Forest Gardens As An Approach To Reforestation in Azuero, Panama

ENVR451 Final Report

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I – Executive Summary

IA) Executive summary in English

Tropical dry forests used to be the most common ecosystem in Central America. Today, it is estimated that it is one of the most threatened tropical ecosystems, especially in Central America where only 1.7% of the original tropical dry forest cover remains. In Panama, and especially in the Azuero Peninsula where the last patches of tropical dry forest can be found, decades of cattle ranching have tremendously altered the landscape and it is now estimated that pastureland have replaced 70% of the originally forested landscape.

In order to address this conservation emergency, the Azuero Earth Project has identified an area of 25 000 hectares within the Azuero Peninsula to reforest in priority, known as the Rio Oria biological corridor.

If there is a wide range of methods to reforest, the corridor is particular in that it encompasses the land of 400 private landowners. In that sense, it is important to offer attractive reforestation alternatives.

The goal of our project was to study forest gardens of Azuero because, not only are they an effective approach to reforestation, but they are also a traditional way to sustain local livelihoods. Revitalizing this tradition would therefore merge conservation and socio-economic purposes.

Our research was divided in three parts: [1)] analyzing the composition and structure of forest gardens of Azuero; [2)] understanding the local perceptions on forest gardens in terms of values, benefits and constraints; [3)] investigating one ecosystem service provided by forest gardens of Azuero, namely carbon sequestration.

In order to have a better understanding of the functions of forest gardens of Azuero, we decided to study their composition and structure. We surveyed three model *fincas* and were

able to assess their plant diversity, their vertical structure through the use of vertical profiles and their horizontal structure through the use of aerial maps. The trees surveyed in these three model *fincas* were also used to calculate the carbon sequestration in each *finca*, hence giving an estimate of the carbon sequestration potential of the forest gardens of Azuero. We conducted seven interviews that allowed us to identify the benefits as well as the constraints generated by forest gardens. The interviews also reinforced our analysis of the composition and structure of these forest gardens. In order to revitalize forest gardens in Azuero, we finally put in place different outreach methods including creating an eco-guide, writing a short story and giving an informative presentation to local communities. For a broader outreach, all of these supports can be found on the Azuero Earth Project website.

The composition of the forest gardens of Azuero showed a great diversity, with over 80 different species surveyed. Of these 80 species, 53% were native to Azuero while 47% were introduced. The three model *fincas* surveyed had 12 plant species in common. Our analysis classifies 9 types of use/value for the different plant species; it appeared that over 40% of the plants had more than one use/value. The vertical profiles revealed a multi-strata system where light and space was used wisely. Indeed, species that required shade were often planted underneath older, taller trees that were resistant to sunlight. Moreover, we identified a time dynamic in the forest gardens investigated: the land was planted with both young and old trees of the same species. The aerial maps helped recognizing the horizontal structure of Azuero forest gardens. The tallest and biggest canopy trees were found on the edge of the properties, far from the house, in order to protect from the noise and/or the destructive winds as well as for leaving enough space for their fall when harvested in the future. We also distinguished more vegetation along the streams; this way, *finqueros* are able to protect the water they rely on. Finally, fruit trees, edible crops and chicken runs were found relatively near the house in order to facilitate the regular access to them. A more social area was

identified very close to the houses, where *finqueros* would install hammocks under trees and plant ornamentals.

The calculation of carbon sequestration showed that forest gardens of Azuero are a land use system that has a very large potential for carbon sequestration. The estimation ranged from 196 $MgCO_2ha^{-1}$ to 379 $MgCO_2ha^{-1}$, which is more than the estimated carbon sequestration of tall secondary forests in the tropics and slightly less than the estimated carbon sequestration of old, natural forests in the tropics.

Finally, the interviews allowed us to identify a variety of aspects that were relevant to the local people of Azuero. The interviewees identified their forest gardens as being both a source of basic food and a source of income from the sale of wood for timber. They also stressed the importance of forest gardens as a tradition of Azuero, mentioning that they embody a part of their identity. Many stated that their forest garden also shows their affection towards nature because it helps protecting the environment and it brings a pleasant microclimate. Our interviewees revealed that there were not really any constraints brought about by having a forest garden, if not a little time and physical investment.

We conclude our study by encouraging the practice of forest gardens both in Azuero and in other parts of the world. Through our research, we have unveiled the importance of forest gardens as an appealing and integrative approach to reforestation, a practice that is underestimated but that can have beneficial impacts on improving both conservation of the ecosystem and local livelihoods.

IB) Resumen ejecutivo en Español

El bosque seco tropical solía ser el ecosistema más común en America Central. Se estima presentemente que es uno de los ecosistemas tropicales más amenazado, especialmente en Centro América donde sólo queda 1.7% del bosque seco tropical original. En Panamá, y especialmente en la península de Azuero, donde se encuentran unas de las últimas y más amplias áreas de bosque seco tropical, décadas de ganadería extensiva han alterado tremendamente el paisaje y se estima hoy en día que los potreros han remplazado 70% de lo que era originalmente cubierto por bosque.

Con el fin de abordar esta emergencia de conservación, el Proyecto Ecológico Azuero ha identificado un área de 25 000 hectáreas dentro de la península de Azuero a reforestar prioritariamente, conocida como el corredor biológico del Río Oria. Existen múltiples maneras de reforestar, pero el corredor biológico es un caso particular debido a que integra las tierras privadas de 400 finqueros. Dentro de tal proyecto, es entonces importante ofrecer alternativas de reforestación que sean atractivas. El propósito de nuestro proyecto es estudiar los huertos forestales de Azuero porque no sólo representan un modo efectivo de reforestación pero también un uso del suelo tradicional que sustenta modos de vida locales. Revitalizar esta práctica tradicional combina entonces propósitos de conservación tanto como intereses socio-económicos de la población local.

Nuestra investigación esta constituida por tres partes: [1)] analizar la composición y estructura de huertos forestales ejemplares en Azuero; [2)] entender las perspectivas locales sobre huertos forestales así como su valor, beneficios y desventajas; [3)] investigar un servicio del ecosistema que los huertos forestales proveen: la captura de carbono. Para comprender analíticamente las funciones de los huertos forestales de Azuero, estudiamos su composición y estructura. Medimos tres modelos de fincas con huertos forestales en la provincia de Los Santos, lo que nos permitió asesorar su diversidad de plantas, su estructura vertical con el uso

de perfiles verticales y su estructura horizontal con el uso de mapas aéreos. Las mediciones de los árboles en las tres fincas modelo también fueron usadas para calcular el carbono capturado en cada una de las fincas, dando así un estimado del potencial de captura de carbono que los huertos forestales de Azuero proporcionan. Llevamos a cabo siete entrevistas que nos permitieron identificar tanto los beneficios así como las limitaciones generadas por los huertos forestales percibidas por habitantes locales de la región. Las entrevistas también reesforzaron nuestro análisis de composición y estructura de los huertos forestales. Con el propósito de revitalizar la práctica de tal uso del suelo en la región, creamos diferentes métodos de alcance a la comunidad regional que incluyeron la creación de una eco guía, el escrito de un cuento y una presentación informativa a la comunidad de Los Higos, Pedasí. Para un alcance más general, estos soportes se pueden encontrar en la pagina web del Proyecto Ecológico Azuero.

La composición de los huertos forestales de Azuero que medimos mostraron una gran diversidad con más de 80 especies identificadas. De estas 80 especies, 53% son nativas de la región mientras que 47% son clasificadas como introducidas. Las fincas modelo que medimos contaron en común con 12 especies de plantas. Nuestro análisis clasifica a 9 categorías de usos/valor atribuidas por la población local para las diferentes especies de plantas; resultó que más de 40% de las plantas medidas consideran tener más de un uso/valor. Los perfiles verticales revelaron un sistema de múltiples estratos donde el uso del espacio y la luz se hacen sabiamente. Ciertamente, especies que requieren de sombra se encontraban plantadas debajo de árboles mayores más resistentes al sol. Además, identificamos una dinámica temporal con la presencia de árboles de diversas edades indicando una actividad de reproducción y plantación. Los mapas de vista aérea ayudaron a reconocer la estructura horizontal de los huertos forestales. Los árboles con copas más grandes se encontraron en los bordes de las propiedades creando una barrera natural contra vientos destructivos y/o ruidos además de

estar suficientemente lejos de las casas ya que se considera el espacio necesario para su futura extracción en el caso de ser maderables. También se distinguió una vegetación abundante a lo largo de las quebradas. De esta manera, los finqueros ayudan a conservar el agua de la cual dependen. Los árboles frutales, cultivos y gallineros se encuentran relativamente cercanos a la casa para facilitar su acceso frecuente. Áreas sociales se identifico en cada una de las fincas modelo cercanas a las casas, donde los habitantes colocaron hamacas debajo de árboles y tenían plantas ornamentales.

El cálculo de la captura de carbono demostró que los huertos forestales de Azuero constituyen un uso de suelo con un gran potencial para dicho servicio del ecosistema. La estimación integró una gama desde 196 $MgCO_2ha^{-1}$ hasta 379 $MgCO_2ha^{-1}$, lo que representa más que la estimación del carbono capturado en un bosque secundario en los trópicos y un poco menos que la estimación de carbono capturado en bosques naturales viejos en los trópicos.

Las entrevistas nos permitieron identificar una variedad de aspectos que son relevantes para los habitantes locales. Los entrevistados identificaron los huertos forestales como siendo una fuente de alimento básico así como también una fuente de ingreso proveniente de la venta de madera. También señalaron la importancia de los huertos forestales como tradición de la región, mencionando que representan una forma de su identidad. Varios indicaron que sus huertos forestales demuestran su cariño a la naturaleza porque protegen el ambiente y crean un microclima agradable. Nuestras entrevistas revelaron que no hay realmente impedimentos por tener un huerto forestal si se tiene el espacio, solamente un poco de tiempo e inversión física.

Concluimos nuestro estudio animando la práctica de tener huertos forestales tanto en Azuero como en otras partes del mundo. A través de nuestra investigación, hemos desvelado la importancia de los huertos forestales como modo atractivo y integral para la reforestación a

pequeña escala, una práctica cuyo valor es subestimada pero que tiene numerosos impactos positivos al mejorar tanto la conservación del ecosistema como la subsistencia de los medios de vida locales.

II – The host institution: Azuero Earth Project

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IIB) Information about the host institution

The Azuero Earth Project (AEP) is an NGO established since 2008 in Pedasi, Los Santos, Panama whose mission is to preserve the Earth's ecosystems, protect biodiversity and promote healthy communities by helping people make informed decisions, take sustainable actions and share knowledge. It is specifically located in Azuero due to threats to the dry tropical forest ecosystem brought about by anthropogenic land use changes. The AEP team is committed to a variety of projects around three main action pillars: conservation, collaboration and education. From funding conferences, organizing visits by experts, supporting partnership with university students, promoting organic agriculture and providing the community with a library, eco-guides and a plant data base, only to mention a few, the AEP is an environmental conservation hub in the Azuero Peninsula. Since 2012, AEP hosts McGill PFSS students to carry out 4-months long internships.

III – Logistics of the internship

IIIA) Time allocation

Table 1: Time allocation throughout the course of the internship

Month	Work Days in Panama	Work Days in Pedasi	Total of Work Days
January	2	3	5
February	4	7	11
March	4	4	8
April	1	14	15
Semester	11	28	39

*Workdays are considered to be 8 hours and do not include travel time required to go to Pedasi (approximately 6 hours of bus each way).

IIIB) Housing and transportation costs

Table 2: Housing and transportation costs of the internship

Month	Transportation costs	Housing costs	Total costs
January	26$	30$	56$
February	26$	0$	26$
March	13$	25$	38$
April	39$	65$	104$
Semester	104$	120$	224$

*Transportation and housing costs are for a single person.

IV – General background and objectives of the project

IVA) General background on the project

Dry tropical forests are becoming increasingly rare along the Pacific side of Central America, where they were once the most common forest type (Griscom & Ashton, 2011). Only 1.7% of the original expanse of dry tropical forest remains in Central America (Calvo-Alvarado *et al*., 2009; Griscom & Ashton, 2011; Miles *et al*., 2006; Olson *et al*., 2001). Containing many endemic and economically valuable species, the increasing loss of dry tropical ecosystems makes their conservation and restoration a high priority (Miles *et al*., 2006). Indeed, the remaining dry forest is considered one of the most threatened tropical ecosystems (Griscom & Ashton, 2011. Murphy and Lugo, 1986; Janzen, 1988; Sabogal, 1992; Maass, 1995; Trejo and Dirzo, 2000; Sanchez-Azofeifa *et al*., 2005; Vieira and Scariot, 2006).

The last remnants patches of this ecosystem are scattered in remote areas along the Pacific coasts of Panama, Costa Rica, Nicaragua and Mexico. Compared to wet tropical forests, dry tropical forests have higher soil fertility, diseases are rare and land is easier to clear, which have made them attractive to humans since pre-Colombian times. This has resulted in a long history of anthropogenic land use change (Griscom & Ashton, 2011). In Panama, pastures have replaced 70% of the native forest cover of the region (Love *et al*., 2009). The Azuero Peninsula in Panama illustrates a history of converting forests into agricultural land; similarly to the rest of Central America, pastures for cattle ranching have been a main cause of loss of dry forests (Griscom & Ashton, 2011; Heckadon Moreno, 1984). The decades following the 1940s have been a particularly significant period in terms of accelerating the rate at which the natural landscape of Azuero has been altered by humans. The expansion of cattle ranching pushed the forest frontiers to the extent that almost all of the

land of the Peninsula was being used for grazing. By the 1990s, most agriculturalists of Azuero had to migrate to other areas of the country to find more land (Heckadon Moreno, 1984).

As a result, the present landscape of Azuero has become a mosaic of agricultural land with scattered forest patches isolated by a matrix of land dedicated to either grazing or small-scale urbanization. Without forest connectivity, the fragments of forest are exposed to further degradation, a threat to the already limited habitat diversity (Garen *et al*. 2009). Deforestation in the Peninsula has brought noticeable negative ecological consequences: from increased soil erosion and nutrient runoff, decreased groundwater recharge and larger floods, to reduced wildlife habitat and biodiversity loss. Moreover, the dryer conditions increase the stress on livestock and disturb cattle ranching, an important economic activity in the area. The remaining forest cover of the region is often found in the form of living fences, agroforestry systems, home gardens or along streams and rivers. It is however important to note that one of the largest patches of dry tropical forest in Central America is protected in the Cerro Hoya National Park, located in southwest of the Azuero Peninsula.

In order to conserve this threatened ecosystem, reforestation projects are blooming throughout Panama. The Azuero Earth Project is spearheading an important conservation project which aim is to create a biological corridor in Azuero. The least cost to greater benefit location for the corridor has been determined in 2013 with the help of GIS techniques. The ideal location for the corridor traverses the Peninsula, connecting The Cerro Hoya National Park to the Achotines Forest through the Rio Oria and its tributaries. The corridor encompasses an area of 25 000 hectares in a length of 120km, most of which is riparian zones. Riparian zones are ecosystems that provide habitat for a high number of species, support significantly different gene pools, protect landscapes against erosion, and filter agricultural contaminants (Sabo, *et al*. 2005). Including water systems into conservation areas

is highly recommended by conservationists (Sabo, et al. 2005). With the conservation goal of protecting targeted habitats -in this case endangered dry tropical forests- that support high species richness and endemism, locating the biological corridor along a riparian zone meets the bill.

The Rio Oria biological corridor is a project that requires the collaboration of landowners, as it crosses approximately 400 privately owned properties, it is important to consider local values, practices and needs in order to ensure the success and sustainability of the project. Remnants of forest in Azuero outside protected areas exist partly because they are valued and protected by local people (Garen, *et al*., 2011). They usually take the form of dispersed trees in pasturelands, living fences, riparian zones, diverse agricultural ecosystems or forest gardens, for instance. All of these offer complementary habitats and landscape connectivity for biodiversity, while sustaining rural livelihoods (Garen, *et al.*, 2011). Understanding how and why local people of Azuero value these landscape structures is key to further support and promote them. By merging conservation goals with stakeholder values, customs, needs and preferences, promoting these landscape structure becomes a promising strategy.

We focused our research project on tropical forest gardens. Forest gardens are mainly perennial polycultures of multipurpose plants, typically located in single home lots to provide with food, medicine, firewood, timber, etc. Forest gardens, also known as home gardens, contain trees of all sizes, shrubs, herbaceous, perennials, climbers, root crops, etc. They are agroforestry systems that are part of the traditions of many countries across the world. They are customarily held for subsistence purposes; they provide the household with basic food and high value products that have the potential to generate an income (Kumar & Nair, 2006; Montagnini, 2006). In Central America, they represent a basic and regular source of food for rural families that have maintained their forest gardens for generations (Montagnini, 2006).

Forest gardens manifest a traditional knowledge in their structure, management techniques and choice of species. In these terms, forest gardens are considered a form of cultural expression (Lok, 1998). Additionally, forest gardens play an important role in biodiversity conservation as they are typically very diverse and provide habitat for wildlife. Forest gardens therefore represent a land use system that brings both environmental and socio-economic benefits. Studying them may unfold an innovative strategy for restoration of the Rio Oria biological corridor.

IVB) Objectives of the project

Our project comes as a subpart of the larger Rio Oria biological corridor project. If the goal of the corridor itself could be seen as a mere reforestation effort, our sub-project aims at providing an innovative way to approach reforestation while improving livelihoods of the inhabitants of the region. In these terms, we comply with AEP's main mission, which is to integrate conservation goals with livelihood needs.

A first problem that we wish to address is the reforestation of Azuero.
As mentioned earlier, the Azuero Peninsula has ones of the last patches of dry tropical forest in Central America. Due to this large-scale deforestation, the biodiversity of the Peninsula is threatened. If the plant biodiversity is directly threatened, other organisms are indirectly threatened as well because their habitats are being progressively removed. The tremendous decrease in the Azuero Spider Monkey population over the past years has been a key indicator to prove the biodiversity loss due to deforestation in the region. Forest gardens give the opportunity to increase the population of a wide range of native tree species in Azuero. More specifically, some fruit tree species such as the *nispero (manilkara zapota)*, the *caimito (chrysophyllum cainito)* or the *nance (byrsonima crassifolia)* can be the target of the Azuero Spider Monkeys and therefore help increasing its endangered population.

Reduced forest coverage also means that less carbon sequestration is occurring. Carbon sequestration is tremendously important in an era of rapid climate change where greenhouse gases contribute in major part to the phenomenon of climate change. In Azuero particularly, the amount of greenhouse gases emissions is specifically high due to the large amount of cattle ranching. By implementing tree species that have a high potential for carbon sequestration in forest gardens, we expect to see both a forest cover increase and an atmospheric carbon decrease in the region, *all things being equal*.

Finally, reforestation along the Rio Oria would greatly help protecting water resources in Azuero. Indeed, Panama is, as many countries in the world, threatened by the lack of freshwater, a situation that is getting worse as climatic changes hit the country; it is therefore highly important to protect the watersheds of Azuero. Through the re-implementation of forest gardens, we wish to increase the amount of trees whose roots would help retaining sediments from collapsing into the Rio Oria and improve water filtration.

If the Rio Oria biological corridor is a tremendously important project in terms of conservation effort, it is equally important that it benefits the inhabitants of the Azuero Peninsula.

Food security is a global issue and, although Panama is coping with it, it is important that all its inhabitants remain food secure. There are different ways to achieve this goal and we believe that forests gardens are one very relevant method to do it. Indeed, one of the great benefits from forests gardens is that they provide with fresh products year-round. As a matter of fact, forests gardens that follow our model *fincas* allow quasi-total self-sufficiency as the *finqueros* can cultivate fruits, tubers, and cereals but also raise livestock. Furthermore, products in forest gardens can provide a source of income through the sales of fruits or, more importantly, timber.

Another issue that forest gardens address is the loss of traditional knowledge. Indeed, as mentioned earlier, forests gardens are an integral part of the Central American culture and they have existed for centuries. Not only are forests gardens an integral part of the Panamanian culture; they also provide its owner(s) with medicinal plants and raw materials for traditional architecture and/or handicrafts. By revitalizing forests gardens in Azuero, we therefore aim at revitalizing a part of the Central American traditional knowledge.

The Rio Oria biological corridor is composed of over 400 private landowners; it is therefore relevant to work on innovative techniques of reforestation that would benefit both the environment and the livelihood needs of the local population. Through our project, we wish to provide adequate information on forest gardens and, as a result, encourage *finqueros* of Azuero, and particularly within the biological corridor, to increase this practice.

V – Methodology

VA) Compliance to the *Code of Ethic* of McGill University

Our research required the collaboration of local people through interviews and studies of their forest gardens. We conducted these social exchanges in accordance with the McGill *Code of Ethic*. Prior to interviews and visits of privately owned forest gardens, we introduced ourselves as interns of the Azuero Earth Project and students of McGill University. We also explained the topic of our research. Individuals whom we spoke to had the right to refuse our request to interview and study their forest garden as well as the right to remain anonymous if they wished, thereby respecting the principles of informed consent and confidentiality. We ensured the principle of respect, always remaining attentive, and respectful of opinions, culture and customs of the people we spoke with. Our opinions during interviews were not stated in order to stay neutral and not judge individuals' reactions. Maps and drawings of forest gardens were kindly delivered to the landowners. The eco-guides produced were

distributed to the community and a presentation explaining our research and displaying the information collected was also given to the host community.

In order to insure that this research was conducted following ethical principles, both of us completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course (*see Appendix 2.a and 2.b)*.

VB) Composition and structure

One of the major objectives of our study is to understand the composition and structure of forest gardens of Azuero. With this mind, we decided to survey thoroughly three forest gardens of the region. The forests gardens n°1 and n°2 are located in Los Higos and the forest garden n°3 is located in Valleriquito. Los Higos and Valleriquito are rural towns where extensive cattle ranching is the dominant type of land use. The two towns are located within the province of Los Santos, a region characterized by a dry tropical climate, where the dry season extends from October to May. The selection of these sites occurred by choosing *fincas* with remarkable forest gardens whose landowners were contacts of the Azuero Earth Project – by this selection method, we do not claim that our sample can be inferred to all the forest gardens of the Peninsula, as we simply aimed at studying model forest gardens of the region. In each property, we focused our survey on the area that included the forest garden, thereby surveying areas of 4734m^2, 3538m^2 and 3029m^2 respectively in each of the *fincas*. The forest garden n°1 was started 30 years ago and provides for one household that lives on the parcel. The forest garden n°2 was started 50 years ago and provides for four households that live on the parcel. Finally, the forest garden n°3 was started 10 years ago and provides for one household that lives on the parcel.

Plant diversity

In order to assess the plant diversity of forest gardens of Azuero, we surveyed all the plants taller than 0.8m encountered in the forest gardens investigated. A total of 706 trees were surveyed, namely 262, 121 and 323 trees in the forest gardens n°1, 2 and 3 respectively.

As a complement to our interviews, we used Eva Garen's *et al*. work on agro-forestry practices in the tropical dry forests of Panama (Garen *et al.*, 2010). If the interviews informed us on the different values of forests gardens in Azuero, Garen's work is a good source for knowing the different uses and values of trees commonly used in agro-forestry practices in Azuero. They reviewed 93 tree species, and according to interviews they conducted among inhabitants of Los Santos, they assigned one or multiple uses/values to each species. The uses and values identified were divided into 6 categories: wood/general construction, fruit/food for human, traditional uses (i.e. artisanal uses or household unique uses of tree), physical attributes (i.e. shade, aesthetics, growth form), environmental purposes (i.e. protection of water quality, soil improvement, shelter from wind, food for wildlife) and food for livestock (*see Appendix 7*).

Vertical structure

In order to understand the vertical structure of forest gardens of Azuero, we decided to use vertical profiles. Although it is difficult to find a standard methodology to make vertical profiles, we drew on Rossana Lok's work on traditional forests gardens of Central America (Lok, 1998) to design the vertical profiles of the forest gardens surveyed.

The profiles were drawn in two-dimension with the y-axis representing the height of each plant and the x-axis representing the distance between each plant.

In order to draw the vertical profiles, we recorded for each plant, its species, the distance to the next plant, the height as well as the diameters of both the trunk and the crown.

Horizontal structure

In order to understand the horizontal structure of forest gardens of Azuero, we decided to build aerial maps.

The maps were built using the software *ArcGIS ArcMap10* and using the projected coordinate system WGS_1984_UTM_Zone17N. The software *PowerPoint* was also used to add visual elements to the maps.

The aerial maps are in two-dimension and show information such as the disposition of plants within the property surveyed as well as the canopy cover.

For each plant we recorded its species, the distance to the next plant, the azimuth gradient as well as the diameter of the crown.

During the interview sessions, we also asked the *finqueros* to make a drawing of the structure of their forest garden, in their perception. Given the simplicity of the drawings collected, we decided to rely on the interviews to interpret the meaning of these drawings (see *Appendix 3.a and 3.b)*.

VC) Interviews

In order to investigate the values of forest gardens from a local perception, we decided to conduct interviews. In order to guide our discussions with the interviewees, we created a semi-structured questionnaire made of 21 questions (see *Appendix 4*) that brings up different aspects of forest gardens relevant to our study such as the benefits and constraints of having a forest garden in Azuero or the type of values the owners attach to their forest garden.

A total of seven individual interviews were conducted, three of which were conducted with the owners of the forest gardens under investigation. Even though we could only interview a small number of individuals, the results of our survey provide a glimpse over a variety of perspectives as our interviewees, were not only from different places of the region (Pedasí,

Los Higos, Valleriquito), but also differed in their socio-economic status, gender and age. The interviewees were selected randomly from the contacts of the Azuero Earth Project.

VD) Carbon sequestration

Forest gardens are agro-ecosystems that provide a wide array of ecosystem services such as protecting the water quality or preventing soil erosion (Kumar & Nair, 2006**).** One known ecosystem services provided by forest gardens is their potential for carbon sequestration, hence their relatively important role in reducing CO_2 concentration in the atmosphere (Kumar, 2006). In order to determine one aspect of the environmental benefits provided by forest gardens of Azuero, we decided to calculate an estimation of the carbon sequestrated by each of the forest gardens studied.

The data collected used to calculate the carbon sequestration included the tree species, height and diameter at breast height (dbh) for each tree surveyed. The trees with a dbh inferior to 1.2cm were not taken into account in the analysis.

The method used to calculate these estimations was designed by R. Camacho and H. Barres (2011) and includes 5 steps:

$$1)\ Volume(cm^3) = \frac{\pi}{4} \times dbh^2 \times height(cm) \times 0.45$$

$$2)\ Biomass(cm^3) = Volume(cm^3) \times 1.5$$

$$3)\ Dryweight(gr) = Biomass(cm^3) \times Specificdensity(gr/cm^3)$$

$$4)\ Carbon(gr) = \frac{Dryweight(gr)}{2}$$

$$5)\ CO_2(gr) = \frac{Carbon(gr)}{0.2727}$$

Given the lack of extensive literature on tropical tree specific densities, we estimated a specific density of 0.54gr/cm^3 that we used for all the trees in the forest garden n°1 and 2. We

found 48 specific densities out of the 80 species of trees surveyed in our research in Reyes *et al.* (1992); this allowed us to calculate an estimate by taking the average of all these 48 values. For the forest garden n°3, we used this estimate for all the tree species except for *plátanos* because their specific density is much lower (0.1gr/cm^3) and they were too abundant in the third forest garden (they represented 64.5% of all the trees) to use the sole estimate of 0.54gr/cm^3.

In order to put the numbers in perspective, we related the total quantity of CO_2 sequestrated in each forest garden to the total area surveyed in each *finca*.

VE) Community outreach

With ultimate goal of our research being to revitalize the practice of forest gardens in Azuero, we included the diffusion of the knowledge collected as one of our methods. In these terms, we identified 4 relevant ways to spread the information.

We produced an eco-guide composed of 4 parts: a definition of forest gardens, their benefits, a species list about their composition as well as a description of their structure (see *Appendix 6a and 6b).* The eco-guide will be available in Spanish and in English, both in printed version at the AEP office and in electronic version on the organization's website.

In order to reach the local communities in a more direct way, we also gave an informative presentation in Los Higos (see *Appendix 5a and 5b*). The presentation was 45min long and included the results of our research presented in a way that would encourage the audience to engage with the subject and make them want to start a forest garden of their own. This presentation was recorded and the video produced will be edited and then posted on host websites such as *Vimeo* or *Youtube.* This initiative is a complement to our project that will be put in place by the AEP team and will help broaden the divulgation of the knowledge collected on forest gardens of Azuero.

Taking into account all different types of audiences, we wrote a short story entitled "*Mi Huerto Forestal en Azuero"*. The support will be available in Spanish, both in printed and electronic version (*see Appendix 11*). The presentation and the short story are two supports that can be used again by the AEP team during their environmental education events.

Finally, we contributed to the Azuero Earth Project's website by adding information to their tree database. Information such as common and scientific names, images of the tree, leaves and fruits as well as the common uses of the tree were hand out to the organization.

VI – Results and Discussion

VIA) Composition and structure

Plant diversity

The species surveyed and their relative abundance in each of the garden are presented in a tree data base (*see Appendix 7)*. The column "Uses/Values" was borrowed from Garen *et al*. (2011) who surveyed farmers in the province of Los Santos and asked them to attribute uses and values of the plants according to the following categories: Wood (W), Fruit/Food for humans (FR), Traditional Use (T), Firewood (FW), Physical Attribute (PA), Living Fence posts (LF), Medicinal (M), Environmental purpose (E), and Food for Livestock (FL). For the species that were not listed in Garen *et al.*, we added the use/value according to the information collected from the interviews.

The forest gardens investigated contained a high plant diversity, as expected and mentioned in the literature (Eyzaguirre & Linares, 2004; Kumar & Nair, 2006). We surveyed more than 80 different species amongst the three forest gardens, in a total area of 11 301m^2. Vegetation was composed by both natives and introduced species close to even: 47% of the species were natives and 53% were introduced. A plant was classified as "native" if it had been part of the Panama flora previous to the Europeans arrival. Otherwise, it was classified

as “introduced”. Species richness was not proportional to the number of individual plants (trees, shrubs or grasses) in each of the *fincas*. As seen in Table 3, forest garden n°2 has the lowest number of plants of but is the most diverse. Contrastingly, forest garden n°3 has the most trees and the less species richness with a strong dominance of *plátano* (*Musa paradisiaca*), *yuca* (*Manihot esculenta*) and *caoba* (*Swietenia macrophyllia*).

Table 3: Plant diversity per forest garden

	Forest Garden n°1 (0.47 ha)	Forest Garden n°2 (0.35 ha)	Forest Garden n° 3 (0.3 ha)
Number of plants:	241	122	228
Species Richness:	46	48	24
Species richness/ha:	98	137	80

Amongst all the 80 plants species surveyed, only 12 were present in the three forest gardens. These species were the *plátano*, *naranjo* (*Citrus sinensis*), *marañón nacional* (*Anacardium occidentale)*, *mango* (*Mangifera indica)*, *macano* (*Diphysa Americana)*, *limón* (*Citrus x. limon)*, *guava machete* (*Inga spectabilis)*, *guanabana* (*Annona muricata)*, *coco* (*Cocos nucifera)*, *cedro amargo* (*Cedrela odorata*) and *caoba*. This observation is interesting because it suggests that they are plants commonly used and valued in the region. However, the fact that there are only 12 out of 80 plant species shared amongst the different forest gardens shows the diversity of plants used and valued in the region and the variation of preferences from household to household.

The forest gardens were composed of plants to which people from Los Santos attribute multiple uses and values (*see Appendix 7*). Out of the 60 plants that were given a value/use, 40% were classified in more than one category. The most common use/value attribute in the

three forest gardens was for fruit/human food. As a result, the composition of the forest gardens investigated emphasized the presence of plants for human food consumption: 73% of the species were used for their fruit/human food, the most dominant being *plátano, coco, cítrico* (*Citrus sp*.), *mango, papaya* (*Carica papaya)* and *yuca*.

57% species are considered to be used for living fence posts. The *caoba*, *indio desnudo* (*Bursera simaruba*) and *macano* were the most present in the forest gardens we visited. Dominant trees valued for firewood included *madroño* (*Calycophyllum candidissimum)*, *caoba* and *teca* (*Tectona grandis)*. Finally, the most prevalent trees valued for wood were *macano* (*Diphysa Americana), indio desnudo, caoba* and *teca*.

Table 4: Composition of forest gardens by use/value attributed

Use/Value	% of plants with attributed use/value
Fruit /Food for humans	73
Living fence posts	57
Wood	32
Fire wood	20
Physical attribute	20
Medicinal	18
Environmental purpose	12
Food for livestock	10
Traditional Use	15

Vertical structure

The vertical structure of the forest gardens we visited is characterized by a very efficient use of light and space. This characteristic has been observed by many other studies on forest gardens around the world (Montagnini, 2006; Gillespie *et al*, 2003). When observing the heights of the plants measured in the tree forest gardens, a continuum of heights from the ground up to 25m constitutes the vertical profile. The drawings of vertical profiles bellow show the complexity of space use and a high species turnover across space.

Figure 1: Vertical profile Forest garden n°1

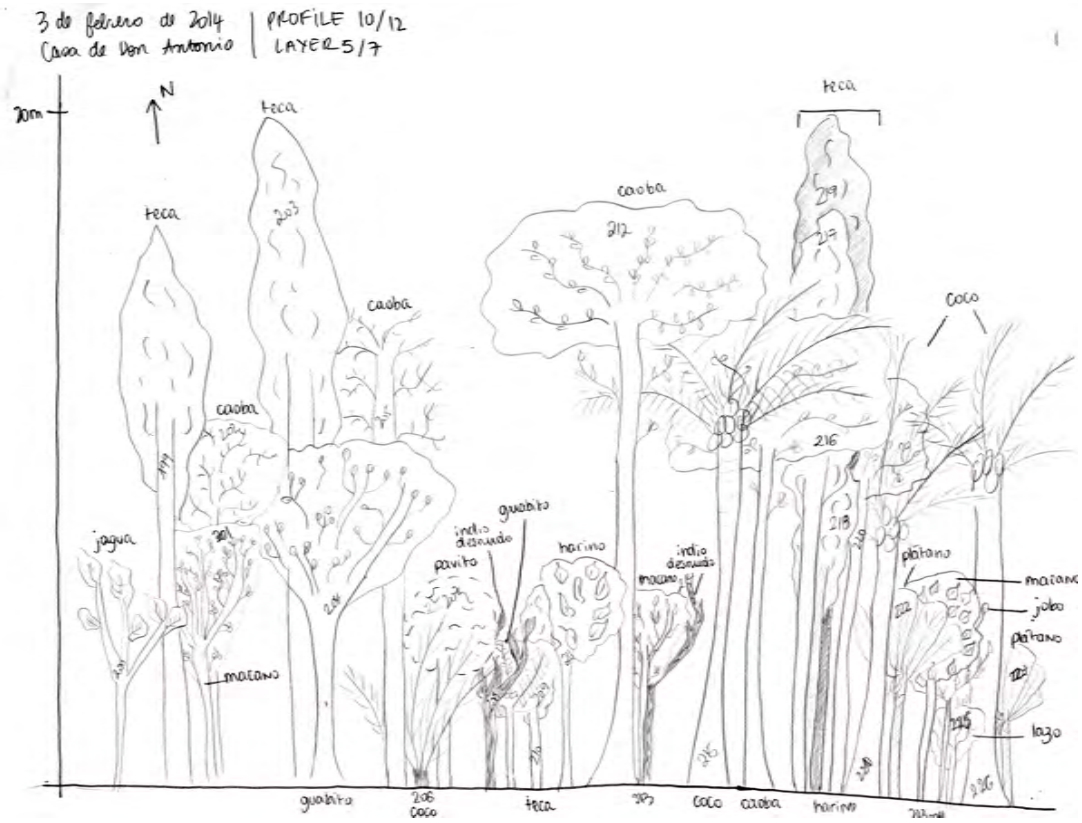


Figure 2: Vertical profile Forest garden n°1

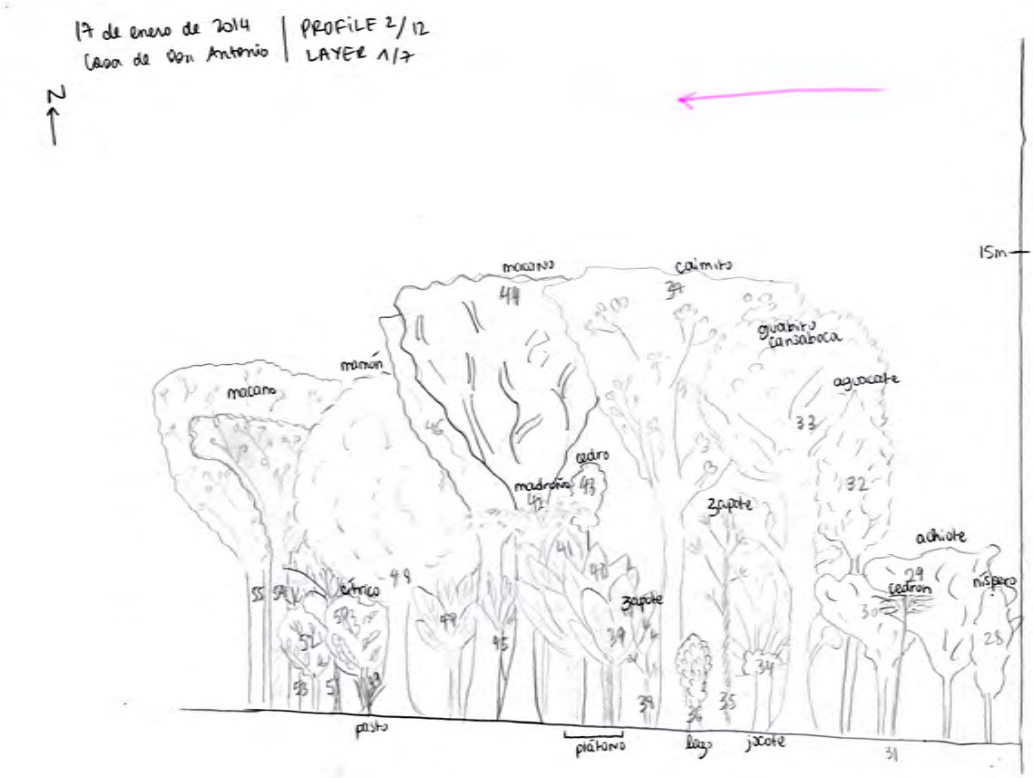


Figure 3: Vertical profile Forest Garden n°2

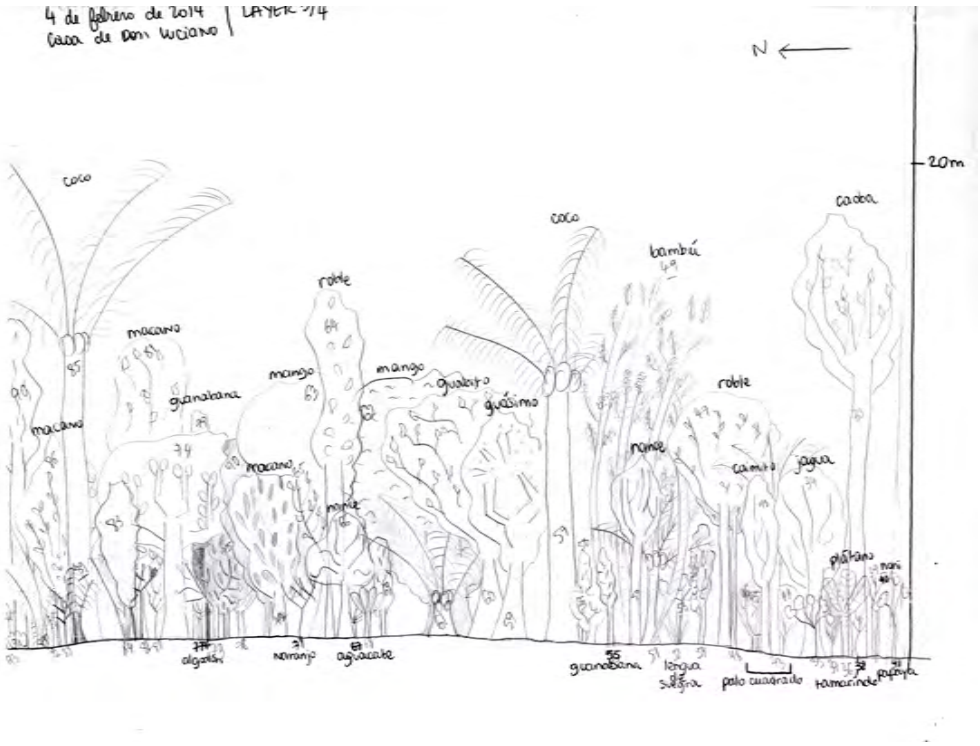
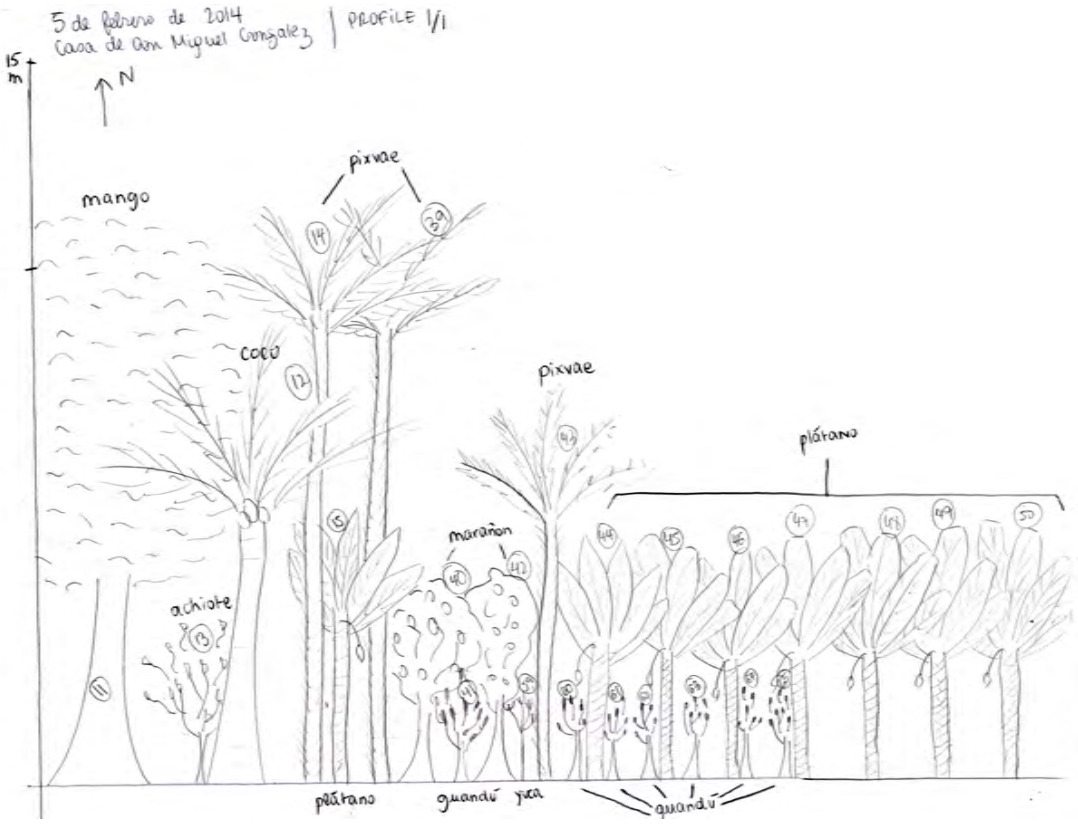


Figure 4: Vertical profile Forest garden n°3



Delineating strata in the forest garden profile is forcefully arbitrary as there are no clear separate layers. However, for the purpose of analyzing the vertical structure of the forest gardens, the following table shows the layers we chose to differentiate in them.

Table 5: Strata composition in forest gardens

Strata	Height	Composition
Herb and low shrub	<1.5 m	*Orégano, guandú, frailecillo, algodon, mirto, chile, vetiver*
Lower tree and tall shrub	1.5-3m	*Guandu, yuca, noni, cana dulce, citricos, macano, plátano*
Middle tree	3-7	*Guanabána, marañón, platano, papaya, macano, teca, guabito, limón, naranjo achiote*
Taller tree	7-12	*Roble, nance, mango, aguacate, teca, coco, jagua*
Upper canopy tree	>12m	*Coco, teca, caoba, palma real, cedro amargo, tamarindo, níspero*

The species composition in the multilayered vertical space of forest gardens was very varied not only in species but also in ages of trees. Even though we did not measure the age of trees per se, we identified young trees that have the potential to grow taller. The same tree could be found in several layers, where reproduction or replanting was occurring, suggesting that forest gardens were dynamic in time. Such is the case for *teca* trees for example, which were found as saplings in lower tree stratum as well as in the upper tree stratum. Taller and upper canopy trees were found relatively distant from one another, giving space for middle and lower trees to grow in between them, alongside lower shrubs and younger trees. Shade tolerant trees such as the *guandú (Cajanus cajan), yuca* or *café* (*Coffea sp.*) were mixed next to taller trees that provided them with shade. The vegetation valued for human food consumption constituted roughly the strata below 10m, while trees valued for their wood constituted the upper canopy layer. For all the forest gardens, the middle tree stratum was the densest in the vertical profile representing about 46% of the plants (an average of the three forest gardens). The second most dominant layer was the lower tree and tall shrub stratum (30%) followed by the upper canopy tree layer (13%). The presence of trees taller than 18m in forest garden n°1 and 2, and their absence in forest garden n°3 convey the maturity of the forest gardens. Indeed, forest garden n°3 was the youngest of all the forest gardens surveyed. Another observation from forest garden n°3 is that *plátanos* were often planted next to each other in rows, more similar to a plantation than to a complex forest garden. As observed in Figure 4, *plátanos* were present without taller trees in between them and only intercropped with *guandú* or *yuca*. This forest garden was also the least diverse with an important dominance *of plátanos* as explained previously. This may suggest that the most species rich forest gardens have the most the efficient use of light and space.

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Horizontal structure

Observations of the maps of the three forest gardens revealed information about their horizontal structure such as trees density across space, the relative differences in canopy sizes and the arrangement of species across the land. Maps of each of the forest gardens can be found in *Appendix 9.a, 9.b*, and *9.c*. The *Appendix 10.a, 10.b* and *10.c* display maps with the coded plant names from *Appendix 7*.

Some similarities can be found in all the forest gardens we mapped, an important one is that trees with bigger canopies are often along the edges of the property. For forest gardens n°1 and 3, this observation is particularly obvious. In forest garden n°1, big canopy trees, probably more mature and often valued for wood, are arranged along the stream and the road – the composition is a mix of trees for wood and for living fences such as *caoba, macano, teca* and *madroño*. In forest garden n°3, the northern edge of the property is densely populated with tall and big canopy trees combined with living fence trees – a mix of *cedro amargo, indio desnudo, caoba*. Similarly, in forest garden n°2, *caoba* were present in the southeast edge of the property. These big trees often extracted for their wood are kept far away from the house, as a measure of security when extracted. Their function may also be to act as a wind barrier (especially in forest garden n°2 where there were traces of strong northerly winds) or as a noise barrier, buffering the noise from the road. Finding vegetation along the stream in forest garden n°1 also deserves an observation: keeping trees along streams is a common practice in the region. Plants along rivers provide multiple functions such as erosion control, keeping the moisture and freshness much needed in the dry season as well as water filtration. Based on the location of trees for wood and timber in the three forest gardens, we observe that they are planted beside a parallel space with low presence of vegetation, this may indicate some thought over future timber extraction. Leaving access for

trees valued for wood is important to consider so that the future selective logging is facilitated.

In forest garden n°3, another type of vegetation is present along the edge of the property that is bordering the road, namely ornamental plants. In forest garden n°2, ornamental plants were also found almost immediately next to the house. Both of these strategic locations for ornamental plants indicate an aesthetic value given to forest gardens.

Between the bigger trees in the edges of the properties and the ornamental plants surrounding the houses, fruit trees and other edible plants are present all throughout the forest gardens we mapped. This middle distance relative to the house coincides with a frequency of use that is higher than non-edible plants. Leaving edible trees relatively closer to the house than is a common practice for efficient human land use: walking to the fruit trees and other crops has to be done more often than checking the trees for timber. The same can be mentioned for chicken runs, situated relatively close to the houses in each of the forest gardens. As seen on the maps, we can also observe that fruit trees are often planted close to each other creating a diverse fruit tree cluster with relatively even canopy sizes. In forest garden n°1, the fruit trees were mixed with *madroños* (*Calycophyllum candidissimum*), which is used for their firewood. This practice may be convenient because gathering firewood is also needed more frequently. We found that *plátanos* are also in clusters or planted in lines intercropped with *yuca* or *guandú*. This is an efficient use of space as mentioned in the previous section. Moreover, *guandú* also makes nitrogen available to the soil, to the benefit of other plants, as they are from the *Leguminoseae* family.

Another common feature of the forest gardens investigated is the presence of a social space under trees with dense, evergreen foliage (*marañón curazao* in forest garden n°1 and 2, and *mango* in forest garden n°3). These social spaces had hammocks, chairs, benches or

tables. These areas where relatively close to the houses, and their social function was made possible by the trees providing with a living ceiling and comfortable shade.

VIB) Interviews

One of the main purposes of our investigation was to get a hold of the local perceptions on forest gardens. By identifying their benefits and constraints and by collecting information on the tradition of forest gardens in the culture of people from Azuero, the AEP will able to better promote and orient both people that do and do not show interest in starting a forest garden of their own.

Motivations to start a forest garden

The interviewees mentioned a broad range of reasons why they decided to start a forest garden in the first place.

Absolutely all of them agreed that one of the most important reasons to start a forest garden is that it provides them with basic food. Species such as the *yuca*, the *plátano* or the *guandú* were often mentioned as the basis of their diet, which explains why each interviewee that had a forest garden would cultivate at least these three crops. The research revealed that many *finqueros* value their forest garden because they can grow organic products that are not available on the market; hence, their forest garden improves their well-being. It was also mentioned that the variety of fruit trees in forest gardens is immensely valuable because only a handful of fruit varieties are offered on the market and cultivating fruit trees is often the only way for *finqueros* to have access to this diversity of fruits.

Finqueros interviewed revealed that they would only buy certain food supplies on the market, namely rice, oil and some animal products –in the case where they did not raise livestock themselves. Many mentioned that cultivating rice requires too much labor and space; therefore they consider it less costly to buy it directly from the market.

Our investigation also revealed that, even though all the participants did own a forest garden, those who lived in a house separated from their *finca* were more likely to buy the majority of their food supplies on the market.

When it came to the economic advantages of forest gardens, the majority of the interviewees showed an interest in growing tree species that have a high value on the wood and timber market. Indeed, *finqueros* that grow trees for wood would often harvest them and either use them for their own construction projects or sell them. In terms of food sales, only one out of the seven interviewees admitted selling the surplus of his harvest on the local market, namely *granadilla (passiflora ligularis*) and *plátano*. The other interviewees saw the economic benefits of having fruit trees and other subsistence crops in their forest garden in that it reduces their food expenses. As said by Don Antonio Vergara "*los alimentos del huerto no son para vender sino para no comprar*" (personal communication, March 29 2014). Some interviewees also mentioned that, even if they would want to sell the food products harvested, there is not a large enough market for this in the region.

A third very important motivation mentioned by *finqueros* to start a forest garden of their own is their affection for nature. The investigation revealed that, there is a growing awareness on the value of the environment and a growing desire for protecting it. One interviewee who did not own a forest garden said that the first reason why she would start one would be for reforestation purposes. Several of the *finqueros* also mentioned the importance of protecting the biodiversity of their region by having forest gardens. If several of the interviewees liked to refer to the plant diversity of their forest gardens, all the interviews showed that forest gardens attract a variety of wildlife. The commonly observed fauna mentioned in individual forest gardens were birds, squirrels, iguanas or more rarely, monkeys. Indeed, one advantage of forest gardens compared to other agro-ecosystems is that they have a large number of fruit trees that are attractive to monkeys.

Some *finqueros* are more aware of the ecosystem services provided by forest gardens. The interviewees that lived on the same parcel of land as their forest garden emphasized the idea that their forest gardens substantially cool the microclimate of the environment they live in.

Another interesting benefit confirmed by *finqueros* is that owning a forest garden brings social and familial cohesion. Indeed, sharing the surplus of products of one's forest garden was often referred to as a way to build a sense of community within the neighborhood. Also, some interviewees described that taking care of their forest garden is a way to show their attachment to a familial heritage and showing their commitment to their land. Through this process, the *finqueros* have the opportunity to build a sense of home that brings cohesion inside their own family.

Revitalizing the tradition of forest gardens

The interviews helped confirming the idea that forest gardens are part of the cultural heritage of the Azuero Peninsula. It seemed that, in the villages under investigation, namely Los Higos and Valleriquito, the great majority of the inhabitants owned a forest garden. The interviewees explained that, the smaller the village, the less supermarkets there is and the more space they have. Therefore, people are encouraged to start growing their own food for subsistence.

Many interviewees mentioned that having a forest garden is a way of fulfilling their identity as people who belong to the countryside. The tradition is systematically transmitted from parent to children but there seem to be a concern about further transmission as the younger generation is increasingly losing interest for the rural life. Interviewees that did not own a forest garden admitted that they worried they are not going to leave this heritage to their children.

Although forest gardens are an important part of the cultural heritage of Azuero, the investigation revealed that this tradition is being lost. Several reasons were mentioned to

explain this phenomenon. The reason that was more often brought up in interviews is that people that do not have a forest garden do not want to invest time and/or physical efforts into making one. As explained by Don Luciano Madriz, "*hay que no tienen y hay que no quieren*" (personal communication, March 29 2014). Interviewees admitted that, nowadays, it is much easier to buy food supplies from the supermarket, if they have enough income to do so. When it came to interviewees that lived in small towns such as Pedasí, they mentioned the lack of space as a barrier to have a forest garden.

Finally, a few interviewees admitted that they lacked the knowledge to start a forest garden. The first issue mentioned was the lack of knowledge for soil management. The second issue mentioned was the lack of knowledge on how to cultivate certain crops, more specifically crops that need a more delicate attention such as vegetables like tomatoes or cabbage.

In the end, the *finqueros* agreed that, even though the tradition is disappearing, there seems to be an interest in revitalizing it. The first motivation for this is because the cost of life is increasing in Panama and people realize that they can save money by growing their own food. The second reason mentioned is that there is a growing awareness on environmental issues in Azuero due to increasing environmental education in schools and in the media.

Encouraging the practice of forest gardens

All the interviews conducted revealed that *finqueros* see no disadvantages in having a forest garden. In fact, they all agreed that it is both a very easy and a very beneficial practice. For example, two of the forest gardens visited were as young as 2 years old and they were already producing, including the fruits of the fruit trees.

Forest gardens have the advantage of not requiring a lot of maintenance or watering, as they are mostly composed of rain fed perennial vegetation and drought-resistant crops. In terms of maintenance, the information collected revealed that *finqueros* usually work on the side and

only spend a few hours per week working on their forest garden. Moreover, the more laborious cleaning of forest gardens usually happens twice a year.

The resources to start a forest garden can be easily found. Most *finqueros* started off by growing seeds that they collected from the members of their social network such as friends, relatives or neighbors. In Azuero, there are also some governmental (e.g. MIDA) and non-governmental (e.g. APASPE) organizations that are willing to support people that start agro-forestry initiatives. The help can include providing information, seeds, and financial or technical support. Having said that, none except for one of the interviewees mentioned taking advantage of the support of these institutions to start their forest garden because simple knowledge and networking are usually sufficient to do so.

The only issue mentioned repeatedly concerned the water supply. The interviewees complained that, because of climatic changes in Panama, there is less and less water each year. One of the forest gardens surveyed was composed of a stream. Where this stream used to supply water during the dry season in the past, they now dry out tremendously. The *finqueros* suggested planting more trees along the streams in order to address this issue.

Allocation of time and space in forest gardens

Another goal of the interviews was to complement our investigation on the composition and structure of forest gardens in the Azuero Peninsula. Even though the interviewees admitted that they had not thought of a specific structure to design their forest garden, they were still able to sort out some elements of importance.

For all the planting part, the *finqueros* identified the beginning of the wet season, namely June in Azuero, as the best time to plant seedlings into their garden.

If the land is totally deforested, it is best to start growing species that need a lot of sunlight such as the *plátano.* Once these trees have grown large enough, their shade provides an adequate habitat for species that need shade such as the *café.* In some forest gardens, plants

that need sunlight or shade are therefore planted in line next to one another. Also, interviewees mentioned the importance of creating areas of shade for themselves, because a forest garden is also a place to live. Furthermore, the trees have to be planted in a way that facilitates movement in the garden, not too close to one another to avoid out-competition between individuals but not too dispersed either to have an easy access to all the products of the forest garden.

In order to take advantage of all the possibilities offered by plants in forest gardens, *finqueros* usually implement species that prevent soil erosion or retain water, especially on inclined land, such as *vetiver (Chrysopogon zizanioides)*. They also plant species that act as natural insect repellent such as *orégano (Oreganum vulgare)*. As mentioned earlier, another element of Azuero forest gardens is living fences constituted of tree species such as *indio desnudo*, *guasimo (Guazuma ulmifolia)* or *macano.*These tree species live a very long time and avoid the need to replace decomposing nonliving fence posts. Most *finqueros* also add livestock to their forest garden, mainly chicken.

VIC) Carbon sequestration

As explained earlier in this report, two characteristics of forest gardens are their high plant diversity as well as their structure that displays multilayered profile. For these reasons, they have been compared to secondary forests (Kumar, 2006). It has been proved that multi-strata systems enhance the carbon sequestration potential of an ecosystem (Kumar, 2006). Moreover, recent studies have confirmed that diverse plant assemblages have a greater likelihood of containing species with a strong response to resources compared to species-poor assemblages, and hence have a greater ability to sequestrate carbon (Kumar & Nair 2006, Ruiz & Potvin, 2011).

Kumar (2006) identified three main mechanisms that explain why forest gardens are good carbon stocks:

1) Carbon sequestration: By growing trees and soil with a high rate of Net Primary Production (NPP) in its forest garden, one can create new stocks of carbon. Another advantage is that forest gardens can grow on weathered soil with low nutrients; marginal lands can therefore be used to create new sites with high carbon sequestration potential. Carbon sequestration through agro-forestry is therefore an attractive option for mitigating atmospheric carbon concentration.
2) Carbon conservation: By preserving existing forest gardens, one can protect existing carbon stocks. Moreover, forest gardens are relatively permanent agro-ecosystems because their owners maintain them, sometimes for generations.
3) Carbon substitution: By replacing fossil fuel by the wood fuel provided in forest gardens, one can decrease the amount of greenhouse gases released to the atmosphere. In addition, forest gardens are amongst the peculiar land use systems that can stock a large amount of carbon without having large carbon costs from the use of fossil fuels.

Table 6 shows the estimations of the amount of carbon sequestrated in each of the forest garden investigated. In order to put the numbers in perspective, we compared them to the carbon sequestration estimations of other land use systems in tropical regions (Kumar & Nair, 2006). According to Kumar estimations, the systems with the highest carbon stocks are old (more than 100 years old), natural forests that can sequestrate up to 500 $MgCO_2ha^{-1}$. On the other hand, the land use systems with the lowest carbon stocks are young pasturelands (between 4 and 12 years old) that sequestrate between 27 and 31 $MgCO_2ha^{-1}$. It is also important to note that these pasturelands have a negative rate of carbon uptake, which reveals that they release more carbon than they sequestrate. Nine-year old woodlots and 23-year old

secondary forests sequestrate respectively between 26 and 178 $MgCO_2ha^{-1}$ and between 95 and 142 $MgCO_2ha^{-1}$ (Kumar, 2006).

The estimation of the carbon sequestrated by the forest gardens we surveyed ranged from 196.20 and 415.73 $MgCO_2ha^{-1}$. According to these results and the literature, the forest gardens surveyed have a carbon sequestration ability that approaches both tall secondary forests and old, natural forests. Even though our calculation method differs from the method used by Kumar, the results show that the Azuero forest gardens can be large carbon stocks than most other human land use systems in the tropics. By using forest gardens as a reforestation approach, we expect to contribute to an increase in the global stock of carbon.

Table 6: CO_2 sequestration in each forest garden

Forest garden number	Size (m^2)	Size (ha)	CO_2 sequestration ($MgCO_2$ per forest garden)	CO_2 sequestration ($MgCO_2$ per ha)
1	4734	0.47	178	378.72
2	3538	0.35	68.67	196.20
3	3029	0.30	124.72	415.73

VII – Limitations and recommendations for the future

VIIA) Limitations

As it is often the case in many research projects, our most significant constraint was the lack of time. Indeed, during the semester, we dedicated 39 full days of work to our internship but we wish we had more time to dedicate to it for the following reasons.

First of all, the time constraint forced us to reduce our sample size. For instance, in order to study the composition and structure of the forest gardens of Azuero, we only surveyed three

fincas in depth. We also realized that, even though several species were common to all the forest gardens studied, each forest garden had species that were not found in others; hence, surveying more *fincas* would have been particularly useful to identify a greater plant diversity present in forest gardens of Azuero. Although we recognize this as an important caveat, we did have the opportunity to visit more than three *fincas* with remarkable forest gardens in the region. This allowed us to roughly assess their plant diversity, and by comparison to the forest gardens we surveyed intensively, be fairly confident regarding the array of plant species we listed as present in forest gardens of Azuero. Similarly, the time constraint limited our ability to interview more individuals. Indeed, although we identified a common trend in the answers given by each interviewee, every interview also revealed new ideas. More specifically, conducting more interviews would have allowed us to identify more disadvantages of forest gardens and would have helped us finding solutions to tackle them.

The second issue brought about by the lack of time in our research is that it constrained our ability to divulge the information gathered. Indeed, sticking with the idea that our project aims at offering an alternative approach to reforestation within the Rio Oria biological corridor, it would have been relevant to meet individually with more *finqueros* that own land within the corridor to inform them and encourage them to start forest gardens. We believe that this very direct method would have had slightly more impact than the methods chosen to reach the community; however, we decided to choose these methods particularly because they were the more appropriate given the lack of time. The AEP team is now in charge of broadening the scope of the community outreach and meeting individually with *finqueros*.

If the lack of time was the largest constraint of our project, we also faced difficulties when it came to calculating and analyzing the carbon sequestration potential of forest gardens of Azuero. First of all, we had to cope with the lack of data about the specific wood density of each tree species surveyed in the forest gardens under investigation. Under the

recommendation of our supervisor, we decided to address this issue by calculating an average wood density using the specific wood densities of tree species that we were able to find, and to further apply this average wood density to all the tree species. This probably hindered the accuracy of our results. The second issue we faced in the analysis of these results was the comparison with other studies. Indeed, there is no set method to calculate carbon sequestration and the one we chose to use might differ to a relatively large extent from other methods. This turned out to be a limitation when we were to compare the carbon sequestration of the Azuero forest gardens to other land use systems in the tropics.

VIIB) Recommendations for the future

Through this project, we gave a fairly extensive description of the forest gardens of Azuero. There is however a lot of potential for this research project to be continued in the future. We have identified two main areas where the study could be taken further.

First and foremost, more research could be done on the already identified benefits of forest gardens. For instance, forest gardens provide a wide array of ecosystem services such as improving the soil and water quality or improving the microclimate. The scope of our study was restricted to quantifying only one ecosystem service, namely carbon sequestration; hence, it would be interesting to study more environmental aspects of forest gardens of Azuero in the future. Studying the nutrient turnover occurring in forest gardens to have a better understanding of its functioning with possible suggestions for improving their management would be interesting. Another benefit that could be studied more in depth is the economic benefits of forest gardens. Indeed, if we were able to identify that there is indeed a profit generated from the sales of wood for timber or fruits, our research did not quantify these benefits in terms of monetary value, through investigating market prices for example. Such

calculation could create a more tangible incentive to revitalize forest gardens in Azuero and we therefore believe that it should be envisaged as a next step in this research project.

The second main area of recommendation for boosting the purpose of this project is broadening the scope of the community outreach. Indeed, the knowledge collected should be divulged more widely if we want it to have an impact. The list of media supports that we would suggest includes the making of a short video and/or a podcast on forest gardens of Azuero, the broad distribution of the eco-guides to the public and especially to the landowners within the Rio Oria biological corridor, the construction of a model forest garden plot that could be created with the help of the community and/or opened to the public to visit, etc. As education is key in conservation projects, we believe that the more communication modes, the more successfully the message will be conveyed.

VIII – Acknowledgements

We would first like to thank McGill University, the Smithsonian Tropical Research Institute (STRI), Dr. Catherine Potvin and the Azuero Earth Project for making this research opportunity possible.

Our greatest gratitude to our supervisor Carlos Navarro for his continued support and guidance throughout the course of this internship. To all the Azuero Earth Project team for their dedication and enthusiasm in this research project but also for doing such inspirational work.

To all the individuals that accepted to participate in our research, namely the interviewees and most particularly the three *finqueros*, Antonio Vergara, Luciano Madriz and Miguel Gonzalez, that let us spent a large amount of time surveying their forest gardens and who were always willing to offer their help and share their knowledge.

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X – Appendices

Appendix 1: Internship timeline

	Date	Hours of Work in Panama city	Hours of Fieldwork in Pedasi	Description of work
January	9	3		Literature review
	10	3		Literature review
	16		6	Travel to Pedasi Meet with AEP team
	17		8	Forest garden 1 data Collection Exploration of plant database
	18		8	Introduction to fieldwork methods Forest garden 1 data collection and processing
	19		1 6	Project design and carbon sequestration lecture by Manuel Navarro Travel to Panama
	30		6	Travel to Pedasi Work plan Literature review
	31		8	Draft progress report
February	1-11		70 6	Data Collection and data processing of forest gardens 1, 2 and 3 Coordinates calculation of vegetation Travel to Panama
	17	6		Literature review
	18	6		Preparation for informal presentation
	27	1		Informal presentation
	28	4		Writing questionnaire for interviews
March	19	4		Office hours and work on recommendations
	20	5		Build final report structure Final report: introduction
	21	6		Final report: introduction and objectives Posters for community presentation
	27		6	Travel to Pedasi
	28		6	Interviews in Pedasi
	29		6	Interviews in los Higos
	31		8	Final report: methods
April	1		8	Final report and ArcGIS maps
	2		8	Ecoguide and vertical profiles
	4		8	ArcGIS maps and carbon sequestration calculation
	5		8	ArcGIS maps and carbon sequestration calculation
	6		8	Interview in Valleriquito
	7		8	Final report results
	8		6	Final report results
	9		6	Travel to Panama
	20		7	Final report
	21		8	Final report edits Ecoguides Executive summary
	22		9	Community presentation prep
	23		8	Community presentation and Final presentation prep
	24		6	Travel to Panama
	25	1		Final presentation
	Sub-totals	39	243	
	Total hours		282	

Appendix 2.a: TCPS 2: CORE Certificate of Completion – Anna Zisa

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Anna Zisa

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **11 January, 2014**

Appendix 2.b: TCPS 2: CORE Certificate of Completion – Pauline Sillinger

Groupe en éthique de la recherche
Piloter l'éthique de la recherché humaine

EPTC 2: FER

Certificat d'accomplissement

Ce document certifie que

Pauline Sillinger

a complété le cours : l'Énoncé de politique des trois Conseils :
Éthique de la recherche avec des êtres humains :
Formation en éthique de la recherche (EPTC 2 : FER)

22 mars, 2014

Appendix 3.a: Sketch of forest garden n°1 by Don Antonio Vergara

Appendix 3.b: Sketch of forest garden n°3 by Don Catalino Gonzalez

Appendix 4: Questionnaire for semi-structured interviews

1. ¿Porque usted tiene un huerto forestal?
2. ¿Cual fue su motivación original para tener un huerto, o para tener los diferentes árboles que tiene?
3. ¿Es algo muy típico de la península tener un huerto?
4. ¿Desde hace cuanto lo tiene?
5. ¿Usted lo plantó? ¿Pensó en el diseño del huerto meticulosamente? ¿Hay una estructura en su huerto? ¿Puede dar ejemplos de porque plantó algunos árboles en lugares específicos?
6. ¿Que recursos alimenticios le da su huerto forestal?
7. ¿Es para consumo propio o vende algo?
8. ¿Que proporción de su alimento diario viene de su huerto forestal?
9. ¿Que productos alimentarios básicos necesita comprar? Seria posible de producir esos alimentos usted mismo? Porqué?
10. Además de recursos alimenticios, ¿qué otros recursos de su huerto usa?
11. ¿Piensa usted que su huerto brinda cohesión social con su comunidad?
12. ¿Piensa que los huertos forestales están perdiéndose en la región? Porqué?
13. ¿Quién le enseñó a mantener su huerto?
14. ¿Usted le ha ensenado a sus hijos sobre los usos de su huerto?
15. ¿Piensa usted que tener un huerto aumenta su bienestar y salud personal?
16. ¿Por qué valora su huerto?
    a. provee alimentos básicos
    b. fuente de ingreso (por la madera, los frutos)
    c. provee material para construcción
    d. crea un microclima agradable
    e. provee servicios al ecosistema (filtración de agua, captura de dióxido de carbono, fijación de nitrógeno etc.)
    f. porque atrae a vida silvestre
    g. por su valor estético
    h. por su importancia cultural
    i. por su valor sentimental
    j. otro
17. ¿Qué animales silvestres ha visto en su huerta?
18. ¿Cuales son las desventajas de tener un huerto? Es costoso mantenerlo? Le toma mucho tiempo mantenerlo? Los beneficios no se ven a corto plazo?
19. ¿Qué piensa usted que desmotiva a otros finqueros a tener un huerto?
20. ¿Cómo animaría usted a otros finqueros a tener huertos forestales?
21. ¿Como ha sido su experiencia con el agua en los últimos tiempos, ha tenido retos con la sequía?

Appendix 5.a: Poster for the presentation in Los Higos

Appendix 5.b: Poster for the presentation in Los Higos

Valorando los Huertos Forestales de Azuero

Miércoles 23 de Abril 2014- hora: 6:00 pm (Gratis)
Escuela de Los Higos

Para más información contacte a
carmela@azueroearthproject.org
(507) 995-299

Appendix 6.a: Eco-guide pamphlet in English

What are forest gardens?

Forest gardens, also known as home gardens in Central America, are multiuse associations of trees and shrubs with annual and/or perennial crops and animals, typically located in home lots. Having forest gardens is a tradition all over the world, mostly in rural areas of the tropics. They are agroforestry systems that integrate, in a very biointensive way, fruit trees, trees for firewood and timber, root crops and other vegetable crops, as well as ornamental and medicinal plants. Forest gardens provide a basic source of food for sustaining the food security of the family. In addition, they generate a source of income through the sale of high value products. Across generations, family members supply the labor required to maintain the forest gardens.

Azuero Earth Project

About Us

The mission of the Azuero Earth Project is the preserve the earth s ecosystems, protect biodiversity, and promote healthy communities by helping people to make informed decisions, take sustainable actions, and share knowledge.

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Structural design of a forest garden

The forest garden is a multilayered system and the plants are arranged in a distance relative to the house according to their frequency of use so that plants used more frequently are closer to the house compared to plants whose use or maintenance is less frequent. The edges of the property can be forested with trees used for living fences and trees for timber. Access for future extraction of trees valued for wood is important to consider in the design of the space. Such trees along edges of the property provide the function of being a wind and noise barrier. If a stream is present in the property keeping trees along its banks is also very important for controlling soil erosion, filtering water and maintaining water in the stream during times of drought. At a distance closer to the house, an area of edible plants such as fruit trees and root crops along with trees for firewood and medicinal plants can be found. These plants should be planted in a way that maximizes the use of light and space. Plantains, for example, are often intercropped with yucca for this purpose. Taking into account shade tolerance and nutrient requirements of each species helps planning a more optimal structure of one s forest garden. An example of this is planting *guandu* for food or *macano* for firewood, two nitrogen fixers, in between other fruit trees, making the nutrient available for the plants around it. For edible plants, it is important to consider the specific harvest seasons. Having different edible plants in a forest garden allows the provision of food regularly throughout most of the year. That way, a time dimension is also integrated into the spatial dimension when designing the structure of a forest garden. Ornamental plants are often located closer to the house or along the road, visible from the house or the entrance of the property thereby showing the aesthetic importance of forest gardens. Another important element in forest gardens is a social space with hammocks or chairs and a table typically found under the shade of trees where people can gather and enjoy the fresh outdoor temperature created by the trees.

FOREST GARDENS OF AZUERO

AZUERO EARTH PROJECT
Apartado 0749-00015
Pedasí, Los Santos, Panamá

10 reasons to have a forest garden

To save money

With an increased dependency on the cash economy, producing one s own food is a way to secure the access to basic food products, thereby avoiding any unnecessary intermediary transaction.

To improve food security

The physical and economic access to nutritious, safe and preferred foods is better accomplished in one s own backyard than in a supermarket, often furthest way, expensive and with less fresh and more processed products.

To maintain a long-term guarantee

Forest gardens add value to a property. The occasional and selective logging of trees for timber represents an advantageous investment that can help the family in the long term, across generations.

To add beauty to the landscape

Who does not enjoy a landscape rich in biodiversity, with different colors, scents and sounds, with flowers and fruits that catch one s eyes and the occasional hummingbirds and interesting insects flying around?

To improve environmental quality

Vegetation creates shade and, with its evapo-transpiration, it also refreshes the air, creating a more pleasant microclimate.

To prevent soil erosion

Vegetation slows down agents of soil erosion such as water and wind. Acting like a buffer, diverse vegetation prevents the loss of soil, which is a non-renewable resource that is incredibly valuable for being the fountainhead of all terrestrial life.

To improve water abundance and quality

By slowing down runoff in times of rain, vegetation allows water to percolate into the soil and replenish groundwater, rivers and streams. Plus, if vegetation is in riparian areas, roots facilitate the movement of the water into the soil allowing the water to be filtered and thereby increasing its quality once it reaches the river.

To nourish and regenerate soils

Due to their diversity, forest gardens bring different nutrients and beneficial microorganisms to the soil. Some trees for example can associate with microbes that fix nitrogen in the soil, making it available for other plants. This avoids the need to add artificial fertilizers.

To preserve nature

Forest gardens are ecosystems of great diversity. If they are composed of native trees, they also provide habitat for wildlife such as birds, iguanas or monkeys that are threatened with extinction.

To conserve a tradition of Azuero

Forest gardens are part of the rural tradition of the Peninsula. From them emerges a culture of family homesteading and gastronomy. With the option of buying food in stores, new generations are losing the knowledge of planting, maintaining and using such valuable local resource that forest gardens provide.

Composition of forest gardens of Azuero

The list bellow shows some of the various plants commonly present in forest gardens of Azuero.

Status indicates whether the plant is native (N) or introduced (I), i.e. after the arrival of European in the Americas. Uses and values are attributed according to the following categories FR= fruit/for human food, M=medicinal, T= traditional use, PA= physical attribute, FL= food for livestock, LF= living fence, FW= firewood and W=wood.

Scientific name	Common name	Status	Uses/Values
Bixa orellana	Achiote	I	FR
Persea americana	Aguacate	N	FR, M
Bambusoideae	Bambu	I	PA
Musa sp.	Banano	I	FR
Coffea sp.	Café criollo	I	FR
Chrysophyllum cainito	Caimito	N	W PA FW E FR
Crescentia cujete	Calabazo	N	T
Saccharum sp.	Cana dulce	N	FR
Swietenia macrophylla	Caoba	N	W FW LF T
Plumeria rubra	Carocucha	N	PA
Averrhoa carambola	Carambola	I	FR
Cedrela odorata	Cedro amargo	N	W LF FW FL
Pachira quinata	Cedro espino	N	W FW LF T
Prunus sp.	Ciruelo	I	FR
Capsicum sp.	Chile	N	FR
Citrus sp.	Cítrico	I	FR
Cocos nucifera	Coco	I	FR
Cordia sp.	Ciruelo	I	FR
Passiflora edulis	Fruta de Mono	N	FR LF
Capsicum annuum	Gandu frijol de palo	I	FR
Inga punctata	Guabito caraboco	N	FR
Zygia longifolia	Guabito de río	N	PA E
Guazuma ulmifolia	Guacimo	N	PA FW LF FR FL T
Annona muricata	Guanábana	N	M FR
Inga spectabilis	Guava machete	N	FR
Psidium guajaba	Guayaba criolla	N	FW E FR
Ficus carica	Higo	N	PA
Bursera simaruba	Indio desnudo	N	W LF FL
Genipa americana	Jagua	N	PA LF E FR FL
Hibiscus sabdariffa	Jamaica	I	FR
Sciadodendron excelsum	Jobo espanto	N	LF
Cordia alliodora	Laurel	N	W PA LF FW T
Citrus x. limon	Limon	I	W FR M
Citrus limetta	Limon dulce	I	W FR M
Citrus Aurantifolia	Limon mandarina	I	W FR M
Dipteryx panamensis	Macano	N	W PA LF
Calycophyllum candidissimum	Madrono barroso	N	W PA FW FL
Xylopia aromatica	Malagueto macho	N	PA FR M
Pouteria sapota	Mamey sapote	N	FR
Melicoccus bijugatus	Mamon	I	FR
Citrus reticulata	Mandarina	I	FR
Mangifera indica	Mango	I	FR
Syzygium jambos	Manzana rosa/Pomarrosa	I	FR
Syzygium malaccense	Manzano curazao	I	FR
Anacardium occidentale	Marañon nacional	I	PA E FR LF M
Murraya paniculata	Mirto	N	M
Byrsonima crassifolia	Nance	N	W PA FW LF FR E
Citrus sinensis	Naranja	I	FR
Manilkara zapota	Nispero	N	W PA FW LF FR
Morinda citrifolia	Noni	I	M
Origanum vulgare	Oregano	I	FR
Roystonea sp.	Palma ornamental	I	PA
Acrocomia aculeata	Palma pacora	I	PA
Attalea butyracea	Palma real	N	T
Macrocnemum roseum	Palo cuadrado	N	T
Byrsonima lucida	Palo santo	N	T
Sterculia apetala	Panarma	N	T
Carica papaya	Papaya	N	FR
Bactris gasipaes	Pixvae	I	FR
Musa paradisiaca	Platano	I	FR
Tabebuia rosea	Roble	N	W LF T
Licania platypus	Sonsapote	N	FR
Terminalia catappa	Tamarindo rojo	I	FR M
Tectona grandis	Teca	I	W FW LF
Bactris major	Uvita	N	FR
Chrysopogon zizanioides	Vetiver	I	E
Manihot esculenta	Yuca	I	FR
Spondias dulcis	Yupisa mangostín	I	FR

Appendix 6.b: Eco-guide in Spanish

¿Qué son los huertos forestales?

Los huertos forestales, conocidos también en América Central como huertos familiares, son asociaciones de árboles o arbustos de usos múltiples, con cultivos anuales y perennes y animales en parcelas de hogares individuales. Los huertos forestales son una tradición en todo el mundo y sobre todo en zonas rurales de los trópicos. Son sistemas agroforestales que integran de forma biointensiva árboles frutales, maderables, tubérculos y hortalizas. Mantenidos por mano de obra familiar a través de generaciones, los huertos forestales proveen alimento básico para el sustento de la seguridad alimentaria familiar además de generar ingresos con la venta de productos de alto valor.

Proyecto Ecológico Azuero

Sobre Nosotros

La misión del Proyecto Ecológico Azuero es conservar el ecosistema, proteger la biodiversidad y promover comunidades sanas ayudando a la gente a tomar decisiones informadas, a tomar acciones sostenibles y a compartir sus conocimientos.

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Diseño estructural de los huertos forestales

El huerto forestal esta compuesto verticalmente de múltiples capas y horizontalmente las plantas están acomodadas a distancias relativas desde la casa de acuerdo a su frecuencia de uso. De esta manera, las plantas que se usan más seguido se encuentran más cercanas a la casa que las plantas que se usan o mantienen con menos frecuencia. Típicamente, los bordes de la propiedad están compuestos de árboles maderables y árboles que se usan en las cercas vivas. Dejar acceso para futura extracción es clave para árboles maderables. Los árboles que bordean la propiedad proveen la función de ser barreras de viento o ruido. Dejar árboles a lo largo de las quebradas también es una benéfica practica para controlar la erosión del suelo, permitir la filtración de agua, y mantener la disposición de agua en tiempos de sequía. A una distancia más cercana a la casa, se encuentra un área de plantas comestibles como árboles frutales, plantas de hortalizas o tubérculos además de plantas medicinales y árboles que se valoran por su leña. Todas estas plantas deben estar plantadas de manera en que se asegure un uso eficiente del espacio y la luz. Los plátanos por ejemplo suelen estar intercalados por yucas para un uso eficiente de la luz y el espacio. Tomar en cuenta la tolerancia a la sombra y los requerimientos nutritivos de las plantas ayuda a planear óptimamente la estructura del huerto forestal. Un ejemplo de esto es plantar intencionalmente guandu para alimento humano y macano para leña entre árboles frutales por su servicio al ecosistema de fijar nitrógeno en el suelo haciéndolo disponible para las plantas que los rodean. Para las plantas comestibles, es importante considerar las temporadas de producción de cada planta. Tener diferentes plantas comestibles con diferentes temporadas de producción permite proveer alimento regularmente a lo largo del año. De esa manera, la dimensión del tiempo también se integra en la dimensión espacial que se debe considerar al diseñar la estructura y composición de un huerto forestal. Las plantas ornamentales se encuentran comúnmente rodeando las casas o cerca de las entradas de la propiedad, visibles desde la casa o la calle demostrando así su importancia estética. Otro elemento importante de los huertos forestales de Azuero es un espacio social con hamacas, sillas o mesa típicamente localizado debajo de la sombra de árboles, donde las personas pueden reunirse y disfrutar de una temperatura exterior fresca creada por los árboles mismos.

10 razones para tener un huerto forestal

Para ahorrar dinero

Con cada vez más dependencia a la economía monetaria, generar su propio alimento resulta una forma de asegurar el acceso a consumos básicos evitando así transacciones intermediarias que desperdician ahorros.

Para mejorar la seguridad alimentaria

El acceso físico y económico a alimentos sanos y preferentes se cumple mejor en nuestro propio patio que en supermercados a veces lejanos, caros y con productos no tan frescos y más procesados.

Para mantener una garantía a largo plazo

Los huertos forestales agregan valor a las propiedades. La venta ocasional y selectiva de maderables a lo largo de los años resulta en una ventajosa inversión que puede ayudar a la familia a través de generaciones.

Para embellecer el paisaje

¿Quién no disfruta de un paisaje rico en diversidad, con variadas tonalidades de colores, olores y sonidos, con flores y frutas que resaltan en la visión además de ocasionales colibríes e insectos interesantes?

Para mejorar el ambiente

La vegetación crea sombra y con su evapotranspiración ayuda a refrescar el aire haciéndolo más agradable. A escala global, los huertos forestales capturan dióxido de carbono ayudando a mitigar el cambio climático.

Para prevenir la erosión de los suelos

La vegetación frena agentes que erosionan los suelos como el agua y el viento. Al actuar como amortiguadores, la vegetación previene la perdida de suelos que son un recurso no renovable y tan valioso por ser la fuente de sustento original.

Para mejorar la abundancia y calidad del agua

La vegetación, al frenar la escorrentía en tiempos de lluvia, permite al agua infiltrarse más lentamente en el suelo, rellenando así el agua del subsuelo, en las quebradas y ríos. Además, si las raíces de la vegetación se encuentran en zonas ribereñas, facilitan el movimiento del agua a través del suelo permitiendo que el agua se filtre y su calidad se mejore al llegar al río.

Para alimentar y regenerar los suelos

Por su diversidad, los huertos forestales aportaran diferentes nutrientes y microorganismos benéficos al suelo. Algunos árboles por ejemplo tienen la capacidad de asociarse con microbios que fijan nitrógeno en el suelo volviéndolo así disponible para otras plantas y evitando la necesidad de aplicar fertilizantes artificiales.

Para conservar la naturaleza

Los huertos forestales son sistemas de gran biodiversidad. Si están compuestos de plantas nativas, en especial ayudan a crear hábitat para especies de animales silvestres como pájaros, iguanas o monos que están en peligro de extinción.

Para conservar una tradición de Azuero

Los huertos forestales son parte de la tradición rural de la península de Azuero. De ellos deriva una cultura hogareña familiar y gastronómica. Con la opción de comprar en tiendas en vez de producir, las nuevas generaciones están perdiendo el saber sembrar, mantener y usar el recurso tan valioso que son los huertos forestales.

Composición de los huertos forestales de Azuero

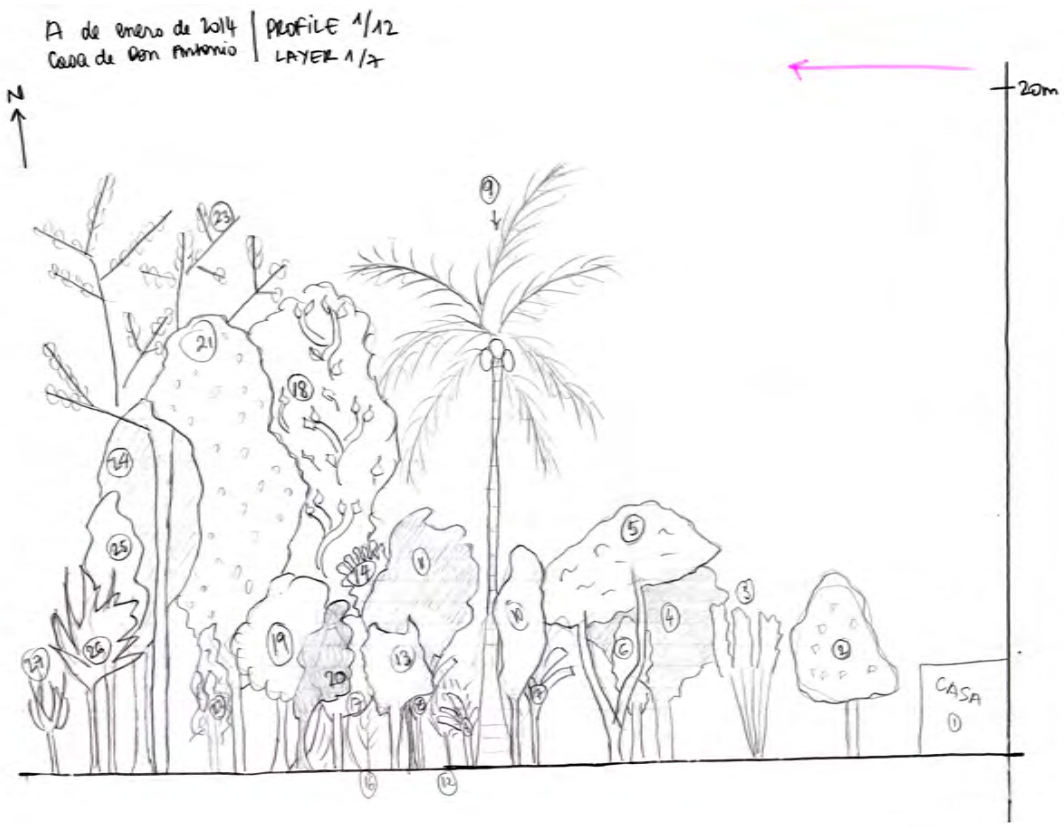
La lista aquí debajo muestra la variedad de plantas comúnmente presentes en huertos forestales en la región de Azuero. El estatus se refiere a si la planta es nativa (N) o si fue introducida (I) después de la llegada de los Europeos a las Américas. La columna de usos y valor cuenta con las categorias siguientes L=leña, AP= atributo físico, CV= cerca viva, C= madera, M=medicinal, T=uso tradicional, FA= función ambiental, AA= alimento para animales y FR=frutal o alimento para humanos.

Nombre científico	Nombre comun	Estatus	Usos/valor
Bixa orayana	Achiote	I	R
Persea americana	Aguacate	N	R, M
Bambusoideae	Bambu	I	A
Musa sp	Banano	I	R
Co fea sp	Cafe c ilito	I	R
Chrysophyllum cain to	Caimito	N	C, A , , A
Crescentia cujete	Calabazo	N	R
Saccharum sp	Cana dulce	N	R
Swietenia macrophylla	Caoba	N	C, , CV
Plumeria rubra	Ca acucha	N	A
Averrhoa carambola	Ca ambola	I	R
Cedrela odorata	Ced o amar go	N	C, , CV, AA
Pachira quinata	Ced o sap no	N	C, , AA
Prunus sp	Ce ezo	I	R
Capsicum sp	Chile	N	R
Citrus sp	Cit co	I	R
Cocos nucifera	Coco	I	R
Coffea sp	C ebo	I	R
Pouteria s lotifl a	uta de Mono	N	R, CV
Co anus cajan	Gandu, f jol de palo	I	R
Inga punctata	Guab la canadbosa	N	R
Zizyphus mauritiana	Guab to de lo	N	A , A
Guazuma ulmifolia	Guacima	N	A , , CV, R, AA
Annona muricata	Guanabana	N	C, R
Inga spectabil a	Guava machete	N	R
Psidium guajava	Guayaba c illa	N	, A, R
Ficus carica	Higo	N	A
Bursera simaruba	Indio desnudo	N	C, CV, AA
Genipa americana	Jagua	N	A , CV, A, R, AA
Hibiscus sabdariffa	Jamai ca	I	R
Sideroxylon mucitanum	Jobo la ga to	N	CV
Cordia a Bullata	au ul	N	C, A , CV, ,
Citrus x limon	limon	I	C, R, M
Citrus limetta	limon dulce	I	C, R, M
Citrus Aurant folia	limon mandi ina	I	C, R, M
Diphysa americana	Macano	N	C, A , AA
Calycophyllum candidissim	Mad ero, ha co	N	C, A , , AA
Xylopia frutescens	Malagueto macho	N	A , R, M
Poutteria sapota	Mamey, sapote	N	R
Hel coccus bi ugatus	Mamon	I	R
Citrus reticulata	Manda ina	I	R
Mangifera indica	Mango	I	R
Syzyg ium jambos	Manzana oca/ oma oas	I	R
Syzyg ium malaccense	Ma anzo cu azao	I	R
Anacardium occidentale	Ma anzo cu azao	I	A , A, R, CV, C
Murraya paniculata	Mi lo	N	M
Byrsonima crass folia	Nance	N	C, A , , CV, R, A
Citrus x nevadi	Na anjo	I	R
Manilkara zapota	Nispe o	N	C, A , , AA, R
Nectandra cibitifol a	Nurd	I	C
Origanum vulgare	O egano	I	R
Rosa rosae sp	alma o narmental	I	A
Acalea a acamon a	alma paco a	I	A
Albizia lebbyracea	alma sal	N	
Macroscenum asasum	alo cadd ado	N	
Erythrina fusca	alo sando	N	
Sterculia apetala	anama	N	
Carica papaya	papaya	N	R
Bactris gasipaes	pixae	I	R
Musa paradi e aca	platano	I	R
Tabebuia rosea	Roble	N	C, CV
Lonc a platyspar	Sencapoto	N	R
Tamarindus indica	ama ndo	I	R, M
Tectona grandis	eca	I	C, , CV
Bactris mayor	Uvita	N	R
Chrysopogon z zan oides	Vetiver	I	A
Manihot esculenta	uca	I	R
Spondias dulcis	ujalan, mangost n	I	R

Appendix 7: Tree database

Scientific name	Common name	Code	Garden Presence 1	2	3	Status	Uses/Values
Bixa oreyana	Achiote	ACH	11	0	1	I	FR
Persea americana	Aguacate	AGC	5	1	0	N	FR, M
Gossypium sp.	Algodon	ALG	0	1	0	I	
Bambusodae	Bambu	BMB	2	0	0	I	
Musa sp.	Banano	BAN	1	0	5	I	FR
Coffea sp.	Cafe criollo	CAF	0	2	0	I	FR
Chrysophyllum cainito	Caimito	CAI	0	2	0	N	W, PA, FW, E, FR
Crescentia cujete	Calabazo	CAL	2	1	0	N	T
Saccharum sp.	Cana dulce	CAN	1	0	0	N	FR
Swietenia macrophylla	Caoba	CAO	7	7	13	N	W, FW, LF, T
Plumeria rubra	Caracucha	CARC	0	3	0	N	
Averrhoa carambola	Carambola	CAR	2	0	8	I	FR
Cedrela odorata	Cedro amargo	CDRA	1	1	1	N	W, LF, FW, FL
Pachira quinata	Cedro espino	CDRE	0	1	0	N	W, FW, LF, T
Prunus sp.	Cerezo	CER	1	0	0	I	FR
Capsicum sp.	Chile	CHI	4	0	0	N	FR
Citrus sp.	Citrico	CIT	7	0	0	I	FR
Cocos nucifera	Coco	COC	6	10	4	I	FR
Croton sp.	Croto	CRO	0	4	0	I	FR
Cavanillesia platanifolia	Cuipo	CUI	0	1	0	N	
Miconia sp.	Doble Cara / Doble Hoja	DBL	0	1	0	N	
Posoqueria latifolia	Fruta de Mono	FDM	0	1	0	N	FR, LF
Cajanus cajan	Gandu, frijol de palo	GAN	4	0	8	I	FR
Inga punctata	Guabita cansaboca	GBT	1	1	0	N	FR
Zygia longifolia	Guabito de rio	RIO	1	1	0	N	
Guazuma ulmifolia	Guacimo	GUA	0	1	0	N	PA, FW, LF, FR, FL, T
Annona muricata	Guanabana	GNB	1	6	1	N	M, FR
Inga spectabilis	Guava machete	GVA	4	4	1	N	FR
Psidium guajaba	Guayaba criolla	GYB	0	2	0	N	FW, E, FR
Ficus carica	Higo	HIG	0	1	0	N	PA
Bursera simaruba	Indio desnudo	IND	4	0	3	N	W, LF, FL
Genipa americana	Jagua	JAG	3	1	0	N	PA, LF, E, FR, FL
Hibiscus sabdariffa	Jamaica	JAM	0	0	4	I	FR
Sciadodendron excelsum	Jobo largarto	JOB	1	0	2	N	LF
Spondias purpurea	Jocote	JOC	4	0	0	N	
Cordia alliodora	Laurel	LAU	0	2	0	N	W, PA, LF, FW, T
Matayba scrobiculata	Lazo	LAZ	1	0	0	N	
Sanseviera trifasciata	Lengua de Suegra	LDS	0	1	0	I	
Citrus x. limon	Limon	LIM	3	1	4	I	W, FR, M
Citrus limetta	Limon dulce	LDC	1	0	0	I	W, FR, M
Citrus Aurantifolia	Limon mandarina	LMA	1	0	0	I	W, FR, M
Diphysa americana	Macano	MAC	31	9	1	N	W, PA, LF
Calycophyllum candidissimum	Madrono, harino	MAD	12	0	0	N	W, PA, FW, FL
Xylopia frutescens	Malagueto macho	MLG	1	0	0	N	PA, FR, M
Pouteria sapota	Mamey, sapote	MEY	0	2	0	N	FR
Melicoccus bijugatus	Mamon	MAM	0	1	0	I	FR
Citrus reticulata	Mandarina	MDR	2	2	0	I	FR
Mangifera indica	Mango	MNG	5	10	5	I	FR
Syzygium jambos	Manzana rosa/Poma rosa	MAN	5	0	0	I	FR
Syzygium malaccense	Maranon curazao	MARC	1	2	0	I	FR
Anacardium occidentale	Maranon nacional	MAR	1	2	2	I	PA, E, FR, LF, M
Murraya paniculata	Mirto	MIR	0	0	12	N	M
Byrsonima crassifolia	Nance	NAN	1	2	0	N	W, PA, FW, LF, FR, E
Citrus sinensis	Naranjo	NRJ	6	4	7	I	FR
Manilkara zapota	Nispero	NIS	1	0	1	N	W, PA, FW, LF, FR
Morinda citrifolia	Noni	NON	0	1	0	I	M
Oreganum vulgare	Oregano	ORE	1	0	0	I	FR
Roystonea sp.	Palma ornamental	PLMO	0	3	14	I	
Aculeata acromonia	Palma pacora	PLMP	7	0	0	I	
Attalea butyracea	Palma real	PLMR	0	1	0	N	T
Macrocnemum roseum	Palo cuadrado	PCD	0	4	0	N	
Erythrina fusca	Palo santo	PSN	0	0	1	N	
Sterculia apetala	Panama	PAN	0	1	0	N	
Carica papaya	Papaya	PPY	7	5	0	N	FR
Bactris gasipaes	Pixvae	PIX	0	0	9	I	FR
Musa paradisiaca	Platano	PLA	51	4	97	I	FR
Tabebuia rosea	Roble	ROB	0	4	0	N	W, LF, T
Licania platypus	Sonzapote	SZAP	0	1	0	N	FR
Tamarindus indica	Tamarindo	TAM	0	3	0	I	FR, M
Tectona grandis	Teca	TEC	15	0	0	I	W, FW, LF
Albertia edulis	Trompito	TRO	0	1	0	N	
Bactris mayor	Uvita	UVI	0	2	0	N	FR
Chrysopogon zizanioides	Vetiver	VET	2	0	0	I	E
Manihot esculenta	Yuca	YUC	8	0	24	I	FR
Spondias dulcis	Yuplon, mangostin	YUP	2	1	0	I	FR
	Total number of trees:		238	122	228		
	Species Richeness:		46	48	24		

Appendix 8.a: Vertical profiles of forest garden n°1



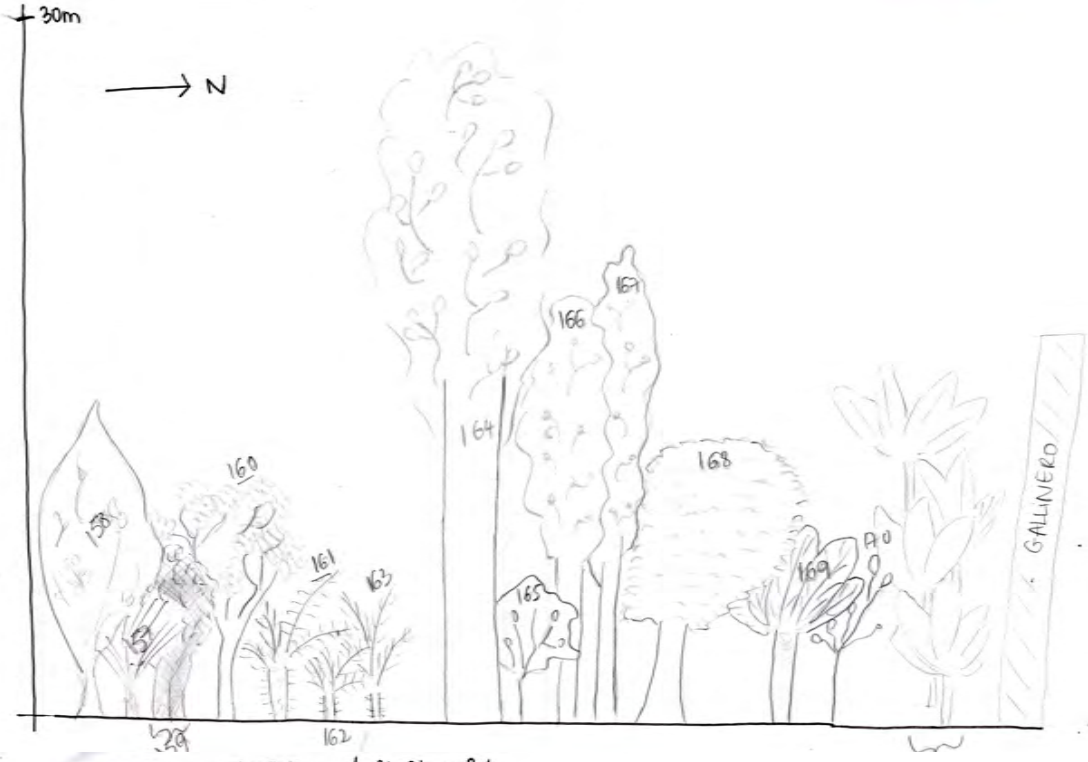
18 de enero de 2014 | PROFILE 3/12
Casa de Don Antonio | LAYER 2/7

18 de enero de 2014 | PROFILE 4/12
Casa de Don Antonio | LAYER 2/7

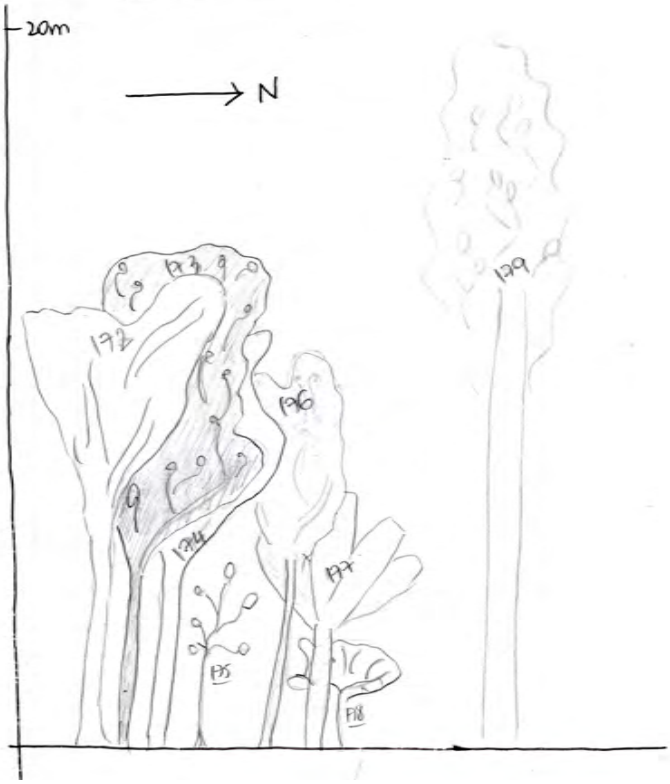
18 de enero de 2014 | PROFILE 5/12
Casa de Don Antonio | LAYER 3/7

18 de enero de 2014 | PROFILE 6/12
Casa de Don Antonio | LAYER 4/7

18 de enero de 2014 | PROFILE 7/12
Casa de Don Antonio | LAYER 4/7



18 de enero de 2014 | PROFILE 8/12
Casa de Don Antonio | LAYER 4/7

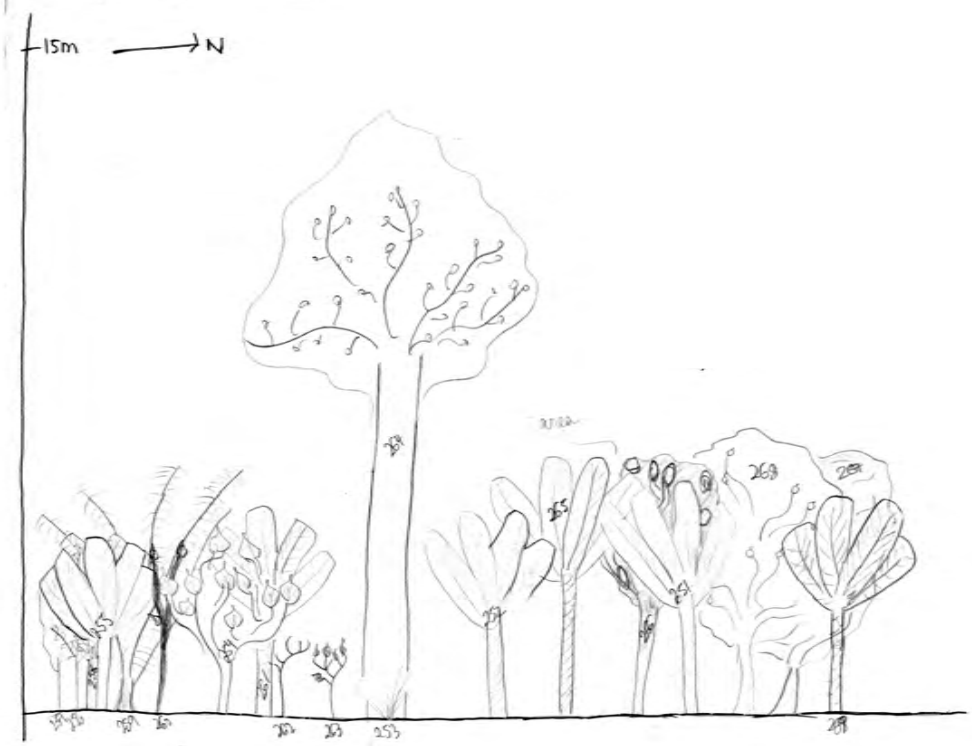



3 de febrero de 2014
Casa de Don Antonio
PROFILE 9/12
LAYER 5/7
20m
N


3 de febrero de 2014
Casa de Don Antonio
PROFILE 10/12
LAYER 5/7
20m
N

3 de febrero de 2014 | PROFILE 11/12
Casa de Don Antonio | LAYER 6/7

3 de febrero de 2014 | PROFILE 12/12
Casa de Don Antonio | LAYER 7/7
(Gallinero)

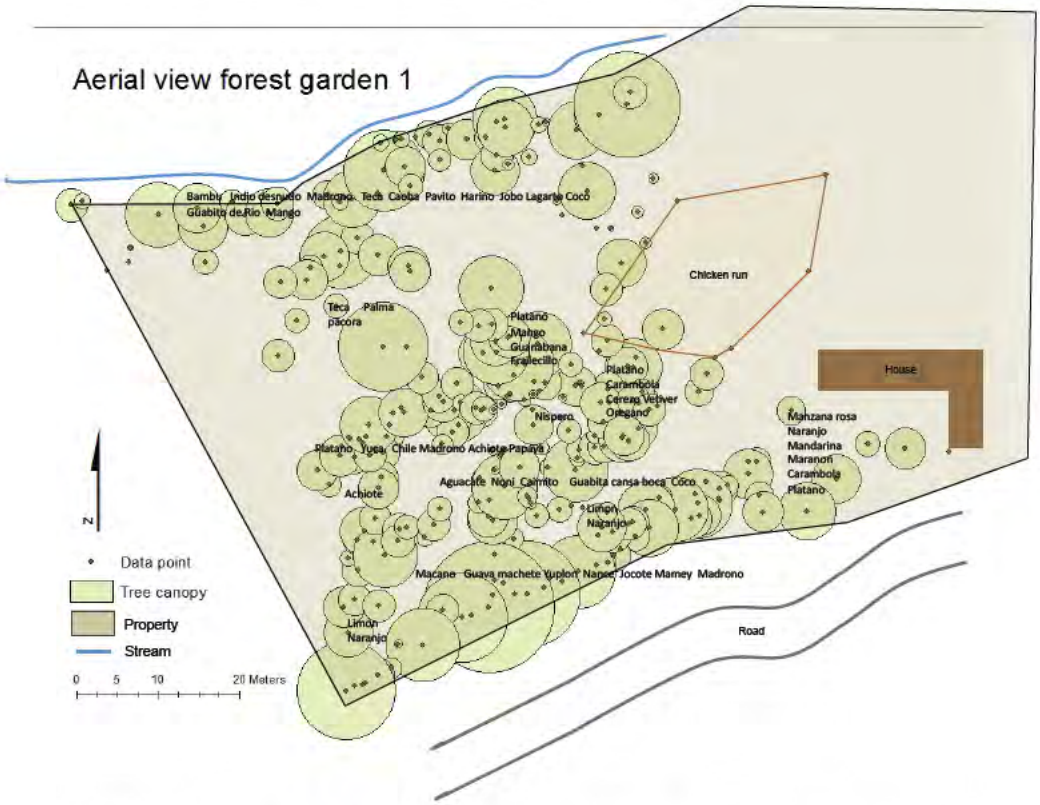


Appendix 8.b: Vertical profiles of forest garden n°2

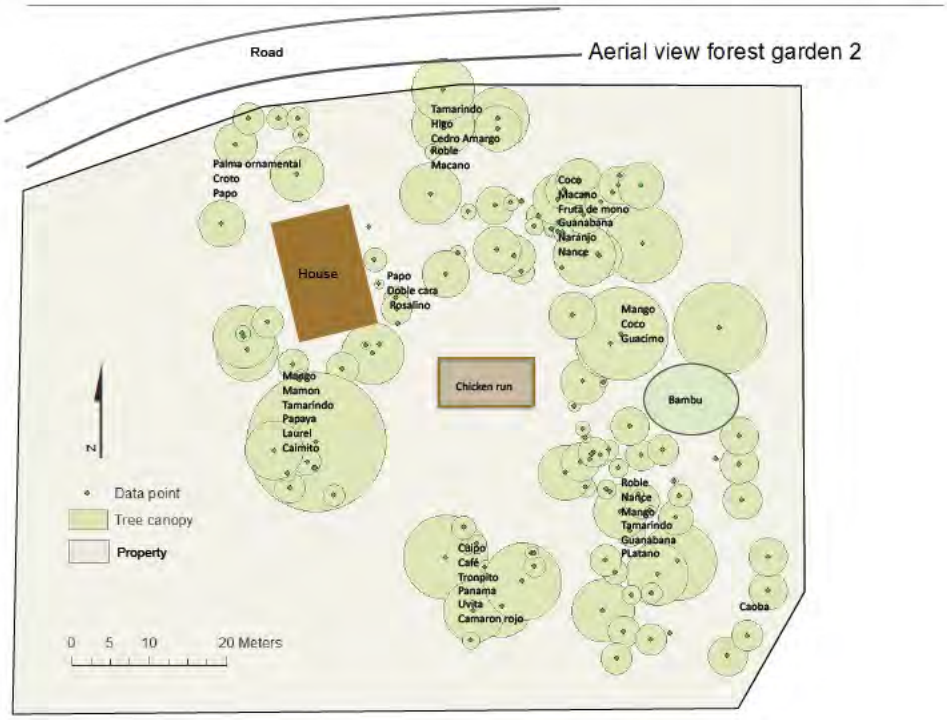
4 de febrero de 2014 | LAYER 3/4
Casa de Don Luciano

4 de febrero de 2014 | LAYER 4/4
Casa de Don Luciano

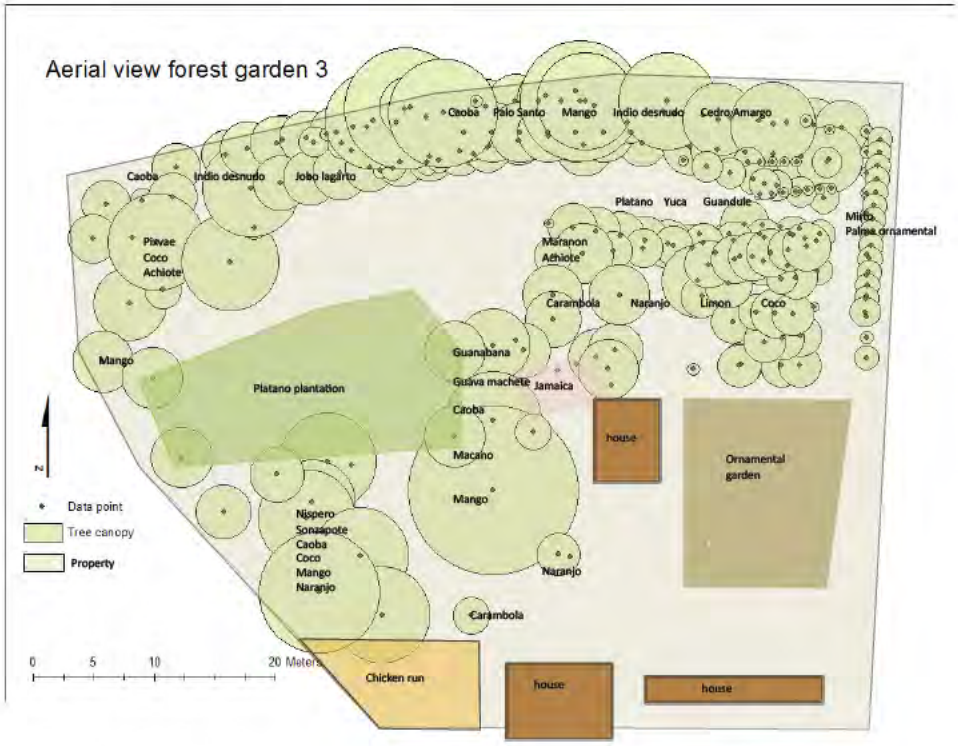
Appendix 9.a: Aerial map with canopy cover of forest garden n°1



Appendix 9.b: Aerial map with canopy cover of forest garden n°2

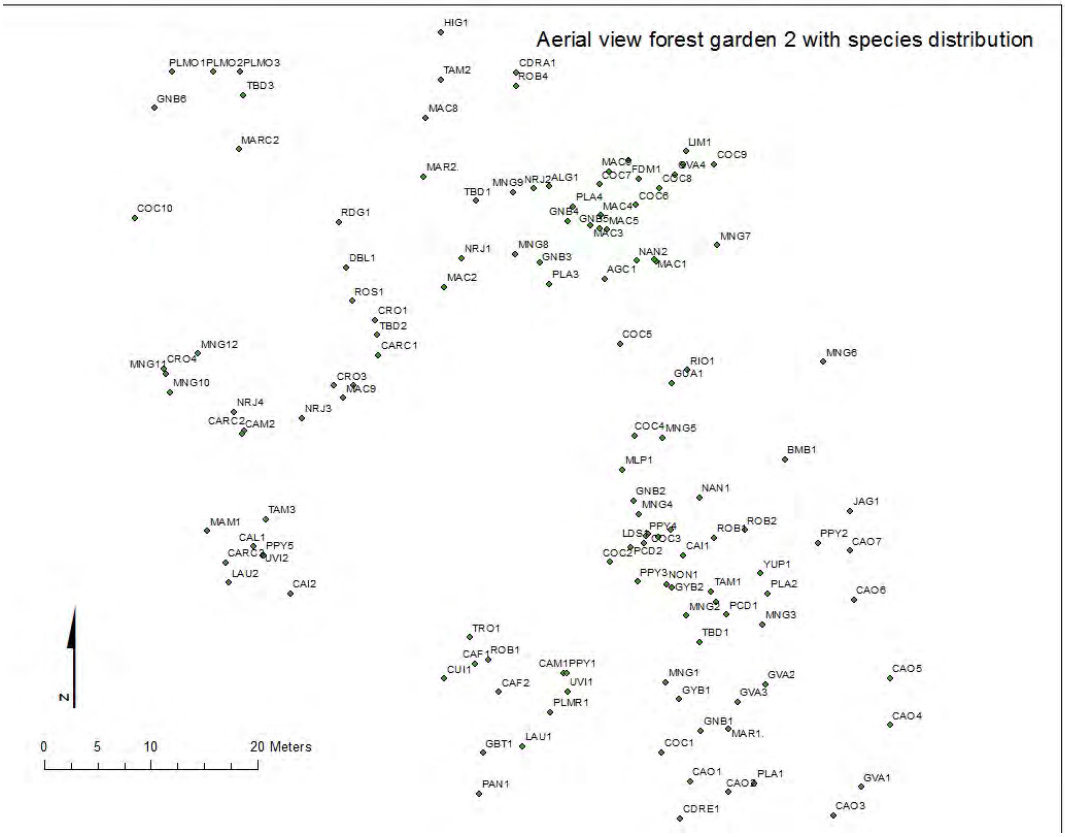


Appendix 9.c: Aerial map with canopy cover of forest garden n°3

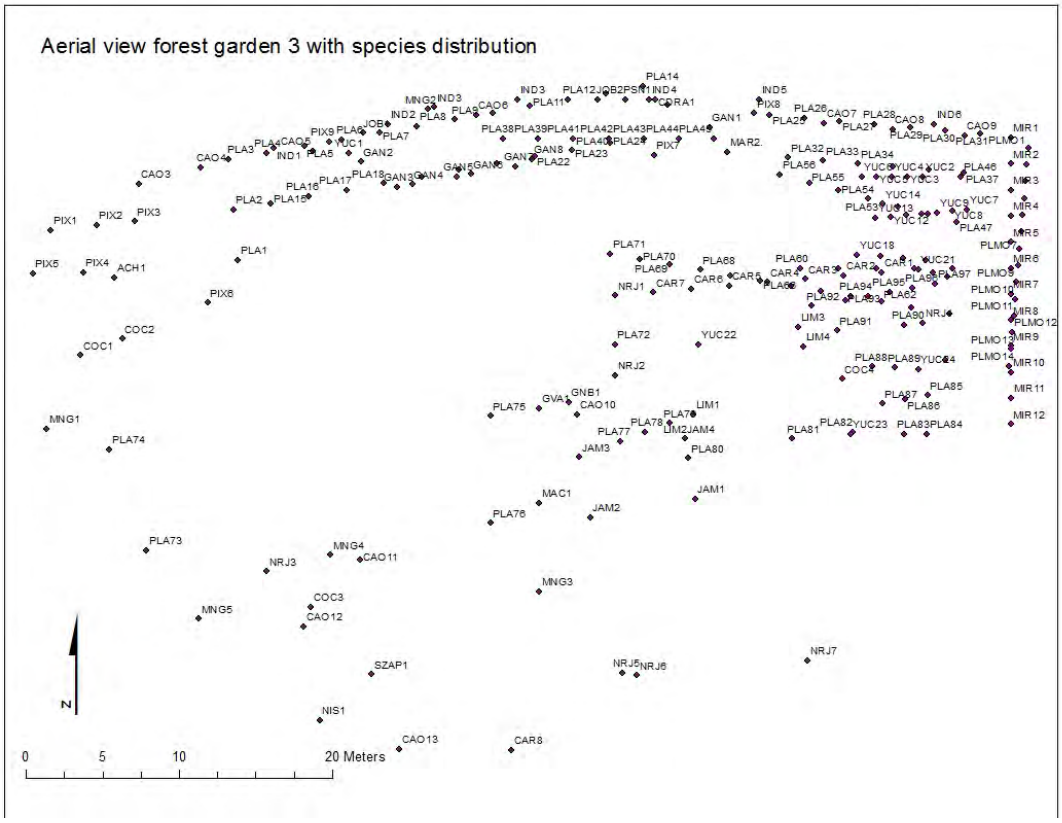


Appendix 10.a: Aerial map with codes of forest garden n°1

Appendix 10.b: Aerial map with codes of forest garden n°2



Appendix 10.c: Aerial map with codes of forest garden n°3



Appendix 11: Short-story "*Mi Huerto Forestal en Azuero*"