting that it can be useful in combination with broad-crowned trees in shading out weeds and other understory plants. Its low to intermediate canopy stature suggests that the species may be useful in creating early stratification in reforestation treatments. Its edible fruits may also help draw in wildlife.

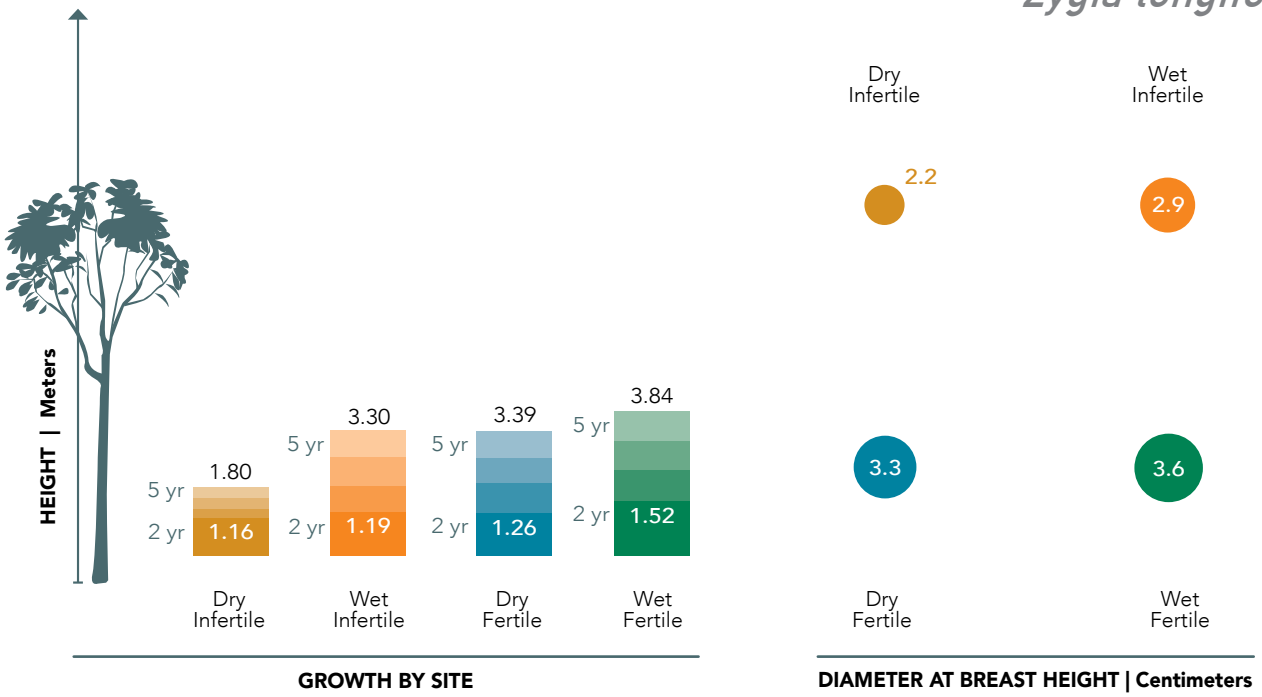
SPACING

This species can be grown two to three meters apart from its neighbors, but may be overtopped and shaded out by faster growing species.

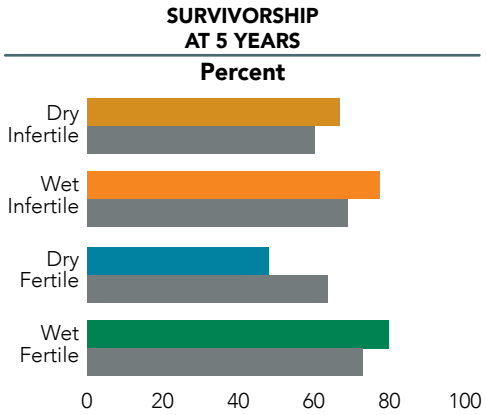
SELECTED USES

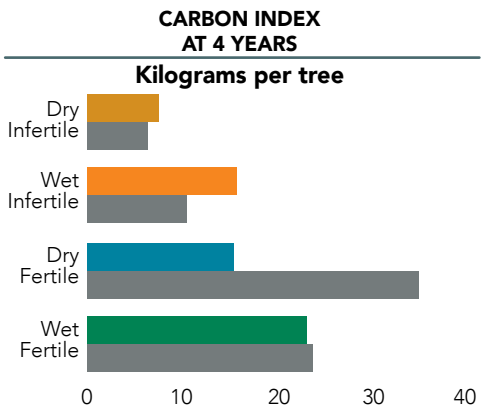
Fence posts, firewood, human consumption (fruits, roots), attracting animal diversity, mid-story structure in reforestation, shade tree (eliminating weeds and grasses), potential soil improvement through nitrogen fixation and use as green manure.

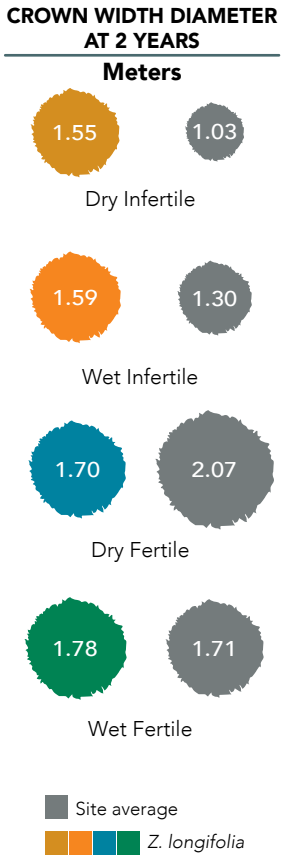
# *Zygia longifolia*




Diameter at breast height taken in the last year of height growth measurement



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World Agroforestry Centre
http://worldagroforestry.org/regions/southeast_asia/resources/db/AFTdatabase

# Appendix 1 *Quick Reference to Species Uses*

| *Species name* / *Selected Uses* | Agroforestry & Human Consumption | Biodiversity | Carbon Sequestration | Ornamental & Other Live Uses | Reforestation & Restoration | Soil Restoration | Wood Products | Other |
|---|---|---|---|---|---|---|---|---|
| *Albizia adinocephala* | | | | 17,18 | 20,25 | 28 | 44 | x |
| *Albizia guachapele* | | | | | 22 | 28 | 36,41,46,44 | x |
| *Albizia saman* | | | | 17,18 | 19,25 | 28 | 31,32,36,38,44,48 | |
| *Anacardium excelsum* | 6 | | | 17 | 19 | | 37,41,47,54,55 | |
| *Anacardium occidentale* | 4,6,7,8 | 12 | | 16 | 27 | | 41,44,48 | x |
| *Astronium graveolens* | | | 15 | | 19 | | 38,46,48,57 | x |
| *Brosimum alicastrum* | 4,6 | | | 18 | | | 38,46,48,57 | |
| *Brosimum utile* | 6,8 | | | | | | 33,38,40,59 | |
| *Byrsonima crassifolia* | 5,6,8 | 11 | 13 | 17,18 | 22,25 | | 38,46,48 | x |
| *Calophyllum brasiliense* | 8 | | | 17,18 | 65 | | 38,46,44,48 | |
| *Calophyllum longifolium* | 8 | 11 | | | 19 | | 38,46,48,57,58,61 | |
| *Calycophyllum candidissimum* | 5 | | | 17 | 19 | | 41,44,46,57 | |
| *Carapa guianensis* | 8,9 | | | 17 | | | 36,38,41,46,58 | x |
| *Cassia grandis* | 2,4,6,8 | | | 17 | 23 | | 38,47 | x |
| *Cassia moschata* | | | | 17 | 21,26 | 28 | 44 | x |
| *Cedrela odorata* | 8 | | 15 | 16,17 | 19 | | 37,41,48,52 | x |
| *Cedrela tonduzii* | | | 15 | | | | 41,48,52 | |

| *Species name* / *Selected Uses* | Agroforestry & Human Consumption | Biodiversity | Carbon Sequestration | Ornamental & Other Live Uses | Reforestation & Restoration | Soil Restoration | Wood Products | Other |
|---|---|---|---|---|---|---|---|---|
| *Chrysophyllum cainito* | 6,8 | 11 | | 17,18 | | | 44,48,57,59 | x |
| *Cinnamomum triplinerve* | | | | 16 | 19 | | 34,41,46 | |
| *Colubrina glandulosa* | | | | 18 | 21,24,25 | | 34,41,44 | |
| *Copaifera aromatica* | 8 | | | | 24 | | 34,36,38,41,46 | |
| *Cordia alliodora* | 8 | | 15 | 18 | | | 44,46,48,62 | |
| *Dalbergia retusa* | | | 13 | | 25 | 28 | 48 | x |
| *Diphysa americana* | | | 13 | 17 | 21,22 | 28 | 36,38,41,44,56,57 | |
| *Dipteryx oleifera* | 6 | 11 | 15 | | 19 | 28 | 34,41,46,47,57,61 | x |
| *Enterolobium cyclocarpum* | 4,6,8 | | 14 | 17,18 | 21,25 | 28 | 32,33,36,38,44,59 | x |
| *Erythrina fusca* | 3,4,8 | | 14 | 16,17,18 | 24,25 | 28 | | x |
| *Gliricidia sepium* | 4,5,6 | | 14 | 17,18 | 22,25 | 28 | 48,57 | x |
| *Guazuma ulmifolia* | 4,5,6,8 | | 14 | 18 | 21,22,25 | | 41,44 | x |
| *Gustavia superba* | 5,6,8 | | | | | | | |
| *Hieronyma alchorneoides* | 8 | | 13 | | 20 | | 30,34,41,44,61,62 | x |
| *Hura crepitans* | 3,8 | | 14 | | 20 | | 32,38,58 | x |
| *Hymenaea courbaril* | 5,6,8 | | | 17 | 24 | | 34,36,38,41,46 | x |
| *Inga laurina* | 6 | 11 | 13 | | | 28 | 33 | x |
| *Inga punctata* | 6 | 11 | | | 21,24 | 28 | 33,46 | x |
| *Lacmellea panamensis* | 6 | 11 | | | | | 31,33,40,57 | |
| *Luehea seemannii* | 5 | | 13 | | 21 | | 31,33,40,59 | x |

| *Species name* | *Selected Uses* Agroforestry & Human Consumption | Biodiversity | Carbon Sequestration | Ornamental & Other Live Uses | Reforestation & Restoration | Soil Restoration | Wood Products | Other |
|---|---|---|---|---|---|---|---|---|
| *Manilkara zapota* | 5,6 | | | 16,17 | | | 31,41,44,57,61 | x |
| *Muntingia calabura* | 5,6,8 | 10 | 14 | 16 | 21,25,27 | | | x |
| *Ochroma pyramidale* | | | 14 | 17 | 21,22,25 | | 35,51,52,53,60 | x |
| *Ormosia macrocalyx* | | | | 17 | 21 | 28 | 34,36,38,48,61 | x |
| *Pachira quinata* | 8 | 11 | 13 | | 25 | | 31,33,43,48,55,64 | x |
| *Peltogyne purpurea* | | | | | 19 | | 36,46,62 | x |
| *Pentaclethra macroloba* | 1,6,8 | | | | 24 | 28 | 31,41 | x |
| *Platymiscium pinnatum* | | | | | 24 | 28 | 32,36,38,45,62 | |
| *Protium tenuifolium* | 8 | | | | | | 36,38,41,42,46,48 | |
| *Pterocarpus officinalis* | 8 | | | | | 28 | 33,38,44 | x |
| *Pterocarpus rohrii* | | | | | | | 31,38,48,49 | |
| *Sapindus saponaria* | 5,8 | 11 | | 17 | 22 | | 44,57 | x |
| *Sapium glandulosum* | 9 | 11 | 13 | 16,18 | 24 | | 33,38,44,58 | x |
| *Schizolobium parahyba* | 5 | | 13 | 17 | 19,22,25 | | 31,33,43,48 | |
| *Spondias mombin* | 4,5,6,8 | 11 | 13 | 16,17 | 25 | | 33,38,41,58,59 | |
| *Sterculia apetala* | 5,6,8 | | | 17 | | | 33,41,44.50.58 | |
| *Swietenia macrophylla* | 8 | | | 17,18 | 19 | | 36,38,48 | x |
| *Tabebuia guayacan* | | | 13 | 17 | 19 | | 34,39,41,57,61 | |
| *Tabebuia impetiginosa* | 8 | | | 17 | 24 | | 41,48 | |
| *Tabebuia rosea* | 8 | | 15 | 17 | 19 | | 31,32,36,46,48,53 | x |

| Species name / Selected Uses | Agroforestry & Human Consumption | Biodiversity | Carbon Sequestration | Ornamental & Other Live Uses | Reforestation & Restoration | Soil Restoration | Wood Products | Other |
|---|---|---|---|---|---|---|---|---|
| *Terminalia amazonia* | | | 13,14,15 | 17,18 | 19,21,25 | | 34,44,46,48,57,61 | x |
| *Trichilia hirta* | | | | 17 | | | 38,44 | x |
| *Vitex cooperi* | | | | 17 | 25 | | 41,44,57 | x |
| *Vochysia ferruginea* | 5,8 | | 13 | 17 | 66 | | 33,38,41,44,50,59 | |
| *Vochysia guatemalensis* | | | 13 | | 66 | | 33,38,41,44,50,59 | |
| *Xylopia frutescens* | 6 | | 14 | | 22 | | 44 | x |
| *Zygia longifolia* | 6 | 11 | | 18 | 24 | 28 | 44 | x |

KEY TO NUMBERS IN CATEGORIES

| | | | |
|---|---|---|---|
| **Agroforestry and Human Consumption** | 1 = cooking oil (seeds)<br>4 = fodder<br>7 = industrial oil (oil from nut) | 2 = dry-zone intercropping in agroforestry<br>5 = honey production<br>8 = medicines | 3 = fishing (resin-based poison)<br>6 = human consumption<br>9 = oil |
| **Biodiversity** | 10 = attracting animal and plant diversity | 11 = attracting animal diversity | 12 = attracting animals |
| **Carbon Sequestration** | 13 = carbon sequestration | 14 = carbon - early | 15 = carbon - long-term |
| **Ornamental and Other Live Uses** | 16 = living fences | 17 = ornamental tree | 18 = shade tree |
| **Reforestation and Restoration** | 19 = canopy species in reforestation<br>22 = early stand structure in reforestation<br>25 = nurse tree for shade-tolerant species<br>65 = streambank restoration and protection | 20 = early canopy structure in reforestation<br>23 = mid-story or canopy in reforestation treatments<br>26 = under- to mid-story structure in reforestation<br>66 = restoration on wet and infertile soils | 21 = early crown cover in reforestation<br>24 = mid-story structure in reforestation<br>27 = understory structure in reforestation |

KEY TO NUMBERS IN CATEGORIES

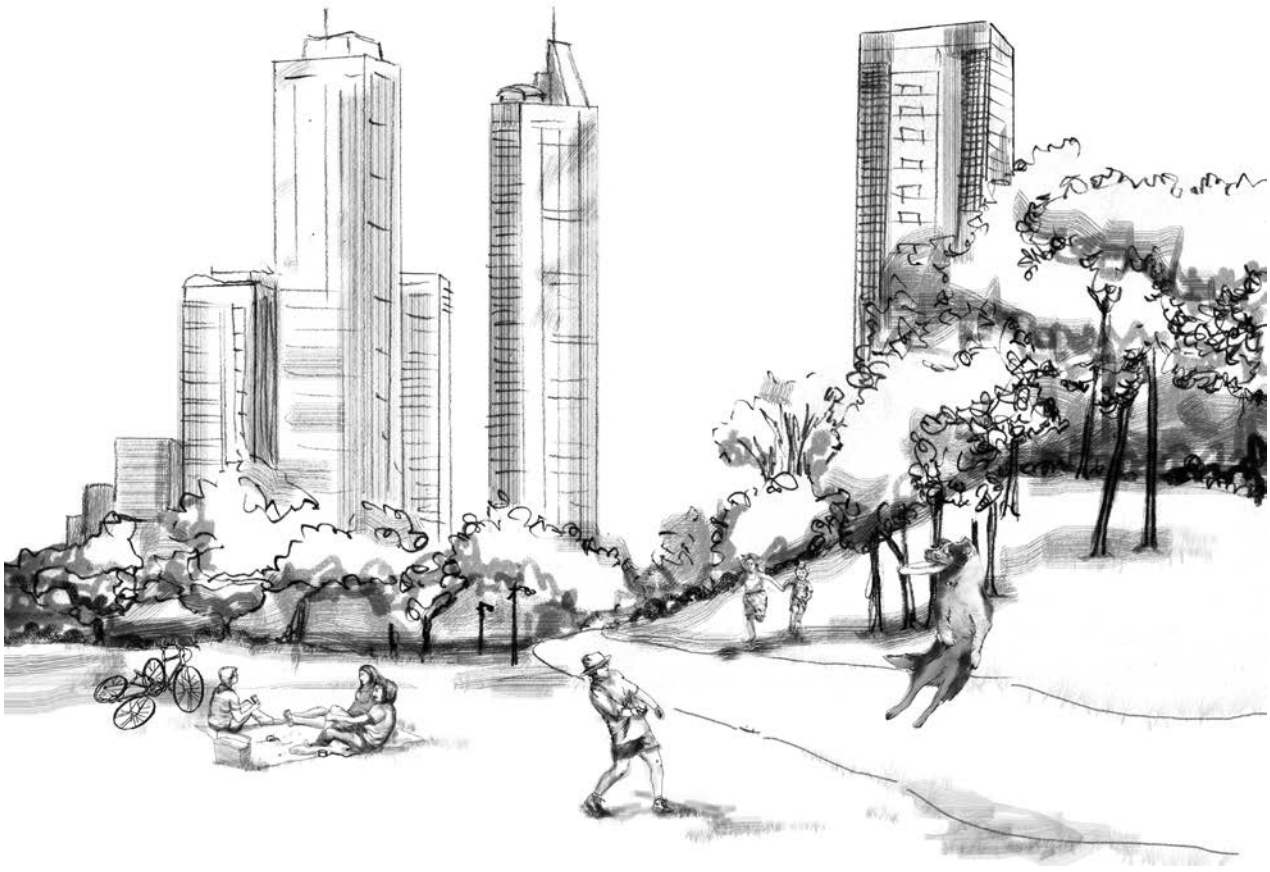
| | | | |
|---|---|---|---|
| **Soil Restoration** | 28 = potential soil improvement through nitrogen fixation and use as green manure | 29 = soil moisture retention through seasonal leaf fall | |
| **Wood Products** | 30 = barrels | 31 = boards | 32 = boat construction |
| | 33 = boxes | 34 = bridges | 35 = buoys |
| | 36 = cabinetry | 37 = canoes | 38 = carpentry |
| | 39 = carriages | 40 = chipboard | 41 = construction |
| | 42 = domestic utensils | 43 = doors | 44 = fence posts |
| | 45 = fine wood turning | 46 = floorboards | 47 = framing structures in tunnels and mines |
| | 48 = furniture | 49 = ladders | 50 = matchsticks |
| | 51 = models | 52 = musical instruments | 53 = packaging |
| | 54 = paddles | 55 = particle board | 56 = pillars |
| | 57 = pitchforks | 58 = plywood | 59 = pulp for paper |
| | 60 = rafts | 61 = railroad ties | 62 = veneer |
| | 63 = wagon bottoms | 64 = window framing | |

# Appendix 2 *Species Distribution in Natural Forest*

| Species | Forest type | | |
|---|---|---|---|
| | Dry | Moist | Wet |
| *Copaifera aromatica* | X | X | X |
| *Cordia alliodora* | X | X | X |
| *Inga laurina* | X | X | X |
| *Inga punctata* | X | X | X |
| *Ochroma pyramidale* | X | X | X |
| *Sapium glandulosum* | X | X | X |
| *Tabebuia guayacan* | X | X | X |
| *Tabebuia rosea* | X | X | X |
| *Zygia longifolia* | X | X | X |
| *Albizia adinocephala* | X | X | |
| *Albizia guachapele* | X | X | |
| *Albizia saman* | X | X | |
| *Anacardium occidentale* | X | X | |
| *Astronium graveolens* | X | X | |
| *Brosimum alicastrum* | X | X | |
| *Byrsonima crassifolia* | X | X | |
| *Calophyllum brasiliense* | X | X | |
| *Calycophyllum candidissimum* | X | X | |
| *Cassia grandis* | X | X | |
| *Cassia moschata* | X | X | |
| *Cedrela odorata* | X | X | |
| *Chrysophyllum cainito* | X | X | |
| *Dalbergia retusa* | X | X | |
| *Diphysa americana* | X | X | |
| *Enterolobium cyclocarpum* | X | X | |
| *Erythrina fusca* | X | X | |
| *Gliricidia sepium* | X | X | |

| Species | Forest type | | |
|---|---|---|---|
| | Dry | Moist | Wet |
| *Guazuma ulmifolia* | X | X | |
| *Gustavia superba* | X | X | |
| *Hura crepitans* | X | X | |
| *Hymenaea courbaril* | X | X | |
| *Luehea seemannii* | X | X | |
| *Manilkara zapota* | X | X | |
| *Muntingia calabura* | X | X | |
| *Pachira quinata* | X | X | |
| *Platymiscium pinnatum* | X | X | |
| *Sapindus saponaria* | X | X | |
| *Schizolobium parahyba* | X | X | |
| *Spondias mombin* | X | X | |
| *Sterculia apetala* | X | X | |
| *Swietenia macrophylla* | X | X | |
| *Tabebuia impetiginosa* | X | X | |
| *Trichilia hirta* | X | X | |
| *Xylopia frutescens* | X | X | |
| *Anacardium excelsum* | | X | X |
| *Brosimum utile* | | X | X |
| *Calophyllum longifolium* | | X | X |
| *Carapa guianensis* | | X | X |
| *Cedrela tonduzii* | | X | X |
| *Cinnamomum triplinerve* | | X | X |
| *Colubrina glandulosa* | | X | X |
| *Dipteryx oleifera* | | X | X |
| *Lacmellea panamensis* | | X | X |
| *Ormosia macrocalyx* | | X | X |
| *Pentaclethra macroloba* | | X | X |
| *Protium tenuifolium* | | X | X |
| *Pterocarpus officinalis* | | X | X |
| *Pterocarpus rohrii* | | X | X |

| Species | Forest type | | |
|---|---|---|---|
| | Dry | Moist | Wet |
| *Terminalia amazonia* | | X | X |
| *Vitex cooperi* | | X | X |
| *Vochysia ferruginea* | | X | X |
| *Vochysia guatemalensis* | | X | X |
| *Peltogyne purpurea* | | X | |
| *Hieronyma alchorneoides* | | | X |



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