



**HAL**  
open science

# Optimizing shade tree species recommendation through the mobilization of local ecological knowledge

Anaïs Carpente

► **To cite this version:**

Anaïs Carpente. Optimizing shade tree species recommendation through the mobilization of local ecological knowledge: Experience from the small-scale coffee agroforestry systems in Matagalpa Department, Nicaragua. Biodiversity and Ecology. University of Copenhagen, 2020. English. NNT: . tel-02613885

**HAL Id: tel-02613885**

**<https://hal.science/tel-02613885>**

Submitted on 25 May 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

UNIVERSITY OF COPENHAGEN

DEPARTMENT OF FOOD AND RESOURCE ECONOMICS (IFRO)



MSC. IN AGRICULTURAL DEVELOPMENT



# **Optimizing shade tree species recommendation through the mobilization of local ecological knowledge.**

Experience from the small-scale coffee agroforestry systems in  
Matagalpa Department, Nicaragua.

**Author:** Anaïs Carpente

**Supervisors:** Aske Skovmand Bosselmann and Lars Holger Schmidt

**Submitted on:** 11 March 2020

**Jury:** Jakob Kronik, Aske Skovmand Bosselmann and Lars Holger Schmidt



---

## ABSTRACT

---

In agroforestry systems, shade trees can provide coffee farmers with a range of ecosystem services which can enhance agricultural production and increase households' food security and economic resilience against price volatility and extreme climatic events. In order to optimize the composition of shade tree species in the coffee agroforestry systems, the heterogeneity of small-scale coffee production systems and the diversity of their needs and constraints need to be acknowledged. This study mobilizes farmers' local ecological knowledge of shade tree species and the ecosystem services they provide to improve recommendations of shade trees in small-scale coffee agroforestry systems in Matagalpa, Nicaragua. Taking a mixed-method approach, household surveys, tree inventories and 65 tree ranking exercises were conducted across three villages in order to grasp the local context and farmers' local knowledge. The results confirm that coffee smallholders have adopted and retained a high diversity of shade trees in their systems, with 106 species listed, and display a wide knowledge of individual species. Respondents identified 13 ecosystem services and 7 disservices from shade trees. Gendered differences appear in both individual species knowledge and ecosystem services preferences, indicating that local initiatives should focus on including both genders. Farmers were willing to further increase the diversity of their systems to obtain specific ecosystem services, e.g., provision of food, soil fertility enhancement. However, one quarter of the surveyed farmers wish to reduce or abandon coffee production due to high maintenance costs and low profitability, representing a threat against tree diversity in the landscape. Local initiatives should facilitate access to seedlings and market opportunities in order to help farmers to improve and diversify their agroforestry income sources.

---

# PREFACE

---

First, I would like to state that the basis for this research stems from my passion for bottom-up approaches to local development. My interdisciplinary background in agriculture and social sciences led me to think that farmer's local knowledge of their farm and its environment is too often disregarded at present. In my opinion, local development projects should acknowledge the importance of local knowledge and put project beneficiaries at the heart of project's objectives definition. I believe that such participatory projects, which also benefit from the mobilization of scientific knowledge, represent the best way to ensure positive results in the long run.

Overall, the aim of this study is to contribute to an improved understanding of the possible barriers, challenges and incentives for smallholder adoption or use of different shade tree species. On a more practical note, it is expected to support the activity of my host organization, the NicaFrance Foundation, which conducts socially oriented projects related to the development of agroforestry practices and community development. In effect, this report aims to help the NicaFrance Foundation to fulfill its objective of involving farmers in the decision-making process for shade tree selection and management by providing them with an in-depth analysis which seeks to understand the underlying causes behind farmer's preferences and disliking. When completed with the scientific knowledge that years of experience and research have given to the Foundation, these results will allow for an informed selection of the most appropriate shade tree species in the different climatic zones studied.

In addition, this study falls under the frame of the BREEDCAFS project whose objectives are to devise new ways of tree breeding in order to improve the sustainability of perennial tree crop agroforestry systems in terms of production and profitability at farmer and industry level. More specifically, the results of this study will contribute to the construction of a data base created under the BREEDCAFS project for the realization of an online decision tool for shade tree selection in coffee (and cacao) agroforestry systems, the Shade Tree Advice Tool ([www.shadetreeadvice.org](http://www.shadetreeadvice.org)). This data base compiles local knowledge on shade trees adapted to local biophysical conditions and end-user's preferences from different regions of the world. Ultimately, this project aims to promote coffee AFS as a more sustainable and resilient alternative to full-sun cultivation.

I would like to express my sincere gratitude to my two supervisors, Aske Skovmand Bosselmann and Lars Holger Schmidt, for their patience and continuous support throughout the past 12 months. Thank you for always being there when I needed you the most, for giving me great advice and reassuring me regardless of the kilometers between us, and for believing in my capacity to lead this project to a term.

Moreover, I would like to thank Philippe Vaast and Clément Rigal who are part of CIRAD and the BREDDCAFS project. Thank you for your indispensable support and feedback throughout this project and for helping me when I was struggling with R.

I would also like to thank the NicaFrance Foundation for making my fieldwork possible and in particular to Mélanie Bordeaux for her precious help and support before and during my fieldwork. I would like to thank the staff from the NicaFrance Foundation for being so kind to me and answering all my questions. A special thank you to Jonny, Abner and Yader for your invaluable friendship, for your help and for making my Nicaraguan stay so much more enjoyable. I also would like to express my sincere gratitude to my host families, without who this all project could not have been carried out. Thank you for letting me be part of your family for these few weeks. I would also like to give a warm thank you to all the people who participated in this study and shared their knowledge with me.

I would like to thank my parents for being an infinite source of encouragements and motivation. Thank you to my boyfriend, roommates, friends and fellow thesis students for giving me great advices, letting me share my ups and downs with you and cheering me up when I needed it

Thank you to the Oticon Foundation for the financial support for this fieldwork.

---

# TABLE OF CONTENTS

---

<b>LIST OF FIGURES AND TABLES</b>	<b>9</b>
<b>ABBREVIATIONS</b>	<b>11</b>
<b>CHAPTER I: INTRODUCTION</b>	<b>13</b>
<b>CHAPTER II: BACKGROUND</b>	<b>17</b>
<b>2.A. PRESENTATION OF THE STUDY CONTEXT</b>	<b>17</b>
2.A.1. LAND TENURE AND THE POLITICAL CONTEXT	17
2.A.2. THE VOLATILITY OF COFFEE PRICES	18
2.A.3. NICARAGUAN COFFEE POLICY	19
<b>2.B. <i>COFFEA ARABICA</i>, THE GOLDEN BEAN</b>	<b>20</b>
2.B.1. GROWING CONDITIONS	20
2.B.2. CURRENT DEBATE ON THE EFFECT OF SHADE	20
2.B.3. CLIMATE CHANGE AND THE FUTURE OF COFFEE PRODUCTION	22
<b>2.C. THEORETICAL FRAMEWORK</b>	<b>22</b>
2.C.1. LOCAL ECOLOGICAL KNOWLEDGE	22
2.C.2. ECOSYSTEM SERVICES AND DISSERVICES	23
2.C.3. ADOPTABILITY OF AGROFORESTRY	24
2.C.4. AGROFORESTRY AND GENDER	26
<b>CHAPTER III: METHOD SECTION</b>	<b>28</b>
<b>3.A. RESEARCH DESIGN</b>	<b>28</b>
<b>3.B. PRESENTATION OF THE STUDY PARTICIPANTS</b>	<b>29</b>
3.B.1. DESCRIPTION OF THE STUDY AREA	29
3.B.2. DESCRIPTION OF THE RESPONDENTS	33
<b>3.C. RESEARCH METHODS</b>	<b>35</b>
3.C.1. QUESTIONNAIRES	35
3.C.2. TREE INVENTORY	36
3.C.3. GPS MAPPING	37
3.C.4. RANKING EXERCISES	37
3.C.5. PARTICIPANT OBSERVATION	39
3.C.6. INFORMAL CONVERSATION AND DIRECT OBSERVATION	39
3.C.7. FIELD ASSISTANTS	40
<b>3.D. DATA ANALYSIS</b>	<b>41</b>

<b>CHAPTER IV: RESULTS</b>	<b>44</b>
<b>4.A. DESCRIPTION OF THE COFFEE AGROFORESTRY SYSTEMS</b>	<b>44</b>
4.A.1 CHARACTERIZATION OF COFFEE SMALLHOLDERS	44
4.A.2 FARM DESCRIPTION	49
4.A.3 SHADE COMPONENT OF THE COFFEE AGROFORESTRY SYSTEMS	52
<b>4.B. COFFEE SMALLHOLDER'S PERCEPTION AND PREFERENCES OF ECOSYSTEM SERVICES AND SHADE TREE SPECIES</b>	<b>57</b>
4.B.1 SMALLHOLDER'S PERCEPTION OF THE ECOSYSTEM SERVICES AND DISSERVICES PROVIDED BY SHADE TREES	57
4.B.2 FARMER'S KNOWLEDGE ABOUT SHADE TREES' PROVISION OF ECOSYSTEM SERVICES	61
4.B.3 FARMER'S PREFERENCES OF SHADE TREE SPECIES	64
4.B.4. THE INFLUENCE OF GENDER IN SPECIES PREFERENCES	67
<b>4.C. IDENTIFICATION OF THE FACTORS INFLUENCING SHADE TREE SPECIES COMPOSITION IN THE COFFEE AGROFORESTRY SYSTEMS</b>	<b>71</b>
4.C.1 CURRENT USE OF SHADE TREES' PRODUCTS AND RELATED CONSTRAINTS	71
4.C.2. ANALYSIS OF THE FACTORS INFLUENCING SPECIES DIVERSITY	73
4.C.3. THE INFLUENCE OF FARMERS' PREFERENCES ON SPECIES ADOPTION	76
<b>CHAPTER V: DISCUSSION</b>	<b>77</b>
<b>5.A. SMALLHOLDER'S PERCEPTION AND PREFERENCES OF THE ECOSYSTEM SERVICES PROVIDED BY SHADE TREES</b>	<b>77</b>
5.A.1. COMMON PATTERNS IN ECOSYSTEM SERVICES PREFERENCES	77
5.A.2. HOW THE LOCAL MICRO-CLIMATE INFLUENCE FARMER'S PREFERENCES OF ECOSYSTEM SERVICES	78
5.A.3. GENDERED DIFFERENCES	79
<b>5.B. COFFEE SMALLHOLDER'S PREFERENCES OF SHADE TREE SPECIES</b>	<b>79</b>
5.B.1. A TASTE FOR BANANAS	79
5.B.2. THE INFLUENCE OF LOCAL INSTITUTIONS AND ORGANIZATIONS ON LOCAL ECOLOGICAL KNOWLEDGE: THE EXAMPLE OF INGA SPECIES	80
5.B.3. GENDER ASPECTS	81
<b>5.C. FACTORS INFLUENCING SMALLHOLDER'S ADOPTION OF SHADE TREE SPECIES</b>	<b>81</b>
5.C.1. DIVERSIFIED SHADE CANOPIES	81
5.C.2. COMPARING FARM DIVERSITY AND SMALLHOLDER'S PREFERENCES	82
5.C.3. FRUIT TREE SPECIES	83
5.C.4. TIMBER	84
<b>5.D. LIMITATIONS</b>	<b>85</b>
<b>5.E. RECOMMENDATIONS</b>	<b>86</b>
5.E.1. TEMPORARY SHADE	86
5.E.2. SERVICE TREES	87
5.E.3 TIMBER TREES	87
5.E.4. FRUIT TREES	88
5.E.5. GENERAL RECOMMENDATION	90
<b>CHAPTER VI: CONCLUSION</b>	<b>91</b>
<b>LIST OF REFERENCES</b>	<b>93</b>

<b><u>APPENDIX A: GANTT DIAGRAM OF THE FIELWORK PERIOD</u></b>	<b><u>100</u></b>
<b><u>APPENDIX B: SATELLITE MAPS OF THE SELECTED COMMUNITIES</u></b>	<b><u>101</u></b>
<b><u>APPENDIX C: CONVERSIONS</u></b>	<b><u>103</u></b>
<b><u>APPENDIX D: QUESTIONNAIRE</u></b>	<b><u>104</u></b>
<b><u>APPENDIX E: RANKING EXERCISE</u></b>	<b><u>109</u></b>
<b><u>APPENDIX F: EXAMPLES OF ES AND SPECIES CARDS FOR THE RANKING EXERCISE</u></b>	<b><u>110</u></b>
<b><u>APPENDIX G: QUALITATIVE DATA</u></b>	<b><u>112</u></b>
<b><u>APPENDIX H: PRECIPITATION AND ALTITUDE MAPS</u></b>	<b><u>136</u></b>
<b><u>APPENDIX I: LIST OF THE SHADE TREE SPECIES PRESENT IN THE STUDY AREA</u></b>	<b><u>138</u></b>
<b><u>APPENDIX J: LIST OF SELECTED SPECIES</u></b>	<b><u>141</u></b>
<b><u>APPENDIX K: ECOSYSTEM SERVICES AND TREE ATTRIBUTES RANKING RESULTS</u></b>	<b><u>142</u></b>
<b><u>APPENDIX L: TREE SPECIES RANKING RESULTS</u></b>	<b><u>144</u></b>

---

# LIST OF FIGURES AND TABLES

---

<b>Figure 1:</b> ICO composite indicator price between 1965 and 2013	18
<b>Figure 2:</b> Illustration of the research design	28
<b>Figure 3:</b> Physical map of the department of Matagalpa and its localization within Nicaragua	30
<b>Figure 4:</b> Localization of the selected communities within Matagalpa department	30
<b>Figure 5:</b> Climate charts for Matagalpa city and Rancho Grande	31
<b>Figure 6:</b> Number of households surveyed in the first phase of data collection, divided per community and per gender of the respondent	33
<b>Figure 7:</b> Relationship of the participants of the questionnaire with the farm owner	33
<b>Figure 8:</b> Number of participants in the second phase of data collection per gender and community	34
<b>Figure 9:</b> Relationship of the participants of the ranking exercise with the farm owner	34
<b>Figure 10:</b> Pictures of ranking exercise participants	38
<b>Figure 11:</b> Gender of the household members participating in the decision-making process regarding coffee cultivation	44
<b>Figure 12:</b> Type of paid job of household members	44
<b>Figure 13:</b> Percentage of households involved in a Local institution or organization's project	46
<b>Figure 14:</b> Frequency of mention of the main problems faced by smallholders with coffee cultivation	47
<b>Figure 15:</b> Percentage of respondents in each community who reported that their coffee was affected by a given disease or pest	49
<b>Figure 16:</b> Species accumulation curve per farm of the study area and of the three communities taken separately	51
<b>Figure 17:</b> ES and tree attributes by community and by the subcategories or functions they are represented by	60
<b>Figure 18:</b> Percentage of respondents who selected a given species out of the total number of respondents who had the option of choosing this species	61
<b>Figure 19:</b> Overview of the rankings of shade tree species by ES or tree attribute in the study area	62
<b>Figure 20:</b> Overview of the rankings of shade tree species by ES or tree attribute and by community	63
<b>Figure 21:</b> Percentage of respondents who selected a given species out of the total number of respondents who had the option of choosing this species per gender and species use-category	67
<b>Figure 22:</b> Ranking of ES and tree attributes by gender	68
<b>Figure 23:</b> Participant's preferences of shade tree species per gender and use-category	69
<b>Figure 24:</b> Influence of farmer's preferences and species' frequency of occurrence on farms in the three selected communities	73

<b>Table 1:</b> List of independent variables considered in this study	28
<b>Table 2:</b> Statistical description of the household's size, farm owner's age and the time that the household members have spent living in the area	43
<b>Table 3:</b> Typology of coffee smallholders based on their economic status	45
<b>Table 4:</b> Number of households where at least one member received training on coffee cultivation from an organization or institution per community	46
<b>Table 5:</b> Coffee diseases encountered in the study area	48
<b>Table 6:</b> Altitude, precipitation and temperature of the selected communities	49
<b>Table 7:</b> Statistical description of the farm size, coffee afs size, percentage of the farm dedicated to coffee and coffee yield	49
<b>Table 8:</b> Previous land-use of the coffee AFS	50
<b>Table 9:</b> On-farm diversification	50
<b>Table 10:</b> Number of native and exotic species	52
<b>Table 11:</b> Method of shade establishment according to the coffee plot previous land-use	53
<b>Table 12:</b> Smallholder's intentions to remove or add different shade tree species in their coffee AFS	54
<b>Table 13:</b> Respondents statement on their intention to extend, maintain or reduce their coffee AFS	55
<b>Table 14:</b> Positive and negative impacts of shade trees mentioned by respondents in the study area and per community	57
<b>Table 15:</b> Justification for the selection of ES and tree attributes for the ranking exercise	59
<b>Table 16:</b> Respondent's recommendations of shade tree species for new coffee farmers	64
<b>Table 17:</b> Regression results for farm species richness	73
<b>Table 18:</b> Regression results for farm abundance of different use-categories of shade tree species	74
<b>Text box 1:</b> Politics of the XXth century: dictatorship and revolution	16
<b>Text box 2:</b> What is an agroforestry system?	20
<b>Text box 3:</b> Anecdote on community selection	29
<b>Text box 4 :</b> Reflections on species identification	36

---

# ABBREVIATIONS

---

ADDAC	<i>Asociación para la Diversificación y el Desarrollo Agrícola Comunal</i>
AFS	Agroforestry System
ANOVA	Analysis Of Variance
CONATRADEC	National Commission for the transformation and Development of the Coffee Sector
ED	Ecosystem Disservices
ES	Ecosystem Services
FSLN	<i>Frente Sandinista de Liberación Nacional</i>
Ha	Hectare
ICA	International Coffee Agreement
ICO	International Coffee Organization
Inhab.	Inhabitants
INTA	Nicaraguan Institute for Agricultural Technology
LEK	Local Ecological Knowledge
Masl	Meters above sea level
MATRICE	Matagalpa Agroforest Resilient Landscape program
mm	Millimeters
NFF	NicaFrance Foundation
NTFP	Non-Timber Forest Products
Tukey HSD	Tukey Honestly Significant Difference

*[...] people in the South [...], among them many of the very poorest, depend on a third type of agriculture which is more difficult, and where yields have changed little since mid-century. Their agriculture is more complex, diverse and risk-prone. The complexity is physical —undulating land, with variable soils, shade, aspect and water supply; biological — with intercropping, agro-forestry, and livestock interlinked; and social and economic — with multi-purpose crops, trees and livestock, and many different activities and enterprises for the farm household at different times of the year. They also know relatively more, compared with their green revolution colleagues, about their conditions than do scientists. And they are experimental and adaptive—they cannot afford not to be. They need, it is now realised, not messages but methods, not precepts but principles, not a package of practices but a basket of choice, not a fixed menu—table d'hote, but a choice, a la carte; not instruction on what to adopt, but ideas about what to try, with support for their own trials and experimentation.*

(Chambers, 1988)

---

# CHAPTER I: INTRODUCTION

---

Nowadays, consumers are becoming increasingly aware of sustainability and biodiversity issues in the agricultural production systems and their demand is driving the coffee commodity chains towards more diversity and sustainability. In coffee growing areas, local organizations are promoting agroforestry practices as a sustainable alternative which could also benefit from higher price premiums and thus, are providing small-scale farmers with free shade trees seedling for their coffee plantations. Nonetheless, coffee smallholders already have a long history of producing coffee in diverse shaded systems and their ecological knowledge of these shade tree species should not be overlooked. Hence, in order to achieve long-lasting positive results, such sustainable local development initiatives should take into account people's needs, priorities and constraints and foster their participation in the decision-making process (Chambers, Saxena and Shah, 1989; Gausset, 2004; Bellec *et al.*, 2012).

Worldwide, an estimated 25-30 million farmers are growing coffee, covering more than 60 countries (Waller, Bigger and Hillocks, 2007). Since its introduction in Central America about a 100 years ago, *Coffea arabica* L. has been as a major source of export earnings for the sub-continent and now covers one million hectares (ha) of land (Philpott and Dietsch, 2003). Among Central American countries, Nicaragua is the 3rd exporting country and the 12th worldwide with a total production of 152 400 tons of coffee for the 2017/2018 harvest for 126 thousand ha under cultivation. According to the Ministry of Agriculture, coffee production sustains approximately 44 000 Nicaraguan farmers and provides 332 000 permanent and seasonal jobs, equivalent to 15% of the labor market and 54% of the agricultural sector. Most of Nicaragua's coffee production is concentrated in the North Central Region of the country in the municipalities of Jinotega, Matagalpa and Nueva Segovia. (Bolaños, 2017)

As it found its place into the landscape of northern Nicaraguan, the golden bean became a culturally important crop for smallholders since “*Coffee dollars build houses, send children to school, and provide hope for the future.*” (Bacon, 2005) Today, Nicaraguan coffee farmers are composed of 80% of small-scale coffee farmers with less than 3,5 ha. However, these small-scale farmers produce less than 15% of Nicaraguan coffee harvest due to a lower intensity of management and a lack of financial resources for purchasing inputs (Donovan and Poole, 2014). Furthermore, Arabica coffee production is getting threatened by climate change due to its high sensitivity to drought, elevated temperatures and pests and diseases outbreaks (Bunn *et al.*, 2015; Craparo *et al.*, 2015). Hence, the increasing changes in climatic patterns, together with the extreme volatility of coffee international prices (ICO, 2014), constitute important threats to the economic stability and food security of coffee smallholders.

Currently, most of the Nicaraguan coffee production comes from shade grown *C. arabica* (Bolaños, 2017). This shaded systems, referred to as agroforestry systems (AFS), have received increased attention within the scientific community and industry due to their capacity to improve both rural livelihood and biodiversity conservation (Perfecto *et al.*, 2007) and mitigate environmental changes in temperature and precipitation patterns (Lin, Perfecto and Vandermeer, 2008). In these perennial crop systems, shade trees can provide a range of

ecosystem services (ES) such as pest and disease control, soil fertility improvement and micro-climate regulation, as well as providing timber and non-timber forest products (NTFP) which can increase profitability of the farming systems through diversification as well as support subsistence consumption (Beer *et al.*, 1998; Vaast, Beer, *et al.*, 2005; Vaast, Kanten, *et al.*, 2005; Gordon *et al.*, 2007). In addition to these socio-economic benefits, shade trees may also be retained by farmers due to their ecological attributes such as wood burning properties, fruit quality or growing patterns (Soto-Pinto *et al.*, 2007). In addition, Gordon *et al.* (2007) emphasizes that in more biodiverse, lower input systems, smallholders show a higher resilience against international coffee price fluctuation. However, shade trees can also have a negative impact on coffee production, also referred to as ecosystem disservices (ED), through e.g. competition for light and nutrients or provision of habitat for pests and diseases. Such ED, negatively impacting coffee yields, have been observed in AFS with a high density of shade, which tends to be the case in smallholder's traditional coffee AFS due to high numbers of shade trees retained as well as a lack of pruning (Soto-Pinto *et al.*, 2000; Matoso-Campanha *et al.*, 2004). Still, losses in coffee yield induced by trees' competition tend to be offset or surpassed by the ES provided by shade trees (Vaast, Beer, *et al.*, 2005). Moreover, it is important to acknowledge that the effectiveness of shade tree species to provide major ES will depend on site characteristics, local climate (especially altitude), management practices and shade tree composition (Idol, Haggard and Cox, 2011; Boreux *et al.*, 2016; Cerda *et al.*, 2017).

Despite of a large amount of literature focusing on coffee productivity, there is little scientific knowledge about the ecological attributes and associated ES and ED of individual shade tree species (Smith Dumont *et al.*, 2018). Previous studies have shown that farmer's local ecological knowledge (LEK) is an important source of information to fill such knowledge gaps as farmers often have a detailed understanding of tree attributes derived from direct experience and observation (Soto-Pinto *et al.*, 2007; Cerdán *et al.*, 2012). In order to generate customized recommendations on shade tree species selection, Van der Wolf *et al.* (2016) have developed a methodology which mobilizes farmer's site specific LEK through ranking exercises, with the aim of developing an online advice tool for customized shade tree species recommendation (i.e. Shade Tree Advice Tool) under the BREEDCAFS project. In the past few years, several studies have contributed to fill this knowledge gap by studying differences in farmer's ES preferences along an altitudinal gradient, a precipitation gradient, according to soil fertility, gender and/or ethnicity (Bukomeko *et al.*, 2017; Gram *et al.*, 2018; Lépine, 2018; Rigal, Vaast and Xu, 2018). Nonetheless, both shade trees' capacity to provide certain ES or ED and the challenges faced by coffee smallholders vary across space and time, thus making trees' suitability for coffee AFS highly context dependent. Hence, many other studies must be conducted in diverse socioeconomic and climatic conditions across the globe in order to provide smallholders with the most appropriate advice possible on shade tree species selection. Furthermore, the previously mentioned studies lack of a qualitative approach which would allow them to explore the reasons why some shade tree species appear to be more suitable.

Hence, this study aims to **identify the most suitable and relevant shade tree species for coffee smallholders' AFS in Matagalpa Department, Nicaragua**, through a mixed-

method approach. This overarching objective will be unfolded through the three following objectives:

- 1. Describe the coffee AFS of the three selected communities in Matagalpa Department, Nicaragua.**
- 2. Document smallholder's LEK about the locally relevant shade tree species and the ES they provide in each of the communities and how it may differ based on gender.**
- 3. Explore the factors influencing smallholder's decision-making process regarding the adoption of shade tree species in the study area.**

It should be noted that the production of *Coffea canephora* Pierre ex A. Froehner was not addressed in this study as it is absent from the study area, although present at the national level. In addition, this report aims to document smallholder's LEK of shade tree species in the selected communities rather than trying to collect data from different coffee growing areas across Nicaragua or monitor changes across time. Hence, the focus is put on gaining a multidisciplinary understanding of the factors influencing shade tree adoption rather than on obtaining a large sample size. Moreover, in the absence of a universally accepted definition of smallholder farmers, it was arbitrarily decided that coffee producers with more than five hectares of coffee would not be included in this study.

Despite of the potential usefulness of the Sustainable Livelihood Framework to understand the livelihood strategies of smallholders and thus to explore the factors related to their decision-making process, it was a deliberate choice from the researcher to not include it in this study. This choice was guided by a desire to focus on farmer's perception of the different tree species with an inductive approach rather than trying to fit their socio-economic profile into a pre-made frame.

Given the limited timeframe allocated for this study, it was decided to collect data on shade tree species presence-absence on farms rather than on their abundance which would have been relevant for this study. Similarly, soil analysis have not been conducted although soil fertility can be expected to be an important factor in shade tree species selection (Lépine, 2018).

The structure of the thesis at hand will now be presented. This paper starts with the introduction and presentation of the research problem and objectives (Chapter 1). Next a background section is presented (Chapter 2), in which some key elements of the Nicaraguan context are introduced (2.A), followed by a description of *C. arabica* growing condition and the opportunities and constraints of its production (2.B). This section ends on the theoretical framework of this study (2.C). The methodology is then described in chapter 3 and includes a presentation of the research design (3.A), a description of the study participants (3.B), an introduction of the research methods applied (3.C) and the data analysis conducted (3.D). Then, the study findings are presented (Chapter 4) following the same order as the research objectives. In chapter 5, these findings are discussed in relation to the existing literature and the conceptual

framework. The discussion ends with a presentation of the study limitations (5.D) and of my recommendations (5.E). Lastly, concluding remarks are presented in chapter 6.

---

# CHAPTER II: BACKGROUND

---

## 2.A. PRESENTATION OF THE STUDY CONTEXT

---

### 2.A.1. LAND TENURE AND THE POLITICAL CONTEXT

---

The golden bean was introduced in Nicaragua around 1850. At that time, the Nicaraguan government, like others in Central America, focused on nation-building and saw in coffee cultivation an entry gate to the world markets. Hence, large land grants, infrastructure and credit were offered to foreigners (attracting many German and Italian immigrants) and elite nationals in order to encourage the expansion of coffee production. As with many other cash crops, coffee was produced in very large landholdings called *latifundios*, often located on land that use to be under the control of indigenous people. Local populations, deprived of their own land, found temporary or permanent jobs in the coffee plantations but were often subject to exploitative working conditions. Peasant dependency toward these large landowners coupled with the big-scale adoption of cash crops for export generated serious unequal land distribution and unequal property relations in rural areas. (Bacon, 2005; Fraser, Fisher and Arce, 2014)

It is in this context that the Frente Sandinista de Liberación Nacional (FSLN) took the power and undertook in 1979 a vast agrarian reform with the aim of eradicating the exploitive capitalist system characteristic of the Somoza regime (see Text box 1 for more information on the XX<sup>th</sup> century political context). The objective of the FSLN was to restructure the country's economy in order to make it less dependent on raw material export. Efforts were made to stabilize rural producers' income by providing access to credit and to suppress the exploitative margins practiced by the *latifundistas* through the control of all agricultural outputs' retailing and wholesaling systems. After Somoza left the country in 1979, the land belonging to his family, representing 20% of the country's farmland, was confiscated and divided into 1500 State farms. The FSLN was concerned that redistributing the land to individual small-scale farmers would negatively impact the country's economy by leading to a decrease in productivity, a shift from export-crops to food crops and a reduction of the wage workers. Thus,

#### TEXT BOX 1: POLITICS OF THE XXTH CENTURY: DICTATORSHIP AND REVOLUTION

Through the last century, Nicaragua have been marked by several conflicts which have shaped today's political landscape. In 1937, the Somoza family took presidential power and drew the country in a 40 years dictatorship, the longest ever seen in the country. It was not until the 1970s that the Frente Sandinista de Liberación Nacional (FSLN), a fully armed rebel group, made his apparition on the political scene with the massive support of poor Nicaraguans and drew the country in a first civil war. When the Somoza family presented their resignation in 1979, the FSLN formed a revolutionary government, but the Civil war had caused the death of approximately 50 000 civilians and left the country's economy in ruins. The elite landowners who were against the Revolution formed militias, called Contras, thus prolonging the Civil war into the 1980s, despite of the FSLN's democratic election in 1984. The Contras pursued their counter-revolutionary efforts until the neoliberalist Violeta Barrios de Chamorro, supported by the US, won the elections in 1990. (Fraser, Fisher and Arce, 2014) The FSLN candidate Daniel Ortega won the following election in 2007 and remain in office at this day despite international denunciation of his violent repression campaign against protesters in 2018.

the revolutionary government clearly favored large-scale production in terms of technical assistance and access to credit. (Saravia-Matus and Saravia-Matus, 2009)

At first, a large proportion of the *latifundos* were merely transferred from private to public hands but pressures from the landless and smallholders gave way in 1981 to the enactment of the Agrarian Reform Law. This led to massive land confiscation for underutilization among other motives. *Latifundistas* went from owning 36% of the total arable land in the country to just 6.4% as more than 2.5 million hectares of arable land were transferred to farming collectives, individual peasant farmers, and state-owned enterprises. An estimated 120 000 families received land including both land transfers to cooperatives and the titling of spontaneously occupied tenant lands. However, excessive State control and the government failure to secure formal tenurial agreements led to a large discontentment of the peasantry class and hindered work incentives. (Saravia-Matus and Saravia-Matus, 2009; Wilson, 2013) In effect, the agrarian reform not only failed to its promise of emancipation of the rural poor but it also altered the country's institutional framework and also led to a severe decline of the volume of exports and GDP, as a result of the combination of poor State performance and the internal war led by the counterrevolutionary forces (Saravia-Matus and Saravia-Matus, 2009).

The tumultuous history of land rights in Nicaragua doesn't stop there. In Matagalpa department, between 1994 and 2000, an agroindustrial conglomerate appropriated about 18 000 ha of estates, formally owned by workers, through the peace accord which brought the war to an end. However, the 2001 international crisis in coffee prices led to the collapse of this agroindustrial conglomerate and the job loss and impoverishment of the farmworkers. Their despair triggered a protest movement demanding the redistribution and retitling of this land promised by the previous agrarian reform. Their story is now famous as it gave way, not without effort, to Las Tunas Accords which redistributed land to 2500 families. This example highlights that the dispossession of indigenous, smallholders and farmworkers from land, as well as labor rights and fair wages, remains a reality and a driver for the perpetuation of structural inequalities in rural areas and injustice in coffee value chains. (Wilson, 2013)

### 2.A.2. THE VOLATILITY OF COFFEE PRICES

---

The price of coffee on world markets are known to be extremely volatile, partly due to market segmentation, speculation and harvesting issues related to climate variability (notably recent climate chocks in Brazil). In response to this, the International Coffee Agreement (ICA) was introduced in 1962 with the aim of stabilizing prices, constraining overproduction and stimulating coffee consumption. In 1963, the International Coffee Organization (ICO) was established in collaboration with the United Nation to oversee the ICA. Until its disintegration in 1989, the ICA effectively maintained coffee prices at a high level thanks to export quotas (Figure 1). The following free market period, however, was marked by a sub-period or record low prices from 1999 and 2004, known as the 2001 coffee crisis. (ICO, 2014)



FIGURE 3: ICO COMPOSITE INDICATOR PRICE BETWEEN 1965 AND 2013. The ICO composite indicator price is calculated based on the indicator prices of Colombian mild arabicas, other mild arabicas, Brazilian and other natural arabicas, and robustas. Since October 2000, the average of the four groups is weighted according to their relative shares in international trade, while before it was a straight average. Source: ICO, 2014

In Nicaragua at the beginning of the XXI<sup>th</sup> century, the combined effects of war, political change and natural disasters together with record lows in international coffee prices left most the country's coffee growers with precarious livelihoods and semi-abandoned farms. During the 2001 crisis, as prices fell below the costs of production, banks stopped giving credit for coffee production and foreclosed on farms with debts. Due to lack of financial capital, many producers stopped applying fertilizers (organic or synthetic) and couldn't afford to rejuvenate and maintain their plantations, bringing down total production. (Bacon, 2005; Bacon *et al.*, 2008)

Coffee prices recovered strongly after the crisis until 2011 before severely deteriorating again (Figure 1) while inputs prices such as fertilizers and labor continued to rise (ICO, 2014). Such low international prices are still a reality and together with the current Nicaraguan political instability, which affects farmer's access to credit, they represent a real challenge for the long-term sustainability of Nicaraguan coffee sector despite of a good productivity at the national level (Bolaños, 2017, 2019).

### 2.A.3. NICARAGUAN COFFEE POLICY

In Nicaragua coffee production is regulated mainly by two laws. First, the *Ley del Café* (368), published in 2000 and implemented by the Nicaraguan Coffee Council, provides a series of fiscal exonerations on investments related to coffee production to the coffee producers. And secondly, the *Ley para la Transformación y Desarrollo de la Caficultura* (Law 853) which was passed in 2013. This law obliges coffee farmers to pay a fee for each coffee bag exported of one to four US dollars, depending on the international coffee prices. The money collected is placed in a fund, administered by the National Commission for the Transformation and Development of the Coffee Sector (CONATRADEC), and should be dedicated to the renovation of the old coffee plantations, in particular in small-scale farms. (Bolaños, 2017) This fund, known as the CONATRADEC Fund, held 25,8 millions of US dollars in August 2019 and is now largely controlled by the government of Daniel Ortega. Given its size, the fund should have already started to provide the support it promised. However, farmers complain that

since its creation, no official report was delivered to publicly document the activity of the fund and thus demand the suppression of the fee applied on coffee exports. (Calero, 2019) Such government policies only add to the tremendous financial pressure that coffee producers are submitted to in the current context of low international coffee prices, increased fertilizers and fungicides' prices (linked to a recent fiscal reform) and climatic variability (Calero, 2019), while it could be mobilized to increase smallholder's ecological and financial resilience by supporting the implementation of agroforestry practices.

---

## 2.B. *COFFEA ARABICA*, THE GOLDEN BEAN

---

---

### 2.B.1. GROWING CONDITIONS

---

*C. arabica* is by nature a shade tolerant species native to the Ethiopian highland forests where it grew at altitudes of 1600–2800 meters above sea level (masl). Optimal climatic conditions for Arabica coffee is mean annual temperatures ranging from 18 to 21°C and annual rainfalls of 1200-1800 millimeters (mm) (DaMatta, 2004).

Sufficient water is critical for coffee growing, especially between six and 10 weeks after flower fertilization and between 29 and 33 weeks after flowering for cherry filling and bean maturation. Lack of rain will reduce coffee yields and have a negative impact on its quality as coffee plants will not properly flower and they will produce small cherries whose skin sticks to the bean, making pulping operations difficult (FEWS NET, 2016).

Temperature is also an important factor in coffee bean development. If temperatures are low, the ripening of the fruit tend to be delayed, and in extreme cases, frost can cause serious damages to the coffee plants. On the other hand, if temperatures are high, the fruit maturation is accelerated which affects negatively the cup quality while photosynthesis and plant growth slows down, limiting total production. High temperatures can also induce defects in the flowers, limit fruiting, and provoke diseases outbreaks and pest infestations, impacting both the longevity and the productivity of coffee plants (FEWS NET, 2016).

---

### 2.B.2. CURRENT DEBATE ON THE EFFECT OF SHADE

---

This study focuses on coffee AFS (text box 2), but should coffee always be grown in shade? Several studies reported that, under similar conditions, the production of full-sun coffee systems outpace those of shaded coffee systems (Abruña *et al.*, 1965; Matoso-Campanha *et al.*, 2004). This tendency can be explained by the fact that shade trees limit the amount of solar radiation reaching the crop thus affecting both flowering and bean maturation and ultimately coffee yield.

## TEXT BOX 2: WHAT IS AN AGROFORESTRY SYSTEM?

The World Agroforestry (2019) defines Agroforestry in very simple and inclusive terms as “*the interaction of agriculture and trees, including the agricultural use of trees.*” More specifically, Agroforestry corresponds to land use systems and technologies where woody perennials are deliberately used on the same land management units as agricultural crops and/or animals, in some special arrangement and temporal sequence. AFS are the result of the interaction of the biophysical conditions (e.g. climate, soil, terrain), farmer’s socio-economic and cultural conditions and the local political and economic development. Their general objective is to reach a sustainable production of food, forest products and cash crops. Hence, any AFS will focus on four key elements: production, seasonality (of resources and food security), soil management and micro-climate management (Nair, 1993). In this study, we focus on coffee AFS which are perennial crop systems composed of coffee trees intercropped with shade-trees.

As early as in 1988, Fournier pointed out that a simple yield comparison between the two systems was not sufficient to recommend full-sun cultivation as the best alternative. Beer *et al.* (1998) confirmed Fournier’s suspicion that the relative yield advantage of full-sun coffee is limited to one or two decades of production, after which production may be reduced by soil erosion and other environmental degradation and to plantations which are frequently renovated as unshaded coffee has a shorter life expectancy. In addition, soil and climatic conditions appeared to be key factors in the impact of shade on coffee productivity (Beer *et al.*, 1998; Vaast, Kantén, *et al.*, 2005). For instance, DaMatta (2004) and Vaast, Kantén, *et al.* (2005) found that while under optimal conditions, shade may have a negative impact on coffee productivity by bringing the air temperature below its optimal range, under sub-optimal conditions, shade has positive effects on coffee yield including heat stress reduction, enhanced coffee growth and productivity. In areas prone to frost, shade trees in AFS can also provide frost protection by mitigating the variation of leaf temperature during frost events, thus leading to higher yields than unshaded coffee over several years (Caramori, Androcioli Filho and Leal, 1996).

Nonetheless, regarding shade as a white or black matter is a simplistic view of the reality. As discussed by Matoso-Campanha *et al.* (2004), coffee yields depends on the intensity of competition between shade trees and coffee, which in turn is influenced by tree density, pruning practices and tree species selection. Soto-Pinto *et al.* (2000) found that a shade density above 50% has negative effects on coffee yield. However, in traditional coffee AFS the shade density is often higher than 50% due to a high density of shade trees as well as a lack of pruning (Matoso-Campanha *et al.*, 2004).

Moreover, even when the presence of shade trees reduce coffee yields due to competition, such losses tend to be offset or surpassed by the ES provided by shade trees (Vaast, Beer, *et al.*, 2005). Indeed, in agroforestry systems, shade trees can provide farmers with fruits, firewood and/or timber, which can be used for household consumption or to generate income, thus significantly contributing to the households’ financial security and/or food security (Peeters *et al.*, 2003; Rice, 2011; Jezeer *et al.*, 2018).

Regarding coffee quality, Vaast, Kantén, *et al.* (2005) argue that shade trees improved coffee bean quality irrespectively of the ecological conditions whereas Bosselmann *et al.* (2009) found that the sensory quality attributes of *C. arabica* cv. Caturra are negatively impacted by shade. Bosselmann *et al.* (2009) hypothesizes that shade tree restriction of sensorial attributes

might be related to high altitudes and conclude that optimal shade management for coffee quality should consider site characteristics and local climate.

### 2.B.3. CLIMATE CHANGE AND THE FUTURE OF COFFEE PRODUCTION

---

Nowadays, Arabica coffee production is getting threatened by climate change due to its high sensitivity to drought, elevated temperatures and pests and diseases outbursts (Bunn *et al.*, 2015; Craparo *et al.*, 2015). Scientists have estimated that forecasted changes in temperatures and rainfalls would negatively impact coffee yield and quality and could also reduce the area suitable for coffee production in Central American between 38% and 89% by 2050 (Barros *et al.*, 2014). Bunn *et al.* (2015) highlight that although new suitable areas may open-up elsewhere, it may not be sufficient to off-set the loss of production and that the consequent climate-related migration of coffee production, if feasible, may result in extended deforestation in Asia. Furthermore, climate change may also lead to range expansion of crop pest and diseases into cold-limited areas, further impacting coffee productivity (Barros *et al.*, 2014).

As pointed out by Tschardtke *et al.* (2011), it is a paradox to see full-sun coffee monocultures gaining in popularity despite of the low resilience and high vulnerability to disturbances of this land-use system, while current climate change patterns are calling for production systems with a higher resilience than ever before. Lin's studies (2007, 2010) have shown that the presence of shade trees in coffee AFS buffers coffee plants against extreme temperatures and high levels of irradiance thus leading to lowered water loss both in the wet and dry season. Furthermore, Lin highlights that AFS represent an affordable and effective coping mechanism for smallholders who are more vulnerable to extreme climatic events such as droughts and food insecurity.

Nonetheless, some shade tree species may take 10 to 30 years to establish a good shade canopy and provide effective protection from climate extremes. Thus, it is necessary to identify both fast growing shade tree species which can provide shade in the first years following shade establishment and long-lived species which will provide shade in the long run.

## 2.C. THEORETICAL FRAMEWORK

---

### 2.C.1. LOCAL ECOLOGICAL KNOWLEDGE

---

In order to establish a list of locally relevant shade tree species to promote in coffee small-scale farms in Matagalpa area, coffee smallholders' knowledge should be used to identify suitable tree species and guide future research (Rigal, Vaast and Xu, 2018).

In the literature, the study of people's knowledge of nature can be referred to as indigenous knowledge, traditional ecological knowledge or LEK. Such knowledge is the result of reiterated trial and error processes over large periods of time and is often intimately embedded in a belief system (Gadgil, Berkes and Folke, 1993). Hence, traditional knowledge

isn't really knowledge in the western sense of the term, rather, aboriginal people prefer to define LEK as a way of life rather than as knowledge. Several anthropologists recognize that traditional knowledge is culturally constructed and embedded in complex networks of social relationships, practices and values which give them meaning. (Nadasdy, 1999) Cruikshank (2004) says about traditional knowledge that it "*is not amenable to direct questions, nor can it be formulated as a set of rules. It must be demonstrated so that others can see how it is used in practice.*". Hence, integrating LEK in the framework of western science can be a challenging task (Gadgil, Berkes and Folke, 1993; Nadasdy, 1999).

Several studies have advocated for the integration of LEK into policy recommendations and conservation programs and indicated its potential to contribute to the protection of the biodiversity (Gadgil, Berkes and Folke, 1993; Nadasdy, 1999; Charnley, Fischer and Jones, 2007). Indeed, LEK can complement scientific knowledge and improve our general understanding of ecosystem and biodiversity management (e.g., multiple evidence approach) (Valencia *et al.*, 2015). Furthermore, Nadasdy (1999) highlights that LEK also has the potential to help wildlife conservation and natural resource managers to re-think the unexamined assumptions they may have about how people should relate with their environment.

It is important to note that LEK is dynamic by nature and thus that traditional knowledge, practices and beliefs can merge with new forms of knowledge in a process of hybridization through which obsolete knowledge components are abandoned (Gómez-Baggethun, Corbera and Reyes-García, 2013). Hence, LEK can be influenced by local organizations through campaigns promoting certain tree species (Valencia *et al.*, 2015; Rigal, Vaast and Xu, 2018). Thus, it will be necessary to identify the different stakeholders acting in the study area in order to interpret LEK correctly. Additionally, comparing LEK based on gender can be useful to highlight discrepancies in tree species perceptions, reflecting the division of priorities and responsibilities at the household level.

---

### 2.C.2. ECOSYSTEM SERVICES AND DISSERVICIES

---

Among other things, LEK will be mobilized in this study to understand coffee smallholder's perception of ES and ED. According to the Millennium Ecosystem Assessment which opened the way for a greater international recognition of the dependency of human wellbeing on healthy and functioning ecosystems at multiple scales, ES are defined as "*the benefits people obtain from ecosystems*" (MEA, 2005) where ecosystems refer to "*a dynamic complex of plants, animals, and micro-organisms and the non-living environment interacting as a functional unit*" (MEA, 2005). They can be grouped in four categories:

- *Provisioning services*, the material benefits derived from ecosystems, such as fresh water, raw materials, food, as well as genetic, medicinal, and ornamental resources.
- *Regulating services* which regulate processes important for human functioning and flourishing and embrace air quality regulation, erosion prevention, climate regulation, flood mitigation, moderation of extreme events, etc.

- *Cultural services* which refer to recreation, spiritual and religious values, educational information and other intangible ecosystem contributions.
- *Supporting services* which secure and maintain the production of the three above categories of ES and include primary production, nutrient cycling, photosynthesis, etc. (Polishchuk and Rauschmayer, 2012)

On the other hand, ED refer to the negative impacts that trees can have on people, the ecosystem and the environment. Some examples of ED are a reduced soil fertility and availability of light for other plants through competition, the provision of habitat or food for pests and physical damages or injuries caused by the fall of a tree, its branches or its fruits.

As discussed previously, shade trees in coffee AFS can provide regulating and supporting services depending on site characteristics, environmental conditions (especially altitude), density of shade and shade management (Caramori, Androcioli Filho and Leal, 1996; Beer *et al.*, 1998; Soto-Pinto *et al.*, 2000; DaMatta, 2004; Matoso-Campanha *et al.*, 2004; Vaast, Beer, *et al.*, 2005). Thus, it should be noted that services such as the buffering of extreme temperatures, for instance, can be perceived as an ES or an ED depending whether the farm is located in sub-optimal or optimal climatic conditions, respectively.

From the discussion provided in section 2.B.2., it appears that, while in sub-optimal edaphic and climatic conditions shade trees can increase coffee productivity through regulating and supporting services, in optimal conditions, the benefits of shaded systems over full-sun are not so evident when focusing solely on coffee yields. However, shade trees also bring provision services to smallholders, including the production of fruits, firewood and timber, which represent important resources both for household consumption and economy (Beer *et al.*, 1998; Méndez *et al.*, 2010; Idol, Haggard and Cox, 2011). Hence, even in optimal conditions, losses in coffee yield caused by competition with shade trees tend to be surpassed by the ES they provide (Vaast, Beer, *et al.*, 2005).

### 2.C.3. ADOPTABILITY OF AGROFORESTRY

---

Research community's interest in understanding smallholder's adoption of complex agroforestry systems took off in the early 1990s. However, research on the adoption and diffusion of agricultural innovations began well before, in the 1950s, fostered by a desire to understand why the introduction of some new technologies met only partial success.

To clarify future use of the term, an innovation refers to “*a technological factor of production with perceived and/or objective uncertainties about its impact on production*” (Mercer, 2004). Over time, such uncertainties will decrease as farmers are gaining experience, becoming more efficient and adapting the innovation. In order to present a rigorous definition of *adoption*, a distinction need to be made between individual (or farm-level) adoption and aggregate adoption (Feder, Just and Zilberman, 1985).

On one hand, individual adoption can be defined as “*the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new*

*technology and its potential*” (Feder, Just and Zilberman, 1985). At the farm-level, individual households take the decision whether to adopt an innovation or not and with which intensity. Therefore, individual adoption studies place emphasis on the factors which influence the household’s decision to adopt an innovation and can take either a static or a dynamic perspective (Feder and Umali, 1993).

On the other hand, aggregate adoption studies are concerned with the adoption pattern of a population or geographical region across time as they seek to identify specific trends in the diffusion cycle (Feder and Umali, 1993). We use the term *innovators* to refer to the earliest adopters of a given technology and the diffusion process can be defined as the spread of advantageous technologies to the other members of the population, gradually merging with or replacing previous alternative technologies. Diffusion studies typically focus on innovations which are already in use and analyze their spread as a dynamic and aggregative process (Feder and Umali, 1993; Mercer, 2004).

In addition, adoption studies can be divided into ex-post studies, focusing on econometric analysis of the factors determining adoption behavior, and ex-ante studies, which are concerned with the profitability, feasibility and acceptability of experimental agroforestry systems (Mercer, 2004). Both are necessary to a better understanding of the complex and dynamic processes of adoption.

The broader literature on adoptability identifies five categories of determinants for technology adoption, which should be kept in mind when designing data collection methods: economic incentives, biophysical conditions, risk and uncertainty, household preferences, and resource endowments (Mercer and Pattanayak, 2003). From an economic perspective, farmers will invest in an innovation such as agroforestry when they expect higher gains from the new system than the previous alternative, for the use of their land, capital and labor (Mercer, 2004). Furthermore, when talking about the adoption of agroforestry, various levels of adoption can be described, depending on the shade tree species selected, their density and their management. While some farmers may select only nitrogen-fixing species for shade, others might adopt a system where coffee is intercropped with bananas and other agricultural crops or adopt a system with a low percentage of shade.

In his book, Chibnik (2011) sheds light on the dichotomy between the economic and the anthropological approach to choice. The rational choice theory is an economic approach to the understanding of human behavior and interactions. This approach relies on a small number of assumptions which make it appealing to many economists and political scientists and at the same time create debate among anthropologists who favors holistic approaches to social phenomena and the recognition of cultural diversity and change. Moreover, *preferences* are viewed as “*individual (or group) rankings of the desirability of different outcomes*” (Chibnik, 2011) with no further analysis about why individuals have them. Hence, Chibnik (2011) argues that economic methods alone are incomplete for understanding the complexity of choice and praises a focus on “*the historical changes, cultural norms, and socioeconomic institutions that constrain the choices possible for different groups of people at particular places and times*”. Although this paper focus on the socio-economic factors influencing farmers

preferences and as such do not aim to provide a deep investigation of historical and cultural factors, their existence should be kept in mind when interpreting the results of the present study.

There is little literature on the barriers limiting the adoption of agroforestry systems. Because agroforestry includes such a diversity of components, its adoption might be limited due to complex management requirements, leading to long periods of testing and adjustments (Mercer, 2004). Powlen and Jones (2019) also identified the lack of technical knowledge as a barrier to reforestation, together with unsuccessful past experiences, distrust in external organizations and elevated initial costs. In this study, identifying the factors limiting the adoption of agroforestry appears as essential to provide appropriate advice on tree species selection.

#### 2.C.4. AGROFORESTRY AND GENDER

---

From a development point of view, most programs promoting sustainability were gender blind until the 1980's and thus engaged exclusively with men as they occupy most of the public space due to their status of head of the household (Meinzen-Dick, Kovarik and Quisumbing, 2014). This shifted as ecofeminist theories posited that women have an inherent connection to nature, due to their biological relationship to reproduction and their role of caretakers, and thus are more likely to protect nature than men. Although such theory has successfully brought attention to the role of women in natural resource management, Meinzen-Dick, Kovarik and Quisumbing (2014) highlight in their review that this vision is only partially true as men and women often have a complementary role in nature conservation. Furthermore, women should not be considered as a homogeneous category as their priorities may differ also based on their economic status (Fortmann and Rocheleau, 1985; Meinzen-Dick, Kovarik and Quisumbing, 2014).

In a recent study, Fortnam *et al.* (2019) showed that ecosystem services' perception is highly gendered and “*embedded within cultures, traditions and socially proscribed gender roles, and in the institutions and governance of natural resource systems, markets and labour relations*” (Fortnam *et al.*, 2019). Hence, men and women will often have a different ecological knowledge and perceive, use and benefit differently from ES. Similarly, tree species preferences and knowledge are often gender based, with women often showing more interest in trees of domestic value (e.g. trees providing fruits, medicine, firewood) while men prefer trees of economic value (e.g. trees providing timber or marketable fruits) (Agarwal, 2000; Meinzen-Dick, Kovarik and Quisumbing, 2014). However, in their study on local tree knowledge among coffee smallholders in Uganda, Gram *et al.* (2018) did not find any significant difference in ES and shade tree species preferences based on gender. This surprising result is further stimulating interest in the incorporation of a gender analysis to this study.

Regarding the role of women in family farm coffee agroforestry, Bose (2017) found in her study in Colombia that during the coffee production stage, the majority of women dedicate themselves to household activities (e.g. cleaning, washing, cooking, taking care of the children) while the men carry activities related the AFS (e.g. nursery management, planting, pruning, stumping). However, when women are done working in the household, they might

also help in the fields. At the time of harvest, women appear to be responsible for picking the coffee and putting it into bags, as well as doing some of the weeding while men are in charge of handling pesticides and fertilizers. Furthermore, the existence of women-headed households, either by choice or as a result of personal events, should not be overlooked. In such households, women are assuming new roles as they undertake tasks that were exclusively carried by man, thus questioning the gender aspect of certain activities (Fortmann and Rocheleau, 1985; Bose, 2017) and introducing even more diversity in mistakenly homogeneous gender categories.

---

## CHAPTER III: METHOD SECTION

---

This chapter describes the methodological structure of this study and the process of data collection and analysis. First, an overview of the research design and how it allowed me to answer my research questions will be presented. Secondly, the study area and the study participants will be described. Then, the different research methods will be presented and explained, followed by the methods of data analysis. Finally, the methodological limitations of the study will be summarized.

---

### 3.A. RESEARCH DESIGN

---

In order to identify the most suitable and relevant shade tree species for coffee smallholders in Matagalpa Department, Nicaragua, I have chosen to follow a mixed method strategy so as to take a broad and multidisciplinary approach. Using various methods also allows me to build on the strengths of each type of data collection and neutralize the potential biases inherent to any single approach (Creswell, 2003). Moreover, taking a multimethod approach to the evaluation of human preferences gives me the possibility to triangulate the quantitative and qualitative results and thus to increase both the validity and the reliability of my data.

This research does not strictly follow one of the research strategies described in the mixed-method literature, rather, it is based on the protocol of data collection for the Shade Tree Advice Tool, as described by Van Der Wolf *et al.* (2016) and revised by Rigal, Vaast and Xu (2018). The data collection was divided into two phases (Figure 2). The first phase aimed at describing coffee smallholders in the study area and their coffee AFS (Research question (RQ) 1) as well as gaining a general understanding of their perception of the shade tree species they have and the ES and ED they perceive from these trees (RQ2). To this end, a questionnaire was carried out together with a tree inventory and GPS mapping and both qualitative and quantitative data was collected. The second phase of data collection was used to collect smallholders' local knowledge regarding different shade tree species and the ES and ED they perceive from them (RQ2). For this purpose, ranking exercises were used as this participatory method offer the possibility to differentiate target tree species based on scores and thus allow the researcher to document local knowledge in a more precise way (Walker *et al.*, 1999). A pre-analysis of the data collected in the first phase allowed me to identify the most relevant ES and ED and the most abundant shade tree species of the study area which served as the basis of the ranking exercise. The factors influencing farmer's LEK (RQ3) were identified through the analysis of the data collected during both phases of data collection and by direct and participant observations. A Gantt Diagram for the fieldwork period is presented in Appendix A to show how time was allocated during data collection. At the end of the study, the quantitative, binary and ordinal data were analyzed using Excel and R and the nominal data was grouped into themes. The results were integrated in the interpretation phase in order to strengthen the knowledge claims of the study or explain any lack of convergence that may result.

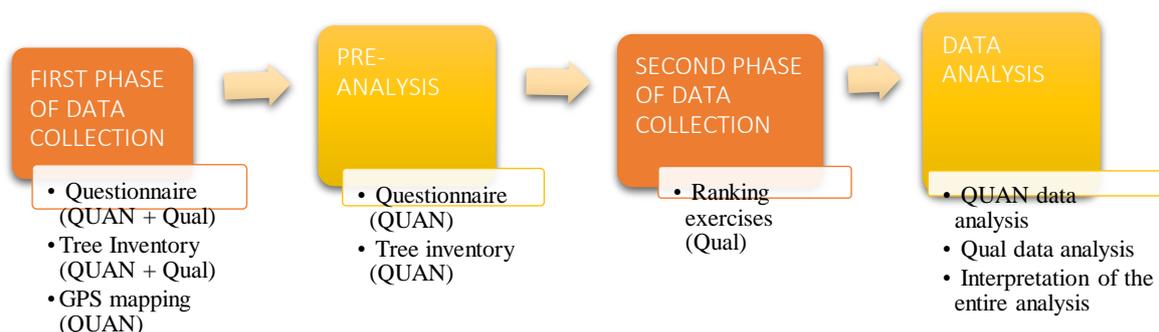


FIGURE 2: ILLUSTRATION OF THE RESEARCH DESIGN. Legend: “QUAN” stands for “Quantitative data” and “Qual” stands for “Qualitative data”.

In this study, the dependent variables of interest are coffee smallholder’s knowledge and preferences regarding different shade tree species and the ES and ED they provide as well as the actual shade tree species diversity on farm. Hence, the two first research questions will focus on describe them in the studied communities. Then, the third research question will analyze how these dependent variables are affected by different socio-economic and environmental variables presented in Table 1 below.

TABLE 2: LIST OF INDEPENDENT VARIABLES CONSIDERED IN THIS STUDY

<b>Independent variables related to the household</b>	<b>Independent variables related to the farm and the environment</b>
Gender of the farm owner	Altitude
Gender of the respondent	Precipitation
Age of the farm owner	Overall farm size
Time spent cultivating coffee	Size of the coffee plots
Time spent living in the area	Distance between the house and the coffee plots
Received training on coffee cultivation	Respondent’s perception of soil fertility
Involvement with NFF or other institution	Previous land-use of the coffee plots
Household member(s) involved in decisions regarding coffee management	

### 3.B. PRESENTATION OF THE STUDY PARTICIPANTS

#### 3.B.1. DESCRIPTION OF THE STUDY AREA

This study was completed in Matagalpa Department, Nicaragua, which produces approximately 28% of the coffee in the country (Bolaños, 2019). This department is the second of the country in terms of population size and the fourth in area, with a density of 69 inhabitants/km<sup>2</sup> and no less than 13 municipalities (INIDE, 2005).

### *a) Selection of the studies communities*

---

Three communities of the department of Matagalpa were selected for this study with the help of my host organization, the NicaFrance Foundation (NFF). NFF is a non-profit entity which is in charge of developing socially oriented projects related to the development of agroforestry and the communities surrounding La Cumplida; which is the main real estate of the Cafetalera NicaFrance SA, an agroforestry company founded in 1992 and specialized in the production of high-quality shade-grown coffee and timber. NFF projects focus on education, health, housing, protection of the environment, research in coffee, cocoa and agroforestry, culture and sports.

The first criteria for community's selection was that NFF had an on-going project in this community in order to facilitate my introduction to the community members and provide assistance to identify coffee smallholders who would be willing to host me during data collection. Among the communities which corresponded to this criterion, the final selection was made based on their difference in altitude and perceived difference of local micro-climate, although some last-minute changes had to be made (Text Box 3). There is a possibility that NFF staff members had other selection criteria that they did not share with me such as their perception of the relative safety of each community, the strength of their connection with community members and the ease of access. In the end, this study was conducted in La Estrellita, located in Matagalpa municipality, and La Inmaculada and Cerro Grande, both located in Rancho Grande municipality.

#### **TEXT BOX 3: ANECDOTE ON COMMUNITY SELECTION**

Initially, the community of La Inmaculada had not been selected to be part of the study. After I completed the first phase of data collection in La Estrellita, staff members of the NicaFrance foundation took me on a three-hours-drive to the next host I was going to stay with, who, according to them, was located in the lower-end of Cerro Grande. Upon arrival, I learned from my new host that we were actually in a different community from the upper one, called La Inmaculada. As the two communities were fairly distant from each other and my stay with this new host had already been planned, I decided to include La Inmaculada as a third studied community. As a consequence, the third community (i.e. El Tepeyac) which had been identified as presenting an intermediary altitude compared to the two others, was replaced by La Inmaculada.

### *b) Geography, demography and accessibility*

---

The study area is located in the mountainous landscape of northern Nicaragua (Figure 3 and 4; see Appendix B for maps of the communities). Unfortunately, the last national population census dates back to 2005 and the high population growth rate (2% per year in the 1995-2005 period) suggests that the current population exceeds the recorded numbers (INIDE 2005). Nevertheless, this census gives interesting insights of demographic differences between the two municipalities of interest. In 2005, Matagalpa municipality counted 133 000 inhabitants (inhab.) for a population density of 215 inhab./km<sup>2</sup>, while Rancho Grande municipality counted only 26 000 inhab. for a population density of 43 inhab./ km<sup>2</sup>. This gap can be explained by the presence of the city of Matagalpa in the municipality of the same name. Indeed, 60% of the municipality's population lives in the urban center of Matagalpa city which counted not less

than 80 000 inhabitants in 2005 whereas the village of Rancho Grande counted only 1 600 or 6% of the municipality’s population.

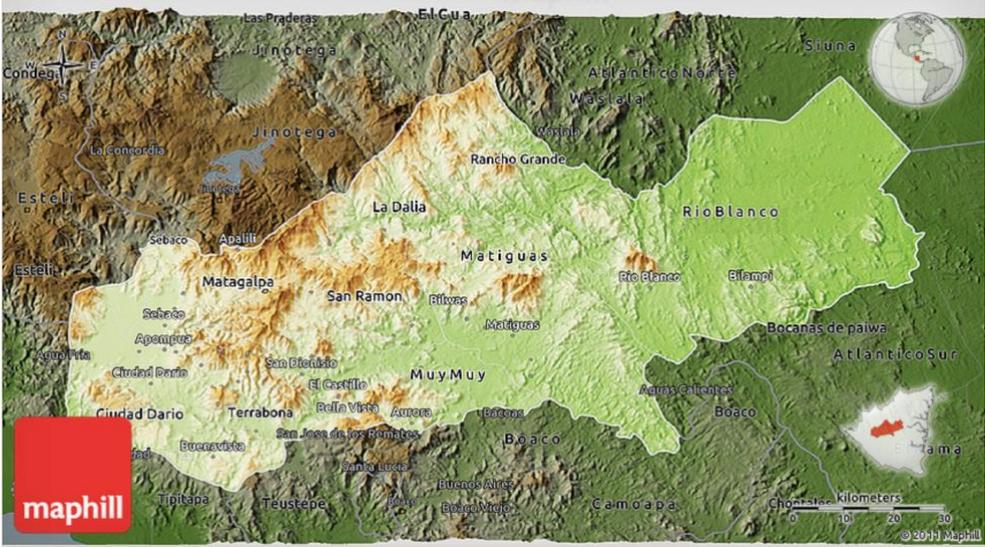


FIGURE 3: PHYSICAL MAP OF THE DEPARTMENT OF MATAGALPA AND ITS LOCALIZATION WITHIN NICARAGUA. Source: (Maphill, 2011)

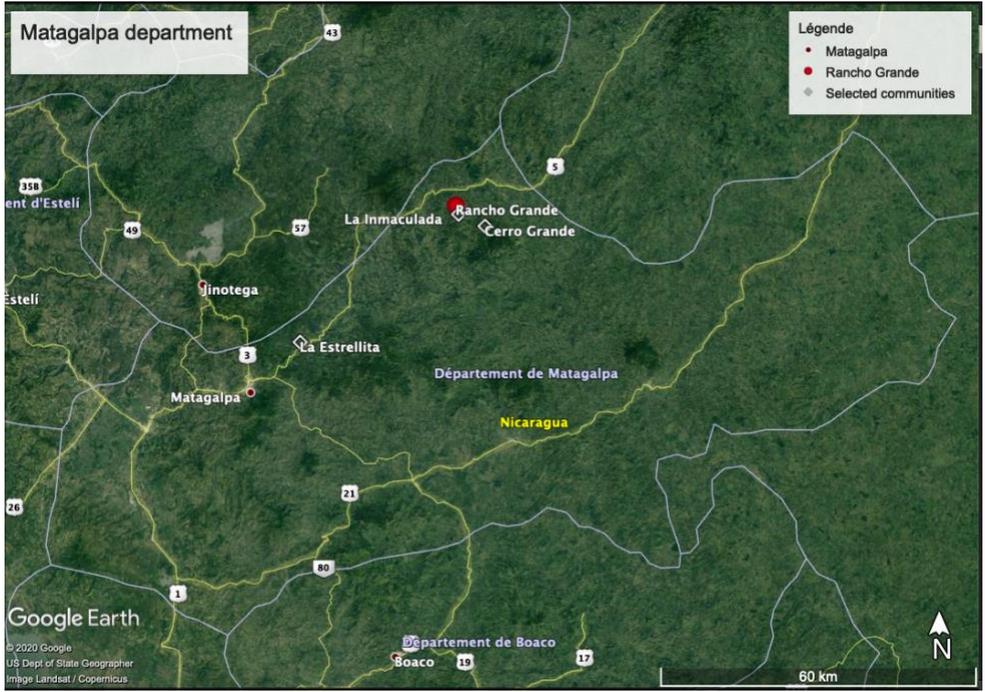


FIGURE 4: LOCALIZATION OF THE SELECTED COMMUNITIES WITHIN MATAGALPA DEPARTMENT. Axes in yellow represent the national roads. Source: (Google Inc., 2019)

With its important urban population and a good road connection to the capital city of Managua (130km in about two hours), Matagalpa represents a key commercial center for the large agricultural areas of the rest of the department. La Estrellita is situated only 18km from Matagalpa. Only one bus per day does the round trip from La Estrellita to the city center. Alternatively, community members can walk for 30 minutes to get to the main road where many buses pass every day. However, the road that they have to walk goes through a community

considered extremely dangerous (e.g. physical aggression, theft) and most people prefer to wait to get a ride to the main road to one of the few pick-up cars which drives there.

La Inmaculada and Cerro Grande are situated at 3,5km and 11km respectively from the village of Rancho Grande. In spite of this apparent short distance, access to the village from the communities was extremely difficult due to the terrible state of the road and the mountainous landscape. Since about a decade, one small bus was making the dangerous round trip once almost every day (depending on the rain) from Rancho Grande to a large coffee plantation higher-up on the road. People living in Cerro Grande reported that they would often do the trip by foot which would take them about two hours and a half, compared to 20mn to 50mn walking for the people living in La Inmaculada. With its small population, Rancho Grande is not capable of absorbing the agricultural products coming from the surrounding rural areas, but it has a relatively good road connection to Matagalpa (81km in about two hours) and thus to the capital of Managua.

*c) Climate*

The city of Matagalpa is located at an altitude of 830 masl and present an average temperature of 22,1°C with 1633 mm of precipitations per year on average. These environmental characteristics classify Matagalpa as having a tropical rainforest climate according to the Köppen categories. On the other hand, Rancho Grande, located at 770 masl, present an average temperature of 21,9°C with 2040 mm of precipitation per year, which classifies it as having a tropical monsoon climate. (Köppen, 1900; Hijmans *et al.*, 2005; Google Inc., 2019) Hence, the dry season is longer and more intense in Matagalpa than in Rancho Grande and the monthly average for precipitation is always higher in the latter (Figure 5). Thus, Matagalpa can be described as having an overall drier climate due to a lower rainfall regime over the year and a long dry season.

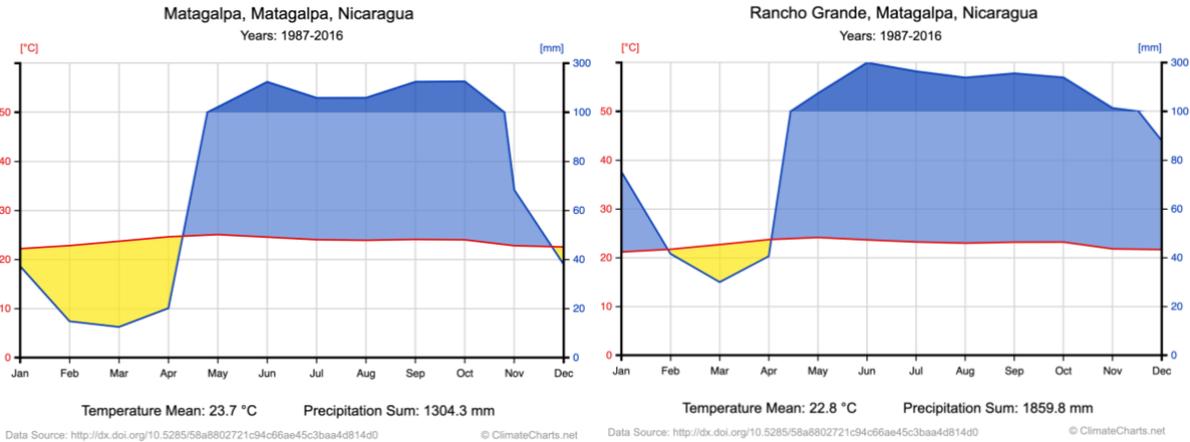


FIGURE 5: CLIMATE CHARTS FOR MATAGALPA AND RANCHO GRANDE. These charts are based on interpolated and simulated climate data for raster cells on the map with a resolution of 0,5°x 0,5° and thus do not represent the exact values for each city. The ratio between temperature and precipitation scale on the chart is 1:2. Above 100mm of precipitation per month, the scale above is aligned, ensuring that the chart doesn't become to miss-shaped. The yellow area corresponds to arid conditions, light blue to humid and dark blue to perhumid. Source: Harris and Jones, 2017

The hurricane season in Nicaragua goes from June to November and hurricanes typically enter the country through the Atlantic coast. Their characteristic strong winds and heavy rains (often causing flooding) can cause important damages to cities and infrastructures but also to forests and agricultural land. The hurricane which had the biggest impact in farmer's memories was the Hurricane Mitch of 1998 which were the deadliest hurricane in Central American history.

### 3.B.2. DESCRIPTION OF THE RESPONDENTS

---

Given its focus on coffee smallholders, the main inclusion criteria for this study were that the respondents should be coffee producers, sell at least a part of their production and own less than 5 hectares (i.e. 7 manzanas; Appendix C: Conversions) of coffee in total.

In the first phase of data collection, the population unit was the household defined as: “a group of people (normally family members) living under the same roof, and pooling resources (labor and income)” (CIFOR, 2007). Indeed, in Nicaragua, several families may live on the same piece of land while managing their financial resources separately as, by tradition, when a couple gets married, the wife moves to her husband's house until they can afford to have their own house, thus making the term household more appropriate than family. In the second phase of data collection, the population unit was the individual.

#### *a) Participants of the first phase of data collection*

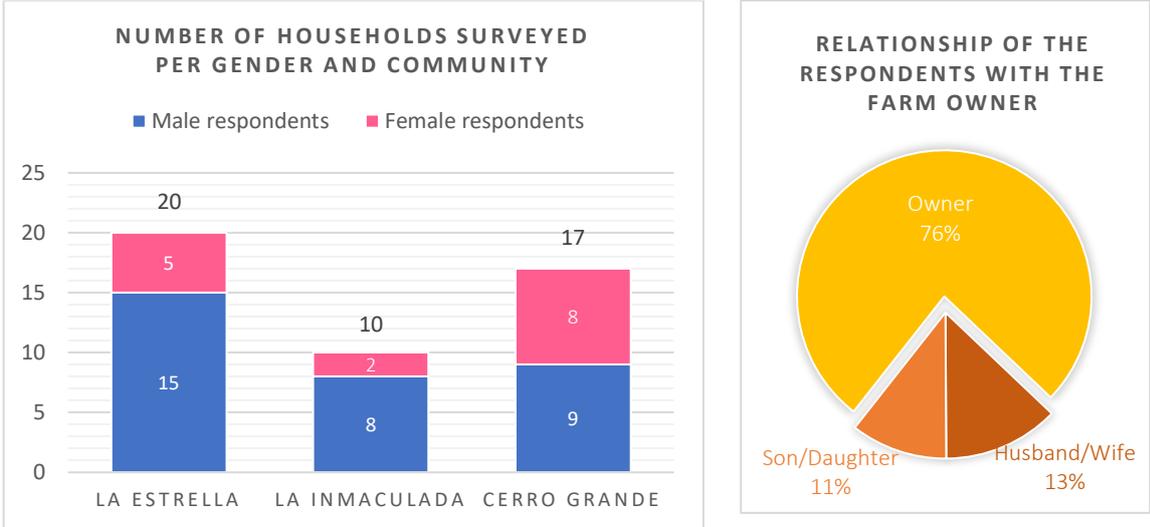
---

Prior to fieldwork, my objective for the first phase of data collection was to reach 30 households per community, based on conversation with Dr. P. Vaast who is part of the team which developed the protocol for the Shade Tree Advice Tool (Van Der Wolf *et al.*, 2016). However, it was not possible to obtain reliable information about the size of my sampling population nor a sampling frame in any of the communities. Hence, I arbitrarily decided to follow a systematic sampling strategy in which I would include every other household along the two sides of the road. If the household didn't grow coffee, I went to the first neighbor. If no one was home, I came back later. If the person refused to participate in the interview, I would go to the next household following the same sampling strategy.

In practice, the questionnaire has been carried out with a total of 47 households (Figure 5), as I did not manage to reach the intended sample size in any of the studied communities. In La Estrellita, following my sampling strategy along the main road resulted in fewer households surveyed than expected. Due to time pressure related to transport logistics as well as safety considerations towards venturing away from the main road, I did not carry extra surveys in this community. In La Inmaculada, I quickly discovered thanks to my host that the sampling population in this community was too small to apply my sampling methodology. Hence, I carried out a census based on the list of coffee smallholders made by my host, which only yielded 10 respondents (Figure 6). Finally, I arrived at Cerro Grande which appeared to be a bigger community, but with a smaller portion of coffee growers, thus making my sampling strategy irrelevant. Hence, my guide took me to people she knew were growing coffee. As I insisted that I wanted to talk to people with different backgrounds and situations, she took me

both to people involved in NFF projects and people she knew directly (mainly from church) and indirectly (through snowballing). This sample strategy can best be described as a convenience sample as respondents were chosen according to their ability of being contacted by my guide.

In total, about a third of respondents were women (Figure 6). Furthermore, three quarters of all the respondents were farm owners (Figure 7). This has a positive effect on the reliability of my findings as farm owners tend to be more knowledgeable about the coffee plots than other family members (Direct observation).



(on the left) FIGURE 6: NUMBER OF HOUSEHOLDS SURVEYED IN THE FIRST PHASE OF DATA COLLECTION, DIVIDED PER COMMUNITY AND PER GENDER OF THE RESPONDENT  
 (on the right) FIGURE 7: RELATIONSHIP OF THE PARTICIPANTS OF THE QUESTIONNAIRE WITH THE FARM OWNER

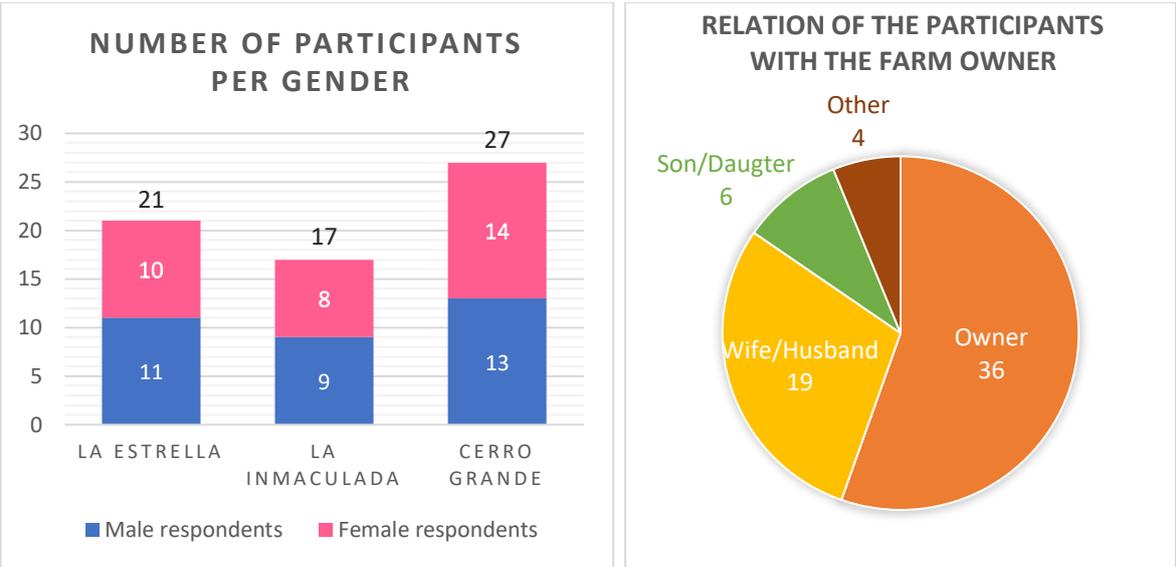
At the end of the first phase of data collection, three respondents were left out of the study sample due to the poor quality and quantity of the information they were willing to give (one in La Estrellita and two in La Inmaculada; Appendix B). In addition, one questionnaire from La Estrellita had to be discarded after the fieldwork due to missing information and poor quality of the corresponding audio recording.

*b) Participants of the second phase of data collection*

During the second phase of data collection, I returned to the households previously interviewed and asked to both a man and a woman (older than 18 years old) from the household if they would agree to participate to the ranking exercise. Due to time pressure, I did not return to the households where only one household member was present if he or she had accepted to do the ranking exercise.

In La Inmaculada, in six out of the 10 households where I returned, both a man and a woman from the same household did the ranking exercise whereas it was the case for only three out of 18 households In La Estrellita and two out of 25 households in Cerro Grande. In La Estrellita, there were three households where I couldn't return: two of them because no one was

home during the second period of data collection and one because the owner refused due to lack of time. Additional participants (i.e. which didn't belong to a household where I carried out the questionnaire) were interviewed when possible in order to obtain a larger sample. Additional participants were chosen through convenience sampling since they mainly include coffee farmers who were visiting a person that I was coming to do the ranking exercise with and farmers coming to the house where I was staying in the evening to visit my host. This yielded one participant in La Estrellita, one in La Inmaculada and eight participants in Cerro Grande. In total, I realized the ranking exercise with 65 participants and with a good balance between male and female respondents (Figure 8). More than half of the respondents were farm owners (Figure 9).



(On the left) FIGURE 8: NUMBER OF PARTICIPANTS IN THE SECOND PHASE OF DATA COLLECTION PER GENDER AND COMMUNITY

(On the right) FIGURE 9: RELATIONSHIP OF THE PARTICIPANTS OF THE RANKING EXERCISE WITH THE FARM OWNER. The Other category include farm owner's brother, son's wife and grandchild.

### 3.C. RESEARCH METHODS

#### 3.C.1. QUESTIONNAIRES

Questionnaires were selected as an appropriate and efficient method to collect information about coffee smallholders' socio-economic profile and coffee AFS. Indeed, they allow for the collection of data in a standardized way, thus making it possible to draw comparisons between different households within and across the selected communities. Questionnaires were used to collect both quantitative and qualitative data as they were composed of both closed and open questions to allow some space for dialogue and avoid misleading answer choices.

Before each questionnaire, I stated the aim of the research and affiliation to the University of Copenhagen. I also gave an approximation of the time that would be needed and explained that the results will be anonymous. Respondents were asked to sign a consent form

and were explained that I would come back later for the second phase of data collection, but that participation was always voluntary. The consent form, formerly presented before the start of the questionnaire, was moved to its end after pilot-testing because two out of four respondents formulated doubts that I was not a student but a government agent and the other two also showed signs of doubts and mistrust in their facial expressions when I asked for their signature. Presenting the consent form at the end allowed respondents to get a better understanding of the objectives of my research and proved that I was not there to collect overly sensitive information.

In addition, the socio-economic section of the questionnaire got reduced and spread out across the different sections after pilot-testing to avoid generating a feeling of mistrust. The final questionnaire in Spanish is presented in Appendix D. It is composed of four sections. The first section includes general information about the respondent such as his relation to the owner of the farm, his age, the number of people living in the household and their involvement with NFF or other institutions. The second section called farm description includes information specific to the coffee plot (e.g. area, yield, previous land use, distance from the household, pest and diseases, shade establishment), general information about the farm (e.g. farm diversification, soil quality, erosion) and some general socio-economic information about the household (e.g. who is taking decisions, do they employ farm workers, how long have they been living in the area, etc.). The third section is composed of the shade tree inventory (see section 3.C.2. below) and some open questions regarding the consumption and sale of fruits, firewood and timber from the farm. The last section explores respondent's perception of some shade tree species, the ES and ED that derive from the shade component, and their vision for the future of their coffee AFS. More specifically, two open questions were used to capture their perception of the positive and negative impacts of shade trees, which can be translated as: "Why do you like to plant trees in your coffee plots?" and "Why wouldn't you like to plant too many trees in your coffee plots?". The spontaneously mentioned ES and ED were noted before engaging in a semi-structured dialogue where I would try to capture their perception of different ES and ED that they didn't mention. Then, respondents were asked which shade tree species they would recommend to a new coffee farmer and which species they would not recommend. Shifting the focus to an imaginary external farmer resulted useful to gain an honest insight on farmer's perception of shade tree species, separated from the respondent's own situation. Finally, respondents were asked if and how they would like to change the shade tree species composition of their coffee plot and if they would like to reduce, maintain or extend their coffee AFS in the future.

---

### 3.C.2. TREE INVENTORY

---

Shade tree inventories were conducted as part of the questionnaires. As I did not have the sufficient knowledge to identify all of the shade tree species of the study area, the shade tree inventory consisted in asking respondents to recall the species present in their coffee plot. When the respondent could not recall more species, I stimulated the conversation by enumerating local species that were not mentioned, especially remnant forest species, which helped respondents to understand that I was not only interested in purposefully planted shade trees. The different

species were recorded by their local name and spontaneous additional information was recorded in a dedicated section of the questionnaire. I didn't systematically visit the coffee plot to realize the tree inventory because NFF staff and various community members strongly recommended that I should not go out to the coffee fields for safety reasons. Nonetheless, the house was located inside the coffee plot in a majority of cases. Admittedly, basing tree inventories on respondent's knowledge and memory is a non-negligible source of bias in my results and should be considered during the interpretation of the collected data.

Species' scientific name was identified by cross-checking the information from a various sources focusing on Nicaraguan biodiversity (*Nombres científico y comunes de plantas de interés para la exportacion*, no date; Schibli, 1999; Garcia Roa, 2003; Zúñiga, Somarriba and Sánchez, 2004; Grijalva Pineda, 2006). The scientific name of all the species which were selected for the ranking exercise and of some species of interest was then confirmed with the expertise of a forest engineer from NFF. However, it should be noted that in a few cases, respondents referred to a group of species by using a single local name and thus the corresponding individual species could not be separated during data analysis (Text box 4). Hence, I recognize that this method of species identification constitutes a potential threat to the internal validity of the present study.

#### TEXT BOX 4 : REFLECTIONS ON SPECIES IDENTIFICATION

Due to a lack of knowledge of the diversity of fruit tree species of the study area, I didn't know until the end of the first phase of data collection that the terms *limon* and *naranja* mentioned by respondents corresponded to several species and not one. Hence, it is important to note that in this study, *Citrus* spp. '*limon*' includes *limon agrio* (*Citrus aurantiifolia* (Christm.) Swingle), *limon dulce* (*Citrus medica* L.), *limon mandarina* (*Citrus limon* (L.) Osbeck) and *limon tahiti* (*Citrus × latifolia* (Yu.Tanaka) Yu.Tanaka). Similarly, *Citrus* spp. '*naranja*' includes *naranja agria* (*Citrus × aurantium* L.) and *naranja dulce* (*Citrus sinensis* (L.) Osbeck).

The banana is identified as *Musa* spp. '*banana*' because several types of bananas were mentioned by respondents, namely: *patriota*, *caribe*, *caribe roja*, *cuadrado*, *quiniento* and *datil*.

In addition, I would like to point out that I am unsure that respondents could clearly distinguish between the different species of the *Inga* genus and *Erythrina* genus.

---

### 3.C.3. GPS MAPPING

GPS coordinates were recorded throughout fieldwork with a Garmin GIS device. When the tree inventory was carried in the coffee plot, the GPS point was taken inside the coffee plot, otherwise it was taken in the house where the questionnaire was carried out.

---

### 3.C.4. RANKING EXERCISES

The ranking exercise is a central part of the methodology developed for the construction of the Shade Tree Advice Tool and revised by Rigal, Vaast, and Xu (2018). Based on a participatory approach, its aim is to integrate local knowledge into recommendation making for shade tree species in agroforestry systems while taking into account the local climate, context and needs. Ranking trees according to their use can also highlight whether

people rely on a few multi-purpose trees, or whether they rely on a diversity of specialized trees. The ranking exercise consisted of four questions which were asked orally:

1. Identify a maximum of 10 shade tree species that you know best out of the list of most abundant species in your community;
2. Rank the 10 ES and tree attributes according to their importance for the adoption or retention of a shade tree species in your coffee plot;
3. Rank the 10 species that you selected according to each of the 10 ES and tree attributes;
4. With all that we have discussed in mind, rank the 10 species that you selected according to your own preference.

In addition, respondents were asked if the 10 selected species were capable of natural regeneration or if they had to be sown or planted and if they thought that any of the selected species had an influence on the occurrence of pest and diseases. Both the rankings and participant's comments were recorded by hand in a matrix which can be found in Appendix E.

Based on a pre-analysis of the questionnaire, the 10 most locally relevant ES and tree attributes for shade tree species selection were identified. Each ES and tree attribute were written in big letters on small plastered cards and illustrated by a picture to avoid misunderstanding (Appendix F). Here, it was important to be very specific for each ES and tree attribute about whether the ranking was about the potential use-value (quality), or about the actual use (frequency, quantity) (Gausset, 2004). As it is based on my results, the selection process of the ES and tree attributes for the ranking exercise will be explained in further details in the Results section below, together with a specification of the type of ranking (i.e. potential use-value or actual use) for each category.

Similarly, the 30 most abundant shade tree species were identified in each community. In La Estrellita, 32 species were selected as the 30<sup>th</sup> place was shared by several species. In La Inmaculada and Cerro Grande, too many species shared the 30<sup>th</sup> place so both lists were reduced to 29 shade tree species. As for the ranking categories, A5 plastered cards were realized for each shade tree species to avoid any confusion between different species. These cards included the local name of the species in big characters and clear recognizable pictures of species' characteristic features such as the tree's shape, bark, fruits, flower and leaves (some examples can be found in Appendix F). All cards were displayed to the respondent, either on a table or on the ground, and all names were read out loud at least one time (Figure 10).



FIGURE 10: PICTURES OF RANKING EXERCISE PARTICIPANTS

---

### 3.C.5. PARTICIPANT OBSERVATION

---

Bernard (2017) describes how participant observation allows the researcher to experience the lives of the study participants and to look into some of the non-verbal aspects of social life. Additionally, Bernard underlines how participant observation is a bodily investment, which demonstrates a sincerity towards the informants you work with. Indeed, by participating and taking an active part in the daily activities my presence in the field became less and less awkward while I was still walking around conducting questionnaires and ranking exercises with a clipboard in hand.

Thanks to the support of NFF, I was able to be hosted in coffee smallholder's house during most of the data collection period. Thus, I was able to spend a lot of time interacting with coffee smallholders and to participate to my host's daily activities such as cooking or feeding chicken. More importantly, participant observation was also carried out with other farmers than my hosts, including activities such as sowing maize, spading vegetables beds and going by foot to projects' meetings. Participating to these activities proved to be a good way to quickly improve the perception that community members had of me and to lose my anonymity in the community. They also represented an excellent occasion to engage in more personal and in-depth conversations.

---

### 3.C.6. INFORMAL CONVERSATION AND DIRECT OBSERVATION

---

As Bernard (2017) argues, conducting questionnaires is a, “*great way to find out what people think they do. When you want to know what people actually do, however, there is no substitute for watching them [...].*”

Direct observation and informal conversations were used to collect qualitative data throughout the data collection period in order to better interpret surprising and conflicting

results during the analysis phase. Often, after the questionnaire or ranking exercise sheets were put away, people would spontaneously engage in a more relaxed conversation which was the occasion for me to get a good insight about their constraints, worries and aspirations by listening to both the questions they would ask and the answers they would give me. Informal conversations with NFF staff members during the preparation phase of my fieldwork were also useful to get a better understanding of the field.

On one hand, doing direct observation in the field make room for taking detailed notes, but on the other hand, the more you are taking notes, the more people will be aware of your gaze, and show only what they want to show (Bernard, 2017). Hence, a good balance must be struck between detached observation and note taking. Notes were recorded directly in dedicated spaces on the questionnaire and ranking exercise forms or in my field notebook. Both explicit and implicit information was recorded and distinguished as well as who were the persons present and/or participating at the time of the conversation in order to provide context.

---

### 3.C.7. FIELD ASSISTANTS

---

Following the advice of NFF and my host families, I was accompanied by a field assistant during both phases of data collection for safety reasons. Most of the time, the field assistant would simply walk with me so that I was not alone and occasionally helped by asking the questions to the farmers. Although I can speak Spanish fluently, the field assistants were also of precious help when someone couldn't understand my accent or the vocabulary I used. Furthermore, arriving to farmer's households with someone from the community, or at least a neighboring community appeared to have a positive impact on the way respondents perceived me. In addition, some of my field assistants could indicate to me who a specific coffee field belong to, show me the coffee field of a specific person and/or indicate the best time and day to visit the different households to make sure we encountered someone at home. Nonetheless, it may have created a bias in my result as different guides accompanied me in the 3 different communities.

In particular, during the ranking exercises in La Inmaculada, I was guided by a 20-years-old-student in journalism who was asking the questions most of the time. Although it drastically improved the fluidity of the exercise, this advantage should be considered a potential source of bias in my results as I was able to note down more observations than when I was leading the exercise myself.

In addition, in Cerro Grande, my host became my field assistant due to availability issues with the person supposed to guide me. As I was staying with her, she felt very confident with me and was very relaxed during the interviews, intervening many times to make jokes or talk about a different subject. Because she knew so many other women, many of them accepted to do the questionnaire although the farm owner was working out in the field. This means that I obtained a higher percentage of female respondents in Cerro Grande than in the two other communities. People, in particular women, who showed a lack of confidence in their answer, would also sometimes ask for her advice on certain questions, thus obliging me to intervene and remind them that there were no right or wrong answer and that I was interested in their own

perceptions of the subject. Although her presence and behavior may have granted me access to information I might not have had otherwise, it should be considered when comparing data from the three communities.

It is important to acknowledge these discrepancies in the sampling method as they constitute potential threats to the internal validity of the study.

### 3.D. DATA ANALYSIS

---

After I returned from the fieldwork, the data collected through the questionnaires was entered in an Excel document. For the quantitative data, mean, standard error and, when relevant, median were calculated for descriptive statistics. Analysis of Variance (ANOVA) ( $\alpha=0,05$ ) was used to compare the means (by hypothesis testing) of the three communities. A Levene's test (based on the median;  $\alpha=0,05$ ) was used prior to the ANOVA to test for the homogeneity of variances between the three samples. If the test revealed heterogeneous variance, a two-tailed two sample T-test for unequal variances ( $\alpha=0,05$ ) was conducted for each pair of samples. After conducting an ANOVA, if the null hypothesis was rejected, a Tukey Honestly Significant Difference test (Tukey HSD test; ( $\alpha=0,05$ )) was used to identify where the difference between the means was the largest.

In addition, an indicator of household's economic status was calculated on Excel using a K-means clustering method. The total farm area, the ownership of cattle and the employment of workers for coffee maintenance (in man-days) was selected through direct observation and informal conversation before being discussed with community members and NFF staff who confirmed their relevance and representativeness for evaluating household's economic status. All variables were rescaled using a Min-Max feature scaling and a weighting factor of three was applied to the total farm area which were designated as more important in discussions.

Coding was used during the pre-analysis of smallholder's perception of ES and ED. Respondent's answers were put into ES and ED categories and attributed a score from 0 to 3 to calculate an average. However, putting farmer's answers into categories felt like distorting their words so the analysis method was abandoned. Instead, I counted how many respondents mentioned a benefice or disadvantage they obtained from trees without trying to categorize their answer into ES and ED, which yielded results that were more in line with the reality I had observed.

Such count data was presented in contingency tables and a Pearson's Chi-square test was used to test the independence between the studied communities and the variable of interest. If at least one of the values of the contingency table was lower than five, A Fisher's Exact Test was used as it is suitable for smaller data sets. When the Fisher's exact test detected that the variable was not independent from the communities, the contingency table was reparametrized into three 2x2 contingency tables, comparing each community against the sum of the others. Fisher's exact tests were conducted on each of the new tables to determine which community was responsible for the difference observed.

The results of the shade tree inventories were analyzed using the BiodiversityR package on R (Kindt, 2019). This package allowed me to calculate an estimation of the total species richness in the study area (using the first- and second-order Jackknife, Chao and bootstrap formulae), produce species accumulation curves for each community and for the study area. Multiple regression analysis was also carried out through this package in order to identify the independent variables which have an impact on farm species richness as well as certain shade tree use categories. All of the continuous variables were rescaled using a min-max normalization and multiple correlation coefficients were calculated preliminarily in Excel to avoid multicollinearity. The negative binomial model was used as it takes into account clumping in the data and thus is recognized to be suitable for ecological data analysis. To start with, the multiple regression analysis was carried out with all the independent variables. Then I sequentially removed the variables with the highest p-value (corresponding to the F-test for the ANOVA output) until I only had variables with p-values smaller than 0,1. If a variable was found to be significant at some point during the variable selection process, this variable was kept in the final model, even if it latter showed a p-value higher than 0,1 in order to account for issues related to deviance. The negative binomial model does not provide the R-squared parameter; hence, a goodness-of-fit parameter was calculated using the following formula:

$$\text{Goodness-of-fit} = 1 - (\text{residual deviance} - \text{null deviance})$$

The coffee AFS coordinates were uploaded to and analyzed in ArcMap. The points coordinates were converted to shapefile and uploaded to ArcMap using the coordinate system WGS84. I used the GADM shape file as a cutting tool to delineate the country borders of Nicaragua. I then used USGS tif file for altitude analysis, CHELSA bioclim 1, 5 and 6 for temperature and CHELSA bioclim 12 for precipitation. Altitude, precipitation, average annual temperature, average temperature of the coldest month and average highest temperature for the warmest month were calculated by the ArcMap Spatial Analyst tool Value to Points. The calculation was run for each of the five variables. However, the obtained values seemed doubtful and did not correspond to the maps. Thus, they were left aside, and the altitude were recorded from Google Earth. The maps obtained from ArcMap were used to get intervals of the yearly precipitation.

The qualitative statements regarding individual shade tree species were recorded into Excel spread sheets in order to structure the data by species. The rest of the qualitative data recorded were transcribed into a Word document to allow for word search. Qualitative statements were used as quotes to confirm or nuance the results of the quantitative analysis.

Ranking data, including both the ranking of tree species and the ranking of ES and tree attributes, were analyzed through the BradleyTerry2 package on R (Rigal, Vaast and Xu, 2018) which is designed to analyze ranking results which include ties in partial rankings. In rankings, items are scored relative to the other items which make their score useful only in pair-wise comparisons. The Bradley Terry analysis yielded combined ranking estimates for each ranked item as well as p-values from Wald comparison tests to indicate if the difference between each ranking estimate is significantly different or not. The ranked items were plotted according to a combination of their ranking estimate and the size of their confidence interval to account for

the fact that some items were ranked only by a few farmers. A decision rule was used to group rank items based on their ranking estimates. A first group was created by starting with the highest ranked item on the plot. The next item was included in the group if its ranking is not significantly different from the first item in that group. If there was a significant difference, a new group was created after which the procedure was repeated. Groups were then labeled 'high', 'medium' or 'low' and a color code was attributed to each label to make the interpretation and comparisons of rankings easier and visual.

---

## CHAPTER IV: RESULTS

---

This chapter follows the structure of the research objectives, beginning with a presentation of the socio-economic characteristics of the coffee smallholders in the study area and their AFS. Then, drawing upon both the questionnaire data and the ranking exercises, farmer's perception, knowledge and preferences of ecosystems services and shade tree species will be explored. Finally, the last section will focus on identifying which are the factors influencing shade tree species adoption in the study area.

### 4.A. DESCRIPTION OF THE COFFEE AGROFORESTRY SYSTEMS

---

#### 4.A.1 CHARACTERIZATION OF COFFEE SMALLHOLDERS

---

##### *a) Socio-economic aspects*

---

Across the three studied communities, coffee farm owners appeared to be relatively young with a mean of about 45 years old and a positive skew in the data (Table 2). According to a t-test for unequal variances, respondents from Cerro Grande had been living on their land for a significantly shorter period (Mean=9,7 ± Standard deviation=6,5; p=0,005) than respondents from La Estrellita (17,1 ± 7,7). This corresponds to my observations as many houses in Cerro Grande were newly built. No significative difference was found between respondents from La Inmaculada (15,7 ± 13,1) and the other communities.

TABLE 2: STATISTICAL DESCRIPTION OF THE HOUSEHOLD'S SIZE, FARM OWNER'S AGE AND THE TIME THAT HOUSEHOLD MEMBERS SPENT LIVING IN THE AREA.

<i>Unit</i>	<b>Houshold size</b> <i>persons</i>	<b>Farm owner's age</b> <i>years</i>	<b>Time spent living in the area</b> <i>years</i>
Mean	4,5	45,3	14,0
Standard deviation	2,0	14,7	9,4
Median	4	44,5	12
Kurtosis	1,5	-0,4	-0,5
Skewness	1,0	0,5	0,6
Minimum	1	21	1
Maximum	11	82	38

Out of the 46 farms surveyed, eight were officially owned by a woman. Four of these were single and managed the farm on their own, while the other four was married and managed the coffee farm together with their husband. From observations, the majority of women spent their days taking care of household chores while the men were out in the coffee fields from early morning to mid-afternoon. Women were involved in coffee harvesting, together with other household members, such as children, and some women reported to participate to weeding activities when they had completed their household duties (Informal conversation).

According to respondents, in more than half of the farms visited, the man of the family was the only one taking decisions regarding the management of the coffee plots whereas women were only in charge of these decisions when there were no adult men in the family (Figure 11).

There was at least one person working on their own farm in all of the household surveyed. On average, 43% ( $\pm 22\%$ ) of all household members were working on their own farm. This percentage refer to the entire household rather than only the adults (i.e. over 18-years-old) because, in several cases, respondents reported more farm workers than adults in the household as teenagers would also participate to the farm activities.

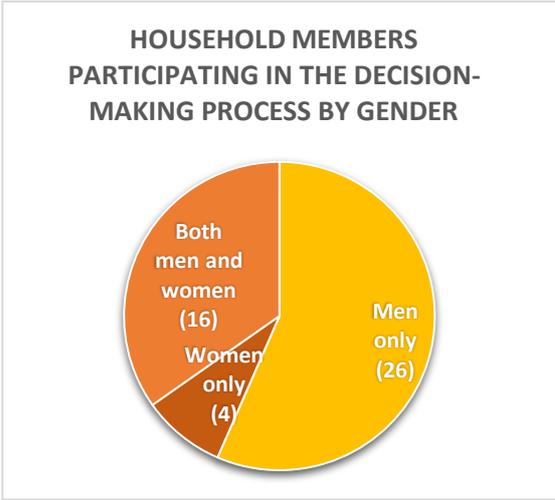


Figure 10: GENDER OF THE HOUSEHOLD MEMBERS PARTICIPATING IN THE DECISION-MAKING PROCESS REGARDING COFFEE CULTIVATION. Numbers in parenthesis represent the number of households for each category.

Regarding off-farm activities, there was at least one person with a job outside of the farm in 29 out of the 46 households surveyed, representing on average 19% ( $\pm 18\%$ ) of the household members. Nearly two thirds of these paid jobs were related to coffee production (Figure 12). Indeed, one out of two people recorded as having a paid job was employed as farm worker on someone else’s coffee farm to realize planting, weeding, pruning, spraying and harvesting. In most cases, these seasonal workers would seek employment during peak season and work on their own farm the rest of the time, thus leaving their own farm unattended at the time when it requires the most labor (Informal conversations). However, according to a t-test, there were no significant difference in the coffee yield between households which had or didn’t have members employed as seasonal workers in coffee production. People with permanent jobs related to coffee worked for the Cafetalera NicaFrance SA. Both jobs in the construction sector and jobs abroad appeared to be temporary jobs (rarely exceeding a year) that people would see as a way to increase the household’s savings (Informal conversation). *Ventas* are small shops that people build on their land, often as part of their house, where they sell all kinds of products for daily life, often including plantain and bananas and sometimes other fruits and vegetables.

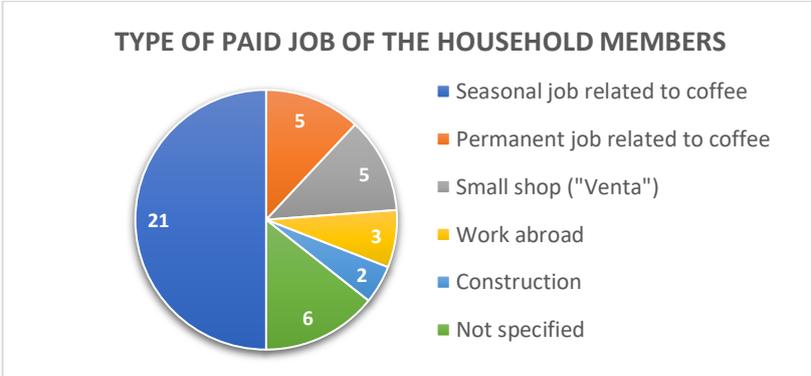


FIGURE 11: TYPE OF PAID JOB OF HOUSEHOLD MEMBERS. Numbers represent the number of household member reported by respodnents for each type of paid job in the study area.

In the study area, 16 respondents out of 37 stated that they did not employ workers for coffee management (i.e. shade trees pruning, coffee plants pruning, weeding and spraying). In addition, one respondent had 2 permanent employees and one old man had an employee who was living in a house in the coffee plots with his family and was allowed to collect non-timber forest products (NTFP) and cultivate some land in exchange of his work. On average, if we exclude the households employing permanent workers, farm owners who had employees for coffee maintenance employed workers for 67 man-days per year ( $\pm 63$ ).

As mentioned in the method section, a typology of coffee smallholders' household was calculated based on their economic status. The typology was constructed using the following variables: total farm area (weighted by three), coffee plot area, ownership of cattle and employment of workers for coffee maintenance (in man-days). An overview of the three clusters identified is presented in Table 3.

TABLE 2: TYPOLOGY OF COFFEE SMALLHOLDERS BASED ON THEIR ECONOMIC STATUS.  
The format used is Mean  $\pm$  standard deviation.

<i>Units</i>	<b>n</b> <i>persons</i>	<b>Farm area</b> <i>ha</i>	<b>Coffee plot area</b> <i>ha</i>	<b>Land dedicated to coffee production</b> <i>% of farm area</i>	<b>Employees for coffee maintenance</b> <i>Man-days</i>	<b>Respondents owning cows (number of cows owned)</b> <i>Persons (cows)</i>
Lower economic status	19	1,3 $\pm$ 0,9	0,8 $\pm$ 0,5	74 $\pm$ 27	7 $\pm$ 16	0
Average economic status	21	4,4 $\pm$ 1,3	2,8 $\pm$ 1,4	65 $\pm$ 27	74 $\pm$ 105	3 (2,7 $\pm$ 1,2)
Higher economic status	6	11,6 $\pm$ 2,3	3,2 $\pm$ 1,0	29 $\pm$ 12	105 $\pm$ 72	4 (4,5 $\pm$ 2,5)

### *b) Sources of knowledge*

Three variables were used to understand respondent's sources of knowledge regarding coffee cultivation: the time they spent cultivating coffee, the fact that received training on coffee cultivation and their involvement with a local organization or institution.

On average, respondents said to have spent 11,8 years cultivating coffee ( $\pm 10,6$ ; Median=8). There were a lot of variation in respondent's answer as values range from 2 to 40 years. According to an ANOVA, no significative difference was found between the three communities.

A large number of organizations and institutions are active in the study area (Table 4). Secondly, according to a Fisher's exact test, the fact that respondents received training in the past from an institution or organization is not independent from the community they live in ( $p=0,001$ ). Indeed, respondents from Cerro Grande received significantly less training on coffee production than respondents from the other communities (Fisher's exact test;  $p<0,001$ ). Furthermore, less organizations and institutions were present in Cerro Grande than in the other communities (Table 4).

TABLE 4: NUMBER OF HOUSEHOLDS WHERE AT LEAST ONE MEMBER RECEIVED TRAINING ON COFFEE CULTIVATION FROM AN ORGANIZATION OR INSTITUTION PER COMMUNITY

Name	Type	La Estrellita	La Inmaculada	Cerro Grande
<b>NicaFrance Fundacion</b>	Private foundation	10	2	3
<b>INTA</b>	National Institution	6		
<b>INATEC</b>	National Institution	4		
<b>Cristo Cafe</b>	Private company	3		
<b>Exportadora Atlantic S.A.</b>	Public company	2	1	
<b>ADDAC</b>	Non-profit organization		2	1
<b>Cooperativa</b>	Association		2	
<b>MAG-FOR</b>	Ministry of Agriculture	1		
<b>UNICAFE</b>	Association		1	
<b>CATIE</b>	National Institution (Costa Rica)		1	
<b>Aldea Global</b>	Association		1	
<b>CISA Exportadora</b>	Private company			1
Number of organizations and institutions represented		6	7	3
None of the household members received training		5	3	14

The most prevalent projects implemented in the study area were two of NFF's projects: Insetting and Matagalpa Agroforest Resilient Landscape program (MATRICE) (Figure 13). The Insetting project aims to offset the carbon emissions of the farm investors by planting 13,728 trees (Penot, Snoeck and Vagneron, 2017). These trees are distributed to small- and medium-scale coffee producers who are part of the project and NFF takes care of the monitoring of trees growth and carbon sequestration. The MATRICE project is implemented with coffee farmers who are part of the Insetting project and consists of the establishment of coffee agroforestry system on bare land (i.e. with no trees). About 20% of the respondents in each community were involved in this project (Figure 13). MATRICE provides coffee growers with coffee plants of the Marsellesa variety, technical support and shade tree seedlings including timber trees (e.g. *Platymiscium pinnatum*) and fruit trees (e.g. lemons (*Citrus* spp. 'limon'), oranges (*Citrus* spp. 'naranja') and mandarins (*Citrus reticulata*)). Inputs and labor cost are also covered by the program. The debt is progressively reimbursed by the producers to the Trust through a system of payment with part of the coffee harvested.

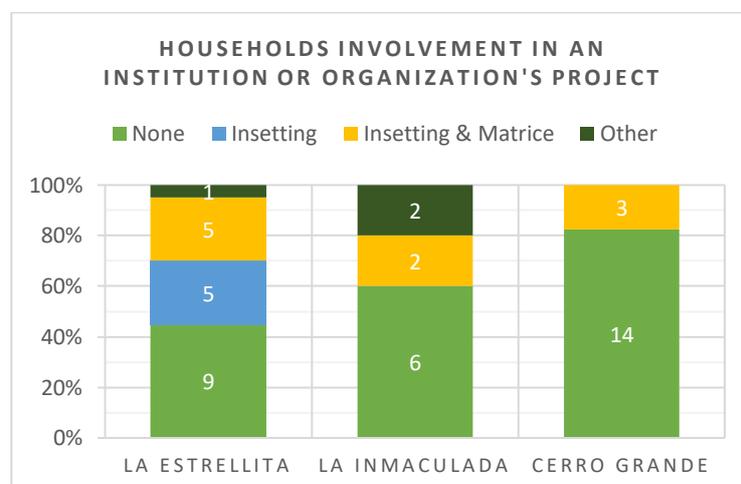


FIGURE 13: PERCENTAGE OF HOUSEHOLDS INVOLVED IN A LOCAL INSTITUTION OR ORGANIZATION'S PROJECT. The numbers indicate the exact number of households for each category

In addition, three households were involved with different organization or institution (Figure 13). In La Estrellita, one farm had been chosen to be a research farm for the Nicaraguan Institute for Agricultural Technology (INTA) with the aim of serving as a test ground for innovative sustainable agroforestry practices and promote the successful practices in the area through farmer-to-farmer teaching. Nonetheless, according to the farm owner, other farmers did not show interest in putting the effort to learn about organic agriculture, which jeopardized the farm’s vocation of being an educational center (Appendix G: Qualitative Data).

In La Inmaculada, one farmer was involved with the *Asociación para la Diversificación y el Desarrollo Agrícola Comunal* (ADDAC), promoting a sustainable, organic, local and commercial agricultural development for disadvantaged socio-economic groups in the north of the country. ADDAC provided training, free tree seedlings and seeds and financial services and also promoted the local dissemination of knowledge. Another farmer was a member of Aldea Global, an association with focus on coffee production which aims to the social, economic and sustainable development of rural families. With Aldea Global, this farmer received free tree seedlings and training on the financial aspects of farm management and sustainable coffee production.

*c) Main problems with coffee production*

Overall, the main problems that respondents faced with coffee production were pest and diseases, the price of inputs and the low price of coffee on the market (Figure 14). There was no significative difference between the three communities regarding the main problems that farmers mentioned except for the lack of capital (Fisher’s exact test;  $p=0,02$ ) which was significantly more important in Cerro Grande than in the two other communities ( $p=0,02$ ).

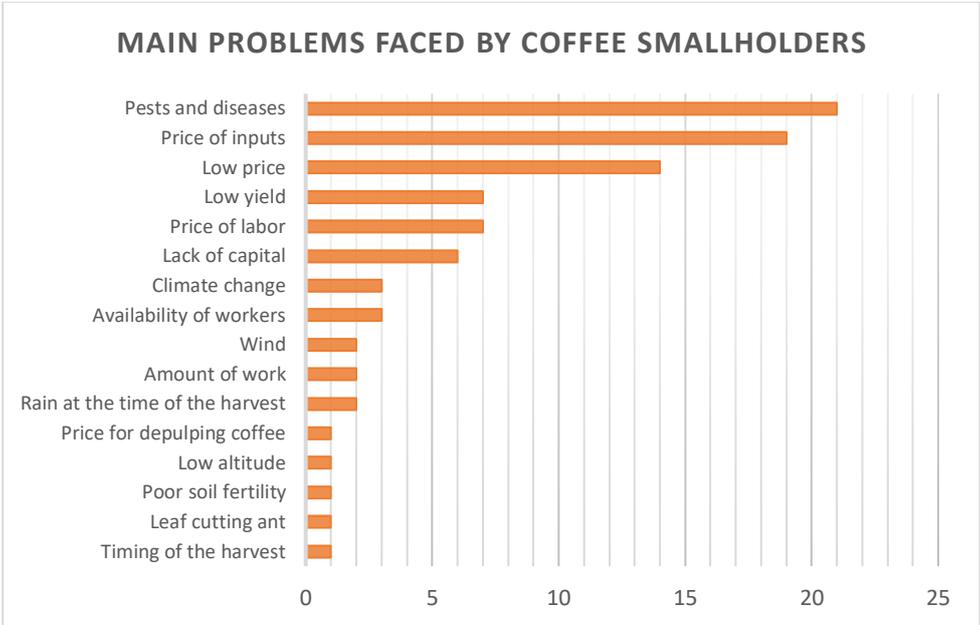


FIGURE 14: FREQUENCY OF MENTION OF THE MAIN PROBLEMS FACED BY SMALLHOLDERS WITH COFFEE CULTIVATION

Respondents reported that their coffee was affected by six pest and diseases which are reported in Table 5.

TABLE 5: COFFEE DISEASES ENCOUNTERED IN THE STUDY AREA. Source: Muller *et al.*, 2009

English name	Local name	Causal organism	Type of organism
American Leaf Spot	Ojo de Gallo	<i>Omphalia flavida</i> Maubl. and Rangel	Fungus
Coffee Berry Borer	Broca	<i>Hypothenemus hampei</i> Ferr.	Insect
Coffee Leaf Rust	Roya	<i>Hemileia vastatrix</i> Berk. and Br.	Fungus
Coffee Berry Disease	Antracnosis	<i>Colletotrichum kahawae</i> Waller and Bridge	Fungus
Kaleroga	Pellejillo	<i>Pellicularia koleroga</i> Cke.	Fungus
Leafcutter Ant	Sampopo	<i>Atta</i> sp. or <i>Acromyrmex</i> sp.	Insect

Overall, more than half of the respondents reported that their coffee was affected by the American leaf spot and the coffee berry borer (Figure 15). There was a significant difference in the occurrence of American leaf spot between the three communities, with the lowest occurrence at the lowest altitude and the highest occurrence at the highest altitude. Moreover, there were significantly less occurrence of the coffee berry disease in Cerro Grande and significantly more kaleroga in La Inmaculada than in the other communities.

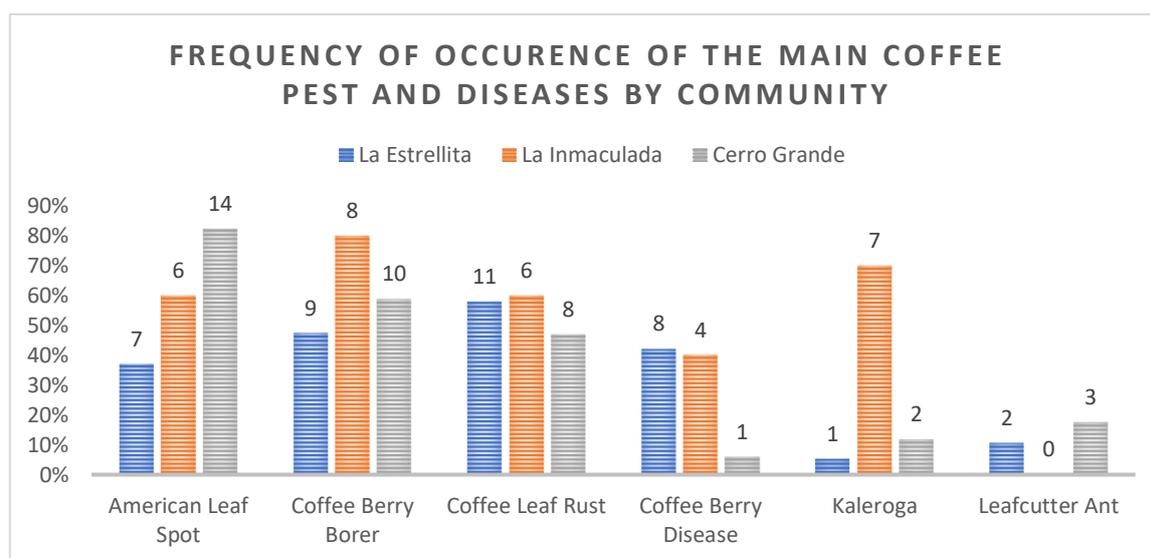


FIGURE 15: PERCENTAGE OF RESPONDENTS IN EACH COMMUNITY WHO REPORTED THAT THEIR COFFEE WAS AFFECTED BY A GIVEN DISEASE OR PEST

#### 4.A.2 FARM DESCRIPTION

All of the coffee plots included in this study were located between 615 and 990 masl (Table 6). There was a smaller amount of precipitations over the year in La Estrellita compared to the other communities. ArcMap maps of the yearly precipitations and altitude can be found in Appendix H.

TABLE 6: ALTITUDE, PRECIPITATION AND TEMPERATURE OF THE SELECTED COMMUNITIES. Source for altitude data: (Google Inc., 2019); for temperature (Appendix H); for temperature (Hijmans *et al.*, 2005)

Community	Altitude range of the coffee plots	Precipitation range	Average temperature
La Estrellita	700-880 masl	1600-2000 mm	22,1°C
La Inmaculada	615-810 masl	2000-3000 mm	21,9°C
Cerro Grande	720-990 masl	2500-3000 mm	21,1°C

Across the three communities, most of the coffee planted by the farmers was Catimor with a few occurrences of Caturra and Pacamara. In addition, as mentioned before, plots of the MATRICE project were planted with Marsellesa. Coffee plants are usually planted at a density of approximately 5000 to 5700 plants per hectare. The average size of smallholder's coffee AFS was 2,0 ha and represented about two thirds of the total farm area (Table 7). Interestingly, 12 out of 46 surveyed household had 100% of their farm dedicated to coffee production which makes this value the mode of the data set. The average yield in the study area was 1554 kilograms of parchment beans/ha ( $\pm 992$ ) or 1243 kilograms of green coffee/ha ( $\pm 794$ ) (Table 7). The extremely high variability of the coffee yields measured in this study, going down to 237 kilograms/ha, suggest that they may not be reliable.

TABLE 7: STATISTICAL DESCRIPTION OF THE FARM SIZE, COFFEE AFS SIZE, PERCENTAGE OF THE FARM DEDICATED TO COFFEE AND COFFEE YIELD

	Farm size	Coffee AFS size	Proportion of the farm dedicated to coffee	Coffee yield
Unit	ha	ha	%	Kilograms of green coffee per ha
Mean	4,0	2,0	64	1243
Standard deviation	3,6	1,4	29	794
Median	3,0	1,9	63	1012
Kurtosis	1,8	-0,7	-1,3	0,7
Skewness	1,5	0,7	-0,1	1,1
Minimum	0,4	0,2	8	237
Maximum	14,1	4,9	100	3537

On average, coffee plantations were 5,1 years old ( $\pm 2,7$ ) although in some cases the plantation age was unknown. Out of the 46 respondents, 24 established their coffee plot at one time, 6 in two times, 5 in three times, 8 in four times and more and 3 couldn't answer this question. Out of the 19 farmers who established their coffee plots in several times, 8 expanded their coffee AFS every year, 7 every second year and 4 every third or more.

Coffee plots were mainly established on agricultural land previously dedicated to maize and beans production, followed by forest and pasture with sparse trees (Table 8). Here, the term shrubland is used as a translation of the Spanish word *monte* which, in this context, refers to a vegetation dominated by tall grass and shrubs with young tree seedlings, usually occurring after a field is abandoned.

TABLE 8: PREVIOUS LAND-USE OF THE COFFEE AFS. This table does not include the coffee plots of the MATRICE project which are established on land with no trees. Five farms mentioned more than one previous land-use, hence the sum of number of farms and percentage are over 46 and 100% respectively.

Previous land use	Number of farms	Percentage
Maize and beans	14	30%
Forest	11	24%
Pasture with sparse trees	11	24%
Coffee	7	15%
Shrubland	3	7%
Banana	3	7%
Pasture with no trees	2	4%
Vegetables	2	4%
Cacao	1	2%
Do not know	1	2%

The Table 9 below describes farm diversification in the study area. In this paper, I refer to farm diversification as the number of farm activities, non-related to coffee, generating production for auto-consumption or sale (e.g. cows, basic grain, banana plot, etc.). This definition excludes both coffee production and the extraction of tree products from the coffee plots. While the majority of farmers had 10 chicken for their consumption, there was one farmer starting to produce chicken commercially who said to have on average 50 chickens on his farm.

TABLE 9: ON-FARM DIVERSIFICATION. 'N/A' stands for not available

Farm product	Number of households	Dedicated area (ha)	Mean number of units
Maize and beans	21	1,1 ± 0,7	N/A
Musaceae	8	N/A	N/A
Cacao	3	0,7 ± 0,5	N/A
Other high value crops	4	N/A	N/A
Forest	4	N/A	N/A
Chickens	28	N/A	11,9 ± 8,2
Pigs	12	N/A	2,1 ± 1,6
Cows	7	N/A	3,7 ± 2,1
Horses	3	N/A	1,7 ± 1,1

Out of 46 households, 17 had no other type of production than coffee on their farm, excluding the ownership of chickens and/or a single pig. Although owning a few chickens or a pig for household consumption is part of farm diversification, these criteria were considered as less relevant to describe farm diversification due to their variability throughout the year. Indeed, several respondents mentioned that they use to have chicken but that they got stolen recently. Similarly, it was a common practice to buy one pig some months before an important celebration, thus some respondents mentioned that they had a pig but already killed it or that they would eat the pig that they currently had in a few weeks.

### 4.A.3 SHADE COMPONENT OF THE COFFEE AGROFORESTRY SYSTEMS

#### a) Species richness

In total, 106 species were listed from the coffee AFS of the study area, excluding coffee, with 68 species listed in La Estrellita, 76 in La Inmaculada and 55 in Cerro Grande. The total list of species can be found in Appendix I where the botanical name (including author's name), local and common vernacular names and frequency of occurrence are presented.

As illustrated in Figure 16 below, the species accumulation curve for the study area does not flatten off for large number of sites, suggesting that the sampling has not captured all the species in the study area and that saturation has not been reached. This phenomenon is even more accentuated in the case of La Inmaculada for which the curve has not even started to flatten off due to a low number of respondents. The total species richness was estimated to range between 120 and 166 species for the study area. Given that 106 species were listed, we can estimate that the tree listing has captured between 64 and 88% of the local diversity. Looking at each community taken separately, the total species richness was estimated to be in the range of 79-100 in La Estrellita, 90-117 in La Inmaculada and 63-82 in Cerro Grande.

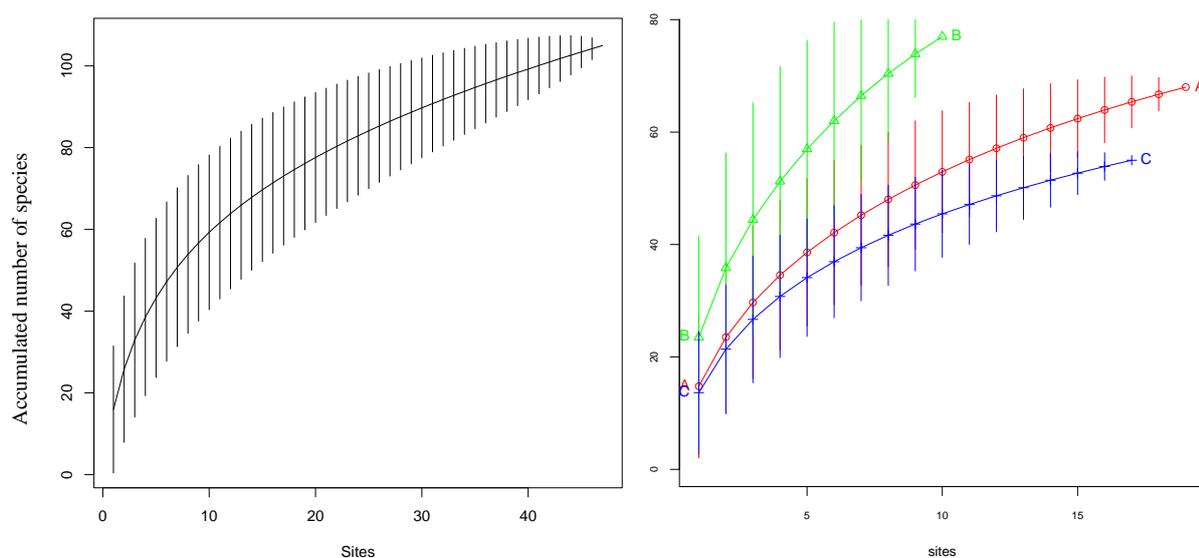


FIGURE 16: SPECIES ACCUMULATION CURVE PER FARM OF THE STUDY AREA (*on the left*) AND OF THE THREE COMMUNITIES TAKEN SEPARATELY (*on the right*). A (in red) stands for La Estrellita; B (in green) represents La Inmaculada and C (in blue) corresponds to Cerro Grande.

On average, 15,4 different species ( $\pm 7,6$ ) were found on each individual farm, with a minimum of three species and a maximum of 38 species listed per farm. There was a significant difference in the individual farm's species richness between the three communities ( $F(2,43) = 7,04; p=0,002$ ). Post hoc comparisons using the Tukey HSD test indicated that the farm's species richness in La Inmaculada ( $23,5 \pm 9,5$ ) was significantly higher than in La Estrellita ( $14,8 \pm 6,5; p=0,007$ ) and Cerro Grande ( $13,6 \pm 5,6; p=0,002$ ).

## b) Description of the species encountered

Most of the species listed with the help of the coffee smallholders were trees with the exception of the banana (*Musa* spp. ‘banana’), plantain (*Musa* sp. ‘platano’), pigeon pea (*Cajanus cajan*) and frijolillo (unknown species) which are all herbs cultivated for food and the castor-oil plant (*Ricinus communis*) which is a shrub used for its ability to produce shade rapidly. In this paper, the term shade tree species include all the species that were listed by coffee smallholders as providing shade for the coffee plants and thus also include the large herbs and shrub mentioned here.

The most represented botanical family were the Leguminaceae with 26 species followed by the Malvaceae (7 species); the Meliaceae and Rutaceae (6 species) and the Anacardiaceae and Lauraceae (5 species) (Appendix I). Nonetheless, in terms of species abundance, coffee AFS appeared to be dominated by *Musa* spp., which were usually planted with a spacing of 4x6 meters, and *Inga* spp. (Questionnaire, Direct observation).

Overall, there were twice as many native species than exotic species among the shade trees of the coffee AFS (Table 10). In the table below, only the principal use of the shade tree species is accounted for although it could be argued that most of these species can fit in several of these categories. Notably, most of the species appeared to serve for firewood when they were pruned for shade regulation or eliminated as young trees, hence it was regarded as a secondary use in most cases. The ‘service’ category corresponds to trees which are cultivated in association with coffee because of their shade and/or because they enhance soil fertility. There were roughly as many exotic than native service trees in the study area. Most of the exotic species were used for food. These exotic fruit trees species correspond to very common fruit trees which are widely distributed across the tropics, including three important cash crops: cacao (*Theobroma cacao*), plantain and grapefruit (*Citrus paradisi*). All exotic timber trees were of high quality. The exotic species that were put into the ‘other’ category are *Spathodea campanulata* which is an invasive species usually planted for its ornamental value and the *Cinnamomum verum* which is used as a spice. The native species which were put in the ‘other’ category include one species only used for firewood, one species used to make crafts, *Crescentia cujete*, one species of medicinal value, *Myroxylon balsamum*, and six species with no apparent use.

TABLE 10: NUMBER OF NATIVE AND EXOTIC SPECIES. Shade tree species in the coffee afs per main use category.

Main use	Fruit	Timber		Service	Other	Unidentified	Total
		High quality	Low quality				
Exotic species	20	4	0	5	2	N/A	31
Native species	14	13	28	4	9	N/A	68
Total	34	17	28	9	11	7	106

The list of the most abundant shade tree species in the study area which will be used thereafter includes 44 species of which 32 (73%) are native species (see Appendix J: List of selected species). It is composed of 16 fruit trees (36%), nine timber trees of high quality (20%),

11 timber trees of lower quality (25%), six service trees (14%) and two trees with no apparent use (5%).

### c) Shade establishment

Farmers were asked how they first established the shade component of their coffee AFS as part of the questionnaires. Their answers are summarized in Table 11 and categorized according to the previous land-use of their coffee AFS.

TABLE 11: METHOD OF SHADE ESTABLISHMENT ACCORDING TO THE COFFEE PLOT PREVIOUS LAND-USE. Numbers in parenthesis represent the number of respondents who reported to use the described method and species

Previous land-use	Method for shade establishment (Number of respondents)
Maize and beans or Vegetables	The year before: planted <i>Musa</i> spp. (5), <i>Inga</i> spp. (3), timber trees (2) At the same time as coffee plants: <i>Musa</i> spp. (4), <i>Inga</i> spp. (2), trees from NFF (4) The year after: <i>Musa</i> spp. and <i>Inga</i> spp. (1)
Banana	Did not plant other trees for shade (2) Planted other trees later (1)
Pastureland	In the same year: <i>Musa</i> spp. (4), <i>Inga</i> spp. (3), castor-oil plant (2), cacao (2), fruit trees (2), <i>Erythrina</i> spp. (1) One respondent said to only let naturally occurring trees grow.
Shrubland	Remove the shrubs and planted <i>Inga</i> spp. two years before (1) Remove the shrubs and preserved the naturally occurring <i>Cordia alliodora</i> (1)
Forest	Eliminated the smallest trees and preserved the tallest ones (5) Preserved only <i>Inga</i> spp. (1) or only <i>Inga</i> spp. and timber trees (2) Preserved <i>Inga</i> spp., <i>Cecropia peltata</i> and <i>Lippia myriocephala</i> because there were no tall trees (1)
Coffee or cacao	Regulate the shade of the trees already present (3)

### d) A continuously evolving system

Out of 44 respondents, 15 did not want to change the shade tree species composition of their coffee AFS in the future. One person highlighted that it is easier to take care of the trees he had than to plant and care for new trees as they take a long time to grow. Overall, respondents who wanted to modify the shade tree composition of their coffee AFS were interested in removing species with no apparent use and adding timber trees, fruit trees and service trees (Table 12).

TABLE 12: SMALLHOLDER'S INTENTIONS TO REMOVE OR ADD DIFFERENT SHADE TREE SPECIES IN THEIR COFFEE AFS. Numbers in parenthesis represent the number of respondents who did the same statement

Smallholder's statement
Add different tree species than the ones he has when a tree dies (3)
Add timber trees
Add <i>Cedrela odorata</i> , <i>Platymiscium pinnatum</i> , <i>Pachira quinata</i> and <i>Swietenia macrophylla</i> in the periphery
Add <i>Platymiscium pinnatum</i> and <i>Swietenia macrophylla</i>
Add <i>Platymiscium pinnatum</i>
Add timber and firewood trees
Remove <i>Inga</i> spp. And add timber trees (2)
Add fruit trees
Add <i>Inga</i> sp. 'extranjera'
Remove old fruit trees and add new ones
Remove <i>Cordia alliodora</i> and add cacao
Add <i>Musa</i> sp. 'platano' and timber trees
Remove <i>Inga</i> spp. and <i>Lippia myriocephala</i> and add timber and fruit trees
Remove <i>Piscidia grandifolia</i> and add <i>Cedrela odorata</i> , <i>Platymiscium pinnatum</i> and fruit trees
Add nitrogen fixing trees (2)
Remove <i>Guazuma Ulmifolia</i> and <i>Lonchocharpus rugosus</i> and add nitrogen fixing trees
Add <i>Platymiscium pinnatum</i> , <i>Erythrina poeppigiana</i> and <i>Inga punctata</i>
Remove <i>Cecropia peltata</i> and add <i>Platymiscium pinnatum</i> and <i>Erythrina poeppigiana</i>
Remove <i>Inga edulis</i> and add <i>Persea americana</i> 'comun' and <i>Inga punctata</i>
Remove the trees with no use
Remove the trees with no use and add more useful trees
Encourage natural regeneration

### e) The future of the coffee AFS

In the study area, there were roughly the same number of respondents who wanted to extend, maintain or reduce the area of their coffee plots (Table 13). Furthermore, there was no significant difference in respondent's will to reduce or increase their coffee AFS between the three communities.

Overall, farmer's statements highlight that, on one side, coffee cultivation is strongly embedded in local tradition and that despite of the current situation, some farmers still hold hope that coffee prices will rise again in a near future. On the other side, several farmers complained about coffee's low productivity, which is often attributed to an increase in the occurrence of pest of diseases, and its low profitability (Table 13).

TABLE 13: RESPONDENTS STATEMENT ON THEIR INTENTION TO EXTEND, MAINTAIN OR REDUCE THEIR COFFEE AFS. 'n' represent the number of respondents for each wish. Questionnaire's code is presented in parenthesis. 'A' corresponds to La Estrellita, 'B' to La Inmaculada and 'C' to Cerro Grande.

Wish	n	Statements
Extend	19	<p>Not every year the prices are so low and it is better than having maize and beans (11A)</p> <p>Coffee is the only thing that helps you to get out of here [i.e. poverty]. (28C)</p> <p>Coffee is a tradition (18A)</p> <p>I want to continue with coffee [...] because when one gets used to it... (5B)</p> <p>I want to extend my coffee plots. If I don't sell it, well, it will be for me! (23C)</p> <p>I would like to extend my coffee in a diverse way [i.e. with a variety of shade trees] (20A)</p> <p>I would like to add timber trees in the periphery and keep planting half a manzana [~0,35 ha] every year. We shouldn't loose hope and we must keep working. (16A)</p>
Maintain	14	<p>Maybe change for a coffee variety which produces more but I am already old so I don't want to put more of it (10A)</p> <p>No, we don't want to have more coffee. It attracts a lot of diseases now. It doesn't compensate for the days of work that one invests in it (13A)</p> <p>I don't have money nor land to extend my coffee plots. If the coffee plants get damaged I will renew it with new plants. (24C)</p>
Reduce	11	<p>I would like to reduce the coffee area and try to do other things. Now, coffee is not profitable but I will always want to leave a piece of land with coffee (18C)</p> <p>One need to invest a lot of money but the profit is low. This year, the harvest only served to pay the coffee pickers. I'm considering making a cowshed and buy cows. (22A)</p> <p>I'm thinking of reducing the coffee area, but it depends on buying policies and the possibility of getting in a project because I want to work with Atlantis Exportadora. Maybe change for livestock because I feel like I'm fooling myself with coffee. (17C)</p> <p>Now there is no money, maybe it would be good to remove some coffee to grow vegetables which is a good business now (14C)</p> <p>I want to change coffee for maize and beans because coffee gets a lot of diseases. One sprays a lot of chemicals and it barely produces. (15C)</p> <p>I want to have a plot with only citrus fruit trees and peach palm (4B)</p> <p>I want to change coffee for cacao because coffee requires money for maintenance while the profit from cacao disrupts hunger every 22 days (11B)</p> <p>I would like to change of crop in the future because coffee prices are low and the harvest is small. I would like to plant cacao although it is not adapted at this altitude (6A)</p>

Among farmers who wanted to reduce their coffee AFS, the most popular alternative by far was cacao production (Appendix G). Nonetheless, it should be noted that respondents had different views on the possibility of intercropping coffee and cacao which meant that the latter was seen either as a replacement or a complement to coffee cultivation. Out of the 16 respondents with who this subject was raised, three said that they could not be planted together and five said that they had little impact on each other. On the other hand, eight respondents said that coffee and cacao did not affect each other at all and were thus completely compatible.

## 4.B. COFFEE SMALLHOLDER'S PERCEPTION AND PREFERENCES OF ECOSYSTEM SERVICES AND SHADE TREE SPECIES

---

In this section I will present and discuss farmer's preferences of shade tree species. In order to apprehend this topic, I will first use the concepts of ES and ED to identify which benefits and drawbacks farmers expect from shade trees. Then, I will present the shade tree species that farmers know best and prefer based on their species recommendation and the results of the ranking exercise. Finally, I will describe farmer's LEK about the capacity of different local shade tree species to provide the ES that they identified as important.

### 4.B.1 SMALLHOLDER'S PERCEPTION OF THE ECOSYSTEM SERVICES AND DISSERVICES PROVIDED BY SHADE TREES

---

#### *a) Insights from the first phase of data collection*

---

First, we will investigate coffee smallholder's perception of the positive and negative impacts that shade trees can have based on the questionnaire data. Respondents mentioned significantly more positive impacts from shade trees ( $4,6 \pm 2,0$ ) than negative impacts ( $1,7 \pm 1,3$ ) according to a t-test ( $t(78) = 8,4; p < 0,001$ ). The community that respondents belonged to had a significant effect on the number of positive impacts mentioned according to a one-way ANOVA ( $F(2;44) = 8,83; p < 0,001$ ). Post hoc comparisons using the Tukey HSD test indicated that the mean number of positive impacts mentioned in Cerro Grande ( $3,2 \pm 1,6$ ) was significantly smaller than in La Estrellita ( $5,5 \pm 1,8; p < 0,001$ ) and La Inmaculada ( $5,1 \pm 1,9; p = 0,02$ ). No significant difference was found in the number of negative impacts mentioned between the three communities.

The fact that shade trees provide shade, keep soil humidity in the dry season, provide organic matter and reduce coffee productivity were spontaneously mentioned by more than half of the respondents in the study area (Table 14). According to a Fisher's exact test, there was a significant difference between the three communities in the frequency of mention of shade provision ( $p = 0,04$ ), erosion control ( $p < 0,001$ ), wind protection ( $p = 0,02$ ) and competition for nutrients ( $p = 0,008$ ) as impacts they obtain from shade trees. In Cerro Grande, shade provision ( $p = 0,01$ ) and erosion control ( $p = 0,001$ ) were less frequently mentioned; whereas erosion control was more frequently mentioned in La Inmaculada ( $p = 0,02$ ) and in La Estrellita, wind protection ( $p = 0,02$ ) and competition for nutrients ( $p = 0,003$ ) were more frequently mentioned. There were no differences in the frequency of mention of tree's ability to maintain soil humidity while the lack of water did not appear as an issue in La Inmaculada and Cerro Grande (Informal conversation).

TABLE 14: POSITIVE AND NEGATIVE IMPACTS OF SHADE TREES SPONTANEOUSLY MENTIONED BY RESPONDENTS IN THE STUDY AREA AND PER COMMUNITY

	All communities		La Estrellita		La Inmaculada		Cerro Grande	
	Rank	Frequency	Rank	Frequency	Rank	Frequency	Rank	Frequency
<b>Positive impacts of shade trees</b>								
Provide shade	1	66%	1	80%	1	80%	2	41%
Keep humidity in the dry season	2	57%	4	55%	2	60%	1	59%
Provide organic matter	2	57%	2	70%	2	60%	2	41%
Benefit the environment	4	49%	3	65%	5	50%	4	29%
Provide timber	5	38%	5	50%	8	30%	4	29%
Provide firewood	6	34%	8	35%	6	40%	4	29%
Reduce Pest and diseases	7	32%	7	40%	8	30%	7	24%
Lower temperature extremes	8	28%	10	30%	8	30%	7	24%
Stabilize the soil (erosion control)	8	28%	8	35%	2	60%	12	0%
Provide fruits	10	26%	11	25%	6	40%	9	18%
Protect coffee from the wind	10	26%	6	45%	11	20%	11	6%
Aesthetic value	12	13%	12	15%	13	0%	9	18%
Support honey production	13	4%	13	5%	12	10%	12	0%
<b>Negative impacts of shade trees</b>								
Lower coffee production	1	64%	1	75%	1	60%	1	53%
Compete for light	2	28%	2	40%	3	20%	3	18%
Increase pest and diseases	2	28%	4	20%	2	40%	2	29%
Compete for nutrients	4	19%	2	40%	6	0%	6	6%
Risk of fall	5	11%	5	10%	5	10%	4	12%
Compete for root space	6	9%	5	10%	6	0%	4	12%
Keep humidity in the rainy season	6	9%	7	5%	3	20%	6	6%

### *b) Additional remarks on ecosystem services*

There was a general agreement among farmers that trees maintain soil humidity although this was not always seen as a desirable property in all of the communities. In La Estrellita where precipitations are lower and periods of droughts can occur, farmers recognized that “*if [the coffee plants] don’t have shade the roots dry out and the plant doesn’t have strength*” (7A; Appendix G) although one farmer highlighted that it was important to prune the shade trees in a way which allows the air to circulate to avoid excess humidity. In La Inmaculada, one farmer exclaimed “*If there is water, there is life!*” (302; Appendix G) but shade trees seem to maintain potentially too much humidity, as one other respondent said: “*It doesn’t matter to me that shade trees keep the soil humid because here it rains a lot.*” (8B; Appendix G). In Cerro Grande, more respondents agreed that they don’t need shade trees because the soil is already humid. Furthermore, several farmers highlighted that a high density of shade results in high humidity and causes diseases to the coffee plants.

In La Estrellita, 12 out of 19 coffee smallholder’s (63%) said to have problems with erosion in their coffee plots, four out of 10 (40%) in La Inmaculada and four out of 17 (24%) in Cerro Grande, which is an important difference although not significant according to a Fisher’s exact test ( $p=0,054$ ). This can be surprising because direct observations suggest that coffee plots were steeper in Cerro Grande than in La Inmaculada which were themselves steeper than in La Estrellita. Discussion with a staff member of NFF highlighted that the term of erosion

is often understood as large landslides. Hence, the interpretation of this term could depend on the level of training that respondent had on soil erosion in the coffee plots. This hypothesis could not be tested as I do not have detailed information about the kind of training that respondents received. In addition, 11 out of 46 respondents said to use physical barriers to reduce soil erosion in the coffee plots. These barriers were made of trees (8 respondents), smaller plants (3) such as hibiscus (*Hibiscus rosa-sinensis* L.), vetiver (*Chrysopogon zizanioides* (L.) Roberty) and *espadillo* (*Yucca gigantea* Lem.) and, to a smaller extent, of dead banana trunks (1) and rocks (1).

In the three communities, farmers mentioned that shade trees can increase soil fertility although respondents had different views on this phenomenon: many of them said that all the trees give fertility to the soil, while two respondents said that trees contribute to soil fertility only when their fruit fall on the ground and rots. One respondent said that he was interested in planting more service trees which increase soil fertility, thus noticing that some species are better than others for this purpose. (Appendix G)

### *c) Additional remarks on ecosystem disservices*

---

There was a general agreement among farmers that having too many shade trees in the coffee plots reduces coffee productivity but the reason behind this causality was unclear (Questionnaire). One farmer said that “*trees disturb each other when they are too close*” (7A; Appendix G) which reminds of some kind of competition, either for light, nutrients or root space; whereas another one mentioned that “*too many trees in the coffee is not good because they bring diseases*” (23C; Appendix G).

In all of the study area, wind appeared to be an important concern. On one side, a few farmers acknowledged that shade trees could protect the coffee plants and the Banana and Plantain from wind damages. On the other side, many respondents said to be scared that the trees they have in their coffee plot, or their branches, might fall and damage the coffee plants (Appendix G). One respondent even said that he planted timber trees only in the periphery of the plot because they grow tall and have higher chances of falling in the coffee. Two women also commented that they refused to have tall trees close to their house by fear that they could hurt someone or destroy the house if they fell. Too much rain was also seen as a reason for a tree to fall. In particular one farmer was drastically reducing the number of Bananas he had in his plot because they would fall and damage the coffee during the rainy season. In both cases, the falling of a tree was often associated to a loss of soil: “*I am scared that a tree fall. When one falls, it pulls a lot of soil and everything goes to the river*” (8B; Appendix G).

### *d) Selection for the most relevant ecosystem services and disservices for the ranking exercises*

---

A list of 10 locally relevant ES and tree attributes were drawn based on the previously presented results and my own interpretation of smallholder’s discourse (Table 15). I decided to exclude ED from this list based on respondent’s reaction to the question regarding the negative impact of shade trees and to avoid mixing ES and ED in the ranking exercise. However, ED

such as competition for light are related to some of the ranking categories selected (Table 15). Furthermore, some ES have been voluntarily left out of this list, including protection of the environment, erosion control and wind protection. The reason behind this choice is that I deemed from the discussion around the questionnaire that these ES were attributed to trees in general and not to certain tree species. In addition, the impact of trees on the occurrence of pest and diseases were also excluded as the questionnaire showed that farmers had limited knowledge about the specific pest and diseases affecting their coffee plants and were more likely to point out to one specific species which had an impact on pest and diseases than to rank a group of species according to this criteria.

TABLE 15: JUSTIFICATION FOR THE SELECTION OF ES AND TREE ATTRIBUTES FOR THE RANKING EXERCISE

Selected ES and tree attributes	Impacts from shade trees mentioned during the questionnaire	Additional justification
<b>Autoconsumption:</b> Most consumed or used products in the household (Actual use-value)	Provide timber, firewood, fruits and small timber	Allow to identify important species for food security
<b>Income:</b> Species that contribute the most to the household' income	Provide timber, firewood, fruits and small timber Support honey production	Allow to identify marketable tree products
<b>Firewood:</b> Quality of the species as firewood (Potential use-value)	Provide firewood	Comments about certain species producing too much smoke to be used as firewood
<b>Timber:</b> Quality of the species as timber (Potential use-value)	Provide timber and small timber	Distinction between maderas preciosas and maderas finas
<b>Shade quality:</b> Species with the highest density of shade over the all year	Provide shade, Lower temperature extremes, Competition for light	Distinction between buena sombra and sombra caliente
<b>Fertility:</b> Species which improve soil fertility	Provide organic matter	Mentioned by more than half the respondents
<b>Soil humidity:</b> Species which maintain soil humidity	Keep humidity in the dry and the wet season	Water shortage was an important problem in La Estrellita
<b>Management:</b> Most difficult species to prune for shade management	Provide shade Competition for light and space	Negative opinion on species with spines or which grew fast and tall
<b>Growth speed:</b> Fastest species to produce useable products	Provide fruits, timber, firewood	Complaints about slow growing timber trees
<b>Adapted:</b> Species which are able to grow with the least human intervention	Provide fruits, timber	Susceptibility to diseases. Fruit trees' capacity to yield fruits

### e) Results from the ranking exercises

The 10 ES and tree attributes presented above were classified by respondents according to their level of importance for species selection and retention and their answers were summarized in Figure 17 below (see Appendix K for the ES and tree attributes ranking figures). Shade density resulted to be of lower importance in Cerro Grande than in the other communities which confirms the previous results. On one hand, shade trees' provision of products for the household consumption typically obtained a high rank, as one farmer illustrated: "*Food comes*

first in order to have strenght and do the work” (116, Appendix G). On the other hand, shade trees’ growth speed, difficulty of management and the fact that they are adapted to the local conditions were consistently ranked last.

High (Group 1)		Community →	ALL	A	B	C
Medium (Group 2)						
Low (Group 3 to 6)						
ES categories ↓	ES subcategories ↓	Ranking category name ↓				
Provisioning	Tree products	Autoconsumption	High	High	High	High
		Income	Medium	Medium	High	Medium
Regulating	Microclimate	Shade quality	Medium	High	Medium	Low
	Soil fertility	Soil fertility	Medium	Medium	Medium	Medium
Provisioning	Tree products	Timber	Medium	Low	Medium	Medium
		Firewood	Low	Low	Medium	Low
Regulating	Microclimate	Soil humidity	Low	Medium	Medium	Low
Tree attributes	Support farmer’s activity	Adapted	Low	Low	Low	Low
		Growth speed	Low	Low	Low	Low
		Management	Low	Low	Low	Low

FIGURE 17: ES AND TREE ATTRIBUTES BY COMMUNITY AND BY THE SUBCATEGORIES OR FUNCTIONS THEY ARE REPRESENTED BY. The first group of ES and tree attributes that were ranked highest and of which the position was significantly different was labelled as ‘High’, the second significantly lower ranked group as ‘Medium’ and the rest of the lower ranked es as ‘Low’. ‘A’ stands for La Estrellita, ‘B’ for La Inmaculada and ‘C’ for Cerro Grande. ES and tree attributes are ordered based on their estimated score for the entire study area.

#### 4.B.2 FARMER’S KNOWLEDGE ABOUT SHADE TREES’ PROVISION OF ECOSYSTEM SERVICES

The 10 species that participants selected for the ranking exercise represent the species that they know best. Remarkably, the 15 most frequently selected species were fruit trees, with the exception of *Inga punctata* (Figure 18). Directly after, we found a few important timber trees, namely *Cordia alliodora*, *Juglans olonchana* and *Cedrela odorata*, as well as some native forest species such as *Guazuma ulmifolia* and *Cecropia peltata*. *Piscidia grandifolia*, a native forest species, is the only species which was chosen by none of the respondents.

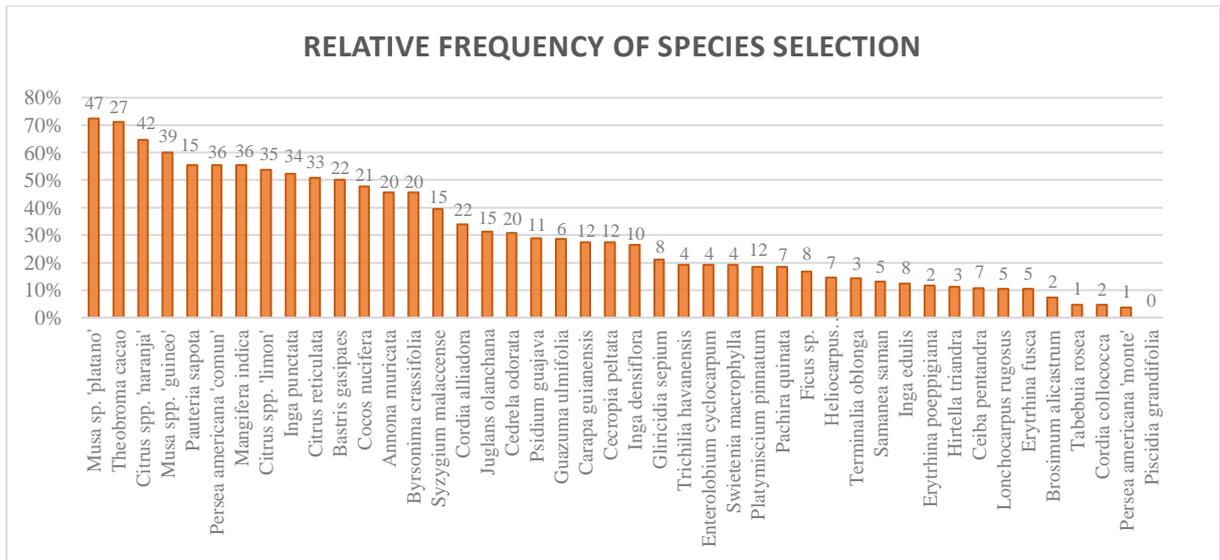


FIGURE 18: PERCENTAGE OF RESPONDENTS WHO SELECTED A GIVEN SPECIES OUT OF THE TOTAL NUMBER OF RESPONDENTS WHO HAD THE OPTION OF CHOOSING THIS SPECIES. The numbers indicate the exact number of times the species were chosen.

The results of the ranking exercise are presented in the summary tables below for the whole study area (Figure 19; see Appendix L for species ranking figures) and for each community (Figure 20; see Appendix L for species ranking figures). Sometimes, there were only four significance groups for a given category, thus, a ‘medium’ rank represents as the lowest rank for this category. Note that in the category ‘Difficulty of pruning’, a high rank is not a desirable feature. Similarly, in the category ‘Density of shade’ a high rank means that a species has a high density of shade and a low rank means that it has a low density of shade or sheds its leaves in the dry season, which can be seen as a positive or negative attribute depending on the farm’s location.

A rapid overview of these two tables shows that service trees obtained high ranks for most categories except the contribution to family income and the provision of timber. Interestingly, there are two species which obtained even higher ranks than the service trees: banana and plantain. These two species obviously obtained lower ranks for the provision of firewood and timber and the difficulty of pruning but were ranked high or very high in all of the other categories. Another interesting result is that fruit trees are systematically ranked in the first significance group for the household auto-consumption although it was emphasized that this category also included firewood and timber.

Tree species ↓	Ecosystem services and tree attributes →	Study area										
		Autoconsumption	Income	Firewood	Timber	Shade density	Soil fertility	Soil humidity	Difficulty of pruning	Growth speed	Adapted	Conclusion
SERVICE	<i>Inga punctata</i>											
	<i>Inga edulis</i>											
	<i>Inga densiflora</i>											
	<i>Erythrina fusca</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Erythrina poeppigiana</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Albizia saman</i>	*	*	*	*	*	*	*	*	*	*	*
FRUIT	<i>Musa</i> spp. 'guineo'											
	<i>Musa</i> sp. 'platano'											
	<i>Brosimum alicastrum</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Syzygium malaccense</i>											
	<i>Theobroma cacao</i>											
	<i>Citrus</i> spp. 'limon'											
	<i>Bactris gasipaes</i>											
	<i>Mangifera indica</i>											
	<i>Persea americana</i> 'comun'											
	<i>Citrus</i> spp. 'naranja'											
	<i>Citrus reticulata</i>											
	<i>Pouteria sapota</i>											
	<i>Psidium guajava</i>											
	<i>Byrsonima crassifolia</i>											
<i>Annona muricata</i>												
<i>Cocos nucifera</i>												
TIMBER (High quality)	<i>Platymiscium pinnatum</i>											
	<i>Cedrela odorata</i>											
	<i>Cordia alliodora</i>											
	<i>Juglans olanchana</i>											
	<i>Pachira quinata</i>											
	<i>Terminalia oblonga</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Carapa guianensis</i>											
	<i>Swietenia macrophylla</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Enterolobium cyclocarpum</i>	*	*	*	*	*	*	*	*	*	*	*
<i>Tabebuia rosea</i>	*	*	*	*	*	*	*	*	*	*	*	
TIMBER (Low quality)	<i>Ceiba pentandra</i>											
	<i>Ficus</i> sp.											
	<i>Cecropia peltata</i>											
	<i>Gliricidia sepium</i>											
	<i>Guazuma ulmifolia</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Lonchocarpus rugosus</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Hirtella triandra</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Cordia collococca</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Persea americana</i> 'monte'	*	*	*	*	*	*	*	*	*	*	*
Other	<i>Trichilia havanensis</i>	*	*	*	*	*	*	*	*	*	*	*
	<i>Heliocarpus appendiculatus</i>	*	*	*	*	*	*	*	*	*	*	*

FIGURE 19: OVERVIEW OF THE RANKINGS OF SHADE TREE SPECIES BY ES OR TREE ATTRIBUTE IN THE STUDY AREA. The species were given labels based on their relative position within the ranking. The first group of species that was ranked highest and whose position was significantly different were labelled as 'Very high'. Following the same methodology, the second group (i.e. next group ranked significantly lower) was labelled as 'High', groups three and four were labelled as 'Medium' and the following groups were labelled as 'Low'. '\*' means that that the tree was selected and ranked by five farmers or less so its ranking was considered less reliable.



TABLE 16: RESPONDENT'S RECOMMENDATIONS OF SHADE TREE SPECIES FOR NEW COFFEE FARMERS. The sum corresponds to the number of times the species was recommended minus the number of times it was disapproved. '\*' mean that the species were both recommended and disapproved by different farmers. 'N/A' means that no additional information were recorded about this species

Name	Sum				Summary of farmer's statements
	All	A	B	C	
<b>Groups of species</b>					
<b>Inga spp.</b>	10	6	2	2	Nitrogen-fixing, fast growing, provide firewood, temporary shade, part of local traditions, easy access to seeds, natural regeneration
<b>Timber</b>	9*	3*	1	5	Resource of critical importance for household consumption, not sold due to the difficulty of getting permits and the scarcity of this resource, increase the value of the property, ' <i>timber trees can be planted together with coffee but they are not for shade</i> ' (119)
<b>Fruit trees</b>	6*	2	0*	4	Important for auto-consumption, donated to family members and farm workers, not harvested due to low market prices, would be better outside of the coffee, problems with thieves
<b>Firewood</b>	2	1	0	1	Used for consumption, not sold because it is a hard labor to collect and transport it, low price
<b>Citrus spp.</b>	1*	0	0*	1	Used for consumption to make drinks and cook, low market prices, has spines
<b>Individual species</b>					
<b>Inga punctata</b>	17	6	4	7	See <i>Inga</i> spp., ' <i>It is the classic one here</i> ' (7A), good structure, easy to manage, doesn't grow too tall, fruits for human and animal consumption, provide a lot of good firewood but less than other <i>Inga</i> spp., increases American leaf spot and kaleroga if not managed properly
<b>Platymiscium pinnatum</b>	8*	4*	2	2	Good quality timber, provide good shade, should be place on the periphery of the coffee plot, difficult access to seedlings, shed its leaves in the dry season for a short time, more adapted to lower altitude, susceptible to an insect which makes holes in the wood
<b>Erythrina poeppigiana</b>	5*	2*	2*	1	Nitrogen-fixing, dense permanent shade, need to be regulated, has spines, susceptible to a pest, poor quality firewood, maintain soil humidity
<b>Musa spp. 'guineo'</b>	5*	4	0*	1	Good shade, fast growing, temporary shade, consumes a lot of nutrients, may damage the coffee plants due to natural fall or thieves
<b>Inga densiflora</b>	3*	3	1	-1	See <i>Inga</i> spp., fruits can be sold, sheds its leaves for a short period of time, increases American leaf spot if not managed properly, could also attract coffee berry borer and irritating worms
<b>Ricinus communis</b>	3	2	0	1	Fast growing, fast decomposition of the leaves
<b>Citrus reticulata</b>	2	0	0	2	Fruits can be sold, produces more than orange trees, not well adapted in La Inmaculada and Cerro Grande, is attacked and attracts leaf cutter ants
<b>Trichilia adolfi</b>	2	2	0	0	' <i>It is good but people remove it</i> ' (18A)
<b>Theobroma cacao</b>	2	1	1	0	Used for making <i>pinol</i> , cash-crop, problems with thieves, increases coffee diseases
<b>Unknown sp. 'cassia'</b>	2	1	0	1	Windbreak, provide firewood, attracts leaf cutter ants and worms
<b>Cedrela odorata</b>	2*	1*	1	0*	Protected species, valuable timber, grow very tall, should be placed on the periphery of the coffee plot, poor quality firewood, increase coffee leaf rust, attacked by an insect which makes a hole in the wood
<b>Trichilia havanensis</b>	2	2	0	0	Good firewood, always has leaves, not very tall, not affected by soil diseases
<b>Mangifera indica</b>	2*	1	0	1*	Native variety not marketable, improved variety marketable but give problems with thieves, good for auto-consumption, absence of yields at higher altitudes, increase coffee diseases and pests, affected by an insect which attacks the wood
<b>Musa sp. 'platano'</b>	2	1	0	1	Easier to sell and better price than banana, good for auto-consumption, affected by fungi and insects, fungi infection can be prevented with ashes
<b>Bixa orellana</b>	1	0	0	1	Great price variability but potentially highly profitable
<b>Ulmus mexicana</b>	1	1	0	0	N/A
<b>Erythrina fusca</b>	1	1	0	0	Nitrogen-fixing, fast growing, poor quality of timber, keep soil humidity, has spines
<b>Inga sp. 'extranjera'</b>	1	0	1	0	N/A
<b>Terminalia oblonga</b>	1	1	0	0	Strong wood, grow tall, good structure, resistant to wind, does not shed its leaves

Species name	All	A	B	C	Summary of farmer's statements
<b>Gliricidia sepium</b>	1	1	0	0	'Hot' shade, recommended as living fence, fast growing, provide organic matter, poor quality firewood, medicinal value
<b>Manilkara sapota</b>	1	0	0	1	N/A
<b>Unknown sp. 'tambor'</b>	1	0	1	0	Low density of shade so does not compete for light with coffee
<b>Mosquitoxylum jamaicense</b>	1	1	0	0	Fast growing, good shade
<b>Persea americana 'comun'</b>	0*	1	0	-1*	Good for consumption, affected by a fungus and/or nematode, low market price, increase coffee diseases, do not produce at higher altitudes, grow fast and tall at lower altitudes
<b>Swietenia macrophylla</b>	0*	0*	0	0*	Protected species, recommended in the periphery, high market price, need to be pruned
<b>Inga edulis</b>	0*	-1	1*	0*	Fruit for consumption, reported to increase coffee diseases by a high number of respondents
<b>Muntingia calabura</b>	-1	0	-1	0	Poor quality firewood, does not produce fruits in La Inmaculada
<b>Ceiba pentandra</b>	-1	-1	0	0	Protected species, grow very tall, high density of shade, difficulty of pruning, keep soil humidity, the wood do not last due to its porosity
<b>Ficus sp.</b>	-1	-1	0	0	Not recommended in coffee, high density of shade, keep humidity, sap burns, grow tall
<b>Zanthoxylum juniperinum</b>	-1	0	0	-1	N/A
<b>Cecropia peltata</b>	-1*	-1	0*	0	Provide timber when it's very old, affected by an insect making holes in the trunk, low decomposition rate of the leaves, keep humidity, poor quality firewood, leaves damage coffee
<b>Syzygium malaccense</b>	-1	0	-1	0	Fruit damage coffee plant when they fall, good for consumption, high density of shade, can only be sold in the city
<b>Unknown sp. 'Pino'</b>	-1	-1	0	0	-
<b>Pachira quinata</b>	-1*	-1*	0	0	'Hot' shade, high quality timber, grow very tall, has spines, recommended in the periphery
<b>Tabebuia rosea</b>	-1	-1	0	0	'Hot' shade, good timber
<b>Piscidia grandifolia</b>	-1	-1	0	0	Shed its leaves in the summer, timber
<b>Chrysophyllum cainito</b>	-2	0	-2	0	-
<b>Hirtella triandra</b>	-2	-2	0	0	Remnant forest tree, grow very straight, difficult to prune, good firewood, natural regeneration
<b>Spathodea campanulata</b>	-2	0	-2	0	Keep the flies away, kill the bees
<b>Cordia collococca</b>	-2	0	0	-2	Poor quality of firewood and timber, shed its leaves
<b>Bactris gasipaes</b>	-2	0	-2	0	Fruits damage coffee plants when they fall, take a long time before producing, has spines, dries the soil, affected by an insect, can be sold
<b>Heliocarpus appendiculatus</b>	-3	-3	0	0	Poor quality firewood, low durability of the wood ' <i>it has to be changed every year</i> ' (438), grow tall, difficult to prune
<b>Croton draco</b>	-3	-1	-2	0	Grows too quickly and produce too much shade, increase coffee leaf rust
<b>Lippia myriocephala</b>	-5	0	-3	-2	Temporary shade, poor quality firewood
<b>Juglans olonchana</b>	-6*	-2*	0	-4	Dense shade, difficult to regulate, grow very tall, keep (too much) soil humidity, poor quality of firewood, wood attacked by 'ants', increase coffee diseases
<b>Lonchocarpus rugosus</b>	-7	-7	0	0	'Hot' shade, increase coffee diseases, natural regeneration, average quality firewood and timber
<b>Guazuma ulmifolia</b>	-7	-6	-1	0	'Hot' shade, leaves are 'acidic', increase coffee diseases, fruits serves as animal food, medicinal properties, need to be pruned
<b>Cordia alliodora</b>	-8*	-4*	-1*	-3*	Good quality timber, fast-growing, shed its leaves in the dry season, dries the soil, provide organic matter, its leaves are said to be 'acidic', appreciated when respondent consider that they live in a cold climate, natural regeneration

The castor-oil plant was given to farmers of the MATRICE project as it could be planted at the time of establishment of the coffee plot and grow sufficiently fast to provide shade to the young coffee plants in the first year. Informal conversation with three farmers of the MATRICE project revealed that they had no previous knowledge of the toxicity of the seeds of this plant for human health. During one of the ranking exercises, I noticed castor oil seeds on a table inside the house and when I explained their toxicity to the farmer, he was surprised and put the seeds in a place where children could not access it. He reported to have collected the seeds from a friend and was interested in sowing them in his coffee plot.

#### *b) General ranking of shade tree species*

---

At the end of the ranking exercises, respondents were asked to realize a conclusion ranking based on their preferences. The results of this conclusion ranking are presented in Figure 18 in section 4.B.2.

*Musa* spp. and *Inga* spp. were consistently ranked high in all of the communities. It is interesting to see that *Inga edulis* obtained a higher score than the other *Inga* species in La Inmaculada, while both in La Estrellita and in Cerro Grande, *Inga punctata* came first, while *Inga edulis* could be found further down in the ranking, in the medium group.

In La Estrellita, the highest ranked species in terms of smallholder's preferences also include three timber tree species: *Platymiscium pinnatum*, *Juglans olonchana* and *Enterolobium cyclocarpum*.

In Cerro Grande, *Ceiba pentandra* was ranked significantly higher than the other species. Other timber tree species can be found in the high rank group, namely *Cedrela odorata* and *Cordia alliodora*, as well as two fruit tree species: avocados (*Persea Americana* 'comun') and oranges.

The results from La Inmaculada can be more difficult to interpret due to a lower number of respondents. The fact that the significance groups are larger shows that there was less consensus between respondents. If we look at the first of the two 'high rank' groups, we can see that it includes all of the *Musa* spp. and *Inga* spp., two timber tree species and one legume tree species. The second of the two 'high rank' groups include several fruit tree and timber species.

#### **4.B.4. THE INFLUENCE OF GENDER IN SPECIES PREFERENCES**

---

Among the list of most abundant shade tree species, women chose fruit trees more often than species from other use category (Figure 20). This highlights that women felt more knowledgeable about fruit tree species. The avocado and the Maya nut (*Brosimum alicastrum*) were the only fruit tree species that were selected as often by men as women. Apart from fruit trees, women selected the *Juglans olanchana*, *Guazuma ulmifolia* and *Cecropia peltata* more often than men and also selected relatively often *Inga punctata*.

The Figure 21 also shows that men selected species from each use category with a relatively similar frequency, showing that they felt knowledgeable about all of the use categories. Indeed, it happened many times that a male respondent said that he knew all the trees presented to him.

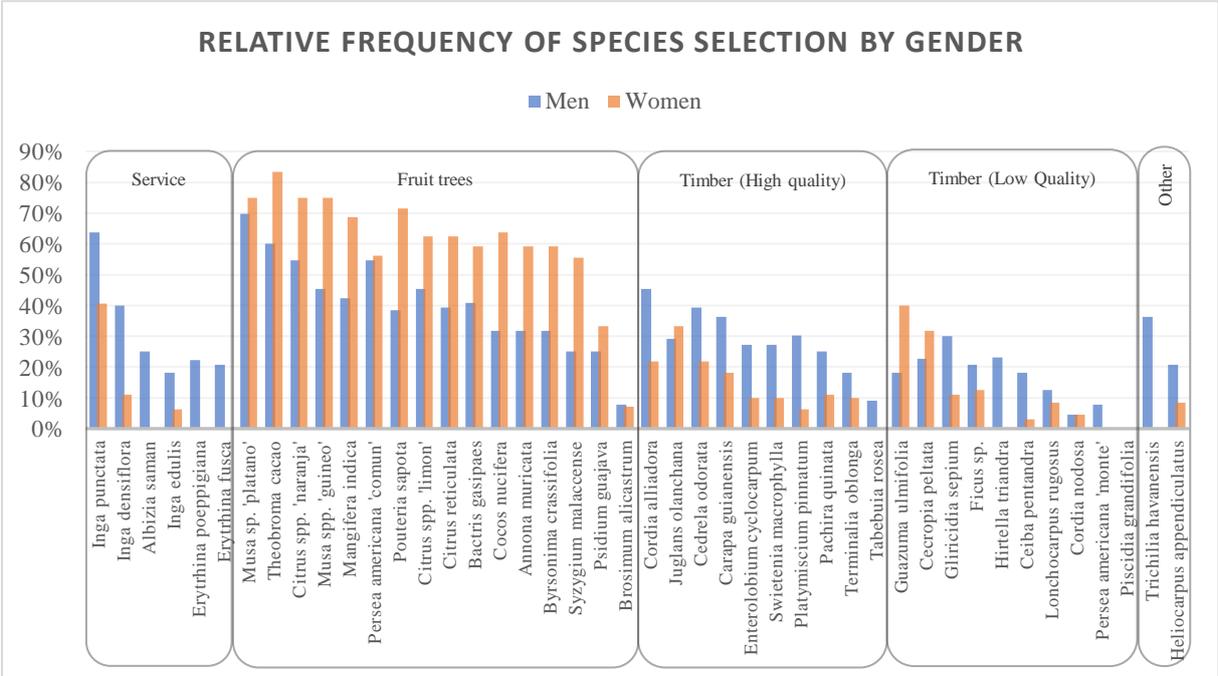


FIGURE 21: PERCENTAGE OF RESPONDENTS WHO SELECTED A GIVEN SPECIES OUT OF THE TOTAL NUMBER OF RESPONDENTS WHO HAD THE OPTION OF CHOOSING THIS SPECIES PER GENDER AND SPECIES USE-CATEGORY

Several women stated before starting the ranking exercise that they were not involved in coffee production and expressed some doubts about their capacity to answer questions regarding coffee cultivation. None of these women was farm owner. While nearly every man ranked the selected species for all of the ranking categories, several women skipped some of the ranking categories because they didn't feel confident enough to talk about them. Only 53% of all women ranked their selected species according to their ability to enhance soil fertility, 59% according to their difficulty of management, 72% according to their ability to maintain soil humidity and 78% according to the quality of their timber (Ranking exercise). Women consistently ranked provision services higher than regulating services (Figure 22).

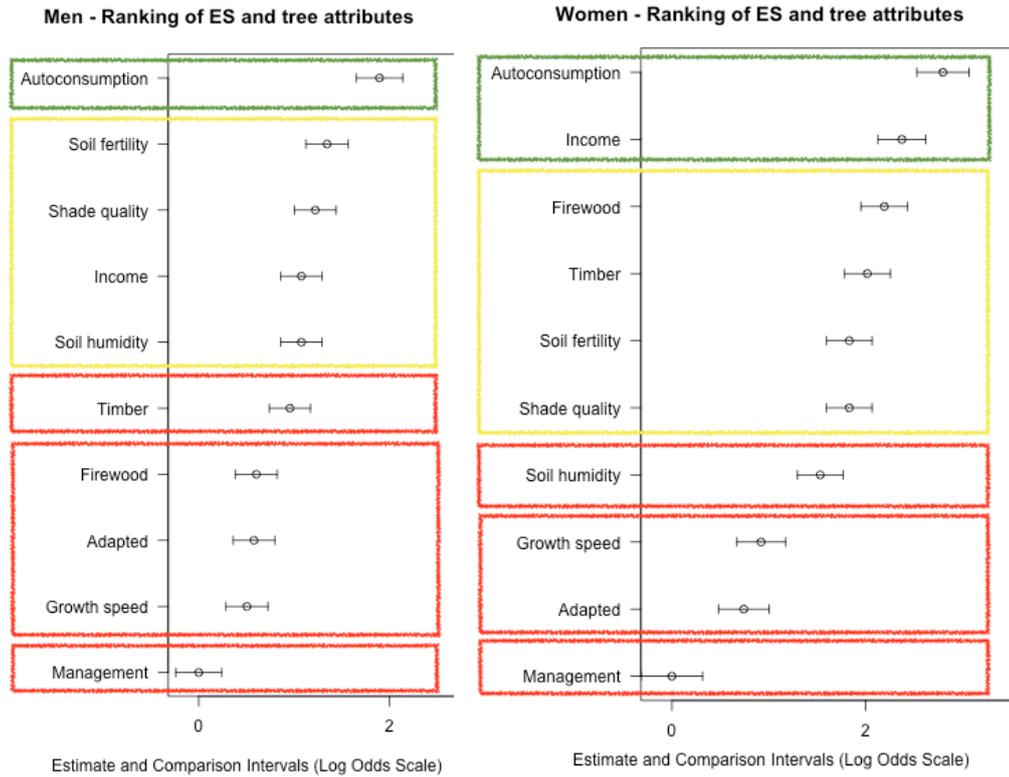


FIGURE 22: RANKING OF ES AND TREE ATTRIBUTES BY GENDER. Ranking estimates were grouped until the next ranking was significantly different from the first ranking of that group

There was no major difference in shade tree species preferences between men and women except for *Guazuma ulmifolia* which were ranked high by women and low by men (Figure 23, see Appendix L). Surprisingly, men preferred bananas over plantains while both obtained the highest rank in women preferences, together with *Cedrela odorata*. Fruit trees were generally ranked slightly higher by women and service trees were ranked slightly higher by men.

Legend:	Very high (Grp. 1)	High (Grp.2)	Medium (Grp. 3)	Low (Grp. 4)	Very low (Grp. 5)	
	<b>Shade tree species</b>			<b>Men</b>	<b>Women</b>	
<b>SERVICE</b>	<i>Inga densiflora</i>					
	<i>Inga punctata</i>					
	<i>Erythrina poeppigiana</i>					
	<i>Albizia saman</i>					
	<i>Erythrina fusca</i>					
	<i>Inga edulis</i>					
<b>FRUIT</b>	<i>Musa</i> spp. 'guineo'					
	<i>Musa</i> sp. 'platano'					
	<i>Persea americana</i> 'comun'					
	<i>Citrus</i> spp. 'naranja'					
	<i>Theobroma cacao</i>					
	<i>Byrsonima crassifolia</i>					
	<i>Citrus reticulata</i>					
	<i>Citrus</i> spp. 'limon'					
	<i>Annona muricata</i>					
	<i>Bactris gasipaes</i>					
	<i>Mangifera indica</i>					
	<i>Pouteria sapota</i>					
	<i>Syzygium malaccense</i>					
	<i>Brosimum alicastrum</i>					
	<i>Cocos nucifera</i>					
<i>Psidium guajava</i>						
<b>TIMBER (High quality)</b>	<i>Cedrela odorata</i>					
	<i>Carapa guianensis</i>					
	<i>Enterolobium cyclocarpum</i>					
	<i>Platymiscium pinnatum</i>					
	<i>Cordia alliodora</i>					
	<i>Juglans olanchana</i>					
	<i>Tabebuia rosea</i>					
	<i>Swietenia macrophylla</i>					
	<i>Terminalia oblonga</i>					
	<i>Pachira quinata</i>					
	<i>Ceiba pentandra</i>					
<b>TIMBER (Low quality)</b>	<i>Gliricidia sepium</i>					
	<i>Guazuma ulmifolia</i>					
	<i>Lonchocarpus rugosus</i>					
	<i>Ficus</i> sp.					
	<i>Cecropia peltata</i>					
	<i>Cordia nodosa</i>					
	<i>Hirtella triandra</i>					
	<i>Persea americana</i> 'monte'					
	<b>Other</b>	<i>Trichilia havanensis</i>				
		<i>Heliocarpus appendiculatus</i>				

FIGURE 23: PARTICIPANT'S PREFERENCES OF SHADE TREE SPECIES PER GENDER AND USE-CATEGORY. The species were given labels based on their relative position within the conclusion ranking. The labels attributed to each of group (grp.) of species is presented below. Blanks mean there was no ranking done for that specific species.

## 4.C. IDENTIFICATION OF THE FACTORS INFLUENCING SHADE TREE SPECIES COMPOSITION IN THE COFFEE AGROFORESTRY SYSTEMS

---

### 4.C.1 CURRENT USE OF SHADE TREES' PRODUCTS AND RELATED CONSTRAINTS

---

#### *a) Fruits*

---

Respondents harvested various fruits from their coffee AFS, of which the most common ones were banana, plantain, cacao, lemon, orange, mandarin, avocado, mango (*Mangifera indica*), and peach palm (*Bactris gasipaes*). Only cacao, plantain and banana appear to be sold on a regular basis. However, several respondents complained about the low price they get for selling bananas (from 0,60 to 0,90 US\$ for a bunch of Bananas). Only people owning a *venta* had no problem to sell their bananas.

The other common fruits mentioned above appeared to be primarily consumed, donated or left on the trees because, as many respondents mentioned, the transport to the city was too expensive and it was not worth it neither for middlemen to do the trip to the farms, nor for the farmers to do the trip to the city to sell their products given the current prices. Hence, farmers said to sell these fruits only if they had an important harvest or if the market price was high. Another factor mentioned by several respondents is that middlemen are looking for improved varieties and cultivars which get a higher price on markets. This is notably the case for mangos and avocados. Similarly, *Citrus x latifolia* were reported to be more important commercially than other species of the genus *Citrus*. Despite of this common knowledge, farmers seem to have little interest in investing in improved seedlings and several are hoping for development projects to bring improved varieties for free. (Appendix G)

Several respondents reported that they did not harvest the fruits from the shade trees due to lack of time and their low market value: “*we consume part of it and the birds eat the rest*” (22C; Appendix G). In all of the communities, many respondents reported to give fruits for free to their relatives or workers employed for coffee maintenance, even in the most precarious households:

*If suddenly our family from Managua comes and they tell us to get this thing or the other, well we must have it ready somewhere to give them. If they come and I tell them that I don't have bananas, this cannot be, there is little but there is some. I can't tell them that there isn't any because they don't have much either (7A; Appendix G)*

When talking about the use of fruits from shade tree species, 17 out of 46 respondents spontaneously mentioned having problems with thieves. This was found to be dependent on the community where the respondents were from ( $p=0,02$ , Fisher's exact test). There were significantly less respondents saying to have problems with thieves in Cerro Grande than in the two other communities ( $p=0,01$ ). Thieves were reported to come at night or at times when they knew no one was in the coffee plots if the latter was located away for the village. The principal

species concerned seemed to be of the genus *Musa* and *Citrus*. Not only farmers would be deprived of the tree's harvest, but thieves would also cause damage to the fruit trees themselves as well as neighboring coffee trees in a careless harvesting process as their sole objective was to accomplish their task rapidly. (Appendix G; Informal conversation)

### *b) Firewood*

---

On average, respondents said to collect 9,4m<sup>3</sup> ( $\pm$  9,1; Median= 6,0m<sup>3</sup>) of firewood from their coffee AFS (Appendix C). The majority of respondents were self-sufficient for firewood production. Four out of 46 respondents had to buy firewood to meet their needs, six said that family members or friends would give them firewood for free when they needed it and one said that the owner of the coffee farm she worked for would let her collect firewood for free. Out of the 13 respondents who do not cover their own needs in firewood, only two stated that they were planning to increase their production of firewood in the future meaning that depending on other people to meet their firewood needs were not necessarily seen as a problem for the others. Moreover, three respondents pointed out that they had started to cook with gas and used firewood only when cooking for events and for preparing beans and tortillas which have a long cooking time (Appendix G). It is very likely that this was in fact the case in several other households. In addition, it was not a popular practice to sell excess firewood because it is a fastidious task to cut and carry the wood and the price is considered to be low compared to the amount of work (6,42 US\$ per m<sup>3</sup> of firewood delivered to the buyer's house; Appendix C, Appendix G). Hence, farmers with excess firewood often prefer to let family, friends or workers collect the firewood themselves for free.

### *c) Species providing timber*

---

None of the respondents said to make a commercial use of the timber they produced. Farmers explained that in Nicaragua, the sale of timber trees is regulated by law and it is compulsory to obtain a permit to cut down and sell a tree. A permit application is refused when the tree is located too close to a water body (e.g. rivers) or if the species is endangered according to the ICLN Red List (e.g. *Cedrela odorata* and *Swietenia macrophylla*). Authorizations for endangered species may be granted if the farm owner has a certificate guaranteeing that he planted the tree himself. There is a strong monitoring system in which one person is designated in each community to report to the authorities any illegal cutting: "*I don't sell timber because sometimes it gives problems with people*" (4B; Appendix G) Several farmers said that they wouldn't get a permit because it was too complicated. However, conversation with NFF staff revealed that although the permits are relatively cheap, the applicant must be up to date in his property taxes and pay off his debts if he is not, thus making the process of getting a permit a lot more expensive. It is unknown to which extent this is actually the case. Perhaps a better explanation lies in the additional cost of cutting a tree. One farmer from La Inmaculada said "*It is not profitable to sell timber given how much there is to pay for the permit, the carpenter and the transport*" (5B; Appendix G). Two respondents mentioned that it was possible to register a tree upon plantation in order to be allowed to sell its wood and that such practice, although expensive for individual farmers, was implemented by ADDAC (Appendix G; Personal notes).

Two respondents also admitted selling timber illegally. The first one said he would only sell timber to people in need who do not own coffee plantations and desperately need it for their own use. The second one explained that some people would come around the communities and offer a price if they were interested in buying a tree. He said that the price offered was very low compared to its real value as the sale was illegal but that in exceptional cases of great financial difficulty it was necessary (Personal notes).

In any case, all farmers who had timber trees said to use it for their own use, mainly to build or repair their house which were always made of wood. Hence, timber trees were a highly valuable resource to have: *“One should always have timber trees in his farm, never let them disappear”* (335; Appendix G). Some farmers recognized that having timber trees, especially high-quality timber trees, in their coffee plot increased the value of their land and that they must be preserved for their children and great children. However, farmers preferred to have timber trees outside of the coffee field or in its periphery. In addition, a few farmers appeared reluctant to the idea of falling a tree: *“It is impossible that I fall down a tree this tall because of all the time that I will have to wait before another give me what this tree was giving me”* (14A; Appendix G)

#### 4.C.2. ANALYSIS OF THE FACTORS INFLUENCING SPECIES DIVERSITY

Table 17 below presents the explanatory variables which were found to have a significant effect on farm species richness during the sequential selection process of variables in the multiple regression analysis. The model explains 58% of the variance. The relatively small value of theta indicates a clumping in the data. The results show that farmers currently involved with other organizations than NFF had a significantly higher number of species in their coffee AFS than farmers not involved with an organization. Farmers with a low economic status according to my typology had a significantly lower species richness than those of the average economic status. Farmers who perceived their soil fertility as average had less shade tree species than farmers those who qualified their soil as being of good or poor fertility. Both the distance between the coffee plots and the house and the altitude of the coffee plot had a negative effect on farm species richness.

TABLE 17: REGRESSION RESULTS FOR FARM SPECIES RICHNESS. Standard errors are reported in parentheses. \*, \*\*, \*\*\* indicates significance at the 90%, 95%, and 99% level, respectively. Variables are ordered based on the importance of their effect in the model (p-value of the anova table)

Constant	2,69 *** (0,10)
Distance	-0,238 *** (0,071)
Soil fertility [poor]	0,363 ** (0,164)
Soil fertility [good]	0,291 *** (0,101)
Economic status [low]	-0,398 *** (0,128)
Economic status [high]	0,028 (0,134)
Altitude	-0,127 ** (0,050)
Organization [NFF - Insetting]	0,268 (0,236)
Organization [NFF - Matrice]	0,023 (0,126)
Organization [Other]	0,521 *** (0,178)
Farm owner's age	-0,046 (0,052)
Goodness of fit	0,581
Akaike Information Criterion (AIC)	297,64
Theta	41,0
No. observations	46

The size of the coffee plot was positively correlated to the abundance of fruit trees for consumption, fruit trees of commercial value and timber trees of high quality but negatively correlated to timber tree of low quality (Table 18). The abundance of fruit tree species for consumption in the coffee AFS was significantly higher when the respondent was a woman and significantly lower when the coffee plot was located far from the house and that the farm owner was a woman. When only the man of the household was responsible of taking decisions relative to coffee AFS management, the abundance of high-quality timber trees was significantly higher while the abundance of lower quality timber was smaller. An average soil fertility was negatively correlated to the abundance of lower quality timber and of species with no apparent use. The abundance of species with no apparent use was also significantly higher on farms involved in the MATRICE project and involved with other organizations but was significantly lower when farmers said that they received training on coffee cultivation.

TABLE 18: REGRESSION RESULTS FOR FARM ABUNDANCE OF DIFFERENT USE-CATEGORIES OF SHADE TREE SPECIES. Standard errors are reported in parentheses. \*, \*\*, \*\*\* indicates significance at the 90%, 95%, and 99% level, respectively. Variables are ordered according to the number of species use-category they have an effect on. 'qual.' stands for quality. None refers to the shade tree species with no apparent use.

	Consumption	Cash-crop	High Qual. Timber	Low Qual. Timber	Service	None
Constant	1,13 *** (0,15)	1,29 *** (0,14)	1,23 *** (0,11)	-0,05 (0,30)	1,05 *** (0,23)	-1,19 ** (0,39)
Coffee plot area	0,315 *** (0,103)	0,146 (0,093)	0,277 *** (0,081)	-0,285 ** (0,136)		
Altitude	-0,286 *** (0,092)		-0,225 *** (0,085)		-0,214 * (0,111)	
Distance	-0,540 *** (0,135)	-0,148 (0,092)	-0,095 (0,095)			
Economic status [low]	-0,408 (0,271)			-0,632 ** (0,321)	-0,631 ** (0,291)	
Economic status [high]	-0,168 (0,230)			0,347 (0,268)	0,304 (0,282)	
Soil fertility [poor]				0,667 ** (0,322)		1,634 *** (0,610)
Soil fertility [good]				0,799 *** (0,223)		0,963 ** (0,441)
Organization [NFF - Insetting]				0,642 (0,443)		-0,222 (1,102)
Organization [NFF - Matrice]				0,854 *** (0,279)		1,956 ** (0,824)
Organization [Other]				1,471 *** (0,391)		2,690 *** (0,906)
Received training [Yes]					-0,352 (0,256)	-1,417 * 0,848
Decision-making [Women only]			-0,676 * (0,375)	0,667 (0,549)		
Decision-making [Men and women]			-0,413 ** (0,192)	0,702 *** (0,239)		
Gender of the respondent [Women]	0,816 *** (0,308)	-0,266 (0,210)				
Gender of the owner [Women]	-0,590 * (0,312)				0,240 (0,290)	
Farm owner's age	-0,200 ** (0,098)					
Farm area		-0,187 (0,121)				
Previous land-use [Sparse trees]		0,191 (0,213)				
Previous land-use [Forest]		0,356 (0,250)				
Previous land-use [Coffee or cacao]		0,306 (0,221)				
Time spent cultivating coffee		0,107 (0,082)				
Goodness of fit	0,541	0,431	0,514	0,491	0,270	0,352
AIC	197,41	175,78	169,41	176,45	151,15	97,048
Theta	16 569	199 619	86 315	29 387	71 152	3 449
No. observations	46	44	46	46	46	46

#### 4.C.3. THE INFLUENCE OF FARMERS' PREFERENCES ON SPECIES ADOPTION

Participant's favorite shade tree species were not necessarily the same ones that were adopted by the largest number of farmers (Figure 24). Among the species with the highest ranking estimate, the banana was the only one which also had a high frequency of occurrence.

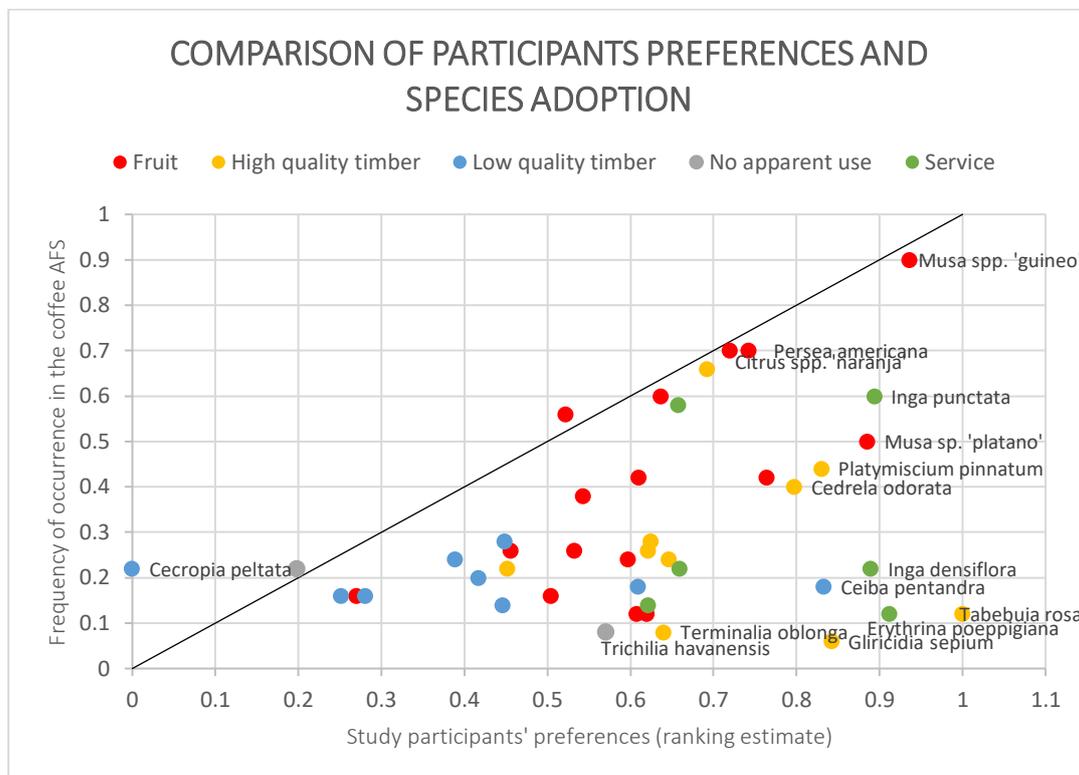


FIGURE 24: INFLUENCE OF FARMER'S PREFERENCES ON SPECIES' ADOPTION IN THE COFFEE AFS. The x axis represent the ranking estimate of each species obtained through the BradleyTerry2 package which have been rescaled using the min-max normalization method. The y axis represent the frequency of occurrence of each species (number of farms where it was present divided by the total number of farms surveyed).

---

# CHAPTER V: DISCUSSION

---

In this chapter, the results will be discussed in relation to the background and conceptual framework to address the overall objective of this study, i.e. identifying the most locally suitable and relevant shade tree species for smallholder's coffee AFS. In the first section of this chapter, smallholder's perception and preferences of the ES provided by shade trees will be discussed, followed by a discussion of their preferences of shade tree species in the second section. Thirdly, the factors influencing smallholder's adoption of shade tree species will be discussed. The fourth section of this chapter will provide a reflection on the methodological limitations of this study. Finally, I will present my recommendation of shade tree species based on the results of this study.

## 5.A. SMALLHOLDER'S PERCEPTION AND PREFERENCES OF THE ECOSYSTEM SERVICES PROVIDED BY SHADE TREES

---

### 5.A.1. COMMON PATTERNS IN ECOSYSTEM SERVICES PREFERENCES

---

Overall, coffee smallholders in the study area have a good knowledge of the ES provided by shade trees but a moderate knowledge of their ED. This indicates that farmers have an overall positive image of shade trees, thus making it easier for them to refer to trees in positive than negative terms. One possible explanation could be that smallholders naturally recognize the importance of their environment due to their high dependence on natural resources and the health of ecosystems. However, it is more likely that such results stem from the work of the organizations and institutions which are promoting the protection of the environment, and thus the planting of trees, in the study area, although these two explanations do not exclude each other. This influence of local organizations and institutions on farmer's knowledge is described as the hybridization of traditional knowledge by Gómez-Baggethun, Corbera and Reyes-García, (2013) and was also found by Rigal, Vaast and Xu (2018) in the case of farmers from mountain ethnicities who appropriated the knowledge of local authorities' promotion activities.

One pattern that was particularly consistent throughout the ranking analysis was that coffee smallholders valued significantly more shade trees' provision of fruits for auto-consumption than other ES, irrespectively of their gender or geographical location. These results are inconsistent with the findings of Gram *et al.* (2018) who found that the provision of food, although ranked higher than other provision services, were systematically ranked lower than ES related to soil fertility enhancement and microclimate regulation. Participant's ranking might have been influenced by the recent climatic changes, such as droughts and elevated temperatures, and the maintained low international coffee prices which have limited the food availability and food access of many poor households in Nicaragua in the past years (Idol, Haggard and Cox, 2011; FEWS NET, 2016, 2019). However, this hypothesis contrasts with the fact that only 26% of the respondents spontaneously mentioned the provision of fruits as a

positive impact from shade trees, giving it the 10<sup>th</sup> position out of the 13 ES mentioned. Based on my observations, I hypothesize that participants may have given such a high rank to shade trees' provision of fruits in the hope that their answer would allow them to receive free improved fruit tree seedlings from one of the numerous organizations or institution in the area. Such grafted fruit trees brought by projects were known to be economically profitable, as opposed to their native equivalent, while still providing food for the household, but respondents were not willing to make such investment. Hence, I also suggest that there might have been a confusion between the 'Auto-consumption' and 'Income' categories during the ranking exercises.

The contribution of shade trees to soil fertility also appeared as a relatively important ES for coffee smallholders. Shade tree's provision of organic matter was the second more frequently mentioned ES during the survey (57%) and was consistently placed in the second significance group in the ranking exercise. These findings are consistent with other studies which highlighted the importance of soil fertility for coffee smallholders (Gram *et al.*, 2018; Lépine, 2018).

Overall, the provision of firewood appeared to have relatively little importance for respondents which corresponds to the findings of other studies (Bukomeko *et al.*, 2017; Gram *et al.*, 2018). This could be explained by the fact that firewood is often not perceived as a limiting resource by farmers and by the increasing use of gas stoves in the study area.

The three tree attributes considered to support farmer's activity, namely, the rapidity of growth, the ease of pruning and the fact that the tree was adapted to the local climate, systematically obtained a lower rank than the ES. This was a surprising result given that smallholders often described the trees based on these three aspects. Possibly, farmers have a higher stake in obtaining products from the trees and benefits for coffee productivity than in easing their labor.

#### 5.A.2. HOW THE LOCAL MICRO-CLIMATE INFLUENCE FARMER'S PREFERENCES OF ECOSYSTEM SERVICES

---

In addition to the above-mentioned common patterns, study participants' preferences of ES appeared to vary between the three communities included in this study. Most notably, smallholder's perception of shade in itself greatly diverged among the communities, perceived as necessary in La Estrellita but facultative in Cerro Grande. Although Cerro Grande is located at a slightly higher altitude, the large overlapping of communities' altitude range doesn't allow to conclude on an effect of altitude alone on farmer's preferences regarding shade. Rather, the low ranking of shade density in Cerro Grande should be attributed to the combination of high precipitations, lower temperature and higher altitude. Since a high density of shade buffers temperature extremes (Vaast, Kanten, *et al.*, 2005; Lin, 2007), the results are consistent with the study of Bukomeko *et al.* (2017) who found that farmers ranked the buffering of extreme temperature significantly higher according to their priorities in the low rainfall zone than in the higher one. In the same way, the retention of soil humidity by shade trees was significantly more important in La Estrellita than in Cerro Grande which coincides with the higher rainfalls

of the latter. The climate in Cerro Grande, or at least in its upper part, is certainly closer to the optimal environmental conditions for coffee cultivation, than in La Estrellita which explains why farmers do not value as much the regulating services from shade trees (DaMatta, 2004; Vaast, Kanten, *et al.*, 2005). Furthermore, at lower altitudes, coffee is more vulnerable to climatic changes such as prolonged drought and elevated temperature resulting in heat and water stresses. This explains why respondents in La Estrellita and La Inmaculada mentioned more positive impacts from shade trees, since they are more dependent on these trees to provide them with ES that can help mitigate and improve their resilience to important climatic extremes. (Bunn *et al.*, 2015; Gram *et al.*, 2018)

---

### 5.A.3. GENDERED DIFFERENCES

---

Men were found to be predominantly in charge of coffee management and the related decision-making process while women were in charge of household chores and occasionally participated in activities related to coffee production, which corresponds to the findings of Bose (2017). Unlike Gram *et al.* (2018) who did not find gendered differences in ES preferences, this study have shown that women perceive provision ES from shade trees as more important than regulating ES while men had no clear preference for one type of ES over the other. The fact that women value more provision services corresponds to the findings of other studies which have found that women prefer trees of domestic value (Agarwal, 2000; Meinzen-Dick, Kovarik and Quisumbing, 2014). The provision of food for auto-consumption were ranked first by both men and women, meaning that this ES is not gendered which is consistent with the review of Yang *et al.* (2018). However, men ranked the provision of quality timber surprisingly low given that most studies agree that men value trees of economic value (Agarwal, 2000; Meinzen-Dick, Kovarik and Quisumbing, 2014). My results suggest that this is partly due to the national regulations on timber extraction which make the exploitation of high quality native timber species difficult and costly for smallholders. This was also found to be a barrier to the adoption of timber species by smallholders in other regions of the world (Rigal *et al.*, 2018). Furthermore, several respondents mentioned that tall timber trees may not be appropriate inside the coffee plots, or at least should be placed in the periphery, as their extraction for the household use or their natural fall due to strong winds is damaging to the coffee plants.

---

## 5.B. COFFEE SMALLHOLDER'S PREFERENCES OF SHADE TREE SPECIES

---

---

### 5.B.1. A TASTE FOR BANANAS

---

The basic pattern in the data demonstrates that banana was among the most important species for coffee smallholders. Present in 90% of the coffee AFS visited and at a high density, the banana consistently obtained a high rank in farmer's preferences, closely followed by the plantain. Indeed, both *Musa* spp. obtained a very high or a high rank in nearly all of the communities for their provision of food for sale and consumption, shade density, improvement of soil fertility, retention of soil humidity, rapidity of growth and suitability to the local

conditions. The ranking also shows that while the plantain has a greater contribution to farmer's income thanks to the higher marketability and prices of its fruits, it is also considered less adapted due to its susceptibility to soil fungi and insect attacks, which explains while it was only present on 50% of the farms. Other studies have found high densities of *Musa* spp. in coffee AFS, often considered an effective way of securing food for the household (Gobbi, 2000; Idol, Hagggar and Cox, 2011; Rice, 2011; Pinoargote *et al.*, 2017; Gram *et al.*, 2018). Idol *et al.* (2011) found that smallholders used *Musa* spp. as a safety net against low coffee prices as, during these periods, a greater presence and productivity from bananas and plantains were recorded. Indeed, in their study of family benefits from coffee plantations in northern Nicaragua, Pinoargote *et al.* (2017) found that bananas represent 20 to 60% of the coffee value. However, they also highlight that when there is a high density of bananas, their role of shade providers surpasses their role as a source of fruits. These findings are in line with my results as *Musa* spp. would be used at times to complement smallholder's income but were also reported to not be harvested, due to lack of time and market opportunities, and thus served primarily the purpose of giving shade in these cases.

Nonetheless, a few farmers wanted to greatly reduce the number of banana plants of their coffee AFS, arguing that they could fall over easily and thus lead to soil erosion and damages to the coffee plants. This opinion provoked strong emotions but was not shared by the majority of farmers. Further investigation would be needed to identify if this problem is linked to the slope, the structure of the soil or the method of plantation of the bananas.

### 5.B.2. THE INFLUENCE OF LOCAL INSTITUTIONS AND ORGANIZATIONS ON LOCAL ECOLOGICAL KNOWLEDGE: THE EXAMPLE OF INGA SPECIES

Together with the banana and plantain, the *Inga* spp. systematically appeared among smallholder's favorite shade tree species. *I. punctata* and *I. edulis* were the most represented of the four *Inga* spp. listed, followed by *I. densiflora*. In all of the communities, they were valued for their provision of firewood, contribution to soil fertility, retention of soil humidity, growth speed and suitability to the local climate. They are qualified by farmers as temporary shade species meaning that they rapidly form a closed canopy but are not meant to survive more than a decade, thus constituting an important source of firewood as they die off. Shade trees providing temporary shade are extremely important in the first year of establishment of a plantation to ensure coffee plants and other seedlings' survival (Hagggar *et al.*, 2002). Furthermore, both *I. punctata* and *I. edulis* produce a pod in which the aril covering the seeds is edible and sweet. As several respondents pointed out, *Inga* spp. have been promoted by the government as perfect species for coffee AFS (Carcache, Jarquin and Rodriguez, 2005) and rapidly, every farmer started to adopt it, to the point that it is now referred to as a traditional shade tree species. Thanks to the large amount of seeds they yield, it was easy for farmers to produce seedlings and transplant them in their coffee fields, thus accelerating their diffusion. However, as reported by Valencia *et al.* (2015), there is a lack of scientific evidence of the benefits of the genus *Inga* on coffee production (Romero-Alvarado *et al.*, 2002; Peeters *et al.*, 2003; Grossman *et al.*, 2006). This discrepancy between farmer's preferences and the scientific literature reveal that farmers are receptive to external sources of knowledge and readily

integrates it to their own knowledge system in a process of hybridization (Gómez-Baggethun, Corbera and Reyes-García, 2013; Valencia *et al.*, 2015).

Nonetheless, smallholders have shown to be capable of putting in perspective the promoted benefits of *Inga* spp. as they witnessed that these species, in particular *I. edulis*, increase the occurrence of American leaf spot and to a lesser extent of kaleroga. Indeed, as time passes, farmers' knowledge keeps evolving through practice and observation and the new hybrid knowledge, due to its dynamic nature, is constantly being reassessed (Gómez-Baggethun, Corbera and Reyes-García, 2013).

---

### 5.B.3. GENDER ASPECTS

---

The basic pattern in the data shows that men and women had similar preferences of shade tree species, which indicates that smallholder's LEK regarding individual species is gender blind and thus reinforce the idea that LEK can contribute to agroforestry research and development (Gram *et al.*, 2018). There was one exception to this pattern: *Guazuma ulmifolia* which was largely preferred by women than men. Farmer's statements about this species indicate that although its fruits are an important source of animal feed and are attributed some medicinal properties, it is not considered as a suitable shade tree in the coffee plots because it sheds its leaves in the dry season and was said to increase coffee diseases. This example corresponds to the study of Yang *et al.* (2018) which suggest that women have a higher interest for medicinal products than men. Furthermore, the fact that women's preference for this tree reflects its provision of products of domestic value and not its suitability for coffee production denotes of their lower involvement in coffee management. Likewise, women showed slightly higher preferences for fruit tree species than men and also appeared to have more knowledge about fruit tree species than other shade tree use-categories. On the other hand, men were found to be significantly more knowledgeable about service trees, high-quality timber trees and remnant forest trees with no apparent use which can also be attributed to the fact that men are predominantly in charge of coffee management and thus to the gendered division of farm and household activities. Indeed, the decision-making power within the household affects the way men and women access and use different trees and thus gender roles and responsibilities are found to shape both farmers knowledge and preferences (Meinzen-Dick, Kovarik and Quisumbing, 2014; Kiptot, 2015) although in the present study, differences in shade trees preferences was only minor.

---

## 5.C. FACTORS INFLUENCING SMALLHOLDER'S ADOPTION OF SHADE TREE SPECIES

---

---

### 5.C.1. DIVERSIFIED SHADE CANOPIES

---

The small-scale coffee AFS of Matagalpa department showed a high degree of biodiversity, with 106 different shade tree species listed from 47 farms but also important variation in farm species richness which ranged from three to 38 species. First, the analysis of farm diversity revealed that farmers who were involved with an institution or organization

different from NFF showed a significantly higher farm diversity than farmers who were not part of any project. Undeniably, the organizations and the institution which formed this category showed a clear focus and interest in increasing farm diversity, either for research purposes (INTA) or certification purposes related to the protection of the environment (Aldea Global). Secondly, coffee plots which were located further away from smallholder's house had significantly less species than those located closer. Indeed, further analysis showed that this result could be mainly attributed to a significantly lower number of fruit tree species dedicated to household consumption on these plots, which will be discussed later in this chapter. Third, the altitude of the coffee plot was found to be negatively correlated to farm diversity. This could be explained by the fact that, at higher altitude, as temperature decrease and precipitations increase, farmers perceive shade trees as less necessary to protect coffee plants from heat and water stresses (DaMatta, 2004). However, this proposed explanation relies on the assumption that a lower percentage of shade is associated with a lower diversity of shade trees, which may not be the case. Finally, the households of the lower economic status group had significantly less species than those of the medium economic status, which could be attributed to the smaller size of their coffee plot and/or a difficult access to tree seedlings due to lower financial resources.

### 5.C.2. COMPARING FARM DIVERSITY AND SMALLHOLDER'S PREFERENCES

---

The results show that the abundance of individual shade tree species in the study area do not necessarily reflect smallholder's preferences nor recommendations, although some exception could be identified, for instance with the banana or with certain species of the genus *Inga*. Although this aspect was not investigated in the present study, one possible reason for the differences between preferences and adoption could be a lack of access to tree seedlings or the lack of land, given that resource endowment is a key determinant for adoption (Mercer and Pattanayak, 2003). In addition, it could be hypothesized that these discrepancies may reveal difficulties to cultivate a given species or some newly acquired knowledge about the benefits of a given species that has not been adopted on a large number of farms yet.

Furthermore, the tree inventories also showed that farmers have retained several species with no apparent use as well as species that were not consider suitable for coffee production, which indicates that farmers retain a wide range of species and not only species of commercial interest (Soto-Pinto *et al.*, 2007). Other studies also found that although farmers may have defined preferences for certain shade tree species, their coffee AFS were not necessarily dominated by these preferred species (Albertin and Nair, 2004; Valencia *et al.*, 2015). Valencia *et al.* (2015) infer from their study in Mexico that farmer's selection of shade tree species consists of a gradual process of removal of disliked species and increase in the abundance of preferred species through voluntary selection of naturally occurring tree seedlings during weeding in reaction to the removal of a mature tree due to natural or anthropogenic causes. The fact that farmers plan for the removal of disliked species and adoption of preferred species is consistent with this theory.

### 5.C.3. FRUIT TREE SPECIES

---

Based on the results of the regression analysis, a higher diversity of fruit tree species was found in the coffee AFS located near the household which appears logical as it allows farmers to access the trees more easily at the time of harvest and avoid transporting the fruits over large distances in hilly terrain. Fruit tree species diversity significantly decreased as the altitude increased since some fruit trees generally grow at lower elevations than coffee and thus do not produce well at high altitudes, limiting their interest to farmers (i.e. mango; Rice, 2011). Interestingly, a significantly larger number of fruit tree species was listed during the tree inventory when the respondent was a woman ( $p \leq 0,01$ ), which was found to be the variable with the largest effect on fruit tree diversity for household consumption. It is possible than women listed more fruit trees because fruits are more integrated in their daily activities than other use-categories of trees (Meinzen-Dick, Kovarik and Quisumbing, 2014; Kiptot, 2015). Likewise, it is possible that men listed less fruit tree species because of their focus on coffee productivity, which is associated to regulating services such as the buffering of temperature extremes and enhancement of soil fertility. Moreover, farmers with a larger coffee plot were more likely to introduce a higher diversity of fruit tree species for household consumption in their coffee AFS, nonetheless, the farmers with the biggest farms who belonged to the high economic status group presented less of these species in their coffee AFS than those of the medium group. It is possible that farmers with large farms still present a high diversity of fruit tree species on their farm but do not place them in the coffee plots. Nonetheless, in the present study, no data was collected on farm diversity outside of the coffee plots and thus further research would be needed to confirm this hypothesis.

Only a relatively small proportion of fruit trees obtained a high rank in farmer's preferences, including bananas, plantains, oranges, avocados and cacao. However, it should be kept in mind that ranking results are only relative and that they show farmer's preference for certain trees over others, hence a medium rank do not necessarily translate into farmer's dislike of this tree. Indeed, several farmers stated their intention to increase the diversity of fruit trees in their coffee fields.

Based on respondent's discourse, the main drawback to the adoption of fruit tree species in the coffee AFS was linked with the presence of thieves in the communities. Thieves not only deprived farmers from harvesting shade trees' fruits but also damaged the trees themselves and the surrounding coffee plants. Nonetheless, in the present study, no data was collected to identify the extent of this phenomenon and its impact on farmer's livelihoods, which should be addressed if local organizations aiming to increase household's food security keep donating fruit tree seedlings. Respondents also complained about the current low market price of several fruits that they usually sell to middlemen or bring to the city's market. Other studies have found that the sale of NTFP is a non-negligible source of income for coffee farmers, in particular at times of low international coffee prices (Rice, 2011). Respondents indicated that improved fruit varieties and cultivars obtain better market prices which could mean that the increase of better-quality fruits on the markets have drawn consumer's attention and as a result the demand for native fruits has dropped. Further market analysis would be needed to support this claim.

In the absence of a market for these fruits, many respondents reported to use them for their own consumption, not harvest them, donate them to family members or let farm workers take them for free. From a Westerner perspective, it is easy to conclude that smallholders are wasting their own resources in fruits due to their relaxed attitude regarding harvesting. Such conclusion dismisses the fact that smallholder's LEK is embedded in a complex network of relationships, values and practices (Nadasdy, 1999). Rather, the cultural importance of being able to offer some fruits as a present if some family of friends visit them or if some landless workers are in need of it should be acknowledged as demonstrating a high form of social intelligence.

---

#### 5.C.4. TIMBER

---

The presence of timber trees on the farm was highly valued by smallholders as it was a necessary resource to build houses, other types of constructions, make furniture and do all sorts of reparations. In addition, farmers recognized that having high-quality timber trees on their land would increase its value and secure the access to this scarce resource for the next generations. No relationship was found between the fact that farmers received training, or was involved with an institution or organization, and the number of high-quality timber species present on the farm, thus this paper cannot conclude that such knowledge is the result of hybridization due to the promotion of timber trees by local organizations. Nonetheless, it should be taking into account that the number of high-quality timber species do not reflect neither the abundance of these species, neither their origin as purposefully planted or retained species.

Interestingly, several respondents recommended that timber trees should be planted on the periphery of the coffee AFS and far from the house by fear of their fall due to strong winds, indicating that the devastating hurricane Mitch (1998) has deeply marked farmer's spirit. The fact that a higher diversity of high-quality timber trees were found in larger coffee AFS further support the idea that farmers do not perceive timber trees as being suitable inside of the coffee plots. According to the results of the ranking exercise, smallholders did not perceive timber as necessarily having a negative impact on soil fertility.

Timber trees were considered to contribute less to household's income than fruit trees. National policies aiming at protecting endangered native species obliged farmers to obtain a legal permit in order to fell and make a commercial use of a tree. Although these permits were delivered for non-endangered species and under specific conditions for other species, they were regarded as difficult and costly to obtain, thus preventing farmers from obtaining a direct financial benefit from their timber resources. Such problems were also reported in China (Rigal, Vaast and Xu, 2018). Nonetheless, local organizations had started to address this problem by registering the tree seedlings that they donated to farmers in order to ensure that they could legally sell these trees.

## 5.D. LIMITATIONS

---

The small number of respondents and participants, in particular in La Inmaculada, can be seen as a potential limitation of the present study. In addition, the way in which the ranking exercise was realized and conducted, and the construction of the socio-economic indicator potentially had a negative impact on the quality of my results.

As discussed previously, in each of the selected communities the targeted number of respondents could not be reached, and different sampling strategies were adopted due to different reasons. Discrepancies in sampling strategies represent a potential threat to the study's internal validity since the inclusion of certain individuals may have been unintentionally favored over others. Small sample sizes limit the generalizability of my study, and thus its external validity, because in within a smaller number of respondents, special cases have a higher effect on the results. Hence, the smaller sample size reached in La Inmaculada should be kept in mind when comparing both species abundance and smallholder's preferences between the three communities. In addition, data was collected over a three months period and thus the results presented are a snapshot of study participant's knowledge and preferences and may have been different if the study was conducted over a larger period of time or at a different time, also limiting the external validity of the results. Nonetheless, since the focus of this study was to gain an in-depth understanding of the barriers and constraints locally affecting coffee smallholders, the quality of the presented results should not be judge only on these criteria.

Although scientific knowledge is segregated into various disciplines and often focus on a single species, population group or phenomenon, in reality, such compartmentalization doesn't exist as people develop knowledge about their environment as a whole (Nadasdy, 1999). Hence, trying to describe LEK by compartmentalizing it into different ES and tree categories is in contradiction with the nature of LEK itself. Indeed, one important problem during the ranking exercises was that participants could not always grasp the idea of ranking ES and tree attributes based on their importance for species selection. In such cases, participants kept referring back to specific tree species as being better than others because they could provide various ES since all of the ES had some degree of importance to them. In addition, it is possible that some confusion arose from the design of the ES and tree attributes cards which might have been too small and comprising too detailed representative pictures, which was potentially confusing for participants with visual disabilities. It is also important to note that some farmers were potentially providing answers with the hope that they could benefit them in a near future as many local organizations were using surveys to identify new project beneficiary. Hence, the results from the analysis of the ranking of ES and ED will have to be nuanced with observations from the field.

Furthermore, the economic categories presented in this study should be interpreted carefully since they are based on a restricted number of variables which may not fully represent household's economic status. Moreover, asking to respondents who in the household was responsible of the management decisions related to coffee production constituted a quick way of assessing the gender aspect of decision-making but it lacked subtlety. A better approach would have been to ask separately to the men and women of the household which activities

related to coffee production they carried in order to assess their degree of participation. However, the data that I collected reveals the respondent's perception of who is in charge of the decisions which is also interesting. In the same way, respondents' perception of their soil fertility should not be considered to be able to replace the results of a soil analysis. Finally, it is regrettable that precipitation could not be included in the analysis of the factors influencing farm species richness due to technical problems encountered during the analysis. Such methodological limitations represent a potential threat of the internal validity of this study since potential important variables might have been omitted and their effect occulted by other variables.

In future research, focus groups should be conducted prior to the ranking exercise to get a better understanding of smallholder's perception of ecosystem services and tree species. Creating an open dialogue with study participants allows the researcher to adopt their vocabulary rather than imposing pre-defined categories onto their words. Nonetheless, focus groups can be difficult to plan and organize as it is crucial to ensure that there are no power imbalances within each of the participants' groups. In addition, I suggest that to increase the standardization of the methodology, BREEDCAFS should provide researchers with a range of ES and ED cards with simple pictograms that researchers could choose from to avoid introducing bias in the visual representation of the ES and ED.

---

## 5.E. RECOMMENDATIONS

---

In order to provide an answer to my overarching research question, this section will present my recommendations of shade tree species which should be included in the coffee AFS, based on my results and the existing literature.

---

### 5.E.1. TEMPORARY SHADE

---

First and foremost, intercropping of coffee with *Musa* spp. have proved to be highly suitable in smallholders' coffee AFS. Banana and plantain contribute both to the household consumption and income thus constituting a safety net against low international coffee prices (Idol, Hagggar and Cox, 2011; Pinoargote *et al.*, 2017). Furthermore, according to van Asten *et al.* (2011), there is no evidence that intercropping coffee with bananas negatively impact coffee yields through competition for water and nutrients although optimal plant densities and appropriate management practices can probably benefit the overall productivity of the system. However, the results suggest that plantain is not recommendable when labor is limiting as it requires far more care than bananas due to its sensitivity to soil fungi.

Secondly, this study suggests that the use of *Inga* spp. to establish temporal shade is also highly suitable for smallholders' coffee AFS. Although the scientific literature does not provide evidence for the agronomic benefits of *Inga* spp. on soil fertility or coffee yields (Romero-Alvarado *et al.*, 2002; Peeters *et al.*, 2003; Grossman *et al.*, 2006; Valencia *et al.*, 2015), *Inga* spp. are fast growing trees which are easy to manage, are easy to propagate by seeds and of which the fruits are commonly eaten by children or turned into drinks. Most

importantly, I would recommend retaining *Inga* spp. on the farms due to their important role as firewood providers. Indeed, *Inga* spp. were reported to produce a firewood of good quality and in large amounts. Farmer's knowledge has shown however that the species from the genus *Inga* could increase coffee diseases, especially when they were not properly managed. Further research will be needed to identify whether such observations are linked with high degrees of shade and humidity or with the species themselves.

Finally, the castor oil plant was distributed to the farmers of the MATRICE project for its capacity to provide shade to the coffee plant without having to plant it prior to the establishment of the coffee plantation. It was also appreciated by farmers for the rapidity of decomposition of its leaves. Nonetheless, this species is highly toxic, both for wildlife and humans and cases of intoxication in humans was reported after the ingestion of only two of its seeds (Stegelmeier *et al.*, 2013). However, it appeared that the farmers who had adopted this species did not know about the toxicity of its seeds. This lack of knowledge appear particularly dangerous as the seeds are quite attractive and could end in the hands of children. In conclusion, it is essential that local organizations provide detailed information about the seeds and seedlings they bring to farmers. In my view however, introducing a new exotic and toxic species in the coffee AFS is not necessary and should be avoided. Rather, based on farmers' current practices, it is more recommendable to plant *Musa* spp. and *Inga* spp. prior to the coffee plants.

---

### 5.E.2. SERVICE TREES

---

Several farmers manifested their interest in planting more trees which would improve soil fertility. Among the service tree species present in the study area, *Erythrina poeppigiana* and *Erythrina fusca* appeared as the most recommendable ones. Indeed, although farmers recommended more *E. poeppigiana* than *E. fusca*, their statements about each tree showed very little difference. Furthermore, relatively few respondents selected them in the ranking exercise, which suggest that they have little knowledge about these species and that they might be confused by farmers. Meylan *et al.* (2017) found that coffee plots under the shade of *Erythrina* spp. showed a higher water infiltration rate and amount of litter cover than in full-sun and banana-shaded coffee, and evidence for biological N-fixation by the species of the *Erythrina* genus. Farmers also described both species as being fast-growing and preserving soil humidity. Hence, practical recommendations for pruning should be provided to farmers who want to adopt these species to ensure appropriate shade management. Even more so, since farmers perceived negatively the fact that these species have spines as it can hurt coffee pickers during the harvest and make the pruning more difficult. In this case, such aspects could be considered negligible compared to the potential benefits of the trees.

Further research should focus on identifying other service tree species suitable in the local climate and with a more suitable density of shade.

---

### 5.E.3 TIMBER TREES

---

Overall, the results of this study indicate that timber is a crucial resource for coffee smallholders as it is the building material for their houses and as such, their presence should be

maintained in the coffee plots. Wood quality is important to consider since it often goes hand in hand with wood durability. Nonetheless, several farmers commented about individual timber species that they should be planted in the periphery of the coffee plots in order to facilitate their extraction and limit damages to the coffee plants in case of natural fall. It should be recognized that it is not always possible and depend on the size of the coffee plot. In addition, one farmer mentioned that timber trees could be planted within the coffee plot but did not undertake the role of shade providers for the coffee plants. Altogether, even if it is not possible to conclude from this study whether farmers think timber trees are suitable for coffee production or not, there is evidence that they are essential trees for coffee smallholders.

The most recommended timber tree species in the study area was *Platymiscium pinnatum*, thanks to the quality of its timber and its capacity to provide good shade, followed by *Cedrela odorata* and *Terminalia oblonga* which were also a species appreciated for the quality of their timber. Nonetheless, both species were reported to be attacked by some insect which made holes in their wood. Farmers also reported their intention to add *Pachira quinata* and *Swietenia macrophylla* in their coffee AFS.

On the other hand, *Cordia alliodora* was the least recommended species. This can be attributed to the fact that it sheds its leaves during the dry season, thus depriving the coffee plants of shade at the time when it is needed the most. Interestingly, there were some disagreement on this species as it was also sometimes recommended by farmers as a fast-growing species of good timber quality and by farmers who considered that high degrees of shade were inappropriate at their altitude due to a colder climate. This suggest that farmers who are reluctant to adopt a high density of shade trees would more likely adopt *Cordia alliodora* than species providing higher densities of shade. Likewise, *Tabebuia rosea* was also not recommended by one farmer as it was qualified of ‘hot’ shade, meaning that it didn’t protect the coffee plants from heat and water stress.

*Juglans olonchana* was also said to not be appropriate in coffee AFS as it brought diseases to the coffee plant due to the high density of its shade and its difficulty of pruning due to the fact that it grows very tall.

In conclusion, I suggest that rather than a single species, a mixture of the recommended species mentioned previously should be adopted by coffee smallholders. This would allow to minimize losses of timber if the different species were attacked by different insects as the distance between several individual of the same species would be greater. In addition, having a mixture of timber trees would allow farmers to retain *Cordia alliodora* as a fast-growing and naturally occurring timber species despite of the fact that it sheds its leaves since other neighboring trees could provide shade for the coffee plants during the dry period.

---

#### 5.E.4. FRUIT TREES

---

The results of this study suggest that smallholders value the presence of fruit trees in their coffee plots, either as a source of income or for the household consumption. In addition, donating fruits to family members or coffee workers appeared as an important tradition. Based

on my findings and the existing literature, I recommend that smallholders should adopt a wide variety of fruit tree species in order to increase their food security in the current context of climatic changes. Given their higher interest and preference for fruit trees, I also advocate for prioritizing women involvement in the selection and planting of fruit tree species in the context of development projects. Planting fruit trees close to the house (eventually outside of the coffee field) would make their access easier to women and potentially increase the amount of fruits harvested. However, in all of the communities, respondents said to be facing problems with thieves coming to still fruits upon maturation and causing damage to the coffee plants. Although little can be done to avoid such situations, it certainly questions the relevance of introducing fruit trees in the coffee AFS. Planting fruit trees in places which are hidden from the paths and roads could be a preventive measure although through time, its effectivity would certainly diminish, and farmers might be less likely to closely follow the maturation of the fruits. Rather, I propose that development projects should focus on beneficiating to the largest number of community members possible and avoid any sort of exclusion in order to ensure that project participants actually benefit from the work they have invested in these trees.

Coffee smallholders appeared to have a strong preference for avocados, which closely followed bananas and plantains in the ranking exercises. Although market prices were currently low for native avocados, they were considered a potential source of income for the household when market price increased or when the harvest was abundant. Nonetheless, farmers perceived avocados very different at lower and higher altitude. Indeed, avocados, like mangos, were reported to not produce well at higher altitudes while farmers said that they grew fast and tall at lower altitudes. Efforts should be invested in identifying cultivars which are more resistant to the lower temperatures found at higher altitude.

*Citrus* spp. were also among the most popular fruit tree species in the study area as they were used to cook and to make drinks and also contributed to the household's income when market prices were high. In the study area, seven *Citrus* spp. were listed, further highlighting their importance. In particular, mandarins were recommended over other *Citrus* spp. due to its apparent better productivity and higher market price although it was also said to be less adapted in the coldest communities. Similarly, *Citrus x latifolia* was reported to currently have a higher market value and thus could be considered more appropriate for commercial purposes. Nonetheless, I prescribe that the high diversity of *Citrus* spp. should not be abandoned and that the agricultural performance of each *Citrus* spp. in the different types of micro-climate of the study area should be documented to inform development projects of the agronomic suitability of individual species.

Cacao was also highly valued by coffee smallholders due to its ability to provide a relatively stable or at least, regular source of income. As other fruits trees, its adoption was limited by low temperatures at high elevations. Although some farmers considered it suitable to intercrop cacao with coffee, I suggest that proper spacing recommendations should be provided to avoid nutrient competition. In many cases, farmers manifested their willingness to abandon coffee cultivation altogether to dedicate their land to cacao. Although such claims are understandable in a context of changing climate, I would recommend that such transition should take place gradually, rather than all at once, as drastic increases of cacao supply could

negatively affect prices. Furthermore, I propose that mixed systems, with a portion of the land dedicated to coffee and the other to cacao would ensure more stability in the face of extreme climatic events and diseases outbreaks.

One interesting cash-crop which was identified in this study is *Bixa orellana*. Although adopted by relatively few smallholders, it was reported to significantly contribute to household's income and thus could buffer the effect of low international coffee prices and production related issues.

In a nutshell, altitude and micro-climate appear to be the most limiting factors to the agronomic suitability of different fruits trees to smallholder's coffee AFS which highlights that there is no one-fits-all package of shade tree species that should be advised to coffee smallholders.

#### 5.E.5. GENERAL RECOMMENDATION

---

Given the importance of micro-climate variation in mountainous terrain, I suggest that development projects providing free tree seedling to coffee farmers should focus on offering a high diversity of species rather than a large number of individuals of a same species to allow farmers to test for the suitability of various species and cultivars on their own field. Furthermore, providing farmers with species that they (as an individual farmer) did not have before can foster both individual and aggregate adoption, even more so with no or minimal initial implementation costs. Indeed, with time, uncertainties toward the introduced species will reduce as farmers gain experience, and it is found suitable, the species could be adopted with a higher degree at the farm level (through propagation or investment). Such farmers could then play the role of innovators and spread their knowledge, and potentially planting material to other farmers thus disseminating the new species in the communities. (Feder and Umali, 1993; Mercer, 2004)

---

## CHAPTER VI: CONCLUSION

---

One paragraph stating what you researched and what your original contribution to the field is...then break into sections•One section on what you researched and how you did it•One section on what are the main findings were... showinglinks across chapters (this explains why you chose thestructure you did)•One section on possible areas for future research•Final section reminding readers of the original contributionand significance of your research to your field

Falling international coffee prices, deteriorating growing conditions and increases of pests and diseases are putting the whole coffee growing system in Matagalpa under threat. In AFS, shade trees can benefit to farmers in terms of food security and economic resilience through the provision of NTFP and timber as well as bioclimate and soil quality regulation. However, for shade-grown coffee systems to deliver such benefits, the shade trees species need to be carefully chosen and managed. Hence, this paper aimed to identify the most suitable and relevant species through the mobilization of LEK, in the context of small-scale coffee production systems in Matagalpa department, Nicaragua.

Coffee smallholder's LEK about the shade tree species of their AFS and the ES they can provide was documented using a mixed-method participatory approach. At first, questionnaires were conducted to grasp the local context and gain a better understanding of coffee smallholder's needs and of their perception of the impacts of shade trees in their AFS. These questionnaires also included a tree inventory to document the biodiversity present on the coffee AFS. Then, ranking exercises were realized with both men and women to document their priorities in terms of ES and their LEK and preferences of shade trees species.

The results indicate that smallholders have retained a high diversity of shade tree species in their coffee AFS, with a total of 106 species listed, and display an important LEK of the ES and ED they provide since they could identify 13 positive impacts and 7 negative impacts from the trees. While the ranking exercises were particularly relevant to collect farmer's LEK and preferences, the data collected through the questionnaire showed to be very useful to cross-validate, explain or nuance my findings. As such, even if shade trees' provision of products for household consumption appeared to be a priority for respondents across the three studied communities, it also appears that certain products such as fruits or firewood are not harvested in their totality. Such observations are important to consider to provide appropriate advice.

Women showed to value more provision services than regulating services, which can possibly be attributed to the division of labor in the household, as women participate to coffee production activities only occasionally. Similarly, women had a higher knowledge of fruit tree species than other use categories. From the ranking exercise, both men and women did not find tree attributes, such as rapidity of growth and difficulty of pruning, as important for shade tree species adoption and retention as providing and regulating services.

The most important species in the coffee AFS, both in terms of frequency of occurrence and farmer's preferences, were species of the genus *Musa* and *Inga*. Indeed, banana

and plantains were found to be important for household consumption as well as significantly complement the income from coffee. Moreover, they were considered as a good source of shade for the coffee plants. *Inga* spp. were highly valued by smallholder's despite of a lack of scientific evidence for their benefit to coffee productivity. In effect, they were appreciated for their ability to provide large amount of firewood and to provide shade relatively rapidly and were easily accessible to farmers.

In addition, cacao appeared to be gaining in popularity among coffee smallholders thanks to the fact that it provides a more regular source of income than coffee. While some farmers were using cacao as a shade tree in coffee AFS, others reported that they were willing to abandon coffee production for cacao. An intermediary solution, in which farmers replace a portion of their coffee plots by cacao AFS, could be recommendable. Another interesting cash crop, *Bixa Orellana*, was identified in this study and I suggest that its agronomic suitability in coffee AFS should be investigated.

The results of this study show that the most frequent species do not necessarily correspond to farmer's preferred species although more research on this topic is needed to understand the reasons behind this finding. In the present study, evidence was found that the shade composition of the coffee AFS is continuously evolving and that smallholders are willing to introduce more diversity in their coffee AFS. Remnant forest species with no apparent use are gradually removed and being replaced by service trees, fruit trees and timber trees.

The local climate appeared to be an important factor affecting farmer's preferences, based on their discourse. Hence, my recommendation to local organizations focusing on smallholders' coffee AFS is to provide farmers with a high diversity of species and varieties rather than on large numbers of seedling of the same species. This would allow smallholders to identify the species which show the best growing pattern in their local micro-climate without being limited in species adoption by financial constraints or access related issues.

In my opinion, the present study would have greatly benefited from conducting focus group interviews between the two phases of data collection in order to ensure that the ES categories selected are relevant and intelligible and to collect information

and eventually after the ranking exercises.

Although the present study gives some interesting insights onto gendered differences in shade tree's knowledge and preferences, future studies should focus on gaining a better understanding of the bargaining power balance between men and women

---

## LIST OF REFERENCES

---

Abruña, F. *et al.* (1965) “Productivity of Nine Coffee Varieties Growing under Intensive Management in Full Sunlight and Partial Shade in the Coffee Region of Puerto Rico,” *The Journal of Agriculture of the University of Puerto Rico*, 49(2), pp. 244–253.

Agarwal, B. (2000) “Conceptualising environmental collective action: why gender matters,” *Cambridge Journal of Economics*, 24, pp. 283–310.

Albertin, A. and Nair, P. K. R. (2004) “Farmers’ perspectives on the role of shade trees in coffee production systems: An assessment from the Nicoya Peninsula, Costa Rica,” *Human Ecology*, 32(4), pp. 443–463. doi: 10.1023/B:HUEC.0000043515.84334.76.

van Asten, P. J. A. *et al.* (2011) “Agronomic and economic benefits of coffee-banana intercropping in Uganda’s smallholder farming systems,” *Agricultural Systems*, 104, pp. 326–334. doi: 10.1016/j.agsy.2010.12.004.

Bacon, C. M. (2005) “Confronting the coffee crisis: Can Fair Trade, organic, and specialty coffees reduce small-scale farmer vulnerability in Northern Nicaragua?,” *World Development*, 33(3), pp. 497–511. doi: 10.1016/j.worlddev.2004.10.002.

Bacon, C. M. *et al.* (2008) “Are sustainable coffee certifications enough to secure farmer livelihoods? The millenium development goals and Nicaragua’s Fair Trade Cooperatives,” *Globalizations*, 5(2), pp. 259–274. doi: 10.1080/14747730802057688.

Barros, V. R. *et al.* (2014) “Climate change 2014: impacts, adaptation, and vulnerability-Part B: regional aspects-Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.” Cambridge University Press.

Beer, J. *et al.* (1998) “Shade management in coffee and cacao plantations,” pp. 139–164. doi: 10.1007/978-94-015-9008-2\_6.

Bellec, F. Le *et al.* (2012) “Evidence for farmers’ active involvement in co-designing citrus cropping systems using an improved participatory method,” *Agronomy for Sustainable Development*, 32(3), pp. 703–714. doi: 10.1007/s13593-011-0070-9.

Bernard, H. R. (2017) *Research methods in anthropology: Qualitative and quantitative approaches*. Rowman & Littlefield.

Bolaños, J. (2017) *Nicaragua, Coffee annual Report 2016/2017*.

Bolaños, J. (2019) *Nicaragua, Coffee Annual Report: Coffee Production Predicted to Fall 15 Percent*.

Boreux, V. *et al.* (2016) “Agroforestry coffee production increased by native shade trees, irrigation, and liming,” *Agronomy for Sustainable Development*. *Agronomy for Sustainable Development*, 36(3). doi: 10.1007/s13593-016-0377-7.

Bose, P. (2017) “Land tenure and forest rights of rural and indigenous women in Latin America: Empirical evidence Purabi Bose Independent Researcher and Filmmaker at Landing Together,” *Women’s Studies International Forum*, 65, pp. 1–8. doi:

10.1016/j.wsif.2017.10.006.

Bukomeko, H. *et al.* (2017) “Integrating local knowledge with tree diversity analyses to optimize on-farm tree species composition for ecosystem service delivery in coffee agroforestry systems of Uganda,” *Agroforestry Systems*. Springer Netherlands, 93(2), pp. 1–16. doi: 10.1007/s10457-017-0172-8.

Bunn, C. *et al.* (2015) “A bitter cup: climate change profile of global production of Arabica and Robusta coffee,” *Climatic Change*, 129(1–2), pp. 89–101. doi: 10.1007/s10584-014-1306-x.

Calero, M. (2019) *Cafetaleros demandan que se auditen 25 millones de dólares de Conatradec, La Prensa*. Available at: <https://www.laprensa.com.ni/2019/08/20/economia/2581183-cafetaleros-demandan-que-se-auditen-25-millones-de-dolares-de-conatradec> (Accessed: March 10, 2020).

Caramori, P. H., Androcioli Filho, A. and Leal, A. C. (1996) “Coffee shade with *Mimosa scabrella* benth. for frost protection in southern Brazil,” *Agroforestry Systems*. Kluwer Academic Publishers, 33(3), pp. 205–214. doi: 10.1007/BF00055423.

Carcache, M., Jarquin, M. C. and Rodriguez, L. (2005) *Establecimiento y manejo de sistemas de cafe ecoforestal*. MARENA.

Cerda, R. *et al.* (2017) “Effects of shade, altitude and management on multiple ecosystem services in coffee agroecosystems,” *European Journal of Agronomy*. Elsevier B.V., 82, pp. 308–319. doi: 10.1016/j.eja.2016.09.019.

Cerdán, C. R. *et al.* (2012) “Local knowledge of impacts of tree cover on ecosystem services in smallholder coffee production systems,” *Agricultural Systems*, 110, pp. 119–130. doi: 10.1016/j.agsy.2012.03.014.

Chambers, R. (1988) “Farmer first,” *International Agricultural Development*, pp. 10–12.

Chambers, R., Saxena, N. C. and Shah, T. (1989) “To the hands of the poor: water and trees,” *To the hands of the poor: water and trees*, (January 2014).

Charnley, S., Fischer, A. P. and Jones, E. T. (2007) “Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest,” *Forest Ecology and Management*, 246, pp. 14–28. doi: 10.1016/j.foreco.2007.03.047.

Chibnik, M. (2011) *Anthropology, economics, and choice*. University of Texas press.

CIFOR (2007) *Poverty Environmental Network (PEN) Technical Guidelines., Version 4*. Available at: <http://www1.cifor.org/pen/research-tools/the-pen-technical-guidelines.html> (Accessed: February 21, 2020).

Craparo, A. C. W. *et al.* (2015) “*Coffea arabica* yields decline in Tanzania due to climate change: Global implications,” *Agricultural and Forest Meteorology*. Elsevier B.V., 207, pp. 1–10. doi: 10.1016/j.agrformet.2015.03.005.

Creswell, J. W. (2003) *RESEARCH DESIGN: Qualitative, Quantitative. and Mixed Methods Approaches*. 2nd ed. SAGE Publications .

Cruikshank, J. (2004) "Uses and Abuses of 'Traditional Knowledge':," in Anderson, D. G. and Nuttall, M. (eds.) *Cultivating Arctic Landscapes*. 1st ed. Berghahn Books (Knowing and Managing Animals in the Circumpolar North), pp. 17–32.

DaMatta, F. M. (2004) "Ecophysiological constraints on the production of shaded and unshaded coffee: A review," *Field Crops Research*, 86(2–3), pp. 99–114. doi: 10.1016/j.fcr.2003.09.001.

Donovan, J. and Poole, N. (2014) "Changing asset endowments and smallholder participation in higher value markets: Evidence from certified coffee producers in Nicaragua," *Food Policy*. Elsevier Ltd, 44, pp. 1–13. doi: 10.1016/j.foodpol.2013.09.010.

Feder, G., Just, R. E. . and Zilberman, D. (1985) "Adoption of Agricultural Innovations in Developing Countries : A Survey," *Economic Development and Cultural Change*, 33(2), pp. 255–298.

Feder, G. and Umali, D. L. (1993) "Special Issue Technology and Innovation In Agriculture and Natural ResourcesThe adoption of agricultural innovations," *Technological Forecasting and Social Change*, 43(3), pp. 215–239. doi: [http://dx.doi.org/10.1016/0040-1625\(93\)90053-A](http://dx.doi.org/10.1016/0040-1625(93)90053-A).

FEWS NET (2016) *Central America Special Report: The impact of the coffee rust outbreak on the coffee sector in Central America*.

FEWS NET (2019) *El Salvador, Honduras and Nicaragua Remote Monitoring Update: The irregular distribution of rains throughout June and July affected grain harvests, mainly in Honduras and Nicaragua*.

Fortmann, L. and Rocheleau, D. (1985) "Women and agroforestry: four myths and three case studies," *Agroforestry Systems*, 2(4), pp. 253–272. doi: 10.1007/BF00147037.

Fortnam, M. *et al.* (2019) "The Gendered Nature of Ecosystem Services," *Ecological Economics*, 159, pp. 312–325. doi: 10.1016/j.ecolecon.2018.12.018.

Fournier, L. (1988) "El cultivo del cafeto (*Coffea arabica* L.) al sol o a la sombra: Un enfoque agronomico y ecofisilogico," *Agronomia Costarricense*, 12(1), pp. 131–146.

Fraser, J., Fisher, E. and Arce, A. (2014) "Reframing 'Crisis' in fair trade coffee production: Trajectories of agrarian change in Nicaragua," *Journal of Agrarian Change*, 14(1), pp. 52–73. doi: 10.1111/joac.12014.

Gadgil, M., Berkes, F. and Folke, C. (1993) "Indigenous Knowledge for Biodiversit Conservation," *Ambio*, 22(2), pp. 151–156.

Garcia Roa, M. (2003) *Estado de la diversidad biológica de los árboles y bosques en Nicaragua*.

Gausset, Q. (2004) "Ranking Local Tree Needs and Priorities Th rough an Interdisciplinary Action Research Approach," *The Journal of Transdisciplinary Environmental Studies*, 3(1).

Gobbi, J. A. (2000) "Is biodiversity-friendly coffee financially viable? An analysis of five different coffee production systems in western El Salvador," *Ecological Economics*, 33(2), pp. 267–281. doi: 10.1016/S0921-8009(99)00147-0.

Gómez-Baggethun, E., Corbera, E. and Reyes-García, V. (2013) “Traditional ecological knowledge and global environmental change: Research findings and policy implications,” *Ecology and Society*, 18(4). doi: 10.5751/ES-06288-180472.

Google Inc. (2019) “Google Earth Pro.”

Gordon, C. *et al.* (2007) “Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystem,” *Agriculture, Ecosystems and Environment*, 118(1–4), pp. 256–266. doi: 10.1016/j.agee.2006.05.023.

Gram, G. *et al.* (2018) “Local tree knowledge can fast-track agroforestry recommendations for coffee smallholders along a climate gradient in Mount Elgon, Uganda,” *Agroforestry Systems*. Springer Netherlands, 92(6), pp. 1625–1638. doi: 10.1007/s10457-017-0111-8.

Grijalva Pineda, A. (2006) *Flora útil etnobotánica de Nicaragua*. Managua: MARENA.

Grossman, J. M. *et al.* (2006) “An assessment of nodulation and nitrogen fixation in inoculated *Inga oerstediana*, a nitrogen-fixing tree shading organically grown coffee in Chiapas, Mexico,” *Soil Biology and Biochemistry*, 38(4), pp. 769–784. doi: 10.1016/j.soilbio.2005.07.009.

Haggard, J. *et al.* (2002) “Building Capacity for Ecological-based Reasoning in Farmer Management of Shaded Coffee in Central America.”

Harris, I. C. and Jones, P. D. (2017) “CRU TS4. 01: Climatic Research Unit (CRU) Time-Series (TS) version 4.01 of high-resolution gridded data of month-by-month variation in climate (Jan. 1901–Dec. 2016),” *Centre for Environmental Data Analysis*, 25.

Hijmans, R. J. *et al.* (2005) “Very high resolution interpolated climate surfaces for global land areas,” *International Journal of Climatology*, 25(15), pp. 1965–1978. doi: 10.1002/joc.1276.

ICO (2014) *World coffee trade (1963-2013): A review of the markets, challenges and opportunities facing the sector*.

Idol, T., Haggard, J. and Cox, L. (2011) “Ecosystem Services from Smallholder Forestry and Agroforestry in the Tropics,” in Campbell, W. B. and Lopez Ortiz, S. (eds.) *Integrating Agriculture, Conservation and Ecotourism: Examples from the Field*. Dordrecht: Springer Netherlands, pp. 209–270. doi: 10.1007/978-94-007-1309-3\_5.

INIDE (2005) *Caracterización Sociodemográfica del Departamento de Matagalpa*.

Jezeer, R. E. *et al.* (2018) “Effects of shade and input management on economic performance of small-scale Peruvian coffee systems,” *Agricultural Systems*. Elsevier, 162(January), pp. 179–190. doi: 10.1016/j.agsy.2018.01.014.

Kindt, R. (2019) “Package for Community Ecology and Suitability Analysis.” CRAN.

Kiptot, E. (2015) “Gender roles, responsibilities, and spaces: implications for agroforestry research and development in Africa,” *International Forestry Review*, 17(S4), pp. 11–21.

Köppen, W. (1900) “Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt,” *Geographische Zeitschrift*, 6(11. H), pp. 593–611.

Lépine, M. (2018) *Connaissances locales des services écosystémiques dans les systèmes agroforestiers à base de caféiers au Laos*. ISTOM.

Lin, B. B. (2007) “Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture,” *Agricultural and Forest Meteorology*, 144(1–2), pp. 85–94. doi: 10.1016/j.agrformet.2006.12.009.

Lin, B. B. (2010) “The role of agroforestry in reducing water loss through soil evaporation and crop transpiration in coffee agroecosystems,” *Agricultural and Forest Meteorology*, 150, pp. 510–518. doi: 10.1016/j.agrformet.2009.11.010.

Lin, B. B., Perfecto, I. and Vandermeer, J. (2008) “Synergies between Agricultural Intensification and Climate Change Could Create Surprising Vulnerabilities for Crops,” *BioScience*, 58(9), pp. 847–854. doi: 10.1641/b580911.

Maphill (2011) *Physical Map of Matagalpa*. Available at: <http://www.maphill.com/nicaragua/matagalpa/3d-maps/physical-map/> (Accessed: March 11, 2020).

Matoso-Campanha, M. *et al.* (2004) “Growth and yield of coffee plants in agroforestry and monoculture systems in Minas Gerais, Brazil,” *Agroforestry Systems*, 63(1), pp. 75–82. doi: 10.1023/b:agfo.0000049435.22512.2d.

MEA (2005) “Ecosystems and Human Well-being Synthesis,” *Island Press, Washington, DC*.

Meinzen-Dick, R. S., Kovarik, C. and Quisumbing, A. R. (2014) “Gender and Sustainability,” *Annual Review of Environment and Resources*, 39, pp. 29–55. doi: 10.1146/annurev-environ-101813-013240.

Méndez, V. E. *et al.* (2010) “Agrobiodiversity and shade coffee smallholder livelihoods: A review and synthesis of ten years of research in Central America,” *Professional Geographer*, 62(3), pp. 357–376. doi: 10.1080/00330124.2010.483638.

Mercer, D. E. (2004) “Adoption of Agroforestry Innovations in the Tropics: A Review,” *Agroforestry Systems*, pp. 311–328.

Mercer, D. E. and Pattanayak, S. K. (2003) “Agroforestry Adoption By Smallholders,” in Sills, E. O. and Abt, K. L. (eds.) *Forests in a Market Economy*. Dordrecht: Springer Netherlands, pp. 283–299. doi: 10.1007/978-94-017-0219-5\_16.

Meylan, L. *et al.* (2017) “Evaluating the effect of shade trees on provision of ecosystem services in intensively managed coffee plantations,” *Agriculture, Ecosystems and Environment*. Elsevier, 245(March), pp. 32–42. doi: 10.1016/j.agee.2017.05.005.

Muller, R. A. *et al.* (2009) “Coffee diseases,” in *Coffee: Growing, Processing, Sustainable Production: A Guidebook for Growers, Processors, Traders, and Researchers*. Wintgens J. Weinheim, pp. 495–549. doi: 10.1002/9783527619627.ch18.

Nadasdy, P. (1999) “The politics of TEK: Power and the ‘integration’ of knowledge,” *Arctic Anthropology*, pp. 1–18. doi: 10.2307/40316502.

Nair, P. K. R. (1993) *An Introduction to Agroforestry.*, KLGWER ACADEMIC PUBLISHERS. doi: 10.1177/003072709402300413.

*Nombres científico y comunes de plantas de interés para la exportación* (no date) *Bio-Nica - Museo Entomológico de Leon*. Available at: <http://www.bio-nica.info/biblioteca/AnonimoNombresCientificosComunes.pdf> (Accessed: January 31, 2020).

Peeters, L. Y. K. *et al.* (2003) “Coffee production, timber, and firewood in traditional and Inga-shaded plantations in Southern Mexico,” *Agriculture, Ecosystems and Environment*, 95(2–3), pp. 481–493. doi: 10.1016/S0167-8809(02)00204-9.

Penot, E., Snoeck, D. and Vagneron, I. (2017) *Creating shared values in agroforestry systems based on coffee and cocoa clusters : exploratory mission AI Propis*. Montpellier. doi: 10.13140/RG.2.2.17590.50243.

Perfecto, I. *et al.* (2007) “Shaded coffee and the stability of rainforest margins in northern Latin America,” pp. 225–261. doi: 10.1007/978-3-540-30290-2\_12.

Philpott, S. M. and Dietsch, T. (2003) “Coffee and and Value Conservation : Context Farmer Involvement,” *Conservation Biology*, 17(6), pp. 1844–1846.

Pinoargote, M. *et al.* (2017) “Carbon stocks, net cash flow and family benefits from four small coffee plantation types in Nicaragua,” *Forests, Trees and Livelihoods*. Taylor & Francis, 26(3), pp. 183–198. doi: 10.1080/14728028.2016.1268544.

Polishchuk, Y. and Rauschmayer, F. (2012) “Beyond ‘benefits’? Looking at ecosystem services through the capability approach,” *Ecological Economics*. Elsevier B.V., 81, pp. 103–111. doi: 10.1016/j.ecolecon.2012.06.010.

Powlen, K. A. and Jones, K. W. (2019) “Identifying the determinants of and barriers to landowner participation in reforestation in Costa Rica,” *Land Use Policy*, 84, pp. 216–225. doi: 10.1016/j.landusepol.2019.02.021.

Rice, R. A. (2011) “Fruits from shade trees in coffee: How important are they?,” *Agroforestry Systems*, 83(1), pp. 41–49. doi: 10.1007/s10457-011-9385-4.

Rigal, C., Vaast, P. and Xu, J. (2018) “Using farmers’ local knowledge of tree provision of ecosystem services to strengthen the emergence of coffee-agroforestry landscapes in southwest China,” *PLoS ONE*, 13(9), pp. 1–18. doi: 10.1371/journal.pone.0204046.

Romero-Alvarado, Y. *et al.* (2002) “Coffee yields and soil nutrients under the shades of Inga sp. vs. multiple species in Chiapas, Mexico,” *Agroforestry Systems*, 54, pp. 215–224.

Saravia-Matus, S. L. and Saravia-Matus, J. (2009) “Agrarian Reform: Theory & Practice. The Nicaraguan Experience,” *Encuentro: Revista Académica de la Universidad Centroamericana*, 84, pp. 21–43.

Schibli, C. (1999) *Percepciones de familais productoras de sus sistema agroforestales con cafe en el norte de Nicaragua*. CATIE-MIP/AF(NORAD).

Smith Dumont, E. *et al.* (2018) “The utility of farmer ranking of tree attributes for selecting companion trees in coffee production systems,” *Agroforestry Systems*. Springer Netherlands, pp. 1–15. doi: 10.1007/s10457-018-0257-z.

Soto-Pinto, L. *et al.* (2000) “Shade effect on coffee production at the northern Tzeltal Zone of the state of Chiapas, Mexico,” *Agriculture, Ecosystems and Environment*, 80(1–2), pp. 61–69. doi: 10.1016/S0167-8809(00)00134-1.

Soto-Pinto, L. *et al.* (2007) “The role of local knowledge in determining shade composition of multistrata coffee systems in Chiapas, Mexico,” *Biodiversity and Conservation*, 16(2), pp. 419–436. doi: 10.1007/s10531-005-5436-3.

Stegelmeier, B. L. *et al.* (2013) “Selected Poisonous Plants Affecting Animal and Human Health,” in *Haschek and Rousseaux’s Handbook of Toxicologic Pathology*. Third Edition. Elsevier Inc., pp. 1259–1314. doi: 10.1016/B978-0-12-415759-0.00040-6.

Tscharntke, T. *et al.* (2011) “Multifunctional shade-tree management in tropical agroforestry landscapes – a review,” *Journal of Applied Ecology*, 48, pp. 619–629. doi: 10.1111/j.1365-2664.2010.01939.x.

Vaast, P., Beer, J., *et al.* (2005) “Environmental services of coffee agroforestry systems in Central America: a promising potential to improve the livelihoods of coffee farmers’ communities,” ... *of Environmental Services in ...*, pp. 35–39.

Vaast, P., Kanten, R., *et al.* (2005) “Shade: a key factor for coffee sustainability and quality.,” *ASIC 20th International Conference on Coffee Science*, 4(December 2016), pp. 887–896. doi: 10.1007/s00464-009-0639-4.

Valencia, V. *et al.* (2015) “The use of farmers’ knowledge in coffee agroforestry management: implications for the conservation of tree biodiversity,” *Ecosphere*, 6(7), p. art122. doi: 10.1890/es14-00428.1.

Walker, D. H. *et al.* (1999) “A systems approach to comparing indigenous and scientific knowledge: Consistency and discriminatory power of indigenous and laboratory assessment of the nutritive value of tree fodder,” *Agricultural Systems*. doi: 10.1016/S0308-521X(99)00058-X.

Waller, J. M., Bigger, M. and Hillocks, R. J. (2007) “World Coffee Production,” in *Coffee Pests, Diseases and their Management*. CAB Intern, pp. 17–33.

Wilson, B. R. (2013) “Breaking the chains: Coffee, crisis, and farmworker struggle in Nicaragua,” *Environment and Planning A*, 45(11), pp. 2592–2609. doi: 10.1068/a46262.

Van Der Wolf, J. *et al.* (2016) “Turning Local Knowledge on Agroforestry Into an Online Decision-Support Tool for Tree Selection in Smallholders’ Farms,” *Experimental Agriculture*, pp. 1–17. doi: 10.1017/s001447971600017x.

World Agroforestry (2019) *What is Agroforestry? | World Agroforestry*. Available at: <http://www.worldagroforestry.org/about/agroforestry> (Accessed: October 16, 2019).

Yang, Y. C. E. *et al.* (2018) “Gendered perspectives of ecosystem services: A systematic review,” *Ecosystem Services*, 31, pp. 58–67. doi: 10.1016/j.ecoser.2018.03.015.

Zúñiga, C., Somarriba, E. and Sánchez, V. (2004) “Tipologías cafetaleras de la Reserva Natural Miraflores-Moropotente, Estelí, Nicaragua 1 Artículos invitados,” *Agroforestria en la Americas*, (N° 41-42).

## APPENDIX A: GANTT DIAGRAM OF THE FIELWORK PERIOD

Week	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Activities\Dates	25/3-31/3	1/4-7/4	8/4-14/4	15/4-21/4	22/4-28/4	29/4-5/5	6/5-12/5	13/5-19/5	20/5-26/5	27/5-2/6	3/6-9/6	10/6-16/6	17/6-23/6	24/6-30/6
Preparation														
Pilot testing of the questionnaire														
Data collection – Phase 1 – La Estrella														
Data collection – Phase 1 – La Inmaculada														
Data collection – Phase 1 – Cerro Grande														
Pre-analysis														
Data collection – Phase 2 – La estrella														
Data collection – Phase 2 – La Inmaculada														
Data collection – Phase 2 – Cerro Grande														
Observations														
Break												SICK		

---

## APPENDIX B: SATELLITE MAPS OF THE SELECTED COMMUNITIES

---

Maps of interviewees were removed from the online version to ensure confidentiality.



---

## APPENDIX C: CONVERSIONS

---

MONEY (based on its value on the 10/02/2020):

1 US dollars = 33,74 Nicaraguan cordobas

100 Nicaraguan cordobas = 2,96 US dollars

AREA:

1 manzana = 0.7044 hectare

FIREWOOD:

1 *marca* = 2x1,5x1 = 3m<sup>3</sup>

500 rajas = 1 *marca*

---

# APPENDIX D: QUESTIONNAIRE

---

Código  Día  Hora  Acompañante

---

## I- IDENTIFICACION DEL PRODUCTOR

---

Nombre del dueño(a) [ \_\_\_\_\_ M / H ] Edad [ \_\_\_\_ ]

Nombre del encuestado [ \_\_\_\_\_ M / H ] Edad [ \_\_\_\_ ]

Relación del encuestado con el dueño [ \_\_\_\_\_ ]

¿En su familia, cuantas personas hay? niños [ \_\_\_\_ ] adultos [ \_\_\_\_ ] de la tercera edad [ \_\_\_\_ ]

¿Trabajan en la finca? [ \_\_\_\_ ] ¿Trabajan por otro lado? [ \_\_\_\_ ] \_\_\_\_\_

¿Usted es miembro de un proyecto de la cumplida? [ Insetting / Matrice / Huertos / Breedcafs ]

¿Usted ha participado en una capacitación sobre el manejo del café? ¿Otra persona en su familia?

---

## II- DESCRIPCION DE LA FINCA

---

¿Cuanto tiempo Ud lleva aquí? [ \_\_\_\_\_ ] ¿Cuándo han empezado a cultivar café? [ \_\_\_\_ ]

Área total de la finca [ \_\_\_\_ ] Área total de café [ \_\_\_\_ ] Área con café produciendo [ \_\_\_\_ ]  
Variedades: [ \_\_\_\_\_ ] Número de plantas de café por manzana [ \_\_\_\_ ]

¿Todo el café ha estado establecido al mismo tiempo? (*edad x área*) [ \_\_\_\_\_ ]

Producción de café 2018/19: [ \_\_\_\_\_ quintales de pergamino] Precio 2018/19 [ \_\_\_\_\_ C\$/q.]

Producción de café 2017/18: [ \_\_\_\_\_ quintales de pergamino] Precio 2018/19 [ \_\_\_\_\_ C\$/q.]

¿A que distancia de su casa están las parcelas? [ \_\_\_\_\_ ]

¿Que había en esta parcela antes? [Bosque / Café / Potrero / Grano básico / \_\_\_\_\_ ]

¿Cómo han establecido la sombra?

¿Quién (en la familia) decida como manejar y cuando establecer las parcelas de café?

¿Tiene un empleado para ayudarle con el mantenimiento del café?

¿Usted tiene problema de erosión en la parcela? [ \_\_\_\_ ] ¿Usa barreras?

¿Como califica la calidad de su suelo? [ \_\_\_\_ ] ¿Porqué?



**Leña:** ¿Cuántas marcas de leña cosechan en su parcela en un año? [\_\_\_\_\_] o en tercios:

¿Es suficiente para el consumo de la familia?

¿Le sobra para vender? ¿A cuál precio?

Si no sabe: ¿Para que usan leña en la casa? ¿Mas o menos, cuanto de lo que usan proviene de la parcela de café?

¿Cuándo poda los arboles, hay algunas ramas que no son usadas para leña? ¿Qué hace con ellas?

**Frutales/forrajeros:** ¿Cuánto sacan de la parcela al año? (Numero de arboles x estimación de la producción de un árbol) ¿De esto, cuanto venden? ¿A cuál precio?

¿Usted tiene problemas para vender los productos de la finca? ¿Dónde los vende?

**Maderables:** ¿Para hacer reparaciones o cercas, Usted compra madera o usa la de su finca? ¿En un año, cuantas tablas y postes necesitan?

¿En el futuro, Usted sabe a qué edad o tamaño van a talar los maderables que tiene? ¿Para vender o para su propia casa?

Si no lo vende, ¿por qué?

#### **IV – EVALUACION DE LOS SERVICIOS ECOSISTEMICOS**

---

Ahora, le voy a hacer preguntas sobre los arboles que Ud. tiene en sus parcelas de café:

1. ¿Por qué a usted le gusta tener arboles?

2. ¿Por qué a usted no le gustaría tener demasiado arboles?

¿Cree usted que los arboles tienen un impacto sobre → .....?

Productividad del cafe		
Tiempo de vida		
Humedad del suelo		
Fertilidad / nutrientes		
Erosion		
Maleza		
Viento		
Temperatura		
Enfermedades del cafe		
Insectos malos		

¿Que tipo de producto le interesa sacar de los arboles de sombra?:

Buena sombra para el café		
Materia orgánica		
Productos para el consumo		
Productos para vender		
Fruta		
Forraje		
Leña		
Madera		
Medicina		

¿Cómo maneja la sombra? ¿Poda todos los arboles de la misma manera?

¿Cual especie de arboles de sombra **recomendaría** sembrar a un nuevo productor de café?

¿Cual especie **no recomendaría**?

¿En su propia parcela, Ud. piensa sustituir los arboles de sombra que tiene por distintas especies?

En el futuro, ¿Usted quiere reducir, mantener o extender su sistema agroforestal de café? ¿Por qué?

## FORMULARIO DE CONSENTIMIENTO

---

Entiendo que mi participación es voluntaria y que soy libre de retirarme del proyecto en cualquier momento y terminar la entrevista sin tener que dar una explicación y sin que haya consecuencias. Si ejerzo mi derecho a terminar la entrevista y no quiero que mis datos sean utilizados, cualquier dato que se haya llenado en mi encuesta, será destruido.

Entiendo que puedo retirar del estudio cualquier dato personal (es decir, datos que me identifiquen personalmente) en cualquier momento.

Entiendo que una vez que los datos que no me identifican personalmente hayan sido incluidos en el estudio, no pueden ser retirados.

Consiento en ser participante en el proyecto

Consiento que mis respuestas sean registradas en papel y / o en formato electrónico usando una tableta

NOMBRE Y APELLIDO: \_\_\_\_\_

Telefono #: \_\_\_\_\_

Fecha: \_\_\_\_\_

Firma: \_\_\_\_\_

# APPENDIX E: RANKING EXERCISE

Codigo: \_\_\_\_\_ Hora: \_\_:\_\_ Fecha: \_\_/06/19 // Presentes: \_\_\_\_\_

Nombre : \_\_\_\_\_ ( M / H ) Edad : \_\_\_\_\_

Relacion con el dueño: \_\_\_\_\_

Arboles	1	2	3	4	5	6	7	8	9	10	Comentarios

<input type="checkbox"/> Consumo	<input type="checkbox"/> Economia	<input type="checkbox"/> Leña	<input type="checkbox"/> Madera	<input type="checkbox"/> Sombra
<input type="checkbox"/> Fertilidad	<input type="checkbox"/> Humedad	<input type="checkbox"/> Manejo	<input type="checkbox"/> Rapidez	<input type="checkbox"/> Pega

---

## APPENDIX F: EXAMPLES OF ES AND SPECIES CARDS FOR THE RANKING EXERCISE

---

### **CEDRO MACHO**



### **GUABA ROJA**



# GUACIMO



## CALIDAD DE LA LEÑA



## CONTRIBUYE A LA ECONOMIA DE LA FAMILIA



---

## APPENDIX G: QUALITATIVE DATA

---

### ALBIZIA GUACHAPELE (GAVILAN)

**[Ranking – comments]** /La Estrellita/ (110) Leña

### ALBIZIA SAMAN (GENIZARO)

**[Ranking - comments]** /La Estrellita/ (116) Da mucha materia orgánica, en La Estrellita no lo conocen /La Inmaculada/ (302) Para potrero (308) Mas adaptado en el caliente (RG) /Cerro Grande/ (334) La madera es vendible para sacar regla, se pela la concha y se deja macerar en agua para hacer un remedio para el dolor de cabeza

**[Ranking – Pest & Diseases]** /La Estrellita//Enfermedades

### ANNONA MURICATA (GUANABANA)

**[Ranking - comments]** /La Inmaculada/ (304) Lleva sombra y comida! Casi no hay en esta zona o se usan solo para sombra (407) (H3) por lo que permanece con sombra y bota mucha hoja /Cerro Grande/ (417) No da fruta aquí (320) Aquí nadie la cultiva (334) No bota la hoja (324) Tarda pero fruta (326) Casi no conocemos aquí, no pega muy bien, le entra mucha plaga (438) Cuesta que se desarrolla aquí

**[Ranking – Pest & Diseases]** None

### BACTRIS GASIPAES (PEJIVAI)

**[Questionnaire]** /La Inmaculada//3B / Nadie lo compra/4B/ Le gusta mucho, quiere sembrar una parcela con solo cítricos y pejivai porque no son buenos en el café por las espinas y porque la fruta daña al café al caerse /8B / Al caer la fruta daña al café /10B / media cabeza se vende a 80 a veces //Cerro Grande//15C / No da

**[Ranking - comments]** /La Inmaculada/ (403) Espinas molestan, es la fruta la mas común (308) Hace Que la tierra se amarra y ya no sirve para otro producto (411) Cuesta que la hoja se pudre /Cerro Grande/ (413) No se poda (414) Tienen 6 años y hace dos años apenas que le pega la fruta, fruta para animales y billete (316) No se regula la sombra porque tiene poca cobertura (317) Solo en la periferia (320) Existe un pejivai mejorado que crece mas rápido (331) Espinas, se mantiene a parte del café (324) Muy dañino (325) Le entra el chicharo (326) Se roba la humedad, Se vende a veces y sirve para el consumo pero solo son dos cosechas al año, nadie se sube al pejivai solo las ardillas (436) Peligroso por la espina no me gusta en el café (337) Seca el suelo y da plaga al café las hojas se ponen de mal color, se vende 300C\$ la caja (438) Lo tenemos bien retirado de la casa, buen precio pero gran costo para cosechar (439) Si es muy tupido se le quita las hojas secas

**[Ranking – Pest & Diseases]** /Cerro Grande//Enfermedades

### BIXA ORELLANA (ACHIOTE)

[Questionnaire] /La Estrellita//18A / produce 6 quintal al año. El quintal varia mucho, antes eran 600 pero este año fueron 3500C\$ el quintal! /Cerro Grande//16C / Sembrado en la periferia del café

### BROSIMUM ALICASTRUM (OJOCHE)

[Ranking - comments] /Cerro Grande/ (326) No me sirve porque no tiene mercado aquí (337) La leña da mucha ceniza, da plaga un animal se come las raíces del café, se come la fruta, durante la guerra sobrevivían en las montañas comiendo ojoche, ahora para gente pobre y no lo quieren decir, se come hervido, en chocolate caliente, tostado, tortilla, tempisque, tamal etc

[Ranking – Pest & Diseases] /Cerro Grande//Enfermedades

### BURSERIA SIMARUBA (JINOCUABO)

[Questionnaire] /La Estrellita//7A / Medicinal. No pega muy bien por el clima aquí

### BYRSONIMA CRASSIFOLIA (NANCITE)

[Questionnaire] /Cerro Grande//14C / No da

[Ranking - comments] /La Inmaculada/ (305) Lo tenemos en el potrero (407) Buenísimo para leña, es veloz para quemar. Bota mucha hoja. Da sombra pero no le ponen en el café por lo que la hoja es muy acida. Mas ramas tiene y mas fruta echa entonces no se poda. Hasta los niños van a vender libra de nance /Cerro Grande/ (316) Palo pequeño y redondo, aquí se le entra un insecto a la fruta (417) No da aquí (320) En lugar árido crece rápido (324) No para forestación porque es poco frondoso (325) Tenemos unos que tienen 12 años y nunca han dado una buena cosecha, ¿será el abono que les falta?, no sirve para sombra porque da ojo de gallo entonces lo vamos podando (421) Echa fruta aquí (436) mi preferido (438) Echa bastante fruta, muy bueno, lo tenemos en la orilla del café

[Ranking – Pest & Diseases] /Cerro Grande//Ojo de Gallo

### CARAPA GUIANENSIS (CEDRO MACHO)

[Questionnaire] /La Inmaculada//4B / Da ojo de gallo

[Ranking - comments] /La Inmaculada/ (300) Crece rápido (402) Muy bueno tenerlo pero hay que sembrarlo en una zona donde no hay nada (403) No necesita cuidarle (305) Nace en el monte, poca utilidad, solo construcción de casa mientras los frutales uno lo necesita diario /Cerro Grande/ (414) No sirve para leña se hace negro (320) Nunca esta pelón (328) Sirve para hacer la casa (337) Tabla, regla, alfajilla, techo, antes para teja (12 tablas por 2000) (438) Fruta peligrosa cuando se cae, no echa muchas ramas

[Ranking – Pest & Diseases] None

### CECROPIA PELTATA (GUARUMO)

[**Questionnaire**] /La Estrellita//15A / Da ojo de gallo//La Inmaculada//11B / Da mucha MO//Cerro Grande//17C / Se quedo de casualidad

[**Ranking - comments**] /La Inmaculada/ (300) Cuando es muy grande se puede sacar madera si no tiene un hueco por dentro, no muy bueno en el café (308) Habría que eliminarlo de Nicaragua (410) Sirve para madera, bota la hoja (311) Me gusta, cuesta que se pudre la hoja, es mala leña /Cerro Grande/ (412) No se vende la madera (317) Crece muy alto, lo guarda por no dañar al café cuando lo acera (323) Hoja grande no se degrada, el agua no penetra el suelo, bota ramas, al caer la hoja golpea los granos de café, tarda mucho en estar grande (418) Cuesta que se engruesa mucha sombra y mantiene humedad alta (439) Se puede usar como madera cuando es ya muy muy viejo, para leña echa demasiado humo, la hoja seca tarda en pudrir y mantiene la humedad

[**Ranking – Pest & Diseases**] /Cerro Grande//Ojo de gallo, pellejillo

### CEDRELA ODORATA (CEDRO REAL)

[**Questionnaire**] /La Estrellita//6A / Muy ancho, gigante /16A / Quiere añadir en la periferia del café en el futuro /21A / Desarrolla rápido y no bota la hoja//La Inmaculada//2B / No se poda//Cerro Grande//13C / Da enfermedad. Queda del bosque de antes, piensa acerarlo el día que lo necesita para su consumo /30C / No poda

[**Ranking - comments**] /La Estrellita/ (109) Atacado por coleopter boreador si sembrado en bloque, leña da mucho humo (116) En la periferia /La Inmaculada/ (300) No pega bien, le molesta una avispa. Se dice que si uno tiene 20-30 matas de cedro real, ya le dan lugar a acerarlo (301) Le afecta un polvo blanco cuando es pequeño. Se acera después de 20 años (401) No lo ve adaptado al suelo porque dilata (302) Salvaje para venderlo. La ley permite venderlo solo si uno lo ha sembrado de su mano o si está matriculado (402) Muy bueno tenerlo pero hay que sembrarlo en una zona donde no hay nada (307) Cuando es pequeño le afecta un polvo blanco, cuesta que levante /Cerro Grande/ (412) Crece rápido (316) EL que mas le gusta por el dinero que genera (323) Es mi favorito! Pero da roya por la hoja que se cae. (331) No es muy buena sombra porque el café nunca desarrolla debajo, solo se ocupa la madera, muy helado aquí CG, cuesta que se desarrolla (328) No se desombra, no se da permiso para acerar pero la madera vale muchísimo billete es como traficar droga (337) Prohibido colectar su leña (12 tablas por 4-5000)

[**Ranking – Pest & Diseases**] /Cerro Grande//Roya

### CEIBA PENTANDRA (CEIBA)

[**Questionnaire**] /La Estrellita//6A / Muy ancho, gigante

[**Ranking - comments**] /La Estrellita/ (118) Muy buena sombra, alto, mantiene la humedad, pero es una madera porosa que no tiene duración. (119) Crece demasiado grande y se extiende: da mucha sombra, no se puede controlar /La Inmaculada/ (307) Se cría rápido (311) Aquí no echa fruta /Cerro Grande/ (316) No pienso que da enfermedades porque es muy alto, prohibido

acerar, muy fresco (335) Árbol importante, Da mucho oxígeno, sombra alta, le tengo bastante cariño porque es gigante y por el oxígeno

**[Ranking – Pest & Diseases]** None

#### CHRYSOPHYLLUM CAINITO (CAIMITO EXTRANJERO)

**[Ranking - comments]** /Cerro Grande/ (324) Da billete, 1 peso por fruta

#### CITRUS SPP. ‘NARANJA’ (NARANJA AGRIA, NARANJA DULCE)

**[Questionnaire]** /La Estrellita//16A / Espinas malas para trabajadores/18A / Ladrones lo roban//La Inmaculada//1B / Recomendaría sembrar pero problema con ladrones /3B / Nadie lo compra /04B / Quiere recibir cítricos injertos de un proyecto porque es difícil encontrar cítricos injertos en el mercado y son mucho mejor porque no crecen tan alto y producen muy rápido. /8B / Producción irregular /10B / para consumo, regala una parte y otra parte la deja sin cosechar. //Cerro Grande//13C / La gente no compra porque las rutas son caras y se le quita todo en el viaje /30C / No se poda

**[Ranking - comments]** /La Estrellita/ (101) Tiene espinas (106) Le gusta mas la naranja que el guineo/platano a la gente porque también se come cruda y en fresco (208) Se vende barata, produce menos que mandarina (209) Se seca (110) No recomendable porque suelta acido (116) Da reales (118) Consumo, sombra, billete /La Inmaculada/ (300) importante porque da sombra y dinero (402) Mueve bastante, se cae la fruta (308) Lo necesitamos y no es tan dañino, casi no bota la hoja (410) No la compran porque se vende barato (311) Las estoy cortando porque nunca me comí una por los ladrones y daña al café cuando cortan las ramas /Cerro Grande/ (413) Se están secando (316) Solo tengo 5 palos (331) Crece rápido, buena leña pero tarda en secar (335) No bota la hoja, lo vamos incorporando (324) Cuesta que crezca (421) No se puede desombrar sino no da fruta (422) Demasiado helado aquí (439) Bueno para hacer fresco, crece solo cuando cae una fruta, si hay muchos hijos tiernos se corta algunos

**[Ranking – Pest & Diseases]** /La Estrellita//Sompopo/El café se pone malo cuando la fruta madura /Sompopo /Sompopo //La Inmaculada//Ojo de gallo, Pellejillo

#### CITRUS SPP. ‘LIMON’ (LIMON AGRIO, LIMON DULCE, LIMON MANDARINA, LIMON TAHITI)

**[Questionnaire]** /La Estrellita//7A/ “Nosotros (el limón) lo ocupamos para fresco. Y también cuando uno tiene toz para tomarlo con miel.” /8A/ Se me secaron /13A/ El limón poco lo traemos, se deja perder /19 / Ahora esta sembrando limón Tahití porque tiene buen mercado //La Inmaculada//1B/ El limón se puede vender pero a veces nadie lo compra. Un árbol adulto da 2000 fruta y se compran 100 limones por 35C\$. El sácate Limón es medicinal /04B/ Quiere recibir cítricos injertos de un proyecto porque es difícil encontrar cítricos injertos en el mercado y son mucho mejor porque no crecen tan alto y producen muy rápido.

**[Ranking - comments]** /La Estrellita/ (209) Variedad indio tiene mejor precio (110) No recomendable porque suelta acido (106) Buena leña pero no se poda (217) No hemos vuelto a sembrar limón porque esta muy perseguido por los sampopos y ahora hay muchos sampopos

en las propiedades de otros alrededor. (119) Sombra y consumo (220) Para hacer fresco, lavar la carne, no se vende (222) Pone muy acida la tierra /La Inmaculada/ (308) Lo necesitamos y no es tan dañino (311) No me gusta por los ladrones /Cerro Grande/ (320) Hasta 600C\$ el quintal (323) Muy tupido, no deja pasar el agua, muy pequeño para sombra, espinas en las ramas malo para cosechar el café. (334) Los que tenemos son injertos (326) Ahora empiezan a comprar Limón, hay un negocio en Rancho Grande (Acopio?) que compra los cítricos que se han caído al suelo (327) Solo tenemos en el patio cerca de la casa

**[Ranking – Pest & Diseases]** /La Estrellita//Sompopo /Sompopo /Sompopo /Sompopo

#### CITRUS RETICULATA (MANDARINA)

**[Ranking - comments]** /La Estrellita/ (208) Produce mas que la Naranja (116) Da reales (220) Vende cuando hay cosecha importante /La Inmaculada/ (300) Se poda (407) Se secaron (311) No me gusta por los ladrones /Cerro Grande/ (317) No afecta al café (324) Cuesta que crezca aquí (438) Le ataca el sompopo

**[Ranking – Pest & Diseases]** /La Estrellita//Sompopo /Sompopo

#### COCOS NUCIFERA (COCO)

**[Questionnaire]** /Cerro Grande//15C / No da

**[Ranking - comments]** /La Inmaculada/ (301) Se cría y a veces no da cosecha. Tiene muchas raíces (401) No se pone en café, en la periferia o en el patio para hacer carretas (302) Tardado para producir, al botar la hoja daña al café, raíz muy profunda que reseca al suelo (304) Sombra caliente (411) Le puede caer un coco en la cabeza!, cuesta que la hoja se pudre /Cerro Grande/ (316) Menos interesante para el consumo que otros frutales (320) Casi no la compran, solo las plantitas (325) Aquí no hay coco casi, nosotros acabamos de sembrar (326) Es de lo caliente, no mantiene la humedad, tarda 7-8 años en echar fruta, el coco verde da fruta mas rápido (422) Aquí la gente no siembra, pega pero cuesta que echa fruta (436) Me gusta mucho pero no en el café (438) Cuando la hoja se cae guarda la humedad de la tierra, el agua de coco baja la tensión y es bueno para el estomago

**[Ranking – Pest & Diseases]** None

#### CORDIA ALLIODORA (LAUREL)

**[Questionnaire]** /La Estrellita//1A / Muy caliente/3A / Muy caliente cuando se defolea /21A / Desarrolla rápido pero botas las hojas y tienen un acido que afecta a las plantas//La Inmaculada//2B / No se poda /5B/ Quiere reemplazar los laureles de su parcela por cacao /7B / Bueno para MO//Cerro Grande//14C / Muy alto, no se puede podar /21C / Da ojo de gallo /23C / Recomienda no sembrar Laurel pero si ya son grandes uno les puede guardar para aprovechar al madera.

**[Ranking - comments]** /La Estrellita/ (101) Muy caliente, la hoja es acida y cree una deficiencia en el café (201) El polvo de la flor es malo para el café (109) Melífera (110) Bueno porque crece rápido (220) Leña /La Inmaculada/ (300) No es bueno (304) No se poda, no es

recomendable en el café (305) No se ocupa para leña, solo construcción, no es recomendable porque tiene la hoja acida, se mantiene por la madera (306) Madera liviana, aparecen grietas en las tablas /Cerro Grande/ (315) Pone la tierra muy seca pero aquí no importa porque el clima es helado (316) No afecta al café (331) El nace solo pero no levanta si uno no le da mantenimiento (335) Lo necesitamos para construcción y si esta bien manejado vamos a ver un buen tipo de sombra (436) Bueno aquí porque el clima es helado (337) Ayuda un poco porque se cae la hoja pero seca el suelo

[**Ranking – Pest & Diseases**] /La Estrellita// Roya /Tarda en desarrollarse //La Inmaculada// Roya/ Ojo de gallo (si le deja crecer mucho) /Ojo de gallo

#### CORDIA COLLOCOCCA (MUÑECO)

[**Questionnaire**] /La Inmaculada//1B / No sirve para leña//Cerro Grande//14C / No sirve para leña

[**Ranking - comments**] /Cerro Grande/ (331) Cambia (bota) la hoja, madera muy suave. (432) No pega aquí

[**Ranking – Pest & Diseases**] /Cerro Grande//Ojo de gallo (sombroso)

#### CROTON DRACO (SANGREGRADO)

[**Questionnaire**] /La Estrellita//7A / Crece muy rápido, demasiado sombra /17A / Aumenta Roya

#### ENTEROLOBIUM CYCLOCARPUM (GUANACASTE)

[**Ranking - comments**] /La Estrellita/ (110) Muy buena madera, no hace braza (118) Barreno /Cerro Grande/ (334) Construcción y leña

[**Ranking – Pest & Diseases**] None

#### ERYTHRINA FUSCA (ELEQUEME)

[**Questionnaire**] /La Estrellita//3A / Fija nitrogeno /17A / No sirve para leña

[**Ranking - comments**] /La Estrellita/ (101) de larga vida y fija nitrógeno (103) Espinas lo hacen difícil de podar, madera para hacer tabla (116) Se cría rápido pero la madera no tiene duración /Cerro Grande/ (315) Protege fuente de agua,

[**Ranking – Pest & Diseases**] /Cerro Grande//Ojo de gallo

#### ERYTHRINA POEPPIGIANA (BUCCARO)

[**Questionnaire**] /La Estrellita//3A / N-fixing/7A / Mejor sombra que hay porque mantiene follaje//La Inmaculada//4B / Demasiado sombra y espinas aunque bueno.

[**Ranking - comments**] /La Inmaculada/ (300) No es muy bueno como leña (304) Buena sombra, fresca, pero hay que regularle mucho (307) Le pega una plaga y casi no se cría, el

primer año hay que echarle urea, tiene espinas, se cría rápido (311) La leña no sirve, le afecta un bicho /Cerro Grande/ (334) Mantiene la humedad

**[RANKING – PEST & DISEASES]** None

#### FICUS SP. (CHILAMATE, MATAPALO)

**[Questionnaire]** /La Estrellita//10A/ No deja el café desarrollarse bien //Cerro Grande//17C / No sirve para leña

**[Ranking - comments]** /La Estrellita/ (102) Bota la hoja, se cría grande (215) No sirve en el café porque se cría muy grande (116) Sombra fresca, guarda humedad /Cerro Grande/ (412) Madera, se engruesa mas rápido (317) Se queda bajo (bueno para sombra aquí), cuando se desrama mucha materia orgánica se pudre (331) Mantiene la humedad, mantiene fuente de agua (337) Leche quema, bueno pero no el café porque le da plaga

**[Ranking – Pest & Diseases]** /La Estrellita//Hongos //Cerro Grande//Ojo de gallo (un poco) /Enfermedades

#### GLIRICIDIA SEPIUM (MADERO NEGRO)

**[Questionnaire]** /La Estrellita//2A/ Da mucha materia orgánica y sirve como forraje/18A / En la periferia para hacer postes, mala sombra/19A / Sombra caliente //Cerro Grande//16C / Bueno como rompe viento

**[Ranking - comments]** /La Estrellita/ (202) Cuesta que la leña se seque (109) Cortar en el verano para secar (116) Bueno tenerlo, se cría rápido (118) Barrera viva en la cerca, postes (220) Baño para picaduras y infecciones, cuando no hay nada que funciona /La Inmaculada/ (305) No bota la hoja, para cerca y hacer conservación de suelo /Cerro Grande/ (334) Importante, lo ponemos como cerca

**[Ranking – Pest & Diseases]** /La Inmaculada//Ojo de gallo, Pellejillo

#### GUAZUMA ULMIFOLIA (GUACIMO)

**[Questionnaire]** /La Estrellita//2A / En periferia, fruta para cerdo/3A/ sombra caliente/10A/ No es adecuado porque las ramas agarran un bicho, las hojas echan un acido, leña/17A / Da Roya//Cerro Grande//21C / Periferia

**[Ranking - comments]** /La Estrellita/ (101) Va eliminando (110) Leña, Muchas raíces que no dejan espacio para el café, sombra muy caliente (116) No sirve (222) Cerca (220) Medicinal la semilla es buena para los riñones /Cerro Grande/ (335) si esta bien manejado vamos a ver un buen tipo de sombra

**[Ranking – Pest & Diseases]** /La Estrellita//Broca/Ojo de gallo/Mancha hierro/Roya, Ojo de gallo

#### HELIOCARPUS APPENDICULATUS (MAJAGUE)

**[Questionnaire]** /La Estrellita//15A / No sirve para leña, bota la hoja//La Inmaculada//1B / No sirve para leña//Cerro Grande//17C / No sirve para leña

**[Ranking - comments]** /La Estrellita/ (103) No es recomendable, madera suave, no se puede subir en el para podar (109) Mucho humo, lo usa para las avispas, flores bonitas (118) Sacamos las cascarras, no sirve para leña (119) No sirve para sombra, trae enfermedades /Cerro Grande/ (412) Se ve escaso (327) Bueno en cerca, nunca lo he sembrado, crece muy alto hay que levantar la sombra, no es muy bueno para sombra, leña se prende solo cuando muy seca (438) "Da sombra, la madera se pone mala hay que cambiarla al año

**[Ranking – Pest & Diseases]** /La Estrellita//Gusano/No da enfermedades/Gusano/Ojo de gallo, roya

#### HIRTELLA TRIANDRA (GUAYABO BORAZON)

**[Questionnaire]** /Cerro Grande//20C / Es un arbol de los bosques

**[Ranking - comments]** /La Estrellita/ (121) Difícil de manejar /Cerro Grande/ (328) Crece muy recto, la leña se puede vender, hecha demasiados hijos hace un rodeón en la tierra

**[Ranking – Pest & Diseases]** None

#### INGA SPP. (GUABA)

**[Questionnaire]** /La Estrellita//3A / Fija nitrógeno /10A / Leña//La Inmaculada//1B/ Ayuda para la fertilidad /2B/ Ayuda para la fertilidad //Cerro Grande//18C/ Sombra temporal /24C/ Es lo que uno conoce, mejor sombra, fácil de obtener semillas/25C/ Tradición y fertilizante

**[Ranking - comments]** /La Estrellita/ (101) de corta vida y fija nitrógeno (110) Leña, Bueno porque crece rápido

#### INGA DENSIFLORA (GUABA BLANCA)

**[Ranking - comments]** /La Estrellita/ (118) Fruta comerciable (121) Tiene un periodo pelón /La Inmaculada/ (307) Fija nitrógeno (308) Mejor para leña (roja?) /Cerro Grande/ (335) Buena leña, cantidad de leña importante, tiene una vida útil de 8 a 10 años, uno tiene que ir pensando en renovar o poner otro tipo de arboles

**[Ranking – Pest & Diseases]** /La Estrellita//Gusano /Broca //La Inmaculada//Ojo de gallo (si no se regula)

#### INGA EDULIS (GUABA ROJA)

**[Questionnaire]** /La Estrellita//7A / "Yo la tengo así porque echa sombra pero las hojas tienen así por detrás como una mancha y eso como que le afecta a la hoja de café. El café se pone amarillo." /18A / Da Ojo de gallo //La Inmaculada//6B / Da ojo de gallo//Cerro Grande//13C / Da enfermedad/25C / Da Ojo de gallo/28C / No da Ojo de gallo

**[Ranking - comments]** /La Estrellita/ (119) Se muere a los 5 años /La Inmaculada/ (301) Crece solito (natural regeneración) mejor que la guaba blanca (307) Fija nitrógeno (308) No sirve para

nada, molesta al cacao pero uno no quiere eliminarlo porque lo ocupa para leña, cogemos la fruta y animales también (311) Tiene una fruta rica /Cerro Grande/ (320) Es bueno pero solo sirve para leña

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo /Broca //La Inmaculada//Ojo de gallo (si no se regula) /Da enfermedades //Cerro Grande//Da enfermedades

#### INGA PUNCTATA (GUABA NEGRA)

**[Questionnaire]** /La Estrellita//6A / "es la clásica de aquí"/7A / Reduce broca/16A / Crece rápido/17A / Sombra y leña/18A / Da Roya//La Inmaculada//11B / Buena para proteger fuente de agua//Cerro Grande//28C / No da Ojo de gallo

**[Ranking - comments]** /La Estrellita/ (103) Buena estructura, fácil de regular (109) Ramifica mas que guaba blanca y crece mas rápido (217) Le atacan los Sompopos pero es mas fuerte (118) Buena sombra, leguminosa que fija nitrógeno, se ocupa en la cocina /La Inmaculada/ (302) Sombra y componer el suelo (305) Único que se puede podar por el uso de leña (307) Fija nitrógeno (308) Casi no se cría, cogemos la fruta y animales también /Cerro Grande/ (335) Buena leña, cantidad de leña importante, tiene una vida útil de 8 a 10 años, uno tiene que ir pensando en renovar o poner otro tipo de arboles (337) rinde menos leña que las otras guabas (327) da leña, sombra y fruta, no se cría demasiado

**[Ranking – Pest & Diseases]** /La Estrellita//Pellejillo /Broca //La Inmaculada//((si muy vieja) Ojo de gallo, pellejillo /Ojo de gallo (si no se regula) //Cerro Grande//Pellejillo, Ojo de gallo (sombroso)/Antracnosis, ojo de gallo

#### JUGLANS OLANCHANA (NOGAL)

**[Questionnaire]** /La Estrellita//13A/ Da gusanos /17A/ Buena madera pero malo para sombra //Cerro Grande//18C/ No es muy bueno porque se extiende mucho. /21C/ Tiene también arboles viejos de Nogal pero dice que no es bueno para el café. Son demasiado grandes para controlar la sombra. Mejor tenerlos en la periferia /27C/ Muy dañino

**[Ranking - comments]** /La Estrellita/ (201) Echa mucho humo (mala leña) (102) Mucho humo, se cría alto (202) Mucho humo, crece muy alto, perseguido por enfermedades y hormigas que se comen el corazón, riesgo que se caigan las ramas /Cerro Grande/ (413) Bueno para proteger las fuentes de agua (331) Hay que darle una buena regulación porque es muy sombroso y eso da enfermedades (334) Guarda bastante (demasiado) humedad, no es tan vendible sirve para la casa (326) No hay por aquí, no se pega, copa muy cerrada (sombra densa), muy húmedo pero como es muy alto no molesta (328) Dilatado para crecer, sirve para hacer muebles, nacen solos pero aquí casi no hay es de lo mas helado, no recomendable en el café porque da plagas (422) Árbol muy grande con fruta dura y grande peligroso durante cosecha del café (436) No sirve para leña solo bien seco

**[Ranking – Pest & Diseases]** //La Estrellita//No da enfermedades /Sompopo //Cerro Grande// Da enfermedades (cuando sombroso) /Ojo de gallo

#### LIPPIA MYRIOCEPHALA (MAMPAS)

**[Questionnaire]** /La Inmaculada//1B / Da Ojo de gallo//Cerro Grande//14C / No sirve para leña/18C / Sombra temporal

**[Ranking - comments]** /Cerro Grande/ (438) No daña al café

### LONCHOCARPUS RUGOSUS (CHAPERNO)

**[Questionnaire]** /La Estrellita//3A / Sombra caliente/7A / hongoso/10A / Leña/12A / Da enfermedades al café, bota la hoja en verano/17A / No sirve para leña /18A/ Voy eliminando uno de dos

**[Ranking - comments]** /La Estrellita/ (102) Da bastante sombra (110) Leña (116) No sirve (118) No crece muy grande, leña, madera fina, no lo dejamos mucho porque da enfermedades /Cerro Grande/ (433) No sirve aquí, ni para sombra, nadie lo quiere, pero crece fácil

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo /Ojo de gallo, roya /Gusano

### MANGIFERA INDICA (MANGO)

**[Questionnaire]** /La Estrellita//17A / Criollo no tiene mercado, solo quieren el rosa /18A / Criollo no se vende, para consumo o animales. //La Inmaculada//1B / Recomendaría sembrar pero problema con ladrones /8B / No es buena sombra. Aquí no se puede lograr cosecha de mango. Cuando viene el invierno, a penas están empezando a echar pequeños frutos y entonces les botan con la lluvia /10B / Vende un poco cuando no es muy abundante y entonces el precio es mas alto. //Cerro Grande//14C/ No da /20C/ Florece pero no echa fruta/25C / No se puede podar, no da cosecha aquí

**[Ranking - comments]** /La Estrellita/ (101) Hay que saber regular la sombra (201) El mango criollo no tiene mercado, solo el rosa, pero el criollo crece fácil. (202) Mucho humo (208) Crece demasiado rápido (110) El café no da bajo un mango (215) Casi no se vende por costumbre, es para el consumo (116) Bueno tenerlo para consumo (220) Muy bajo (220) No le gusta al café, se pone feo /La Inmaculada/ (302) Mango rosa echa bastante pero mango criollo echa apenas solo algunos (402) No da (403) Hay que regular la sombra, madera muy suave, leña regular (308) Seria bueno pero aquí no echa y atrae ardillas /Cerro Grande/ (413) La gente no lo compra (414) No echa fruta pero yo digo que al tiempo van a echar fruta, bota la hoja (323) La cascara del mango sirve como abono, Los ladrones dan problema (324) Sombra fresca por las hojas que tiene, aquí solo para sombra no da fruta, el café que crece debajo bota la hoja (antracosis?) (325) No echa fruta aquí, es dilatado, solo ha dado una cosecha, una animal le barrena la madera y bota la flor, no es buena sombra porque pronto se seca (428) La leña se prende bien, aquí echa fruta (421) Da poca fruta (438) No produce aquí, cuesta que se seque la leña por la leche, su hoja se puede utilizar para reducir inflamaciones o para golpes (439) la hoja seca tarda en pudrir y mantiene la humedad

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo /Gusano en la fruta (solo el criollo) /Insectos, Antracnosis, broca /Sompopo /Roya //Cerro Grande//Antracnosis

### MOSQUITOXYLUM JAMAICENSE (TROTON)

**[Questionnaire]** /La Estrellita//14A/ Buena sombra

**[Ranking - comments]** /La Estrellita/ (110) Bueno porque crece rápido

#### MUNTINGIA CALABURA (CAPULIN)

**[Questionnaire]** / La Inmaculada//1B / No sirve para leña

**[Ranking - comments]** /La Inmaculada/ (311) Aquí no echa fruta

#### MUSA SP. 'GUINEO' (GUINEO)

**[Questionnaire]** /La Estrellita//7A / El guineo al estar debajo un árbol no fruta bien porque la sombra no lo deja crecer /12A / Vende 200 cabezas de guineo al año a 20 córdobas. Viene gente de Matagalpa a comprarlo. /13A / El Guineo vendemos un poco. Da 50 cabezas por mes y por manzana cuando es la temporada. Nosotros comemos unas dos cabezas al mes y damos 10 al cerdo por mes. Vamos eliminando el guineo porque da demasiada sombra. El cuadrado le da enfermedades /14A / Se vende barato pero fácil /15A / Muy buena sombra pero consume muchos nutrientes y ladrones dañan al café/16A / Como sombra temporal. No vende porque el precio es muy bajo. Problema con el guineo: cuando llueve mucho se cae y arranca tierra con el. /21A / no le resulta venderlo porque el precio es demasiado barato, es solo para el consumo //La Inmaculada//1B / Una cabeza se vende por 25 córdobas//Cerro Grande//14C / Los cerdos comen yuca y guineo y así no hace falta comprarlos comida /17C / El cerdo come 200 guineos por mes /20C/ Guineo para el consumo, comen bastante. Hay una parte que se pierde. En Rancho Grande lo pagan muy barato, No renta llevarlo. /23C / Es solo para el consumo. Niños vienen a pedir si se le puede regalar entonces uno le da. Cosecha 10 cabezas por mes y las deja a madurar. /25C/ Dice que casi no se da la vuelta por sus raíces /28C / La mitad se consume, lo resto se pierde o se regala

**[Ranking - comments]** /La Estrellita/ (110) Bueno porque crece rápido (116) Es bueno porque da reales y se puede consumir. Ahora lo tengo que trozar porque se da la vuelta y daña al café. (217) Una cabeza de guineo da 25-30C\$ y producen todo el tiempo /La Inmaculada/ (307) Quita mucha fortaleza a la tierra porque quita potasio, favorito porque sino "no tendría nada" (407) Mas usual poner guineo que platano en el café /Cerro Grande/ (413) Aquí no se vende (331) Dicen que es bueno para humedad pero por experiencia reseca el suelo. (432) Las matas se dan mucho la vuelta (433) Si la gente viene a buscar lo regalo (428) Cascara sirve como abono (421) Fruta para los mozos

**[Ranking – Pest & Diseases]** /La Estrellita//Da enfermedades

#### MUSA SP. 'PLATANO' (PLATANO)

**[Questionnaire]** /La Estrellita//7A / Ahora esta por meter mas platano porque la gente lo pide mas. “Tiene mas comercio” /18A/ Tiene 0,75 manzana de platano. Produce 10 a 30 fruta por mes, lo compran a 3,50C\$ en la venta. Queda un poco para el consumo. //Cerro Grande//28C / Esta empezando con el platano ahora porque es mas vendible que el guineo.

**[Ranking - comments]** /La Estrellita/ (101) Fácil de manejar, no produce enfermedades, solo produce tres años pero da buen billete (202) No se debería poner el café por demasiado humedad (116) Temporal porque le molesta la chichara (217) Hongo se cura con cenizas (119) Comer y sombra y económico= valor agregado (222) Se vende muy caro pero hay que esperar (220) Si se le cura el hongo crece /La Inmaculada/ (300) importante porque da sombra y dinero (302) Cada 6 meses (305) necesita buena tierra /Cerro Grande/ (320) Se pudren los tallos (323) Le afecta mucho hongo y tartusa, no se puede sembrar en terreno muy alto ni muy suave porque el viento lo desraíza, problema con ladrones pero da sombra y reales. (331) Lo sembramos a parte, se requema, con cal en la raíz para evitar hongo, muy bajito tiene un sistema que da vuelta. (325) Se da vuelta, solo da un año y luego se va para el suelo, con costo da para el consumo de uno (328) Las hojas sirven como abono y aportan humedad (337) 1 carga (20 cabeza) le da 160-200 córdobas y el pasaje cuesta 120 (80 por persona y 40 por carga (439) Súper importante

**[Ranking – Pest & Diseases]** /La Estrellita/No da enfermedades /Hongos /Da enfermedades

#### NEPHELIUM LAPPACEUM (MAMON CHINO)

**[Ranking - comments]** /Cerro Grande/ (316) tiene mucha regeneración natural porque la fruta se deja perder. (326) Quiero sembrar mamon chino

#### PACHIRA QUINATA (POTCHOTE)

**[Questionnaire]** /La Estrellita//16A / Quiere añadir en la periferia del café en el futuro /19A / Sombra caliente

**[Ranking - comments]** /La Estrellita/ (202) Espinas, crece mucho, peligro que se caigan las ramas (118) Madera preciosa muy cara (119) Solo para reforestación /La Inmaculada/ (305) Casi no se encuentra

**[Ranking – Pest & Diseases]** None

#### PERSEA AMERICANA 'COMUN' (AGUACATE COMÚN)

**[Questionnaire]** /La Estrellita//7A / Se me han perdido/8A / Se van secando por nematodos /13A / el aguacate se regala cuando hay /18A / Se murió la mayoría por un hongo/19A / Se seca por un hongo/20A / Se secaron//La Inmaculada//10B / Vende un poco cuando no es muy abundante y entonces el precio es mas alto. //Cerro Grande//13C / La gente no compra porque las rutas son caras y se le quita todo en el viaje /14C / da 300 a 1000 frutas. A veces se vende /17C / Se da al cerdo porque precio bajo y alto coste para el transporte, produce plaga /20C / para el consumo /25C / A veces saca unos aguacates al mercado cuando hay muchos. Lo van quitando por miedo que se caiga una vez seco

**[Ranking - comments]** /La Estrellita/ (101) Crece grande (102) Se puede sembrar salteado (202) Se daña el corazón (207) Crece rápido, se secan (109) Atacado por un hongo si uno no lo cuida, injerto tiene poca hoja (209) Se seca (215) Se secan a veces (116) Bueno tenerlo para consumo (217) Han dado solo dos cosechas (220) El que mas me gusta, no se puede podar (121) Da hongos a la tierra, se secan después de 4 cosechas /La Inmaculada/ (302) Cuando llueve mucho, en el verano se carga hasta 3000-4000 fruta por árbol, casi no dura, echa un polvo que

afecta al café se pone amarillo (308) Aquí no sirve, se daña en la raíz y no da fruta porque se seca por arriba. /Cerro Grande/ (414) Le pega una enfermedad pero se compusieron con cenizas (316) He trozado un aguacate hace poco “no sirve aquí” (320) Aquí no bota mucha hoja (432) No da cosecha (335) Da sombra y sirve para el consumo humano (325) Es muy grande, se seca y se da vuelta (326) Casi no puede haber en el café, da hongo, guarda demasiado humedad (428) Se come mientras los cítricos son solo de chupar, El aguacate se queda bajito por la luna, ahora va a cambiar y va a crecer mas (422) muy helado aquí para aguacate

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo /Sompopo, Gusano /Roya, Ojo de gallo //Cerro Grande//Hongos

#### PERSEA AMERICANA 'MONTE' (AGUACATE MONTE)

**[Questionnaire]** /La Estrellita//14A / Muy susceptible al viento

**[Ranking - comments]** /La Estrellita/ (110) Este es buena madera pero el aguacate común no /Cerro Grande/ (337) Cerdo come la fruta, la hoja del café debajo se pone 'pimpo' como el

#### PISCIDIA GRANDIFOLIA (ZOPILOCUABO)

**[Questionnaire]** /La Estrellita//21A / Bota la hoja en verano

**[Ranking - comments]** /La Estrellita/ (119) No sirve porque muy caliente en verano, maderable y quita maleza. /Cerro Grande/ (334) Mantiene verde, cualquiera lo compra

**[Ranking – Pest & Diseases]** /La Estrellita//Mancha hierro

#### PLATYMISCIUM PINNATUM (COYOTE)

**[Questionnaire]** /La Estrellita//7A/ el coyote es palo de utilidad y tengo tres sembrados y eso no los toco porque son madera de construcción. /16A/ Quiere añadir en la periferia del café en el futuro /18A/ Buena madera y buena sombra /20A/ Da gusano /21A/ En la periferia //Cerro Grande//17C/ lo recomendaría poner en el café pero es difícil conseguir /20C / “Dijeron que el coyote traído por el proyecto se podrá vender.”

**[Ranking - comments]** /La Estrellita/ (202) Temporal, necesita regulación constante (116) En la periferia, no se puede tener en el café (118) Buena sombra, madera preciosa, leña /La Inmaculada/ (304) Se poda cuando pequeño, bota la hoja bastante (307) No da mucha sombra (311) Bueno tenerlo en el café /Cerro Grande/ (334) Hay un animalito que lo destroza por el medio en terreno con mucho hongo, no es tan vendible sirve para sombra y la casa (335) En el verano bota la hoja pero no dura mucho tiempo, ayuda a que la luz penetra (324) No crecen aquí, es de lo caliente.

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo

#### POUTERIA SAPOTA (ZAPOTE)

**[Questionnaire]** /Cerro Grande//14C / No da

**[Ranking - comments]** /Cerro Grande/ (413) Tabla, Leña (316) Fruta y madera pero muy tupido, si no le regula da enfermedad (323) Es peligroso cuando bota la fruta porque son grandotes (418) Casi no hay (324) Se vende pero no crece aquí (325) No es muy bueno porque cuando crece muy grande (422) Casi no hay por aquí (337) Casi no hay, no hemos sembrado nosotros, no se vende, se dice que es la comida de los pobres, durante corte del café se puede coger una fruta para desayunar

**[Ranking – Pest & Diseases]** None

#### PSIDIUM GUAJAVA (GUAYABA)

**[Ranking - comments]** /La Estrellita/ (201) La guayaba nativa no tiene mercado, solo la grande, pero la nativa crece fácil. (103) No es recomendable porque no desarrolla el café, se mantiene para leña (208) No se vende casi (110) No recomendable porque suelta acido (217) Poco la consumen porque la nativa es acida /La Inmaculada/ (300) solo para los animales (404) Casi no hay por aquí, se engusana la nativa (306) gusano en la fruta (407) Rinde mas leña que la naranja, mas difícil de pegar (308) Lo que hay aquí no sirve para nada, solo la extranjera se consume. Gusano en la fruta. La leña tarda un año para secarse

**[Ranking – Pest & Diseases]** /La Estrellita//Gusano /Da enfermedades //La Inmaculada//Ojo de gallo, Pellejillo

#### RICINUS COMMUNIS (HIGUERA)

**[Questionnaire]** /Cerro Grande//25C / La hoja se pudre rápido

**[Ranking - comments]** /La Estrellita/ (110) Bueno porque crece rápido

#### SPATHODEA CAMPANULATA (LLAMADA DEL BOSQUE)

**[Questionnaire]** /La Inmaculada//1B / Aleja las moscas/2B / Mata avispas /7B / Mata avispas //Cerro Grande//20C / Aleja las moscas

#### SWIETENIA MACROPHYLLA (CAOBA)

**[Questionnaire]** /La Estrellita//1A/ Se muere /16A/ Quiere añadir en la periferia del café en el futuro

**[Ranking - comments]** /La Estrellita/ (119) Hay que esperar 30 años para que llegue a 30cm de diámetro /La Inmaculada/ (302) Salvaje para venderlo. La ley permite vender Caoba y Cedro solo si uno lo ha sembrado de su mano o si está matriculado /Cerro Grande/ (334) Casi solo sirve para sombra, es bueno árbol si se le quita unas ramas

**[Ranking – Pest & Diseases]** None

#### SYZYGIVM MALACCENSE (PERA DE AGUA)

**[Questionnaire]** /La Inmaculada//8B / No recomienda tenerlo en el café porque la fruta daña al café al caerse

**[Ranking - comments]** /La Estrellita/ (101) Crece por arriba muy recta (102) Da mucha sombra (202) No se puede tener cerca de la casa porque las gallinas lo secan (116) Bueno tenerlo /La Inmaculada/ (304) Casi no se vende (407) La compra en la ciudad aquí no porque la gente esta aburrida (308) Daña al café cuando se cae la fruta

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo/Sompopo, Gusano

#### TABEBUIA ROSEA (ROBLE MAQUALIZO)

**[Questionnaire]** /La Estrellita//12A/ tiene planeado cortarlo cuando tendrá 20-25 años, sembrado a 10x10 metros / 19A / Sombra caliente

**[Ranking - comments]** /La Estrellita/ (121) Da hongos a la tierra, madera para mesas y muebles

**[RANKING – PEST & DISEASES]** None

#### TERMINALIA OBLONGA (GUAYABON)

**[Questionnaire]** /La Estrellita//14A / Madera dura, no es flexible a los vientos, buen crecimiento y altura

**[Ranking - comments]** /La Estrellita/ (103) Alto y liso (116) Bueno tenerlo (220) Muy grande y con el viento riesgo que se caiga, lo pone en la periferia /Cerro Grande/ (334) Solo esta en la montaña no lo hemos probado en el café, no es tan vendible sirve para la casa (335) Estoy encariñado porque es una madera preciosa de utilidad, tiene buen crecimiento, crece grande y mantiene su follaje

**[Ranking – Pest & Diseases]** None

#### THEOBROMA CACAO (CACAO)

**[Questionnaire]** /La Estrellita//6A / Le gustaría sembrar cacao en vez del café, aunque dice que no es adaptado a esta altitud. /7A/ “Cuando lo sacamos pues lo vamos a vender porque no se puede usar mucho. A veces cuando hacemos un pinol lo revolvemos allí para estar. pero mas para venderlo porque no se puede tener que ciegue el cacao... ya por ultimo se pierde y entonces mejor sacarlo. El cacao tiene buen precio.” /17A / Se ha secado un tercio de los que ha sembrado /18A/ 1 quintal se vende a 3500C\$ /19A / No lo quiere mezclar porque necesita mas sol que el café. /21A / Por los precios en el mercado, ahora es mas recomendable poner mixto café y cacao. //La Inmaculada//6B/ Tiene 6 arboles para consumo propio /8B / El cacao no rinde aquí sin abono //Cerro Grande// 20C / Le gustaría pasar al cultivo de cacao cuando se termina el proyecto.

**[Ranking - comments]** /La Estrellita/ (101) Le pega la manilla, ladrones (“Para tener cacao, habría que ponerle un cuidadero todo el tiempo sino perdería un 60% por ladrones, sin hablar de las enfermedades! Necesita cuido para sacarle producción. Lo pondría en una parcela sola, no con el café.”) (215) No da mucha leña, le entra enfermedad (116) Me gustaría tener cacao pero no en el café (119) No sirve en el café, se pone por separado /La Inmaculada/ (300) La leña no es muy buena, sombra baja, humedad, da reales (302) Como se poda no tiene mucha cobertura, sembrado en el café atrae enfermedades que afectan a los dos (403) Se consume poco

solo en fresco, no se da muy bien con revuelto con café porque se pasan plagas (304) Por veces se seca (monilla) (306) No sirve revuelto con el café (407) Mucho billete, poco para el consumo solo pinol, no se necesita mucho, solo leña (308) Da reales y para consumo, casi no bota la hoja (311) Hay personas que no le echan abono pero con el café no, no se quieren

**[Ranking – Pest & Diseases]** /La Estrellita//Ojo de gallo, antracnosis /Antracnosis, Roya /Sompopo //La Inmaculada//Da enfermedad /Da enfermedad /Roya, Antracnosis /Ojo de gallo

#### TRICHILIA HAVANENSIS (LIMONCILLO)

**[Questionnaire]** /La Estrellita//14A / No bota la hoja

**[Ranking - comments]** /La Estrellita/ (102) Buena leña (116) No es tan grande entonces da poca sombra (119) Incorporativo, Bota 25% de sus hojas pero nunca queda pelón (121) Muy sombrero, muy tupido, da mucho trabajo /Cerro Grande/ (334) Este palo es fuerte porque no le molesta el hongo de la tierra

**[Ranking – Pest & Diseases]** None

#### TRICHILIA ADOLFI (CACAHUILLO)

**[Questionnaire]** /La Estrellita//18A / Es bueno pero la gente lo elimina

#### UNKNOWN SPECIES (CASSIA)

**[Questionnaire]** /La Inmaculada//3B / Atrae gusanos y Sompopo//Cerro Grande//21C / Rompe viento y da leña

#### UNKNOWN SPECIES (BARBESOL)

**[Questionnaire]** /Cerro Grande//14C/ Árbol regalado por ADDAC

#### UNKNOWN SPECIES (GUANO)

**[Questionnaire]** /La Inmaculada//1B / No sirve para leña

#### UNKNOWN SPECIES (PINO)

**[Questionnaire]** /La Estrellita//19A / Sombra caliente

#### UNKNOWN SPECIES (TAMBOR)

**[Questionnaire]** /La Inmaculada//11B / No compite por la luz

## MADERABLES

**[Questionnaire]** /La Estrellita//13A/ Algún palo se bota cuando se necesita para construir la casa. Sacar el permiso es una “vuelteria”. / 14A / Aceramos un palo cuando uno se seca o el viento bota un árbol, tal vez una vez por año. “Es imposible que vaya cortando un árbol así grande por todo el tiempo que voy a tener que esperar para que otro árbol me dé lo que me daba” /15A / Saca arboles cuando la casa necesita reparaciones /17A / “Es bueno tener maderables sembrados porque mejora el valor del terreno para mis hijos”/18A/ Se cortan para necesidades graves. Sino se dejan para los nietos. La madera preciosa aumenta el valor de la propiedad para los nietos. /19A/ A veces vende palos a sus vecinos por necesidad, pero no a los que son metidos en el café. /21A/ Pienso acerar los maderables para hacer reparaciones en la casa cuando serán grandes pero no tengo planes. /22A/ Corta en raras ocasiones cuando es necesario para la casa. No le gusta tener maderables cerca de la casa /La Inmaculada//1B/ solo para construcción, no se vende. Talamos arboles cuando se han criado bastante grande. No lo vendemos para que quedan arboles de reserva si lo necesitamos para la casa, La madera es muy escasa por aquí. /3B/ No vende madera porque es complicado sacar permiso. A veces no se puede obtener permiso porque el árbol se encuentra muy cerca de una fuente de agua. /4B/ No vende la madera porque a veces son problemas con la gente. /5B/ No es rentable vender madera, con lo que cuesta el permiso, el carpintero y el transporte. /10B/ “La madera es lo mas importante.” Ahora tiene tres palos maderables para su consumo. /11B/ Madera solo para consumo porque no dan permisos para vender y porque es muy poco los arboles que tiene entonces no es rentable. /Cerro Grande//14C/ Compra madera, hay que renovar la casa cada 10 años. /17C/ Es caro sacar permiso por la ley. Cuando tendrán 3 años, quieren aprovechar el Areno, Troton, Laurel y pino para su consumo /20C / No tiene maderables /21C / No vende la madera que tiene en su terreno para asegurar una fuente de madera para sus nietos. Como sus parcelas están a 300 y 600m de su casa, seria bueno poner maderables /22C/ Se mira mas bonita la finca con muchos arboles. Da lastima botar un árbol cuando uno lo necesita. /23C / Ha construido su casa con dos arboles solo, un guayabon y un Areno de 30 pulgadas. /25C/ No tiene en el café porque tiene en la montaña donde también tiene una fuente de agua. /26C / Solo para la casa “hay apena”. Espera que los arboles serán bastante grandes el día que los necesita, sino tendrá que comprar. /30C / Compra cuando lo necesita, tiene maderables “solo para tenerlo allí”

**[Ranking - comments]** /La estrellita/ (101) Siempre uno prefiera maderables. A mi me gustan porque son de larga vida. Son atractivos en la parcela. Siempre nos van a servir cuando se pierden otros. Ayuda el guineo a pasar el verano. (106) Realmente cuando uno siembra café, no siembra este tipo de arboles, típicamente solo siembra guaba negra y guineo. No piensa en maderables. (119) “Los maderables conviven con el café pero no son para sombra.” “En su momento se hacen grandes y se pueden acerar sino se dejan para el medio ambiente” /La Inmaculada/ (311) No en el café /Cerro Grande/ (335) Hay que siempre mantener maderables, no dejar que desaparecen de la finca.

## FRUTALES

[Questionnaire] /La Estrellita//7A / “A veces cuando hay alguna necesidad de comprar otra cosa pues vendemos y sino pues para el consumo de nuestra casa. Como si viene de repente la familia que tenemos en Managua del lado de Rio blanco, nos dice consigue tal cosa pues debemos tenerlo pendiente para el ladecito y le damos. Porque así viene de repente y dice ‘No tiene guineo’ ‘como no, si es poco pero hay’ no les puedo decir que no hay porque también es poquito lo que ellos tienen. Entonces así hacemos nosotros. Casi no lo vendemos. Y lo comemos nosotros y los servimos a alguien que lo necesita.” /11A / No tiene problema para vender producto porque los vienen a comprar aquí (Guineo) pero lo dejan perder por falta de tiempo. /13A / Muchos problemas con ladrones, pero sobre todo es un problema de falta de tiempo. Casi solo esta el hijo para cuidar las 4 manzanas. El está interesado en la producción de fruta para el mercado. /18A/ “Tengo muchos frutales en el café, no le afectan al café” /19A/ Solo para el consumo. Tiene un ¼ de manzana de café sembrado con plátano y el resto con guineo, a 6x4. Le interesa sacar frutas para el mercado, ahora esta sembrando “limón Tahiti”. Before he had many problems with thieves, but now he almost doesn’t have problems anymore because he gives things for free when someone asks. /20A/ Recomienda frutales (Mango, Aguacate, Cacao) porque son cosas que se ocupan. El problema (para venderlo) es que el transporte a Matagalpa es caro y hace falta un permiso, te pueden quitar todo si lo vendes en la calle. /21A/ Guineo solo para consumo porque el precio es demasiado barato, “no me resulta” /22A/ Puede vender sus productos directamente en la venta. Vende 20-30 cabezas de guineo, 10 meses por año. Tiene ¼ de malanga que usa para consumo y venta. /La Inmaculada//1B/ El limón y la naranja se venden pero a veces nadie lo compra. Vienen con un camión a comprar los productos de la finca. Recomendaría sembrar Naranja y mango pero “la gente molesta” maltratando los arboles de café /2B/ No tiene ningún negocio el guineo, el precio es demasiado bajo. “No se puede vender los productos de la finca porque los precios son muy bajos. No le alcanza al intermediario llevarlo a Rancho Grande.” Esposa triste que se pierdan unas cosas porque no se cosecha a tiempo. /5B/ Los frutos se pierden porque el precio es muy bajo. Deja que se lo llevan los trabajadores /6B/ No quiere vender madera porque le gusta los arboles. /8B/ Tiene frutales, pero la fruta se pierde. No recomienda tener frutales por los ladrones, y Peras porque la fruta daña al café al caerse. “Cuando uno es muy pobre, pone todos los frutales en la parcela con el café, pero seria mejor tenerles a parte porque dañan al café.” /10B/ El mayor problema que tiene para vender fruta es que el precio es muy bajo. /11B/ Frutas principalmente para el consumo y si alguien lo necesita lo regala. /Cerro Grande//13C/ solo sirven al consumo. Es útil. También se lo comen los animalitos. Si hay alguno que busca, uno le da. Aguacate y Naranja, La gente no compra porque las rutas son caras y se le quita todo en el viaje. /16C/ No lo sacamos, no hay bastante. Es solo para el consumo. A veces viene gente para buscar naranja. /18C/ Esta buscando como sembrar mas frutales para el consumo, el cerdo y las gallinas /20C / Le gustaría tener mas frutales pero de otro lado (limón injerto, Aguacate injerto, mango rosa...) /21C / Si (las parcelas de café) estuviesen mas cerca, seria bueno poner leña y frutales también. / 22C/ Los frutos consumimos una parte y el resto es para los pajarillos /25C / No da lugar, no le queda el tiempo para cosechar. /26C / solo para el consumo. /27C/ Casi no la saca, a veces regala a

familiares. Los animales se comen los aguacates que se caen al suelo. / 28C / Su mayor problema para vender es que tiene poco. / 29C / Para el consumo, regala la mayoría

**[Ranking - comments]** /La Estrellita/ (201) Solo los frutales injertos tienen mercado pero la gente no tiene interés en comprar siembras (106) Realmente cuando uno siembra café, no siembra este tipo de árboles, típicamente solo siembra guaba negra y guineo. (217) Le gusta los árboles que se usan en la cocina y se usa la fruta pronto (Guineo, Naranja, Aguacate, Limón) (222) “No me gusta poner frutales en el café por los ‘niños’ y por lo que cubre mucho espacio.” (también se refiere a los ladrones) /La Inmaculada/ (302) Frutales (Cacao, Mango, Limón, Aguacate, Coco, mandarina) se alimentan de los nutrientes de la G. negra, Coyote, Plátano y Cedro real. Los frutales solo ayudan para la fertilidad si se cae una fruta y se pudre. (402) Todos necesitan abono para dar fruta. (306) No le gusta los frutales porque le entra muchas enfermedades al café, “les arruina al café” /Cerro Grande/ (315) Consumo: Es útil tener vitaminas en el terreno de uno (317) No se siembra en el café porque no se podan (335) Año por año regeneran ganancia (324) Se siembra en partes amplias donde no hay café

### LEÑA

**[Questionnaire]** /La Estrellita//12A / No necesita mucha leña porque tiene gas. Solo la utiliza para cocer frijoles y tortilla que es más dilatado. (1 marca) /13A / No vende leña porque es mucho tiempo y trabajo. /14A / Leña es mucho trabajo para venderla y tiene un precio bajo. /19A/ Mucho trabajo, cosecha lo que necesita por tercios y deja que la gente se la lleve gratis. /20A/ Le dan leña gratis en la finca donde trabaja. /21A/ Usa toda la leña disponible /22A/ Solo usa leña para cocer frijoles y eventos. Recoge la que está cerca y deja que los cortadores se lleven el resto. /La Inmaculada//5B/ No vende leña porque “el problema es la traída” /6B/ Todavía no produce bastante leña para su consumo, tiene que comprar una media marca /Cerro Grande//13C/ Saca dos marcas de leña de su parcela, lo cual es suficiente para la mitad del año. Luego, su mamá le regala. Todo es bueno para leña. /18C/ Los árboles grandes se aceran para leña, solo se dejan los tiernos /27C / No sabe muy bien cuánto, pero hay bastante. En el invierno tiene 1 metro, en general van y traen lo que necesitan. Todo sirve.

**[Ranking - comments]** /La Estrellita/ (116) Es bueno tener leña, así ya no estamos buscando madera podrida para hacer el fuego. (217) “Yo no sé de qué palo será la leña que me traen. Me la traen ya picada y solo tengo que echarla al fuego” /La Inmaculada/ (300) Con la leña no hay mucho problema aquí. (302) “En el café mejor poner leña (que frutales) porque es viable”

### PROYECTO NICAFRANCE

**[Questionnaire]** /La Estrellita//3A/ Este proyecto es muy bueno, nos ayuda mucho a nosotros porque pagan por todo /10A / Se retiró de la cumplida porque los técnicos le daban poca atención al café. Era café malo, sembrado en pleno sol. Pasado la fecha del foleo.... /19A/ “los árboles de la fundación se mueren” /La Inmaculada//1B/ Le gustaría tener más café con el proyecto pero no propio. Solo puede echar abono a su café una vez al mes mientras el café del proyecto recibe abono cuatro veces al mes. /4B/ Quiere recibir cítricos injertos de un proyecto porque es difícil encontrar cítricos injertos en el mercado y son mucho mejor porque no crecen tan alto y producen muy rápido. /Cerro Grande//17C/ Muy interesado en proyectos /20C / No

puede elegir los arboles de sombra que están en la parcela del proyecto. Parte de su terreno se encontraba en una zona de bosque, entonces la mandaron a desombrar porque la política del proyecto es de hacer reforestación. Esta prohibido tener cerdo cuando eres parte del proyecto o tienes que comprar malla para dejarlo encerrado. Iban a traer frutales pero no lo hicieron.

**[Ranking - comments]** /Cerro Grande/ (316) Ha rechazado el proyecto de NicaFrance porque no puedes tener gallina ni chanco y no se puede pasear en la parcela. Después que se haya retirado, han autorizado gallinas y pasear para atraer a clientes. Dice que no ayuda al pobre que necesita dinero para comprar comida, uno no levanta ese dinero.

### PROBLEMAS CON EL CAFÉ

**[Questionnaire]** /La Estrellita//10A / Se va alejando la lluvia en la zona. En estos terrenos muy secos no dan estas variedades de café. /12A / “El café no esta dando demasiado resultado. Antes no había tantas enfermedades como ahora.” /16A / “Sufre mas uno por tener GB. No le da bastante, se le va en nada.” “Con el café, pueden conseguir préstamo con la exportadora, es como vender la cosecha adelantada. Yo nunca lo he hecho pero allí esta la opción.” /17A / Le gustaría tener otras cosas que el café, como GB, pero tendría que alquilar tierras y no es rentable /18A / Ha sembrado el café cada año por área de 0,25 o 0,5 manzana por falta de recursos /19A/ Menos producción de café este año por maduración temprana de los granos dado a una temperatura alta /20A/ Para despulpar su café, tiene que ir cargándolo y pesa mucho, esta lejos y es caro /La Inmaculada//10B/ La sombra tiene que esta controlada, emplea un mozo para la poda porque ella no sabe. Piensa vender su terreno porque es demasiado trabajo para una persona y no tiene el dinero para estar pagando a mozos. Solo tiene hijas casadas por Matagalpa, no tiene ningún hijo que le pueda ayudar. Es divorciada, se dejaron hace 1 año, el vendió su parte y la dejo con la mitad del terreno /Cerro Grande//14C/ Señora mayor quien vive sola. Dice que es mucho trabajo y que es difícil trabajar en al finca sola. Tiene que pagar a mozos pero no tiene el dinero para ello. No tiene mas de 1 empleado por el precio de la mano de obra “Antes no se echaba nada y el café nunca tenia enfermedades” /17C/ El café solo produce bien durante dos años, luego hay que hacer renovación. /18C/ Ahorita, no rinde ni el precio del café ni el grano. Pero siempre voy a querer dejar una parte de café. /21C / “Antes, cuando había mas sombra, era café de mejor calidad por la variedad. Pero ahora con las enfermedades hay que usar otras variedades e invertir para que de. Este año, esta temeroso de invertir en el café por la mala cosecha del año pasado.” /25C/ Padre: “El es solito, le toca todo hasta mantenerme a mi. Para hacer un trabajo hay que echarle un mozo.” Mi guía: “No le gusta echar mozo porque le gusta que las cosas sean echas de una forma en concreto.” Encuestado: “No hay cultivo que no lleva trabajo, /27C / (Notas de la reunión de Heifer) No le ha gustado la reunión porque no traen fertilizantes y a uno le hace falta dinero para comprar fertilizantes y fungicidas. /28C / Dice que tener arboles tiene un impacto sobre las enfermedades del café pero cuando le pregunto cuales y si aumenta o disminuye dice “uno no sabe”.

### ECOSYSTEM SERVICES

**[Questionnaire]** /La Estrellita//7A / “Como dice el dicho pues los arboles de uno al otro se perturban, al quedarse cerca. Entonces por eso, no hay que sembrar muchos arboles.” En terreno árido, si no tiene sombra las raíces se secan y la planta “no tiene fuerzas para nada mientras que

los arboles se ayudan entre ellos porque le dan la sombra y le dan el sol también.” Pero ya esta muy escondido de arboles entonces tenemos que botar un poco los palos que no hay utilidad. /10A / Mejor dejar la sombra alta, que no pega al café, así pasa el aire /12A / Los arboles mantienen el suelo humedo, aquí no es un problema porque el terreno es quebrado. “Lo que mas se necesita aquí es sombra rápida” /16A / Deja las ramas que no ocupa para leña en las calles como barrera para la lluvia, para que una rama muerta no daña al café al caerse”. Tiene maderables en la orilla por miedo que se caigan. /18A / Guarda 1 quintal de café para consumo propio /La Inmaculada//4B/ Los arboles de sombra protegen al guineo del viento /7B/ No tengo problemas de erosión porque tengo curvas de nivel. Aquí no hay piedras para hacer barrera muerta entonces hacemos barreras vivas. La erosión viene por quemar el suelo con químicos. Aquí, la maleza se chapoda no muy corto y se mantiene allí. Mejora el suelo y con las raíces de las plantas no hay erosión. /8B/ Le gusta mas producir café sin sombra. No le importa que los arboles mantengan la humedad del suelo porque allí llueve mucho. Tiene miedo de que se caiga un palo. Cuando uno se cae, arranca mucha tierra y se va todo al rio. /Cerro Grande//12C/ Me gusta tener muchos arboles pero no puedo sembrar mas porque no tengo mucho terreno. Muchos arboles en el café le afecta por la sombra, no da cosecha, y pueden caerse. /13C/ Los arboles son una gran cosa. Dan un ambiente sabroso y aire fresco. Hacen que el agua no se seca. “Como es pequeño el terreno, uno pone de todo” Es bueno sembrar arboles para construcción pero hay que sembrar de todo. No hay árbol que es malo para el terreno. /14C/ “por costumbre aquí le ponemos sombra al café. Si ha estado sembrado con sombra, al quitársela se pone amarillo el café” “pero con mucha sombra el café no echa nada”. Me gustaría sembrar mas arboles que ayudan a la tierra. /15C/ No sembraron arboles en el café. La tierra es húmeda, no necesita arboles. Pero dice que quiere poner mas arboles para evitar que se secan las fuentes de agua. /17C/ Mucha humedad da hongos. /18C/ Tiene problema de erosión cada vez que llueve. /22C/ Cuando hay viento, pueden caerse (las ramas secas) y dañan al café. /23C/ Dice que los arboles protegen el medio ambiente y las fuentes de agua pero luego dice que demasiado arboles en el café no sirven porque traen enfermedades.

**[Ranking - comments]** /La estrellita/ (101) En el café se necesita arboles de corta y de larga vida. Los maderables ayudan al guineo a pasar el verano (209) No les gustaría acerar un árbol maderable porque los necesitamos para el oxígeno y el medio ambiente, aunque los frutales dan menos reales, lo buscan. (116) El Yuca también es bueno tenerlo, se siembra en la calle de café mientras el guineo y los palos de construcción se desarrollan. “Todos los arboles son buenos para la fertilidad pero nosotros somos mas acostumbrados a la guaba y el guineo” Ninguna planta crece si uno no le pone mente. Solo crece si sale solo. La alimentación de uno primero para tener fuerza y hacer el trabajo. Después la leña. Solo el guineo y el platanos son buenos en el café, los otros van en la orilla. (220) “¡Es que no puedo elegir, lo necesito todo!” “los maderables también para la madera. Los arboles dan fuerzas a la tierra (humedad y fertilidad)” “Solo guardo los arboles que no se crían muy grandes cerca de la casa porque le tengo miedo al viento” /La Inmaculada/ (300) Arboles que crecen muy alto: malo porque al podarlo las ramas dañan al café. (302) Los frutales se alimentan de los nutrientes de la G. negra, Coyote, Platano y Cedro real. Los frutales solo ayudan para la fertilidad si se cae una fruta y se pudre. “¡Si hay agua, hay vida!” (402) Todos necesitan abono para dar fruta. Todos dan fertilidad al suelo. (305) En tierras áridas los arboles sirven a que no se destruye el suelo, le da vitaminas. /Cerro

Grande/ (316) Ahora en el café, es bueno no tener sombra (320) Ahora ha tenido una capacitación y le han dicho de no dejar que los arboles crezcan como palencón, hay que hacer una buena regulación desde el principio. La rapidez de crecimiento depende de la luna. Si uno le siembra 3 días antes de la luna llena no se crece alto y da fruta pronto. (335) Hay que mantener un 40% de sombra. No vamos a descuidar los suelos, hay que mantener la fertilidad. Management: Cuando uno lo maneja del principio es mas fácil darle la forma y altura correcta. Humedad: todos los arboles son de utilidad. Ningún tipo de árbol es malo sino que tiene que tener un sistema de manejo adaptado. En la naturaleza crecen todos tipos de arboles. Solo si tenemos una sola especie, allí si es malo. Todo árbol mal manejado puede dar enfermedades. Un árbol muy copado da muchas enfermedades. (418) Todos los arboles botan la hoja y dan fertilidad al suelo cuando entra el verano (430) Fertilidad: Todo tipo de cascara o fruta que cae al suelo sirve de abono. Humedad: toditos los arboles sirven, no dan lugar a que la tierra se seque (428) Humedad: cuando cuesta que crezca un palo entonces no guardan el suelo húmedo porque no tienen desarrollo

## FUTURO

**[Questionnaire]** /La Estrellita//6A / Quiere cambiar de cultivo en el futuro por el precio del café y la producción baja. Le gustaría sembrar cacao aunque no es adaptado a esta altitud. /7A / “No hemos tenido muy buena intención de meterle mas por lo que falta la plata para poder invertirle mas entonces estamos con lo que hay. Si que con mas terreno pues es bueno. Pero estar con planta nueva.” Seria mejor tener cacao: “La idea de nosotros es solo sacarle tres cosechas porque en parte esta pequeño el café y da todavía. Y ya luego le ponemos de siembro.” Ahora lo que va ha hacer es hacer un huerto, sembrar maíz y frijoles para tener comida. Y al mismo tiempo buscar siembro para tener mas plata. Sembrar plátano, mas guineo, algún árbol que me gusta. “Es bonito pues porque todo palo hace falta” /10A / Tal vez cambiar por un café que produce mas pero ya el es muy viejo y no quiere extender. /11A / Extender el AFS de café le gustaría. No todos los anos el precio es tan bajo y es mejor que tener GB. / 13A / “No queremos extender no. Se mete muchas enfermedades al café ahora. No compensa para los días de trabajo que se mete” /15A/ Quiere extender el café o pasar al cacao /16A / Añadir maderables (Cedro, Coyote, Potchote, Caoba) en la periferia. Quiere seguir sembrando media manzana cada año “No hay que perder la esperanza, hay que seguir trabajando.” /18A/ Quiere extender el café “es una tradición” Sembrarlo con plátano (porque se vende bien) y cacao. Por lo menos que haya una manzana de cacao en las 5 manzanas de café. /20A/ Le gustaría extender “de forma variada” (con especies de arboles distintos) /21A/ Extender. “Ahora es mas recomendable poner mixto café y cacao” /22A/ Ahora, no me quiero dedicar solo al café. Hay que hacer mucha inversión pero la ganancia es poca. Este año, la cosecha solo a servido a pagar los cortadores.” Quiere hacer una cabaña y comprar vacas. /La Inmaculada//1B/ Quieres tener mas maderables y guaba en el futuro /3B/ No quiere cambiar los arboles de sombra que tiene. Tiene un vivero con plantas de cacao que quiere sembrar pero ahora hay muchos arboles y hay que dejar espacio para tener acceso a las plantas. Primero, dice que seria bueno tener mas café pero no hay mas espacio. Luego dice que le gusta mas el cacao pero ahora con el café no tiene espacio para poner mas /4B/ Quiere sembrar una parcela con solo cítricos y pejibai (reducir café para tener espacio). /5B/ Quiere seguir y extender con el café porque “cuando uno se acostumbra”. Quiere quitar Laurel para poner cacao /8B/ En el futuro, quiere dejar una parte del café, y reemplazar

los que son malos. El cacao es algo barato ahora – no le compensa cambiar. /10B/ Piensa vender su terreno porque es demasiado trabajo para una persona y no tiene el dinero para estar pagando a mozos. Solo tiene hijas casadas por Matagalpa, no tiene ningún hijo que le pueda ayudar. Es divorciada, se dejaron hace 1 año, el vendió su parte y la dejó con la mitad del terreno. /11B/ Quiere cambiar del café al cacao porque el café tiene un precio para mantenerlo mientras el cacao “corta el hambre cada 22 días” /Cerro Grande//14C/ No hay billete ahora, tal vez sería bueno quitar un poco de café para hacer hortalizas que es un buen negocio. /15C/ Quiere cambiar café por GB porque le da mucha enfermedad al café. Uno le pone muchos químicos y casi no da. /17C/ Piensa reducir el café que tiene, pero depende de las políticas de compra y de los proyectos. Quiero trabajar con Atlantis. Tal vez pasar al ganado porque siento que me estoy engañando con el café. /18C/ Le gustaría reducir el café para diversificarse con ‘otros rublos’. “Ahorita, no rinde ni el precio del café ni el grano. Pero siempre voy a querer dejar una parte de café. /22C / Le gustaría extender el café si tenía más terreno. /23C / Quiere extender su sistema de café “si no se vende pues para el consumo” /24C / No tiene plata ni terreno para extender. Si el café se daña, renovar con plantas nuevas. /28C / extender porque “el café es el único rumbo que le saca a uno de aquí” /29C / Si hay plata, me gustaría poner solo cacao y guardar media manzana de café para que pueda tomar mi cafécito”

#### OTROS

**[Questionnaire]** /La Estrellita//19A/ Notes: 9 years ago, INTA came to the área. They gave “capacitaciones” to 27 farmers about organic agriculture (Guineo liquado+Cal+Melaza=foleo / Bouilli bordelaise+cobre+Cal=fungicide). But people were not really interested because they had to put the effort. They selected this farm because of the respondent’s interest and work. There is a lack of conscientiousness ‘falta de consciencia’ from the producers. The government have brought many good things. The government is promoting maize instead of coffee because they want to solve the small producers. When you have more than 3 manzanas of coffee, it is not enough to only use family work. /La Inmaculada//2B/ Miembro de Aldea Global: Solo puede usar productos recomendados señalados con la etiqueta azul, guardar limpio el suelo, Cuidar el medio ambiente, Construir una fosa para el trastero y baño, dar un buen salario a sus empleados, Rotular la casa, Hacer un mapa de la finca, Hacer barreras vivas, Cuidar los animales salvajes. “No le ponemos mente a lo que podemos sacar de la parcela, a los gastos que hay que hacer para el fertilizante.” “Me lo piden para aldea (saber lo que puede sacar de la parcela)” /3B/ Ella esta tomando las decisiones en la finca porque su marido esta trabajando en Costa Rica al momento. /4B/ El era parte de una cooperativa a donde vendía el café. Cuando uno es socio, puede obtener un préstamo y comprar abono que puedes pagar cuando viene la cosecha. /5B/ Miembro de ADA y Cooperativa de Rio de agua viva que ayuda para financiamiento y madera /7B/ Ahora no es rentable producir GB porque hay muchas enfermedades y es mas caro alquilar terreno. Es mejor trabajar con reforestación. /8B/ “Aquí hay demasiada agua, se vuelve un negocio, aunque no falta” “vuelve el pobre mas pobre” (agua potable y electricidad) “Uno a veces se quiere ir por otro lado pero haría mejor mejorar lo que ya tiene.” Notes: Very poor man, only thinks about timber and firewood because they are things that he doesn’t have and he can’t pay the bills. No long term vision because the day to day life is very hard. Use to sell fruits but as prices has dropped he stopped doing it. /Cerro Grande//14C/ She has 6 benches of coffee drying for consumption and if someone wants to buy. /15C/ The

actual owner is the father who owns 60 manzanas. But the son and his family are exploiting 1 manzana of coffee which has been informally given to them. The couple just moved there. Full sun coffee with trees only around the field giving a bit of shade.

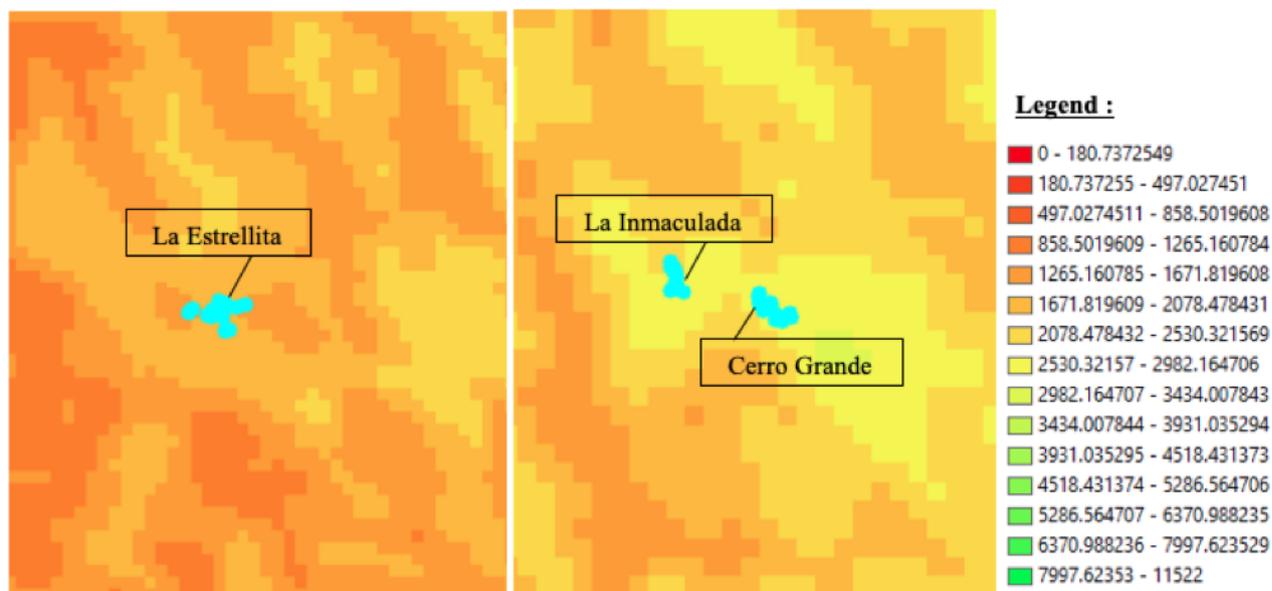
**[Ranking - comments]** /La Estrellita/ (103) **Todos estos** arboles (the ones he selected for the ranking) son los que no me gustan manejar. Los seleccione porque les conozco y quiero dar mi opinión sobre ellos. (116) “Para mi son importantes todas estas cosas” (talking about the ranking categories) /La Inmaculada/ (302) Si un proyecto le da semilla, a los dos años vienen y le matriculan la mitad. La alcaldia trabaja con INAFOR y dan la matricula gratis. La ley permite vender Caoba y Cedro solo si uno lo ha sembrado de su mano. Palo de 8-10 años ya se puede vender y es carísima una planta matriculada. /Cerro Grande/ (315) Before he was in ADDAC but he dropped out because he doesn’t like going to the meetings. “A uno le dan un fresco que vale 1à o 15 C\$ mientras uno esta perdiendo su día de trabajo.” “Claro esta bueno aprender, pero no es bueno estar metido en demasiadas cosas.” He is very interested in receiving seeds and seedlings but without having to go meetings. For him, coffee produces very little with shade, that’s why he has only few trees, and mainly bananas. Now that the wet season is beginning, he cuts off the old leaves of the banana to leave only 4-6 leaves (knowledge from ADDAC) (316) Los chimicos solo resultan a los que producen los chimicos. Por ejemplo el ojo de gallo, solo el sol lo controla.

---

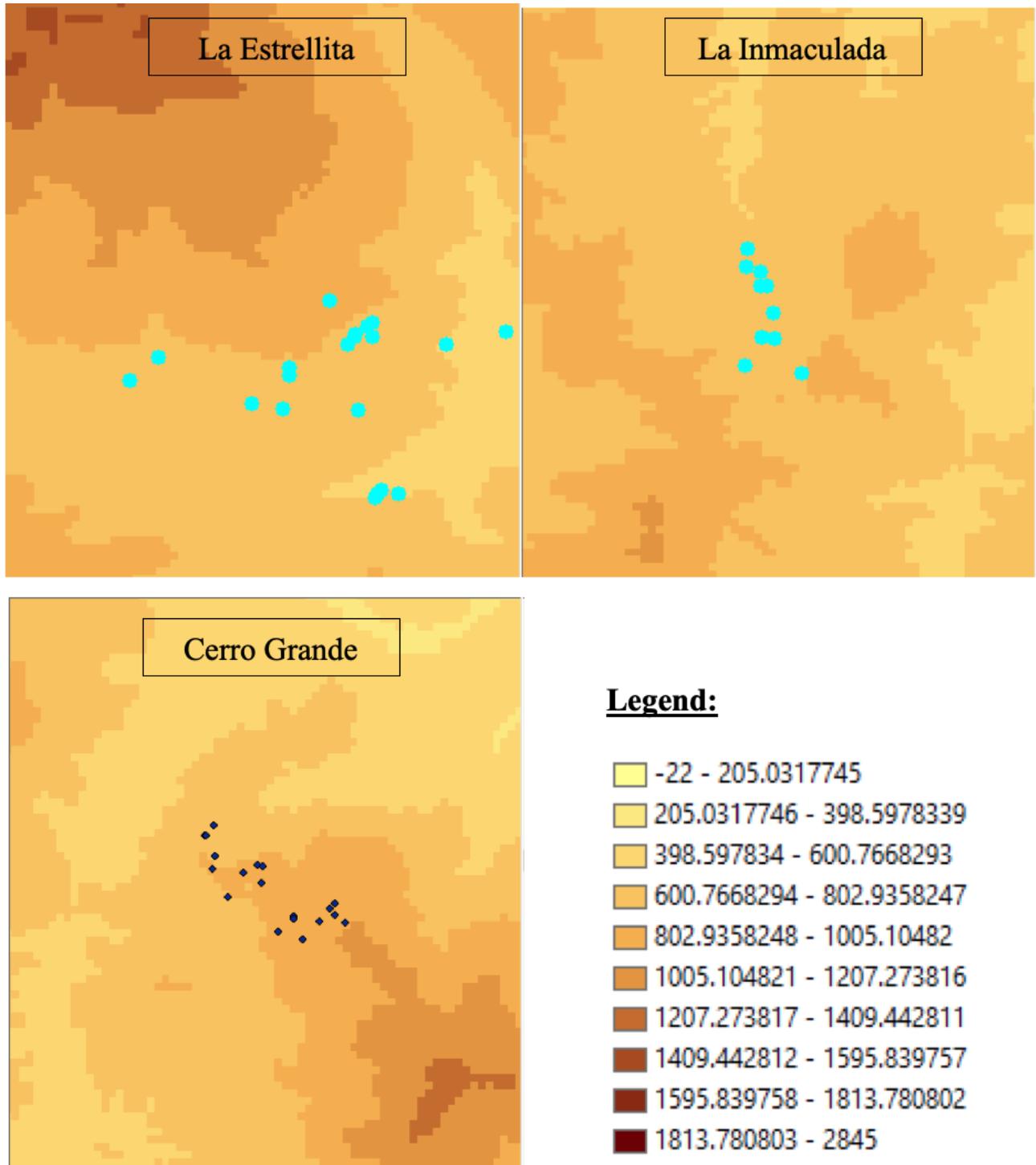
# APPENDIX H: PRECIPITATION AND ALTITUDE MAPS

---

AVERAGE PRECIPITATION OVER THE YEAR (in mm). Dots represent individual coffee plots. Source: ArcGIS



ALTITUDE MAP OF THE SELECTED COMMUNITIES (IN MASL). Dots represent individual coffee plots. Scale: 1:60 000. Source: ArcGIS



# APPENDIX I: LIST OF THE SHADE TREE SPECIES PRESENT IN THE STUDY AREA

**Legend:** ‘\*’ designates the species of which the identification was confirmed by an expert from NFF. ‘Fq.’ corresponds to the frequency of occurrence of each species in the study area. ‘N’ and ‘E’ correspond to native and exotic species respectively. Category refer to the main use of the tree. ‘Low Q’ and ‘High Q’ stand for Low quality and high quality respectively. ‘N/A’ means that the information was not available, mainly because the species could not be identified.

Botanical family	Scientific name	Local name	Common name	Fq.	N/E	Category
Anacardiaceae	<i>Anacardium occidentale</i> L.	Marañon	Cashew	0,02	E	Fruit
	* <i>Mangifera indica</i> L.	Mango	Mango	0,56	E	Fruit
	* <i>Mosquitoxylum jamaicense</i> Krug & Urb.	Troton	-	0,04	N	Low Q
	* <i>Spondias mombin</i> L.	Jocote	Yellow mombin	0,06	N	Fruit
	<i>Spondias purpurea</i> L.	Jocote ciruela	Purple mombin	0,02	E	Fruit
Annonaceae	* <i>Annona muricata</i> L.	Guanabana	Soursop	0,12	N	Fruit
Arecaceae	* <i>Bactris gasipaes</i> Kunth	Pejivai	Peach Palm	0,38	N	Fruit
	* <i>Cocos nucifera</i> L.	Coco	Coconut	0,26	E	Fruit
Bignoniaceae	<i>Crescentia cujete</i> L.	Jicaro	Calabash tree	0,02	N	Ustencil
	* <i>Spathodea campanulata</i> P.Beauv.	Llamada del bosque	African Tulip Tree	0,04	E	Ornamental
	* <i>Tabebuia rosea</i> (Bertol.) Bertero ex A.DC.	Roble maqualizo	-	0,12	N	High Q
Bixaceae	* <i>Bixa orellana</i> L.	Achiote	Annatto	0,08	N	Fruit
Boraginaceae	* <i>Cordia alliodora</i> (Ruiz & Pav.) Oken	Laurel	Salmwood	0,66	N	High Q
	* <i>Cordia collococca</i> L.	Muñeco	Clammy Cherry	0,16	N	Low Q
Burseraceae	<i>Bursera simaruba</i> (L.) Sarg.	Jinocuabo	Gumbo Limbo	0,02	N	Low Q
Calophyllaceae	* <i>Mammea americana</i> L.	Mamey	Mammee Apple	0,02	E	Fruit
Chrysobalanaceae	* <i>Hirtella triandra</i> Sw.	Guayabo borazon	-	0,16	N	Low Q
	<i>Licania platypus</i> (Hemsl.) Fritsch	Sonzapote	Sansapote	0,02	N	Fruit
Combretaceae	* <i>Terminalia oblonga</i> (Ruiz & Pav.) Steud.	Guayabon	-	0,08	N	High Q
Euphorbiaceae	* <i>Croton draco</i> Schltld.	Sangregrado	Sangre de Drago	0,08	N	Nothing
	* <i>Ricinus communis</i> L.	Higuera	Castor Oil Plant	0,08	E	Service
	<i>Sapium glandulosum</i> (L.) Morong	Lechoso	Milk tree	0,04	N	Low Q
Fagaceae	<i>Quercus</i> sp.	Roble encino	-	0,02	N	Low Q
Juglandaceae	* <i>Juglans olanchana</i> Standl. & L.O.Williams	Nogal	-	0,26	N	High Q
Lauraceae	<i>Cinnamomum costaricanum</i> (Mez & Pittier) Kosterm.	Aguacate canelo	-	0,1	N	Low Q
	<i>Cinnamomum verum</i> J.Presl	Canela	Cinnamom tree	0,02	E	Spice
	<i>Nectandra reticulata</i> Mez	Aguacate pozan	-	0,04	N	Low Q
	* <i>Persea americana</i> Mill. 'comun'	Aguacate comun	Avocado tree	0,7	N	Fruit

Botanical family	Scientific name	Local name	Common name	Fq.	N/E	Category
Lauraceae	<i>*Persea americana</i> Mill. 'monte'	Aguacate monte	-	0,14	N	Low Q
Leguminosae	<i>Acrocarpus fraxinifolius</i> Arn.	Cedro rozado	Shingle tree	0,04	E	High Q
	<i>Albizia guachapele</i> (Kunth) Dugand	Gavilan	Chime tree	0,06	N	High Q
	<i>*Albizia saman</i> (Jacq.) Merr.	Genizaro	Rain tree	0,14	N	Service
	<i>Cajanus cajan</i> (L.) Millsp.	Gandul	Pigeon Pea	0,02	E	Fruit
	<i>Calliandra</i> sp.	Caliandra	-	0,02	N/A	N/A
	<i>Cassia grandis</i> L.f.	Carao	-	0,02	N	Low Q
	<i>*Dalbergia tucurensis</i> Donn.Sm.	Granadillo	Guatemalan rosewood	0,02	N	Low Q
	<i>Dialium guianense</i> (Aubl.) Sandwith	Comenegro	-	0,02	N	High Q
	<i>*Enterolobium cyclocarpum</i> (Jacq.) Griseb.	Guanacaste	Elephant Ear	0,06	N	High Q
	<i>*Erythrina fusca</i> Lour.	Elequeme	Coral tree	0,22	N	Service
	<i>*Erythrina poeppigiana</i> (Walp.) O.F.Cook	Buccaro	Mountain Immortelle	0,12	E	Service
	<i>*Gliricidia sepium</i> (Jacq.) Walp.	Madero negro	Gliricidia	0,2	N	Low Q
	<i>Hymenaea courbaril</i> L.	Guapinol	-	0,02	N	High Q
	<i>*Inga densiflora</i> Benth.	Guaba blanca	-	0,22	N	Service
	<i>*Inga edulis</i> Mart.	Guaba roja	-	0,58	E	Service
	<i>*Inga punctata</i> Willd	Guaba negra	-	0,6	N	Service
	<i>*Inga</i> sp.	Guaba extranjera	-	0,04	E	Fruit
	<i>Leucaena leucocephala</i> (Lam.) de Wit	Leucaenia	Leucaena	0,02	E	Service
	<i>*Lonchocarpus rugosus</i> Benth.	Chaperno	-	0,28	N	Low Q
	<i>Lysiloma auritum</i>	Quebracho	-	0,04	N	Low Q
	<i>Myroxylon balsamum</i> (L.) Harms	Balsamo	Tolu Balsam	0,02	N	Medicinal
	<i>*Piscidia grandifolia</i> (Donn.Sm.) I.M.Johnst.	Zopilocuabo	-	0,08	N	Low Q
<i>*Platymiscium pinnatum</i> (Jacq.) Dugand	Coyote	Panama Redwood	0,44	E	High Q	
<i>*Tamarindus indica</i> L.	Tamarindo	Tamarind	0,08	E	Fruit	
N/A	Cassia	-	0,02	N/A	N/A	
N/A	Frijolillo	-	0,02	N	Fruit	
Malpighiaceae	<i>*Byrsonima crassifolia</i> (L.) Kunth	Nancite	-	0,24	N	Fruit
Malvaceae	<i>*Ceiba pentandra</i> (L.) Gaertn.	Ceiba	Kapok tree	0,18	N	Low Q
	<i>*Guazuma ulmifolia</i> Lam.	Guacimo	-	0,18	N	Low Q
	<i>*Heliocarpus appendiculatus</i> Turcz.	Majague	-	0,22	N	None
	<i>*Luehea seemanii</i> Triana & Planch	Guacimo molenillo	-	0,02	N	Low Q
	<i>Ochroma pyramidale</i> (Cav. ex Lam.) Urb.	Guano	-	0,06	N	Low Q
	<i>*Pachira quinata</i> (Jacq.) W.S.Alverson	Potchote	Red ceiba	0,22	N	High Q
	<i>*Theobroma cacao</i> L.	Cacao	Cocoa	0,42	E	Fruit
Meliaceae	<i>*Carapa guianensis</i> Aubl.	Cedro macho	Andiroba	0,24	N	High Q
	<i>*Cedrela odorata</i> L.	Cedro real	Cedar Wood	0,4	N	High Q
	<i>Guarea guidonia</i> (L.) Sleumer	Pronto livio	Muskwood	0,02	N	High Q
	<i>*Swietenia macrophylla</i> King	Caoba	Big leaf Mahogany	0,28	N	High Q
	<i>*Trichilia havanensis</i> Jacq.	Limoncillo	-	0,08	N	None
<i>*Trichilia adolfi</i> Harms	Cacahuillo	-	0,04	N	None	
Moraceae	<i>*Artocarpus altilis</i> (Parkinson ex F.A.Zorn) Fosberg	Castaño	Breadfruit	0,02	E	Fruit

Botanical family	Scientific name	Local name	Common name	Fq.	N/E	Category
Moraceae	<i>*Brosimum alicastrum</i> Sw.	Ojoche	Maya nut	0,12	N	Fruit
	<i>*Ficus insipida</i> Willd.	Higo	-	0,06	N	Low Q
	<i>*Ficus</i> sp.	Chilamate, Matapalo	-	0,24	N	Low Q
Muntingiaceae	<i>*Muntingia calabura</i> L.	Capulin	-	0,14	N	Fruit
Musaceae	<i>*Musa</i> sp. 'guineo'	Guineo	-	0,9	E	Fruit
	<i>*Musa</i> sp. 'platano'	Platano	-	0,5	E	Fruit
Myrtaceae	<i>Eugenia</i> sp.	Arrayan	-	0,02	N	Firewood
	<i>*Psidium guajava</i> L.	Guayaba	Guava	0,16	N	Fruit
	<i>*Syzygium malaccense</i> (L.) Merr. & L.M.Perry	Pera de agua	Malay Apple	0,26	E	Fruit
Pinaceae	<i>Pinus</i> sp.	Pino de montana	-	0,02	N	High Q
Poaceae	N/A	Bambu verde	-	0,02	N/A	Low Q
Rutaceae	<i>*Casimiroa sapota</i> Oerst.	Matasano	-	0,02	N	Fruit
	<i>Citrus</i> spp. 'limon'	Limon	Lemon	0,6	E	Fruit
	<i>Citrus</i> spp. 'naranja'	Naranja	Orange	0,7	E	Fruit
	<i>*Citrus paradisi</i> Macfad.	Greifu	Grapefruit	0,04	E	Fruit
	<i>*Citrus reticulata</i> Blanco	Mandarina	Mandarin	0,42	E	Fruit
	<i>Zanthoxylum juniperinum</i> Poepp.	Chinche		0,02	N	Low Q
Sapindaceae	<i>*Melicoccus bijugatus</i> Jacq.	Mamon	Spanish lime	0,06	E	Fruit
	<i>*Nephelium lappaceum</i> L.	Mamon chino	Rambutan	0,02	E	Fruit
Sapotaceae	<i>*Chrysophyllum cainito</i> L.	Caimito extranjero	Star Apple	0,04	E	Fruit
	<i>Pouteria campechiana</i> (Kunth) Baehni	Zapotillo	Canistel	0,02	N	Fruit
	<i>*Pouteria sapota</i> (Jacq.) H.E.Moore & Stearn	Zapote	Sapote	0,16	N	Fruit
	<i>Sideroxylon capiri</i> (A.DC.) Pittier	Tempisque	-	0,02	N	Low Q
	<i>*Ulmus mexicana</i> (Liebm.) Planch.	Areno	Membrillo	0,04	N	Low Q
Urticaceae	<i>*Cecropia peltata</i> L.	Guarumo	Trumpet tree	0,22	N	Low Q
Verbenaceae	<i>*Lippia myriocephala</i> Schltldl. & Cham.	Mampas	-	0,12	N	None
Vochysiaceae	<i>Vochysia ferruginea</i> Mart.	Manga larga	-	0,02	N	Low Q
Salicaceae	<i>Banara guianensis</i> Aubl.	Areno blanco	-	0,06	N	Low Q
N/A	N/A	Barbesol	-	0,02	N/A	N/A
N/A	N/A	Caricillo	-	0,02	N/A	N/A
N/A	N/A	Cupalchile	-	0,02	N/A	N/A
N/A	N/A	Guayabo livio	-	0,02	N/A	N/A
N/A	N/A	Pino	-	0,06	E	High Q
N/A	N/A	Sorrillo	-	0,02	N	N/A
N/A	N/A	Tambor	-	0,04	E	Service
N/A	N/A	Tusa	-	0,02	N	None

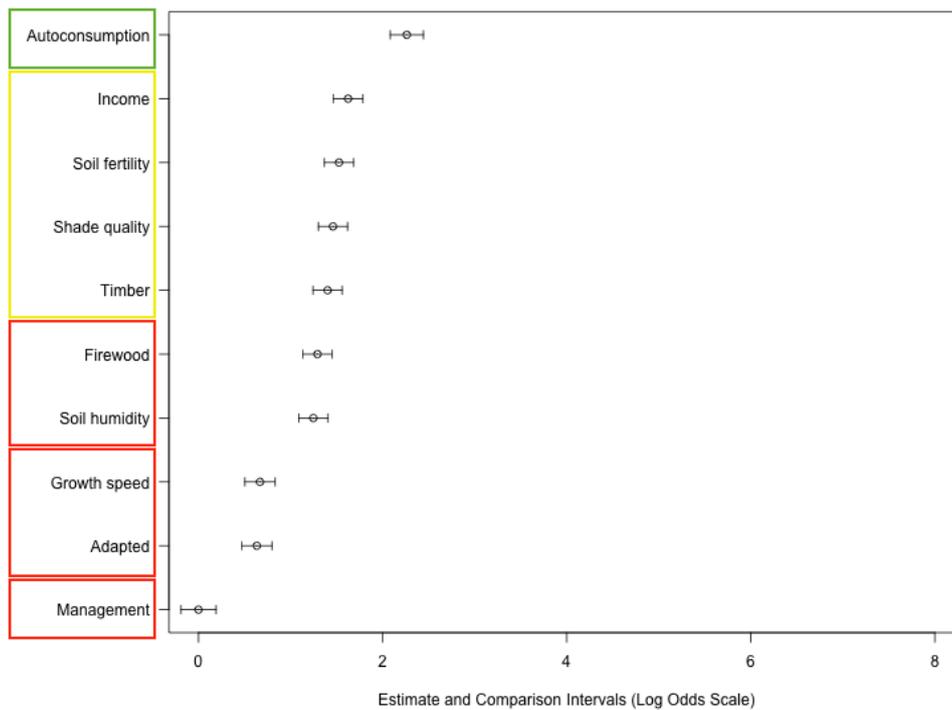
# APPENDIX J: LIST OF SELECTED SPECIES

**Legend:** ‘\*’ designates the species of which the identification was confirmed by an expert from NFF. ‘A’, ‘B’ and ‘C’ corresponds to the frequency of occurrence of each species in La Estrellita, La Inmaculada and Cerro Grande respectively. ‘N’ and ‘E’ correspond to native and exotic species respectively. Category refer to the main use of the tree. ‘Low Q’ and ‘High Q’ stand for Low quality and high quality respectively.

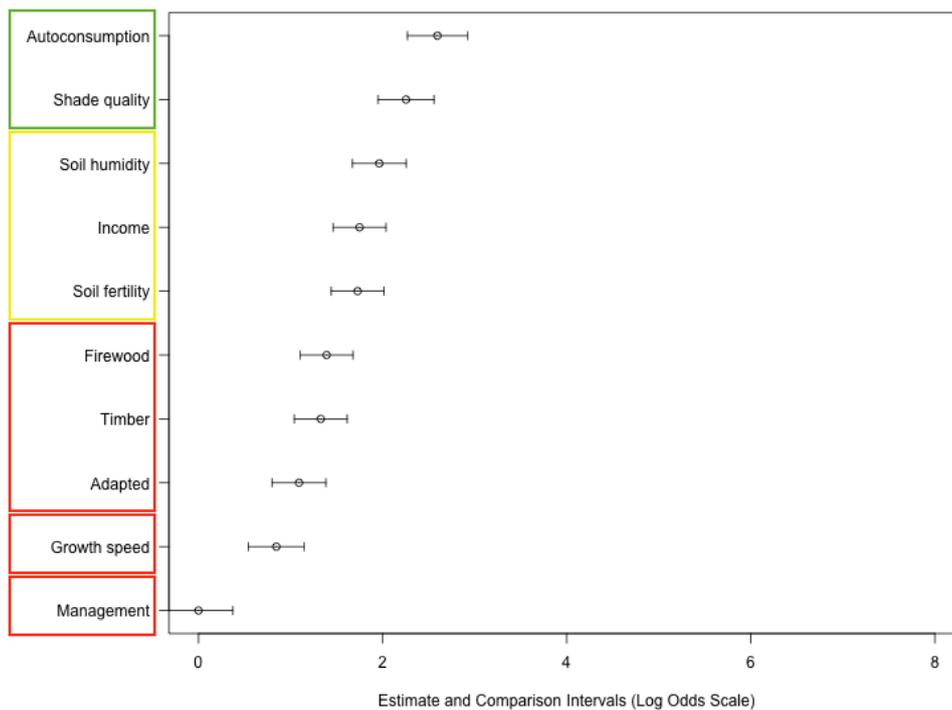
Botanical family	Scientific name	A	B	C	N/E	Category
Anacardiaceae	* <i>Mangifera indica</i> L.	0,55	0,64	0,53	E	Fruit
Annonaceae	* <i>Annona muricata</i> L.	0	0,27	0,16	N	Fruit
Arecaceae	* <i>Bactris gasipaes</i> Kunth	0,05	0,64	0,58	N	Fruit
	* <i>Cocos nucifera</i> L.	0,10	0,55	0,26	E	Fruit
Bignoniaceae	* <i>Tabebuia rosea</i> (Bertol.) Bertero ex A.DC.	0,25	0,09	0	N	High Q
Boraginaceae	* <i>Cordia alliodora</i> (Ruiz & Pav.) Oken	0,45	1,00	0,68	N	High Q
	* <i>Cordia collococca</i> L.	0,05	0,27	0,21	N	Low Q
Chrysobalanaceae	* <i>Hirtella triandra</i> Sw.	0,05	0,18	0,26	N	Low Q
Combretaceae	* <i>Terminalia oblonga</i> (Ruiz & Pav.) Steud.	0,20	0	0	N	High Q
Juglandaceae	* <i>Juglans olanchana</i> Standl. & L.O.Williams	0,20	0,18	0,37	N	High Q
Lauraceae	* <i>Persea americana</i> Mill. 'comun'	0,70	0,73	0,68	N	Fruit
	* <i>Persea americana</i> Mill. 'monte'	0,10	0,18	0,16	N	Low Q
Leguminosae	* <i>Albizia saman</i> (Jacq.) Merr.	0,15	0,27	0,05	N	Service
	* <i>Enterolobium cyclocarpum</i> (Jacq.) Griseb.	0,10	0,09	0	N	High Q
	* <i>Erythrina fusca</i> Lour.	0,20	0,18	0,26	N	Service
	* <i>Erythrina poeppigiana</i> (Walp.) O.F.Cook	0,10	0,36	0	E	Service
	* <i>Gliricidia sepium</i> (Jacq.) Walp.	0,30	0,27	0,05	N	Low Q
	* <i>Inga densiflora</i> Benth.	0,40	0,27	0	N	Service
	* <i>Inga edulis</i> Mart.	0,25	0,82	0,79	E	Service
	* <i>Inga punctata</i> Willd	0,75	0,45	0,53	N	Service
	* <i>Lonchocarpus rugosus</i> Benth.	0,45	0,18	0,16	N	Low Q
	* <i>Piscidia grandifolia</i> (Donn.Sm.) I.M.Johnst.	0,20	0	0	N	Low Q
	* <i>Platymiscium pinnatum</i> (Jacq.) Dugand	0,65	0,55	0,16	E	High Q
	Malpighiaceae	* <i>Byrsonima crassifolia</i> (L.) Kunth	0,10	0,55	0,21	N
Malvaceae	* <i>Ceiba pentandra</i> (L.) Gaertn.	0,15	0,27	0,16	N	Low Q
	* <i>Guazuma ulmifolia</i> Lam.	0,40	0	0,05	N	Low Q
	* <i>Heliocarpus appendiculatus</i> Turcz.	0,10	0,18	0,37	N	None
	* <i>Pachira quinata</i> (Jacq.) W.S.Alverson	0,20	0,45	0,11	N	High Q
	* <i>Theobroma cacao</i> L.	0,50	0,82	0,11	E	Fruit
Meliaceae	* <i>Carapa guianensis</i> Aubl.	0,05	0,73	0,16	N	High Q
	* <i>Cedrela odorata</i> L.	0,30	0,64	0,37	N	High Q
	* <i>Swietenia macrophylla</i> King	0,65	0,09	0	N	High Q
	* <i>Trichilia havanensis</i> Jacq.	0,20	0	0	N	None
Moraceae	* <i>Brosimum alicastrum</i> Sw.	0,05	0,18	0,16	N	Fruit
	* <i>Ficus</i> sp.	0,30	0,09	0,26	N	Low Q
Muntingiaceae	* <i>Muntingia calabura</i> L.	0	0,45	0,11	N	Fruit
Musaceae	* <i>Musa</i> spp. 'guineo'	0,90	0,91	0,89	E	Fruit
	* <i>Musa</i> sp. 'platano'	0,45	0,64	0,47	E	Fruit
Myrtaceae	* <i>Psidium guajava</i> L.	0,15	0,36	0,05	N	Fruit
	* <i>Syzygium malaccense</i> (L.) Merr. & L.M.Perry	0,30	0,55	0,05	E	Fruit
Rutaceae	<i>Citrus</i> spp. 'limon'	0,65	0,64	0,53	E	Fruit
	<i>Citrus</i> spp. 'naranja'	0,55	0,91	0,74	E	Fruit
	* <i>Citrus reticulata</i> Blanco	0,35	0,45	0,47	E	Fruit
Sapotaceae	* <i>Pouteria sapota</i> (Jacq.) H.E.Moore & Stearn	0,05	0,18	0,26	N	Fruit
Urticaceae	* <i>Cecropia peltata</i> L.	0,05	0,36	0,32	N	Low Q

# APPENDIX K: ECOSYSTEM SERVICES AND TREE ATTRIBUTES RANKING RESULTS

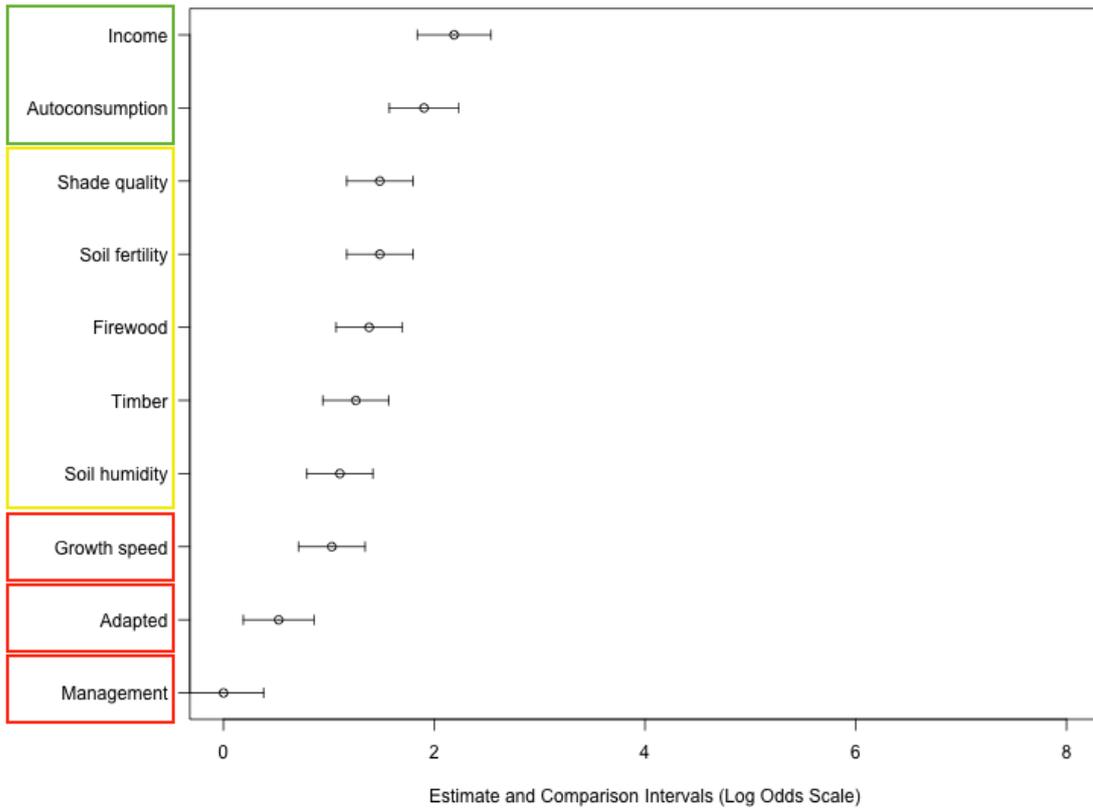
**Study area - Relative importance of Ecosystem Services - Ranking scores**



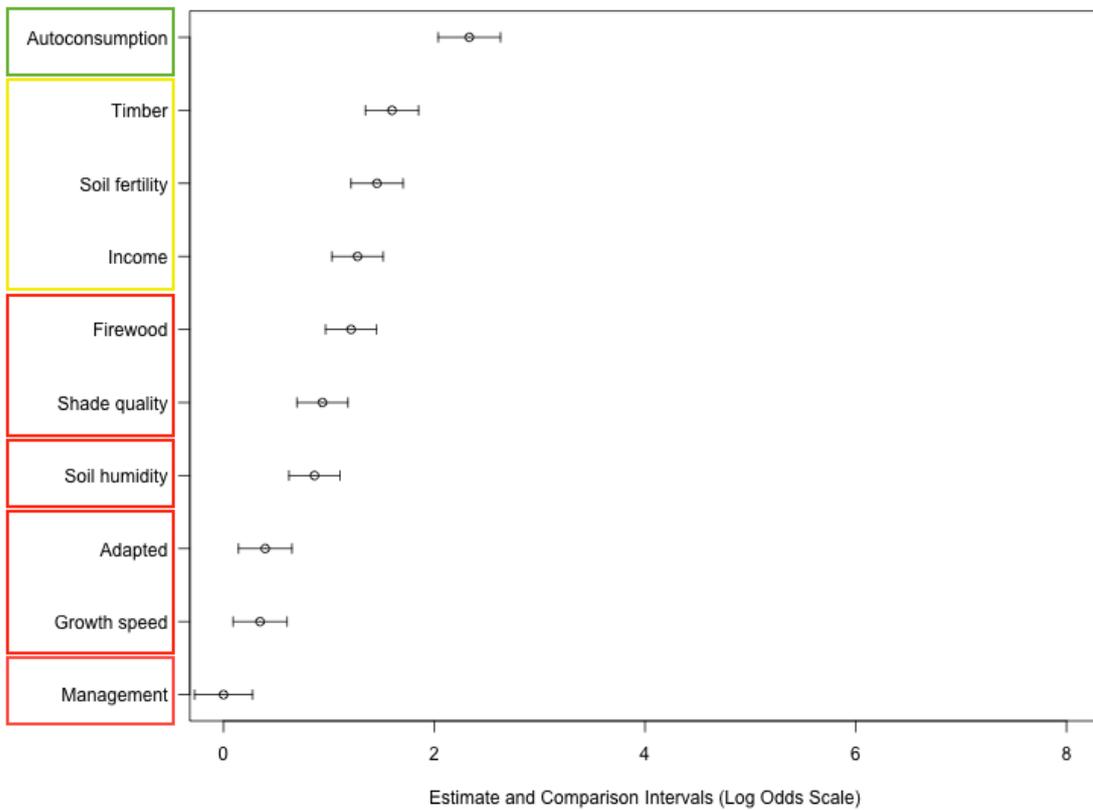
**La Estrella\_General - Ranking scores**



La Inmaculada\_General - Ranking scores



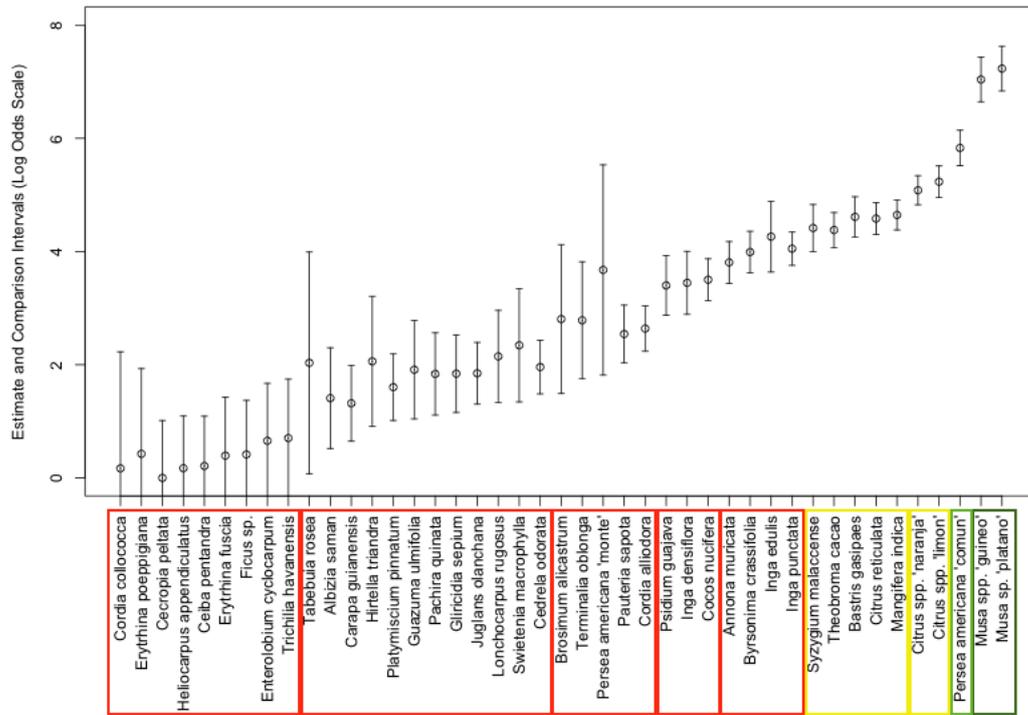
Cerro Grande\_General - Ranking scores



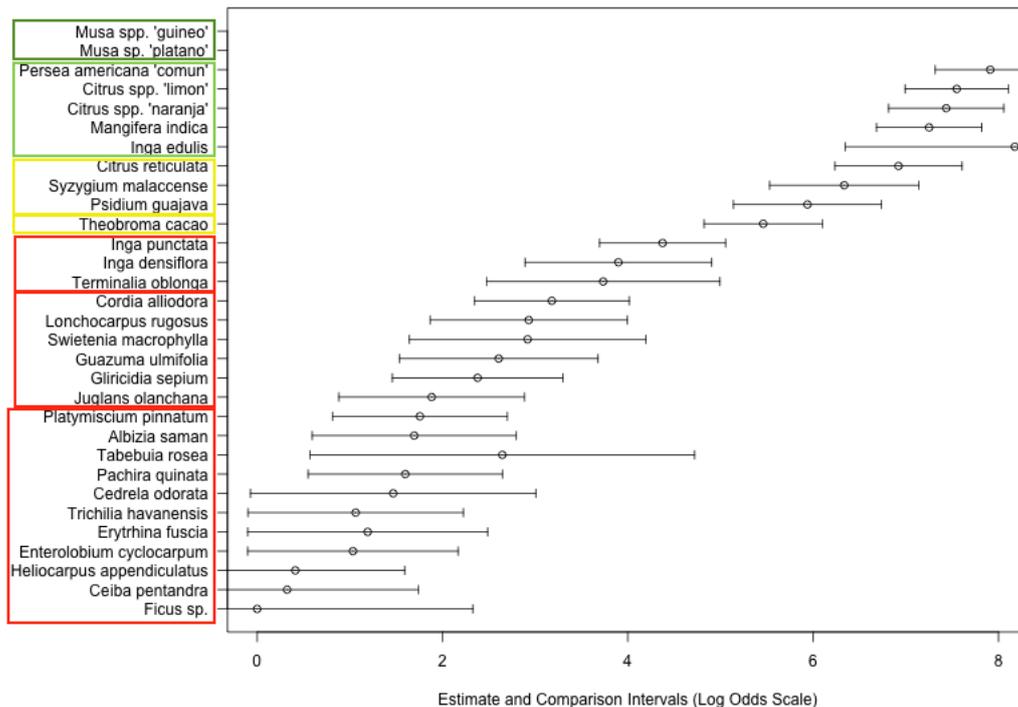
# APPENDIX L: TREE SPECIES RANKING RESULTS

## IMPORTANCE FOR AUTO-CONSUMPTION

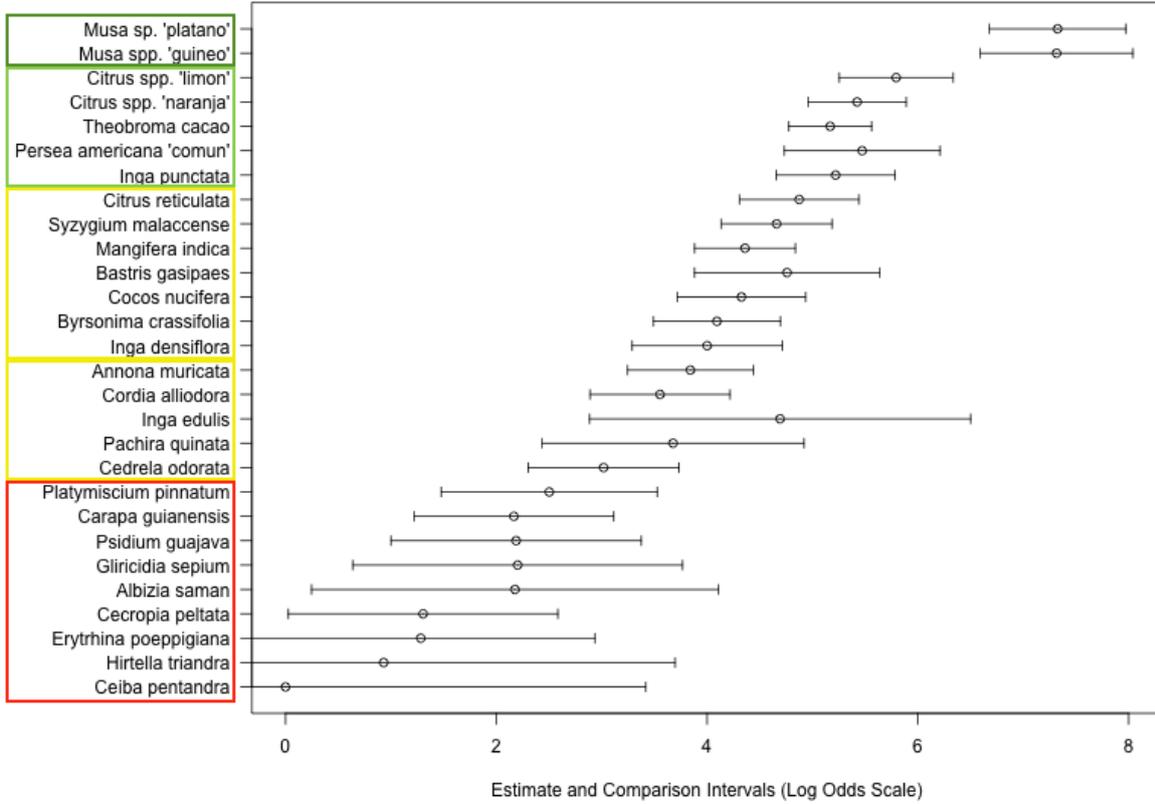
Study area - 01\_Autoconsumption - Ranking scores



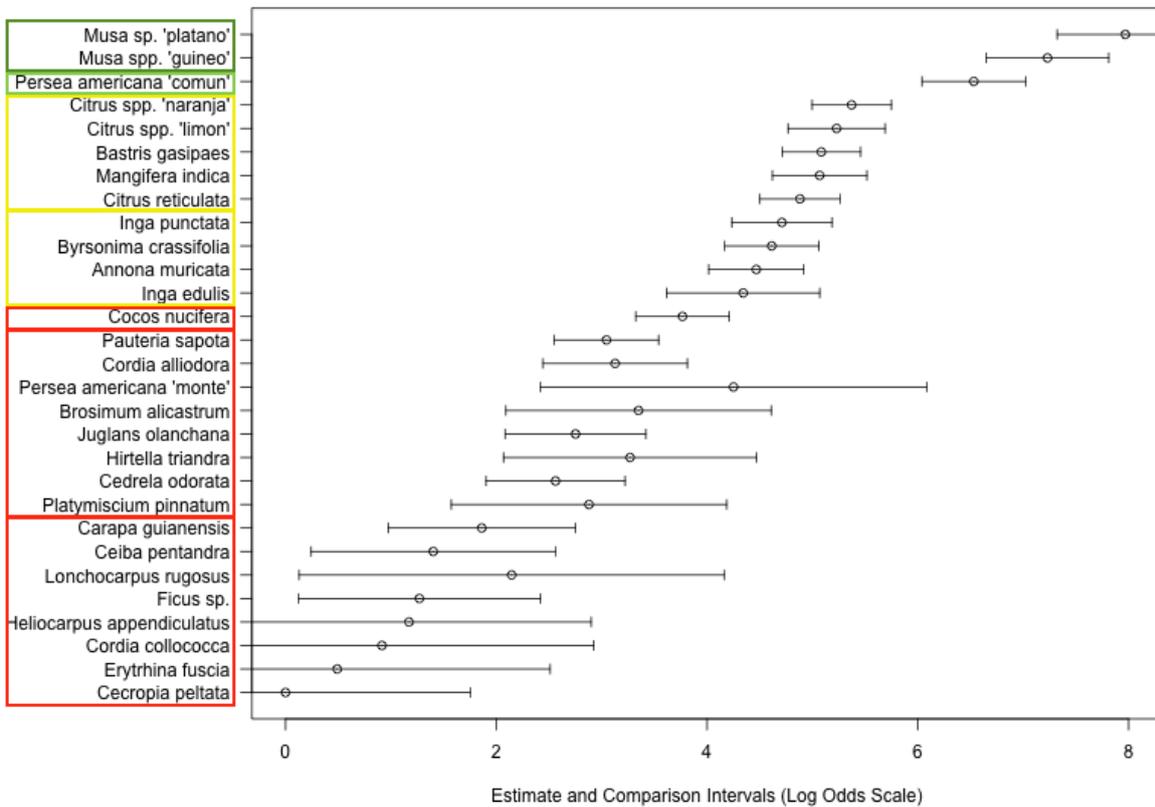
La Estrellita - 01\_Autoconsumption - Ranking scores



La Inmaculada - 01\_Autoconsumption - Ranking scores

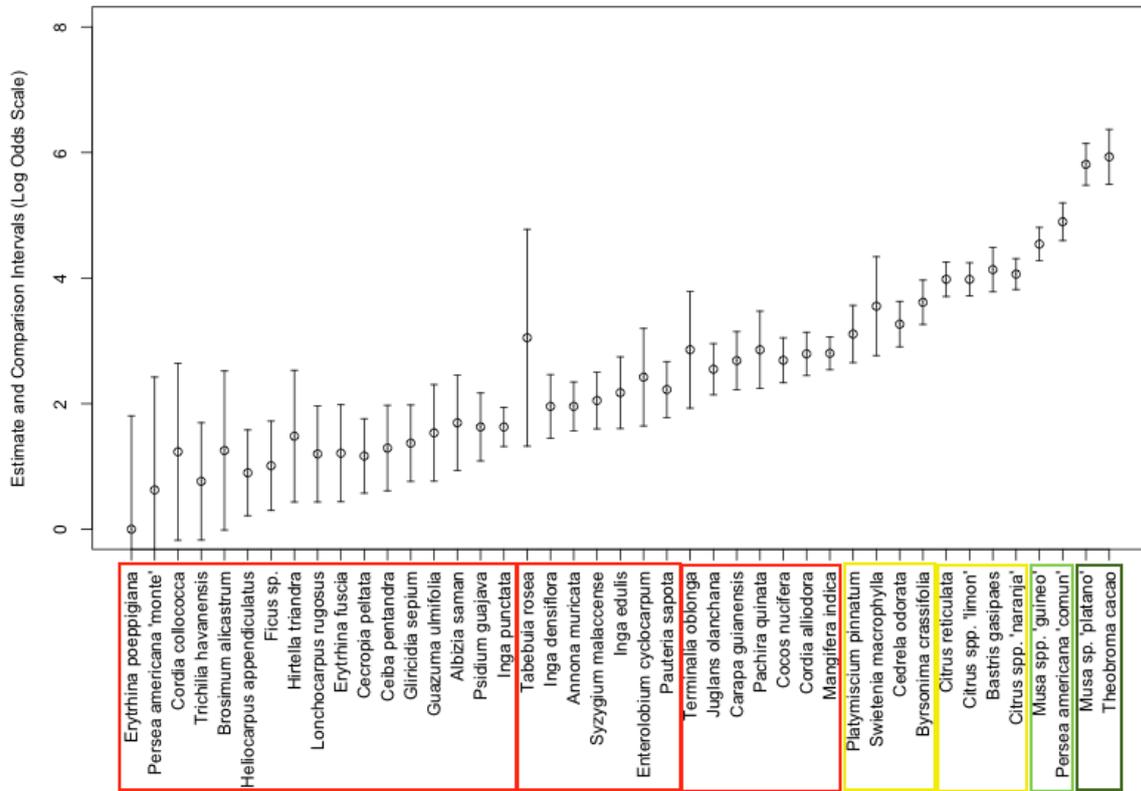


Cerro Grande - 01\_Autoconsumption - Ranking scores

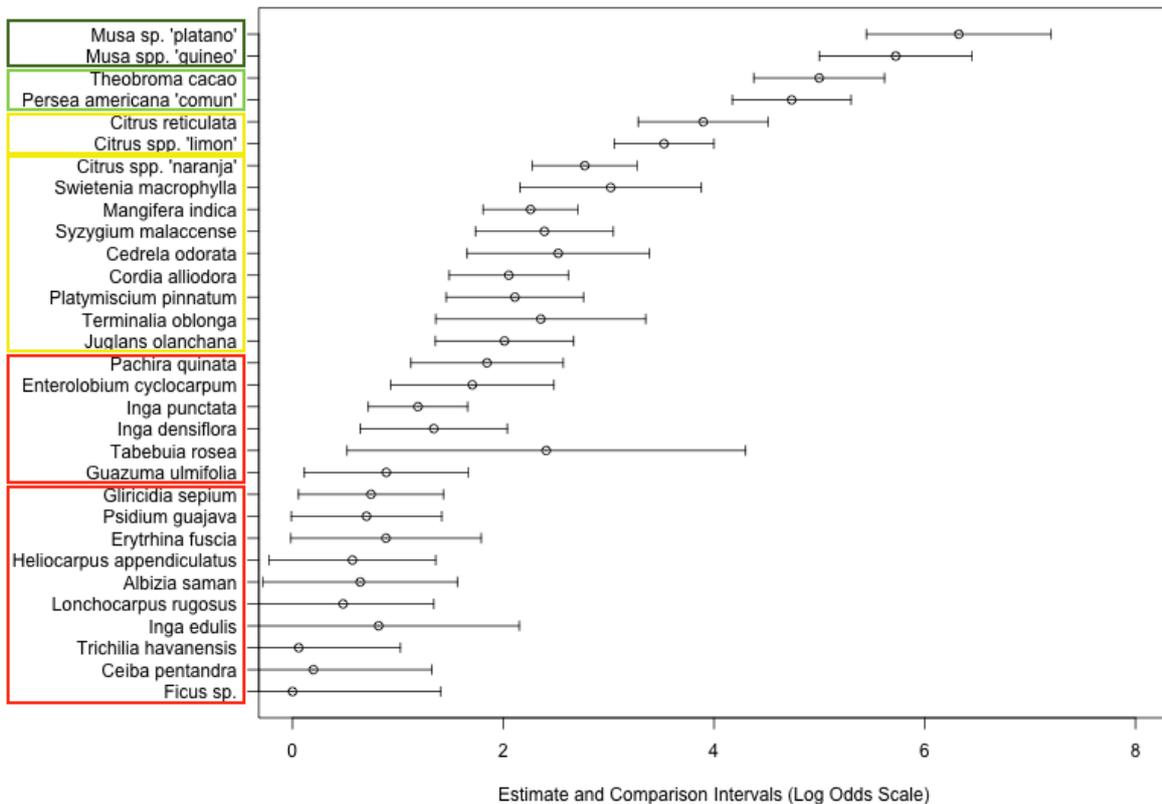


## CONTRIBUTION TO HOUSEHOLD'S INCOME

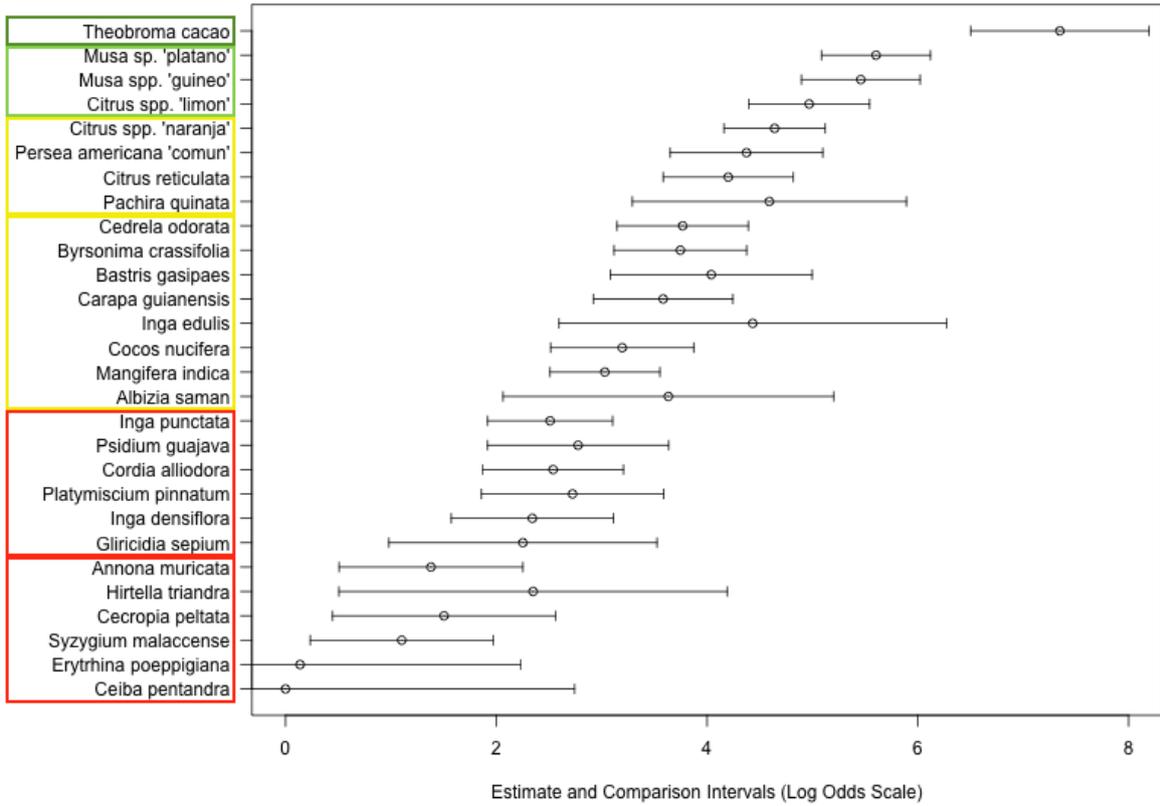
**Study area - 02\_Income - Ranking scores**



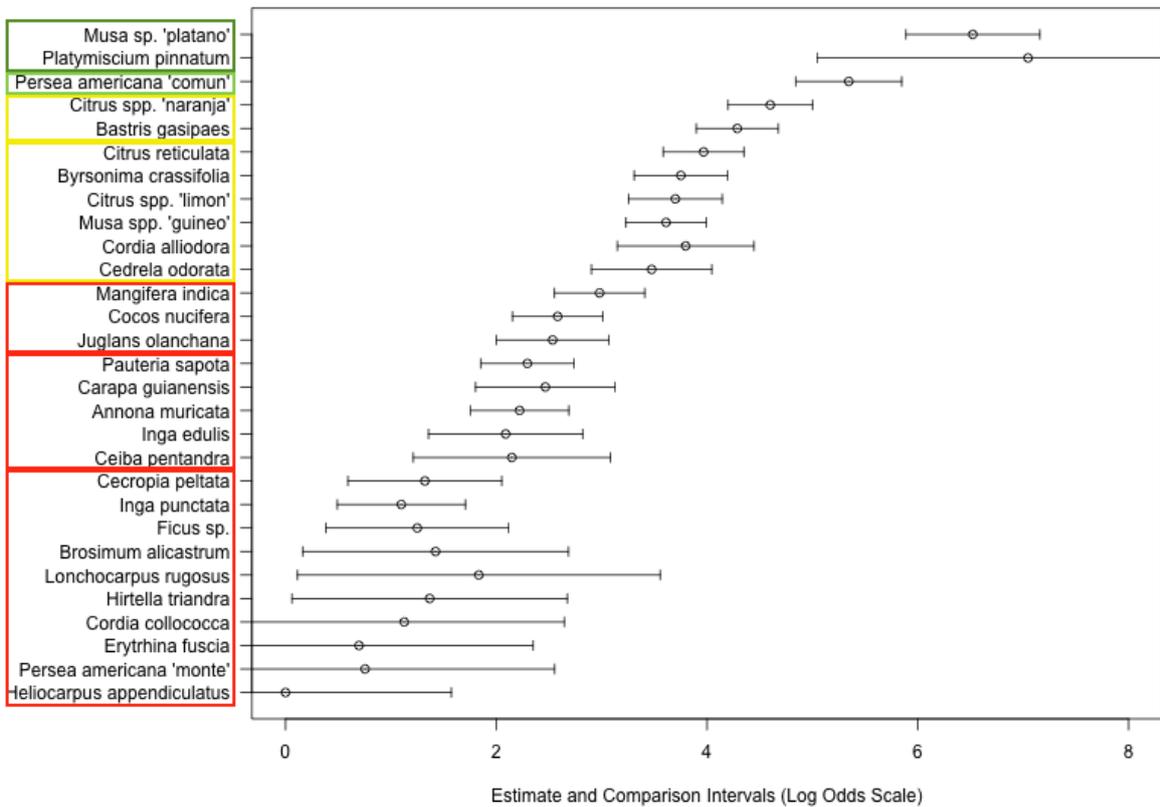
**La Estrellita - 02\_Income - Ranking scores**



**La Inmaculada - 02\_Income - Ranking scores**

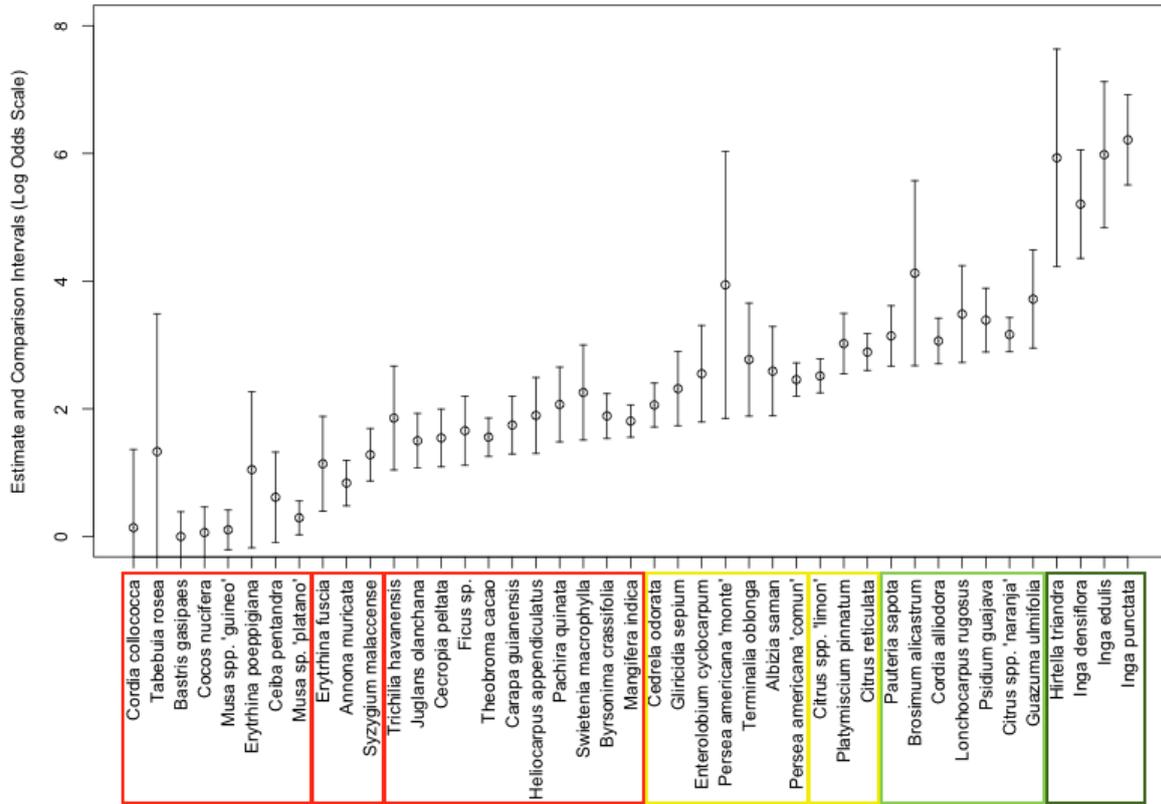


**Cerro Grande - 02\_Income - Ranking scores**

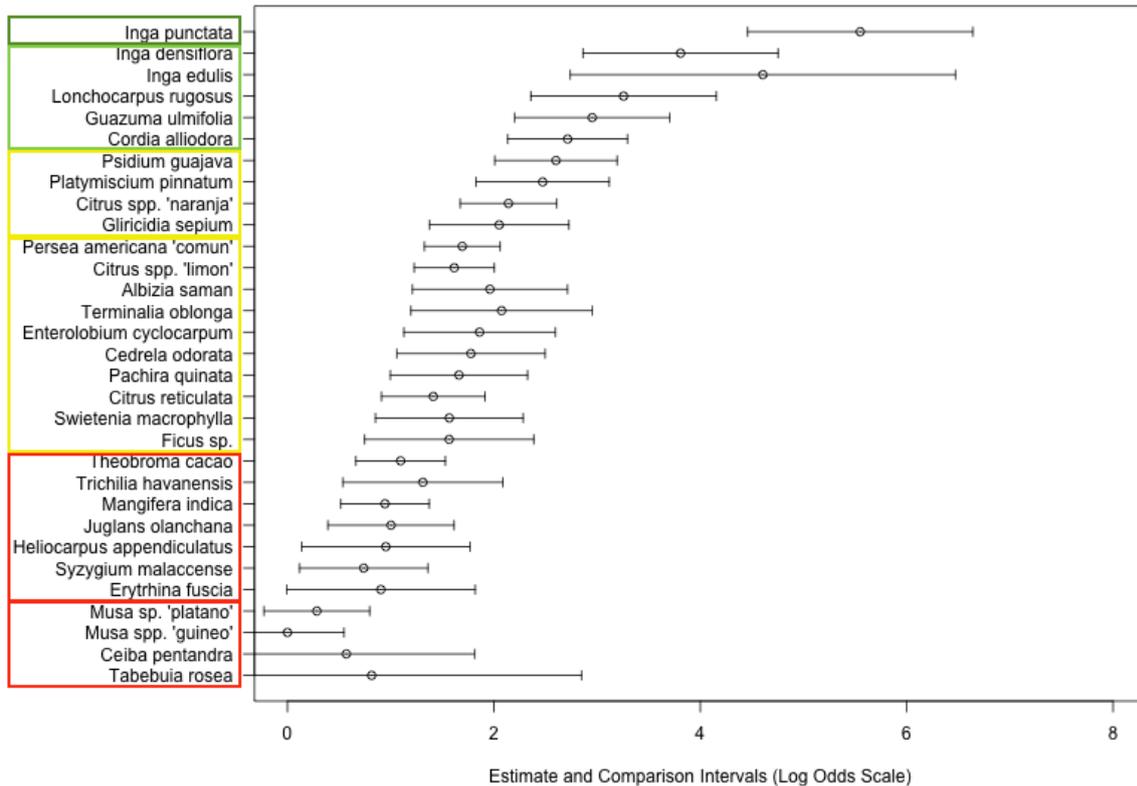


## QUALITY OF FIREWOOD

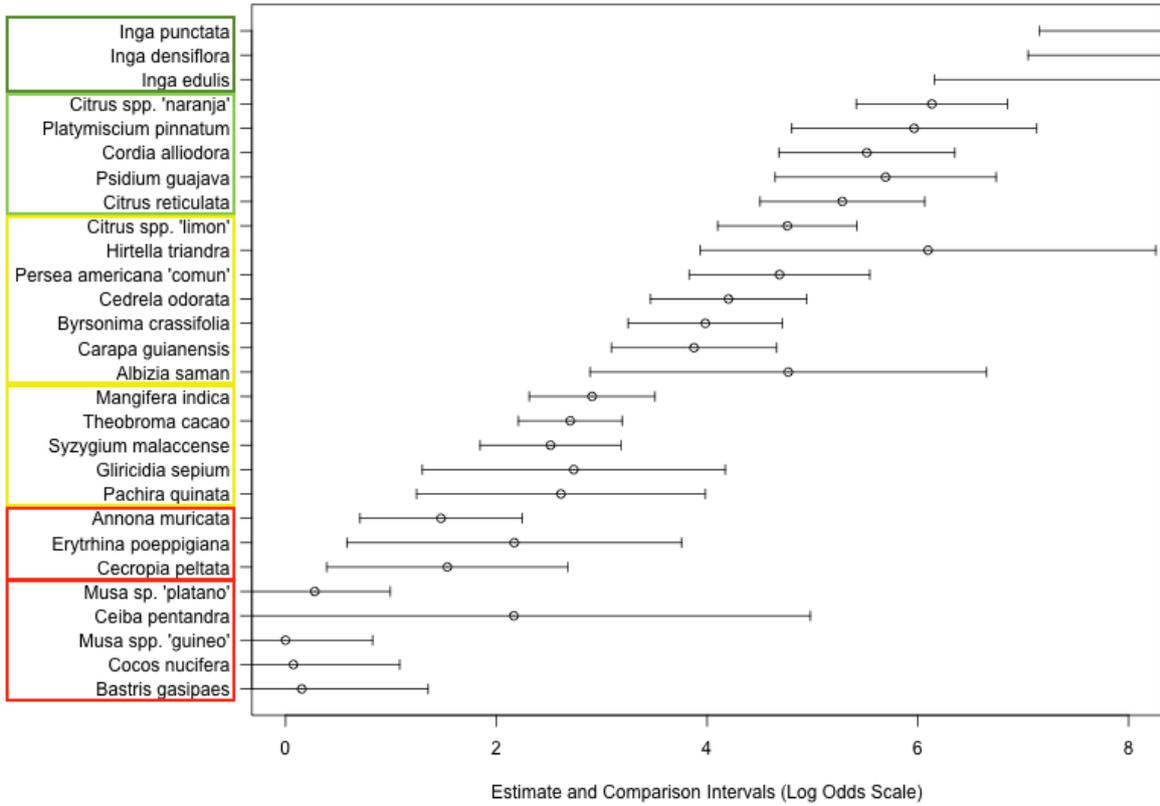
**Study area - 03\_Firewood - Ranking scores**



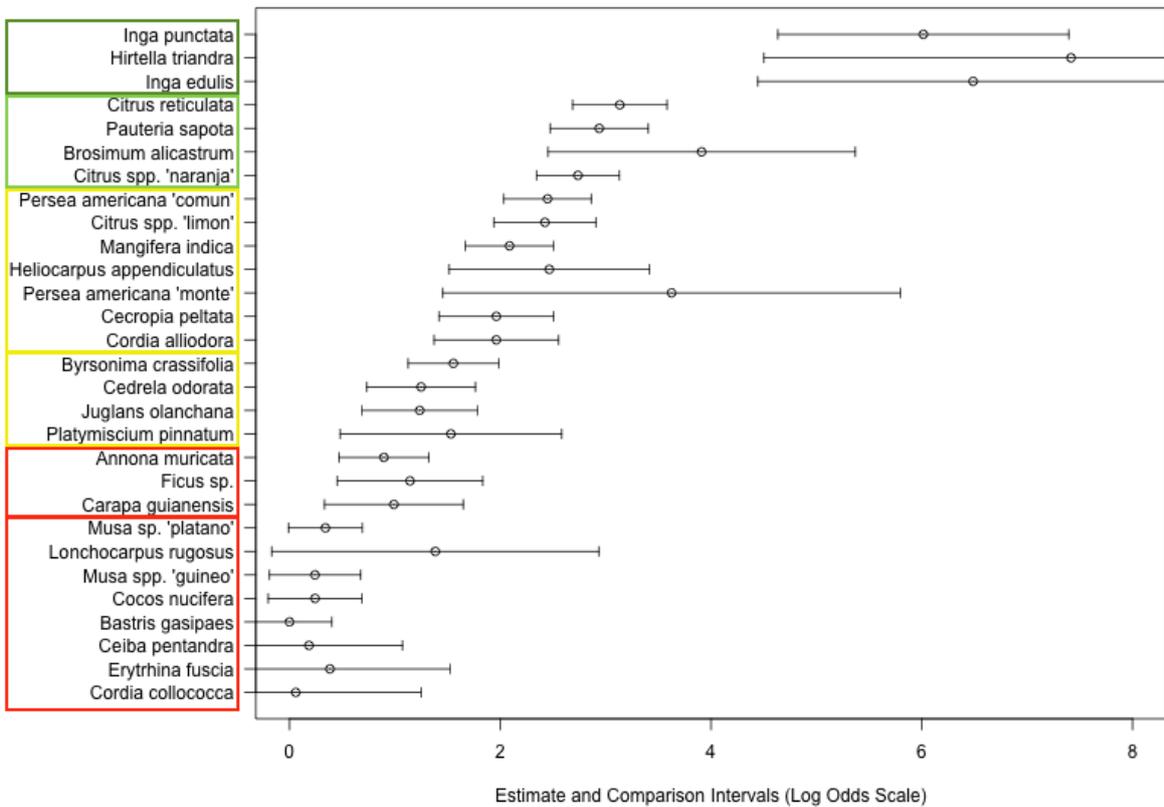
**La Estrellita - 03\_Firewood - Ranking scores**



La Inmaculada - 03\_Firewood - Ranking scores

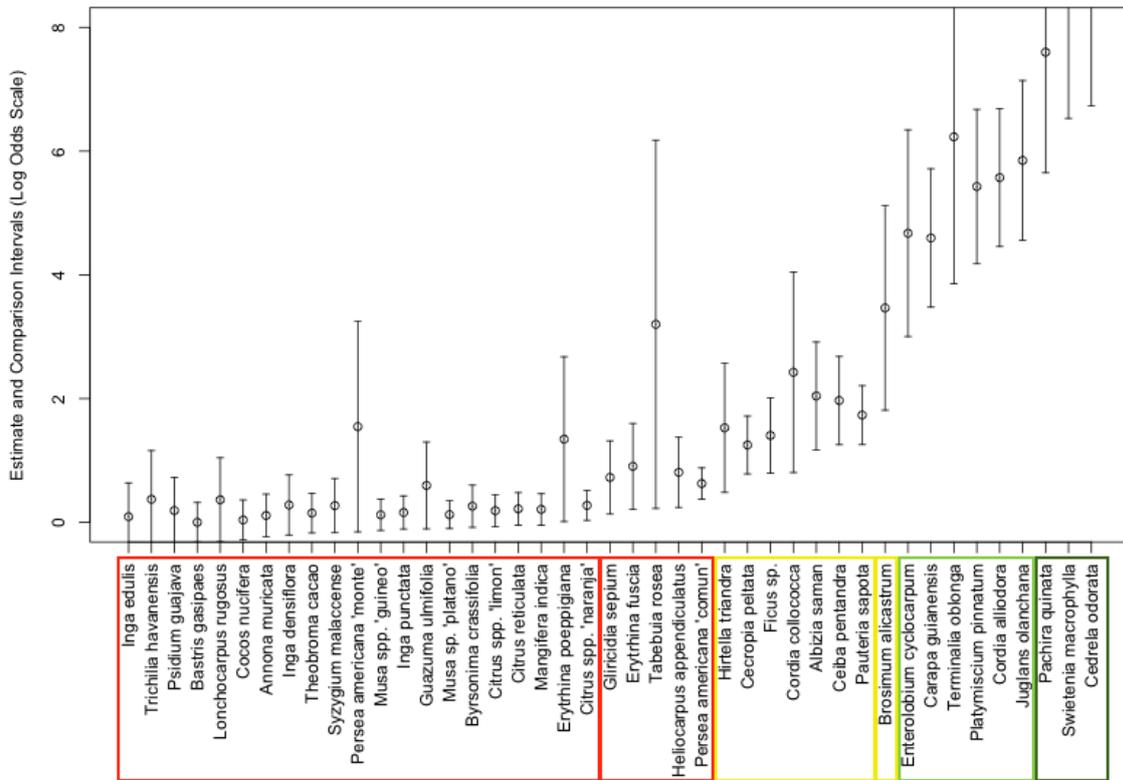


Cerro Grande - 03\_Firewood - Ranking scores

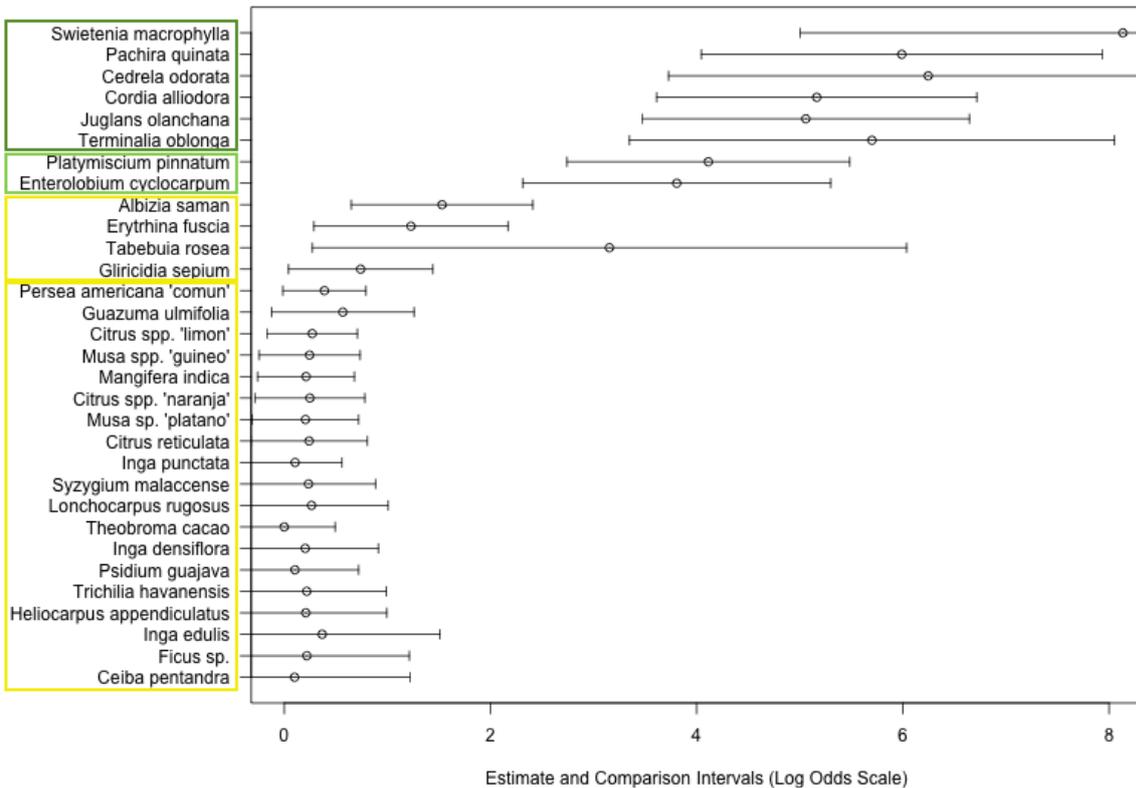


## QUALITY OF TIMBER

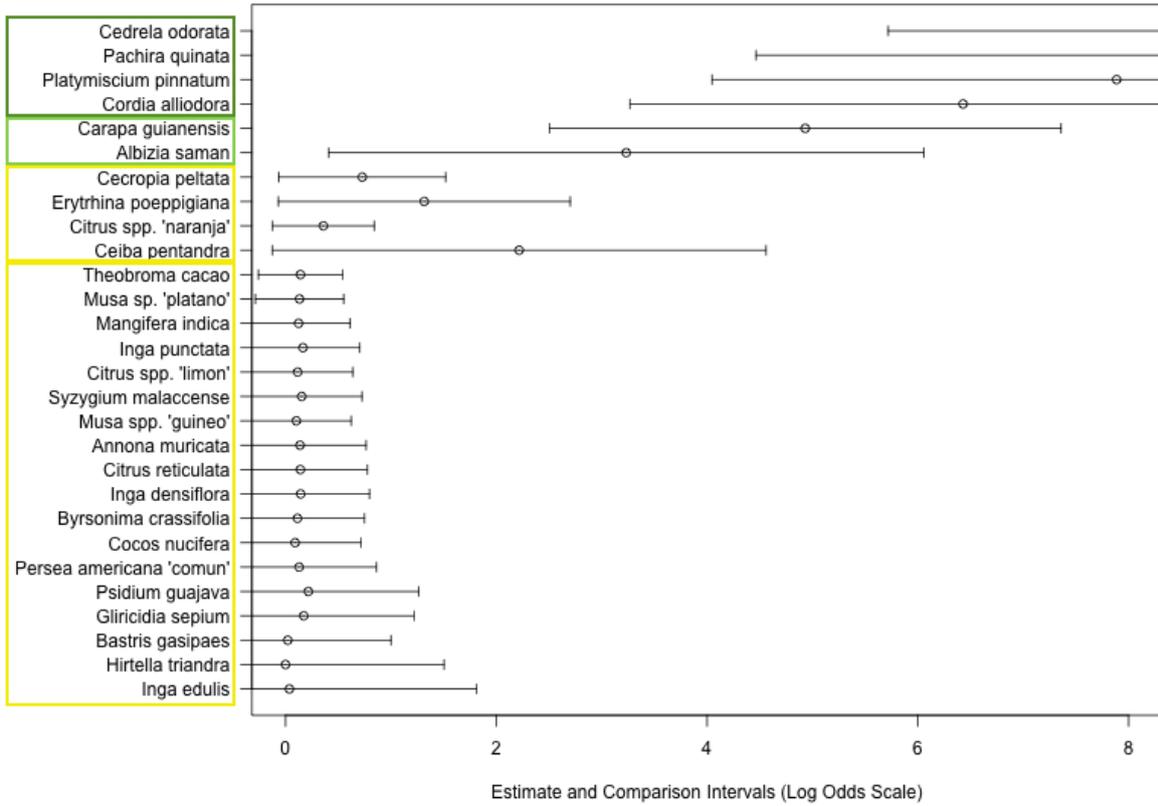
**Study area - 04\_Timber - Ranking scores**



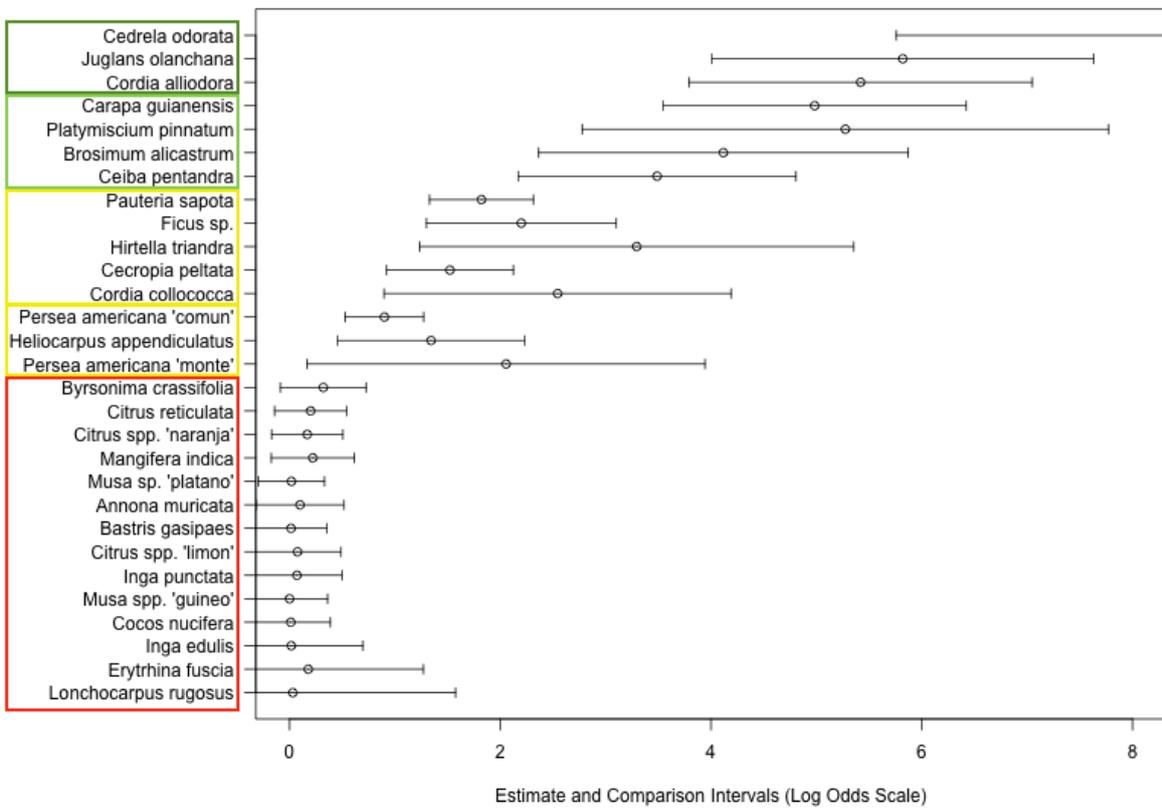
**La Estrellita - 04\_Timber - Ranking scores**



### La Inmaculada - 04\_Timber - Ranking scores

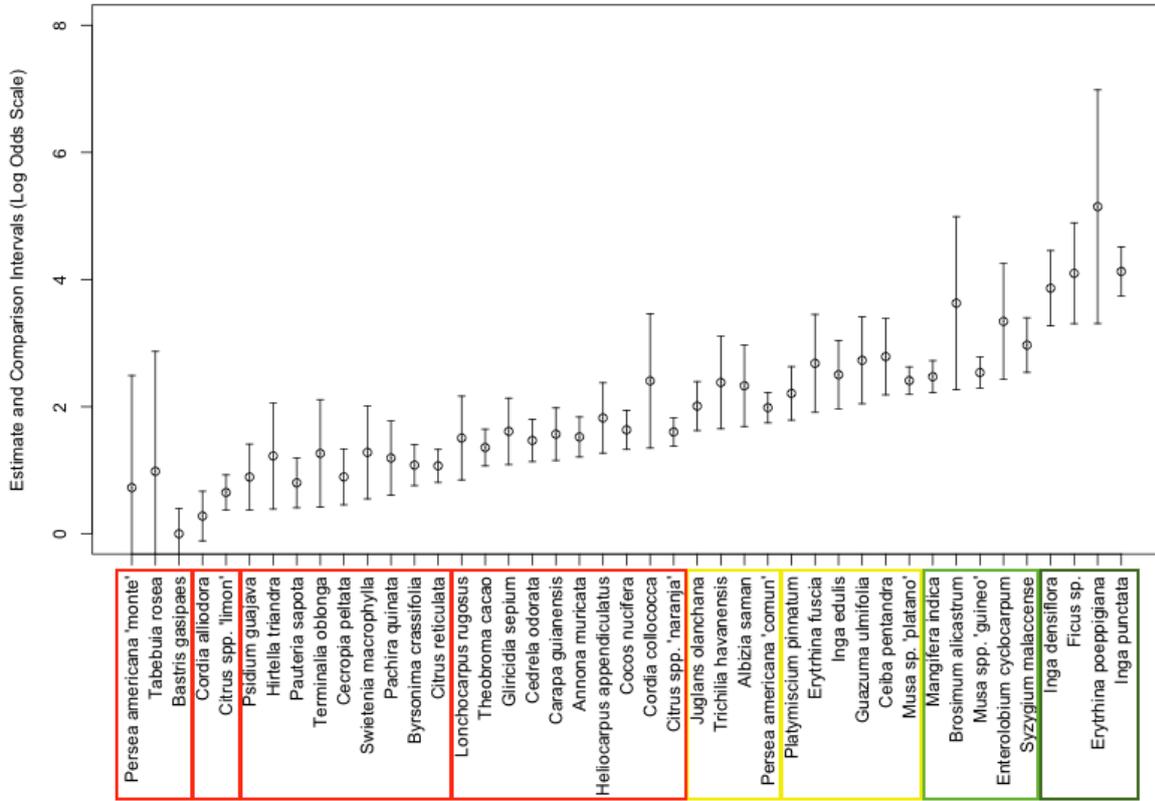


### Cerro Grande - 04\_Timber - Ranking scores

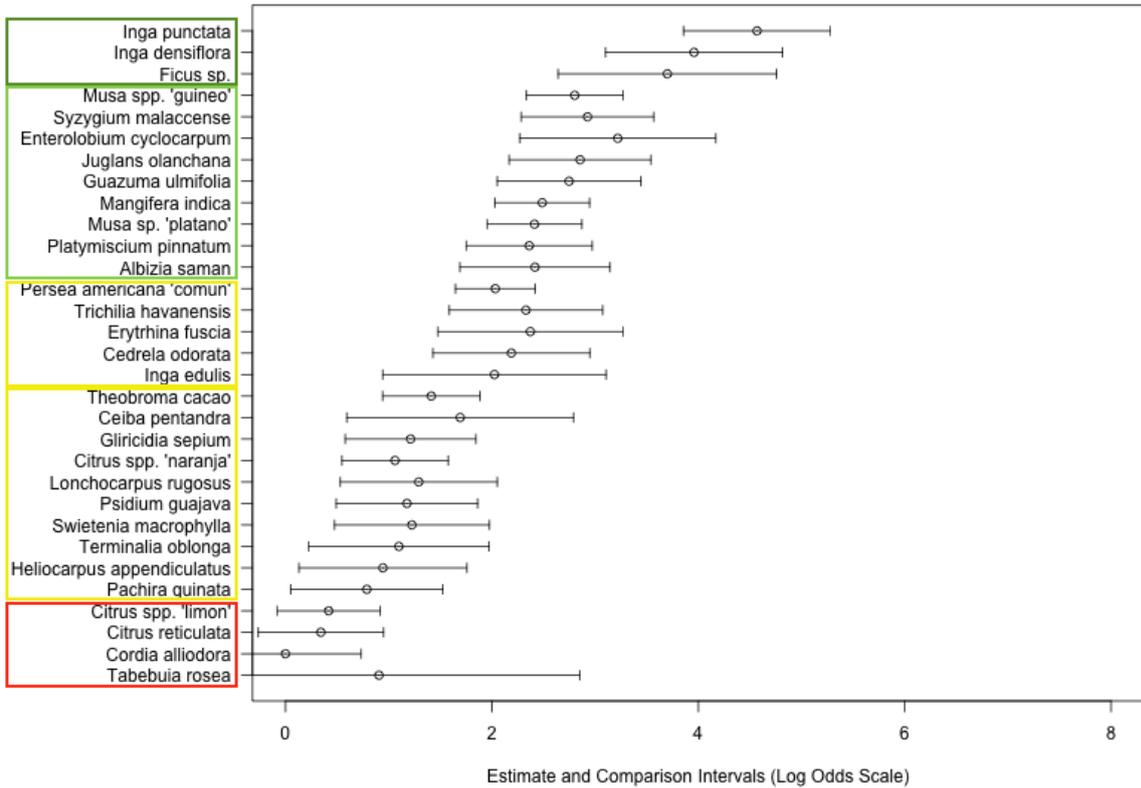


## DENSITY OF SHADE

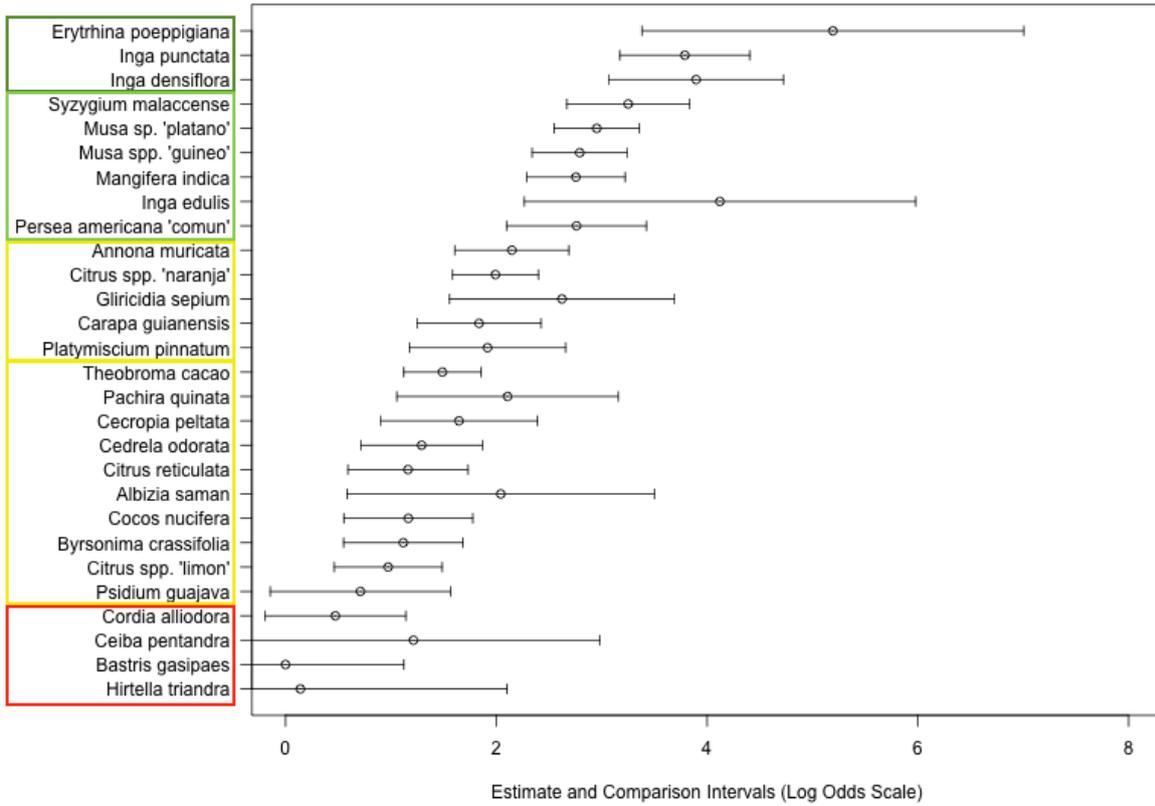
**Study area - 05\_Shade quality - Ranking scores**



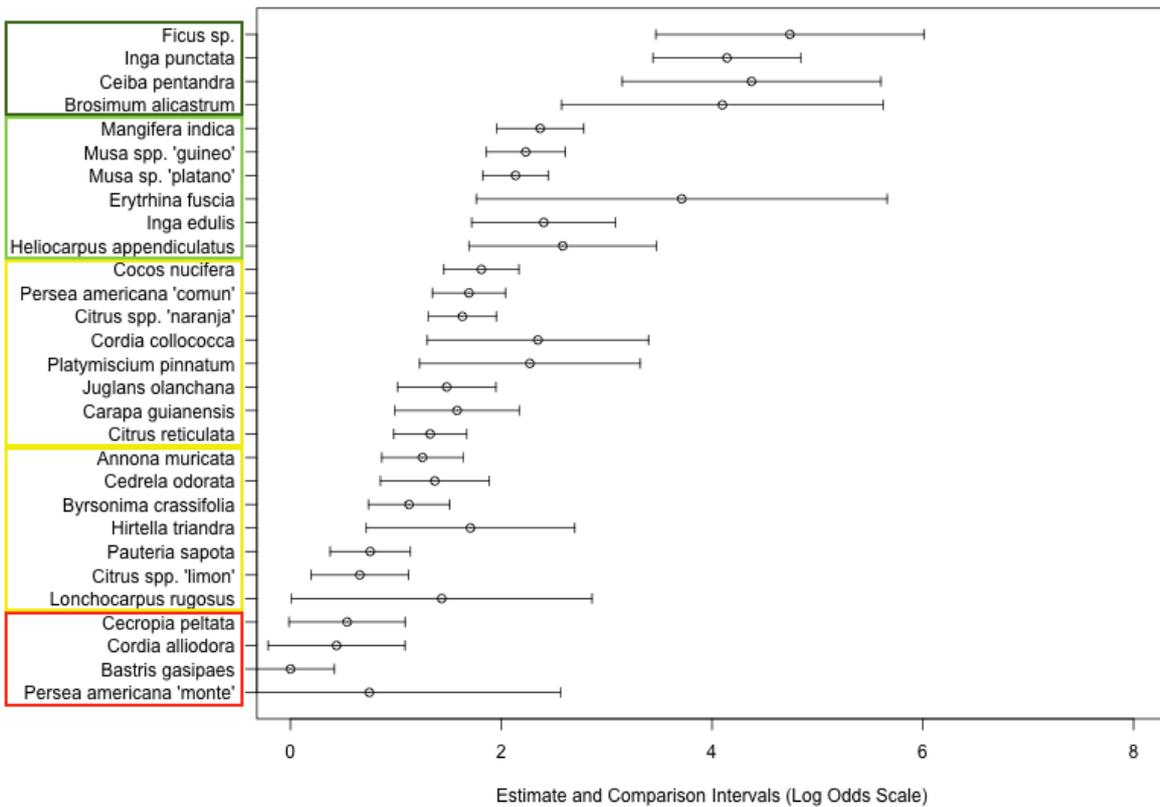
**La Estrellita - 05\_Shade quality - Ranking scores**



**La Inmaculada - 05\_Shade quality - Ranking scores**

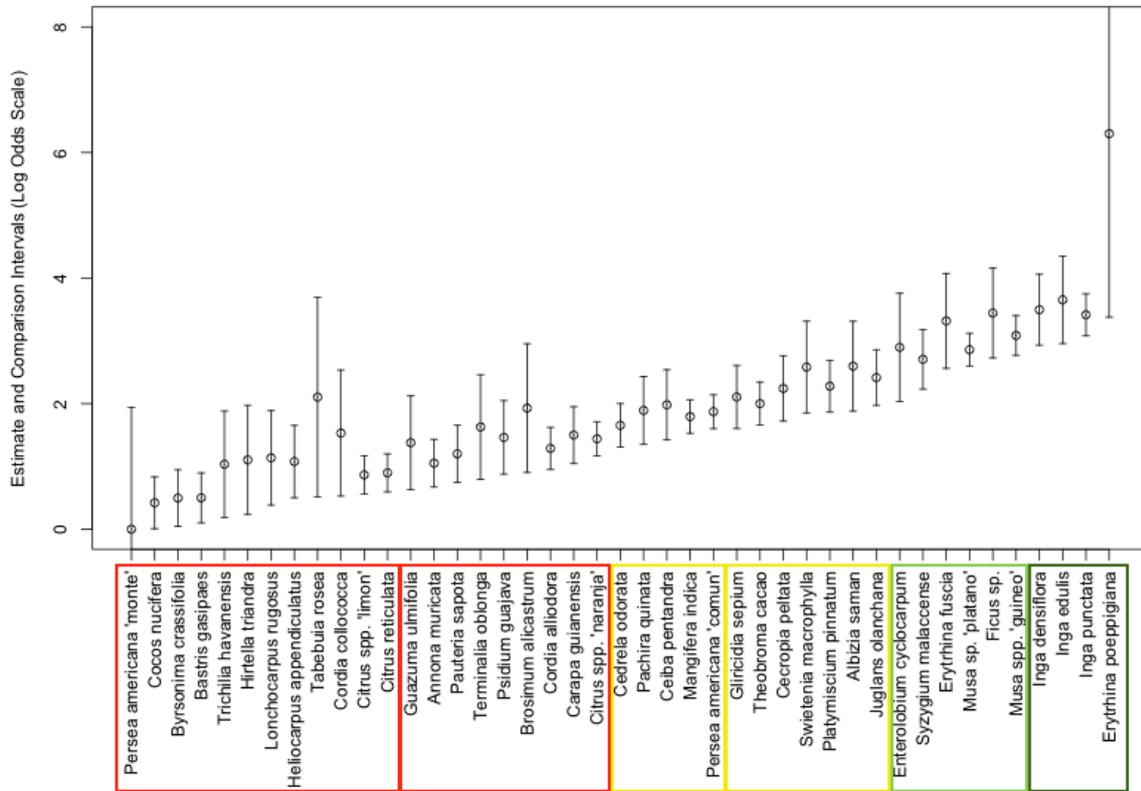


**Cerro Grande - 05\_Shade quality - Ranking scores**

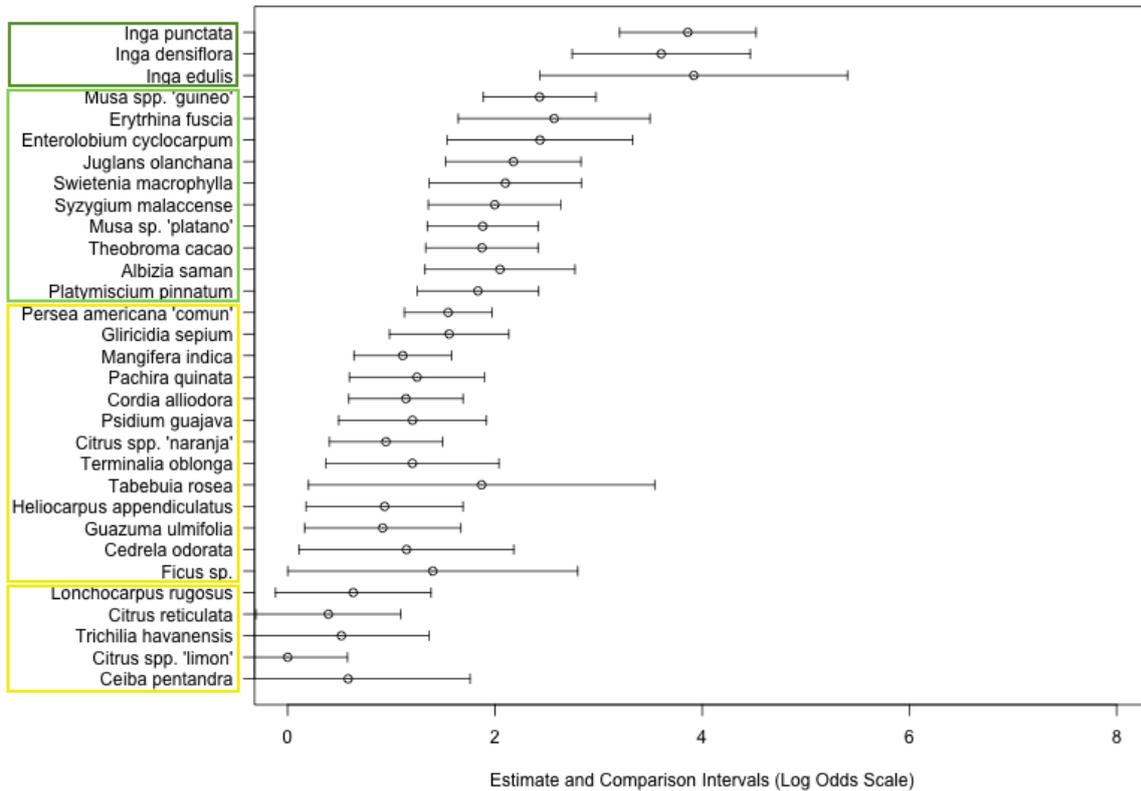


## ENHANCEMENT OF SOIL FERTILITY

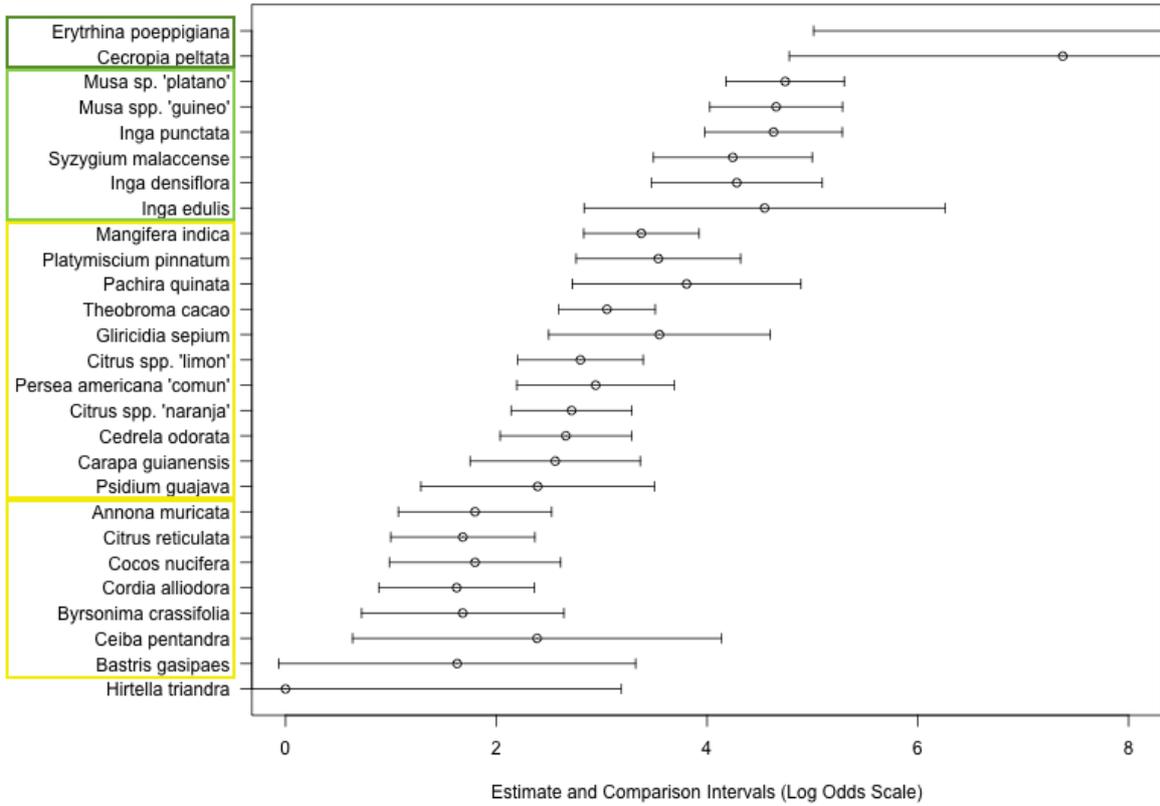
**Study area - 06\_Soil fertility - Ranking scores**



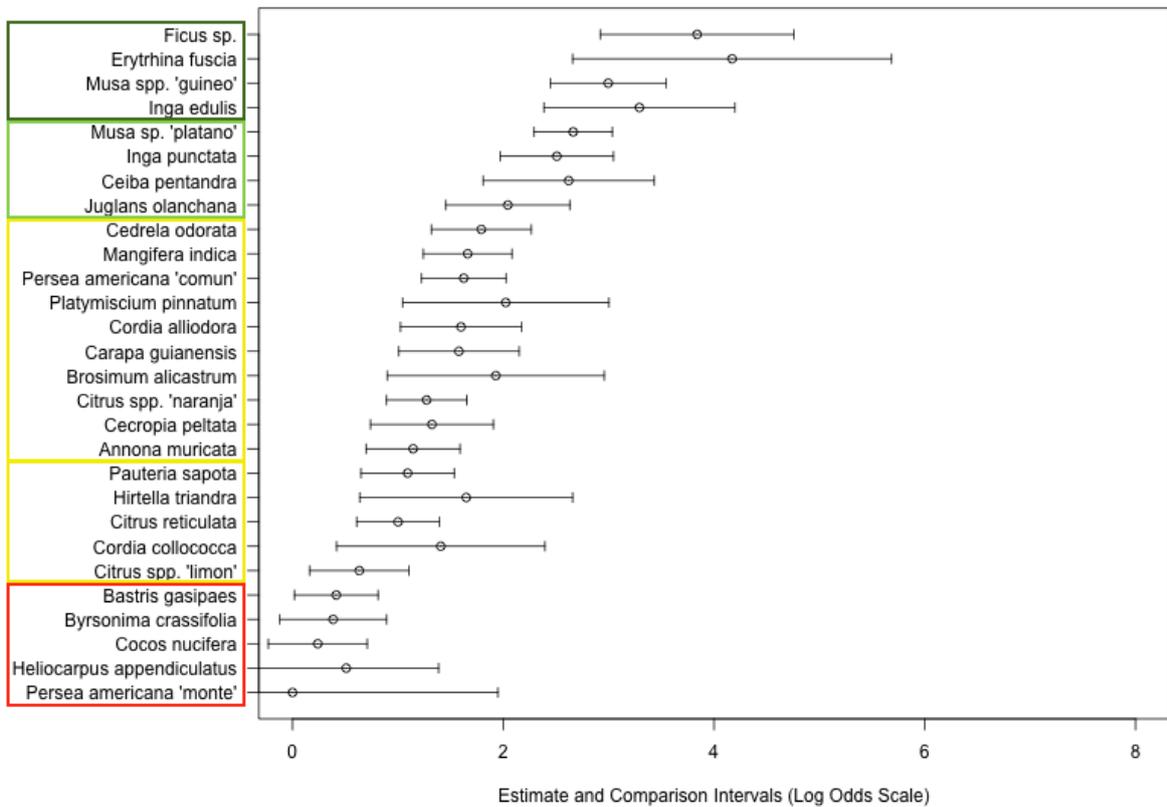
**La Estrellita - 06\_Soil fertility - Ranking scores**



La Inmaculada - 06\_Soil fertility - Ranking scores

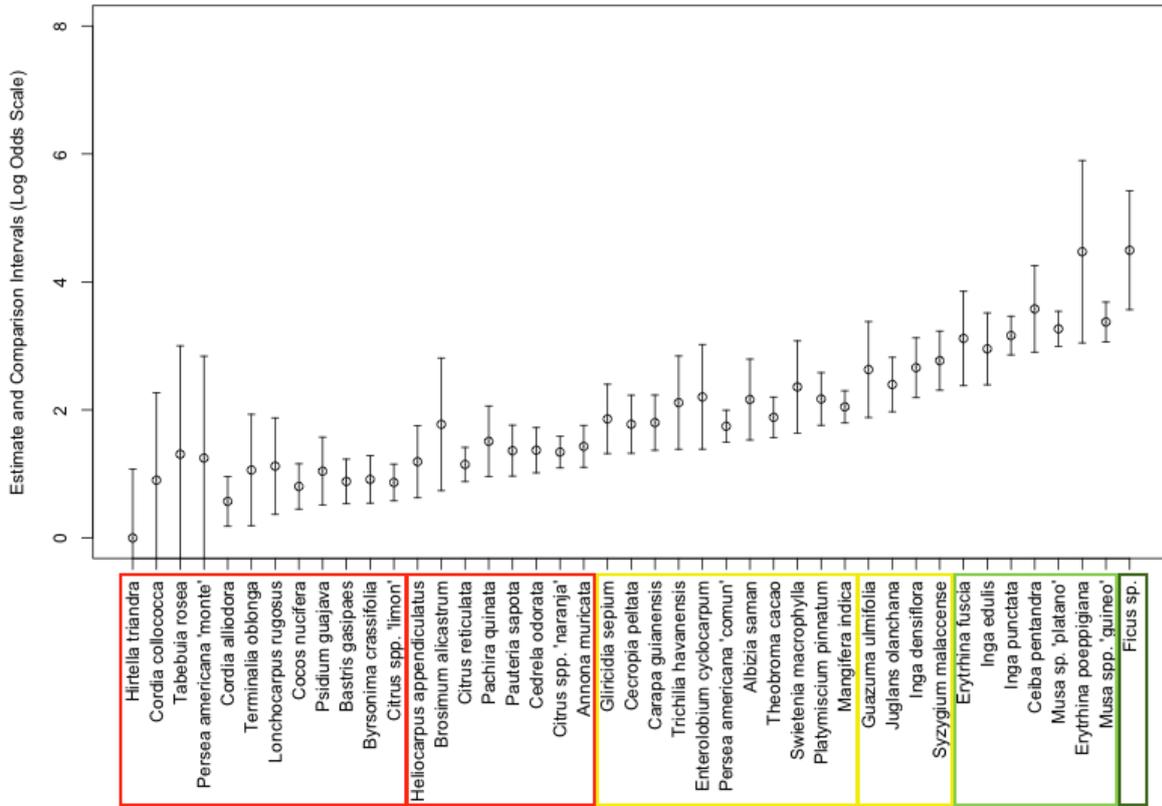


Cerro Grande - 06\_Soil fertility - Ranking scores

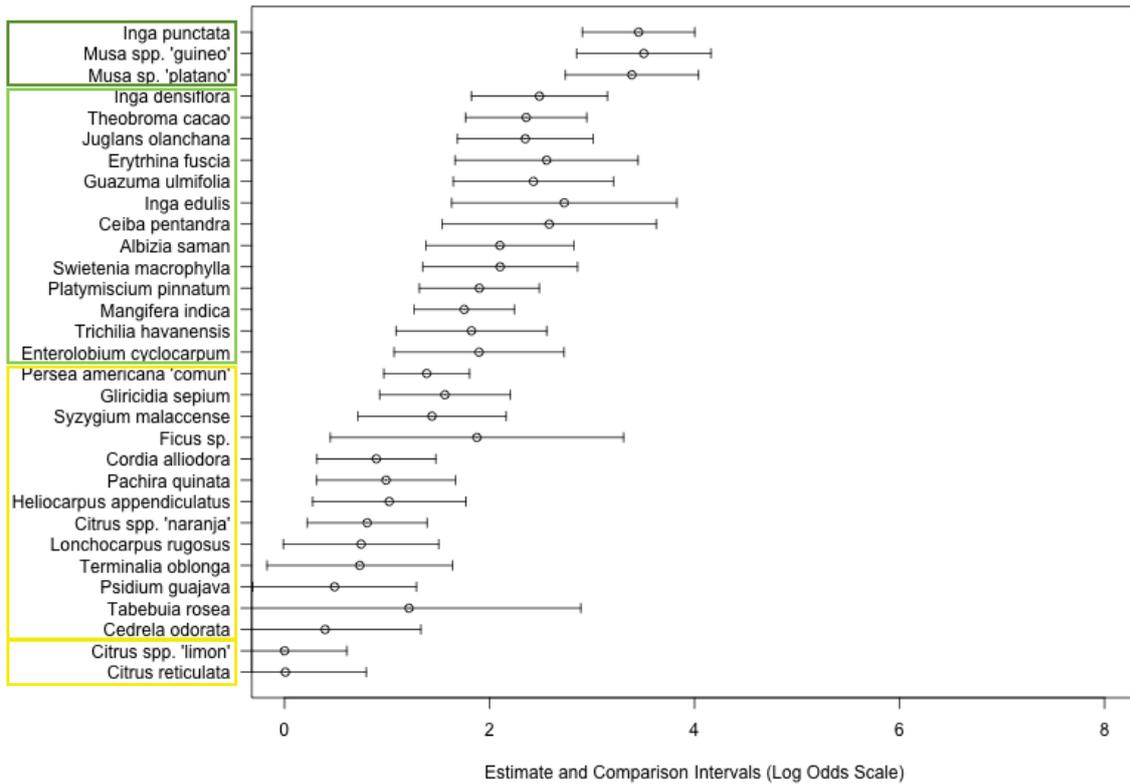


## MAINTAIN SOIL HUMIDITY

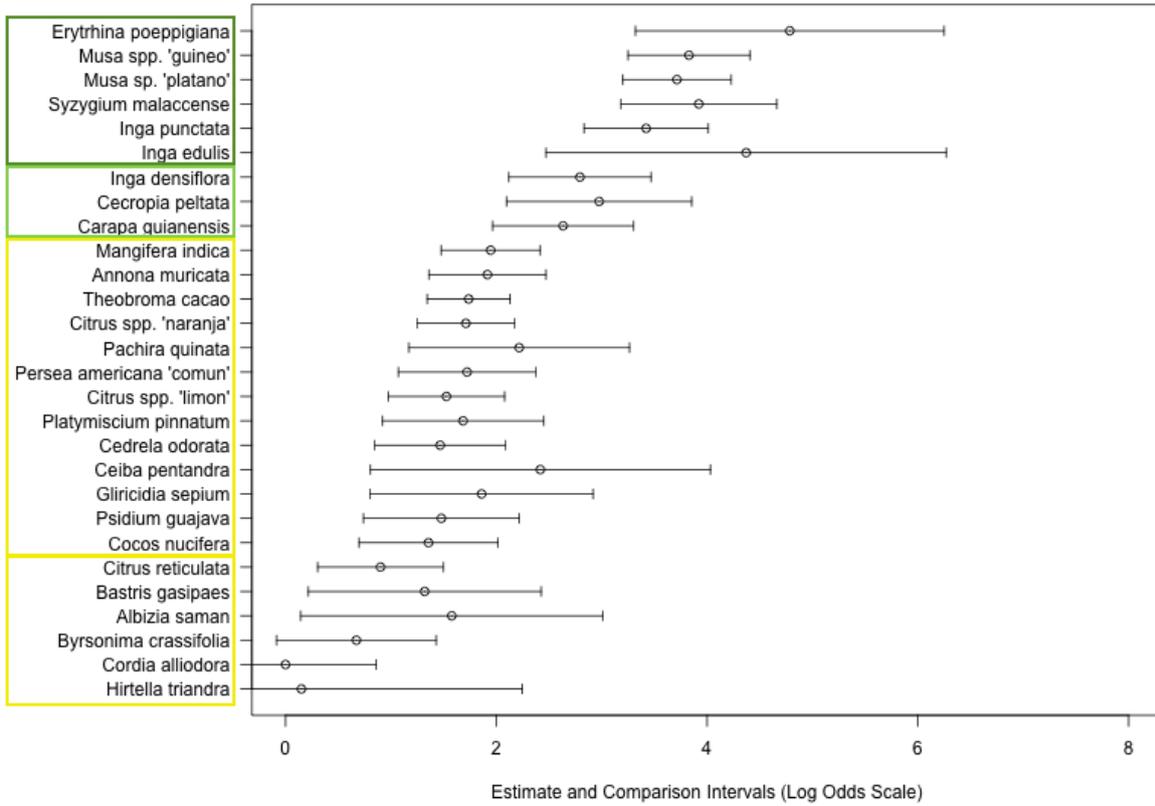
Study area - 07\_Soil humidity - Ranking scores



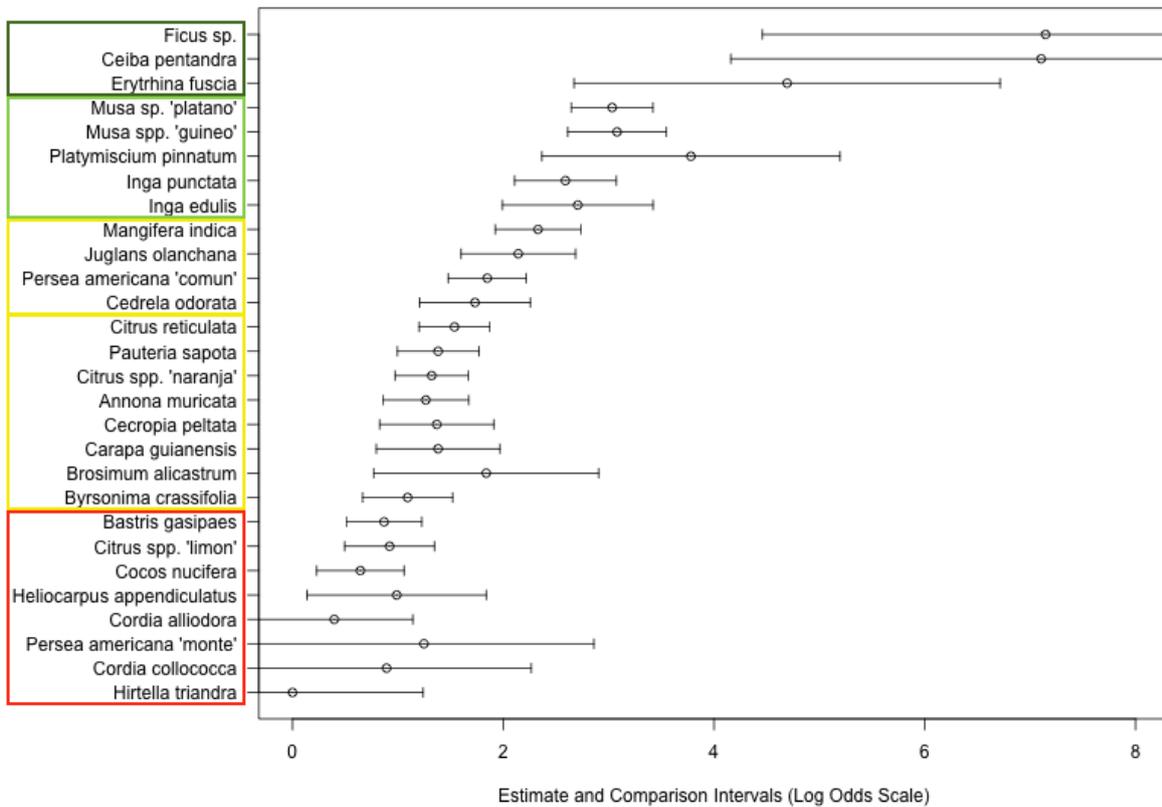
La Estrellita - 07\_Soil humidity - Ranking scores



**La Inmaculada - 07\_Soil humidity - Ranking scores**

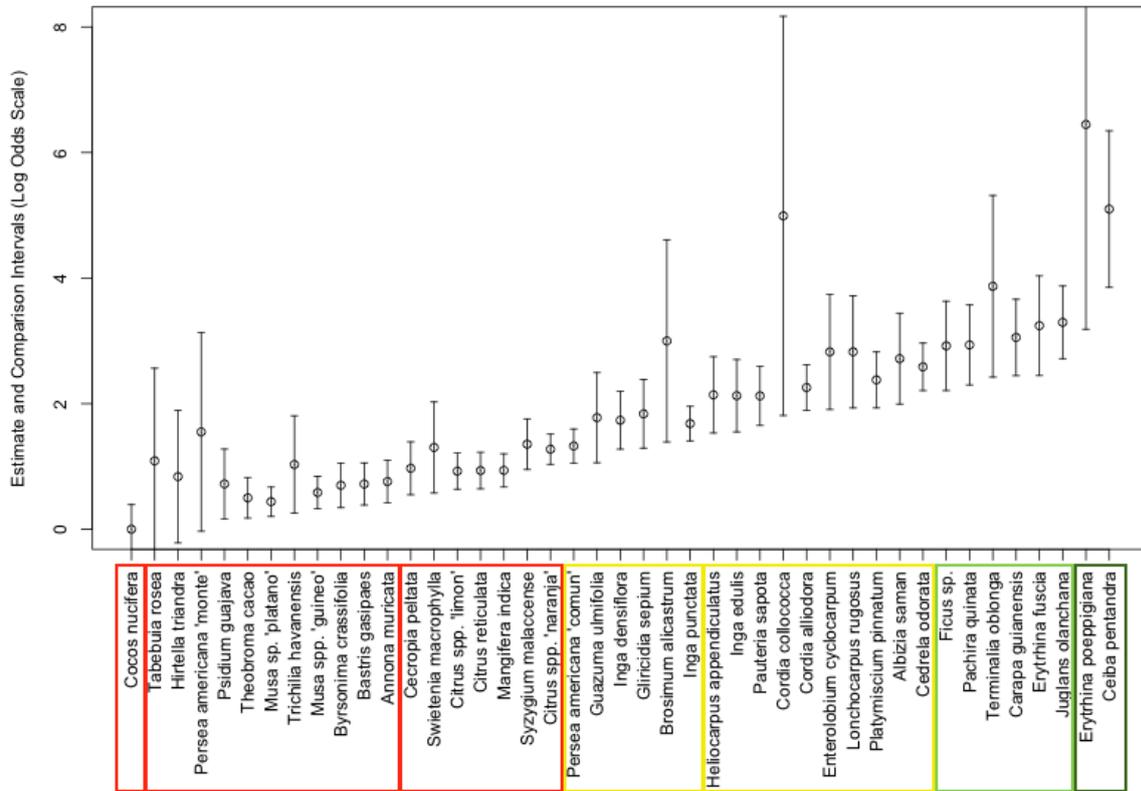


**Cerro Grande - 07\_Soil humidity - Ranking scores**

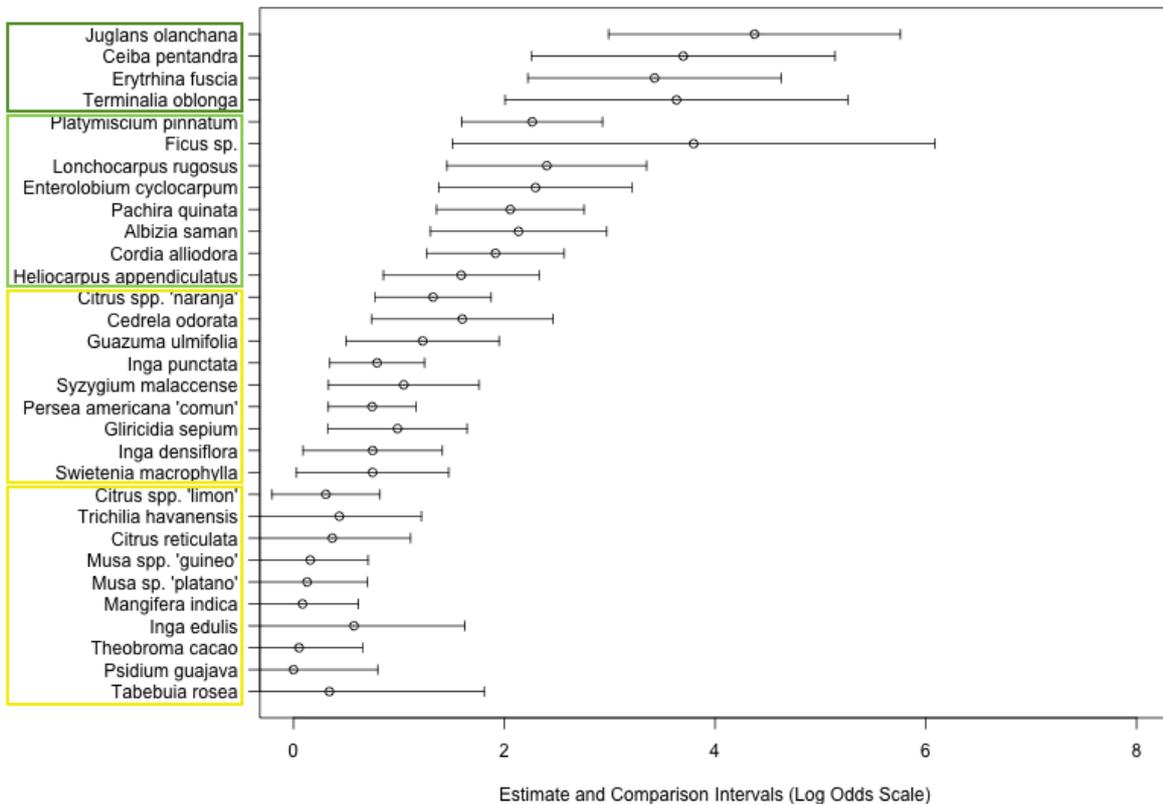


## DIFFICULTY OF PRUNING

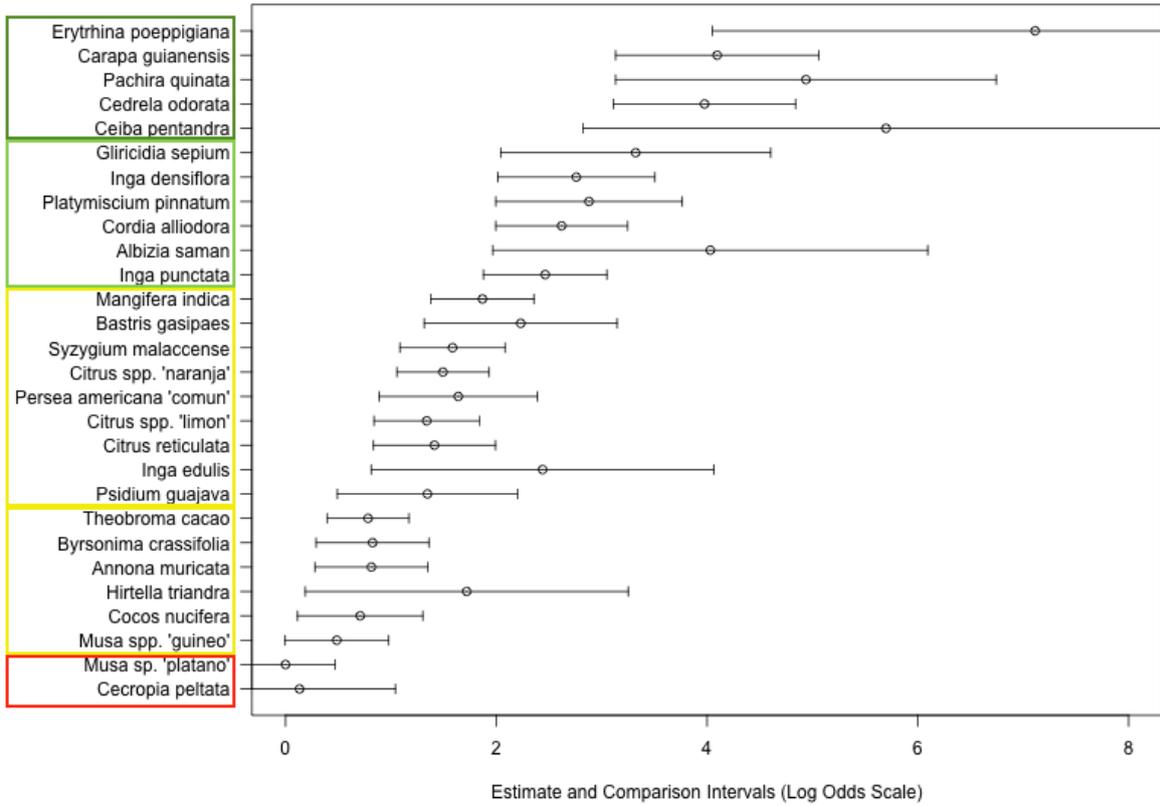
**Study area - 08\_Management - Ranking scores**



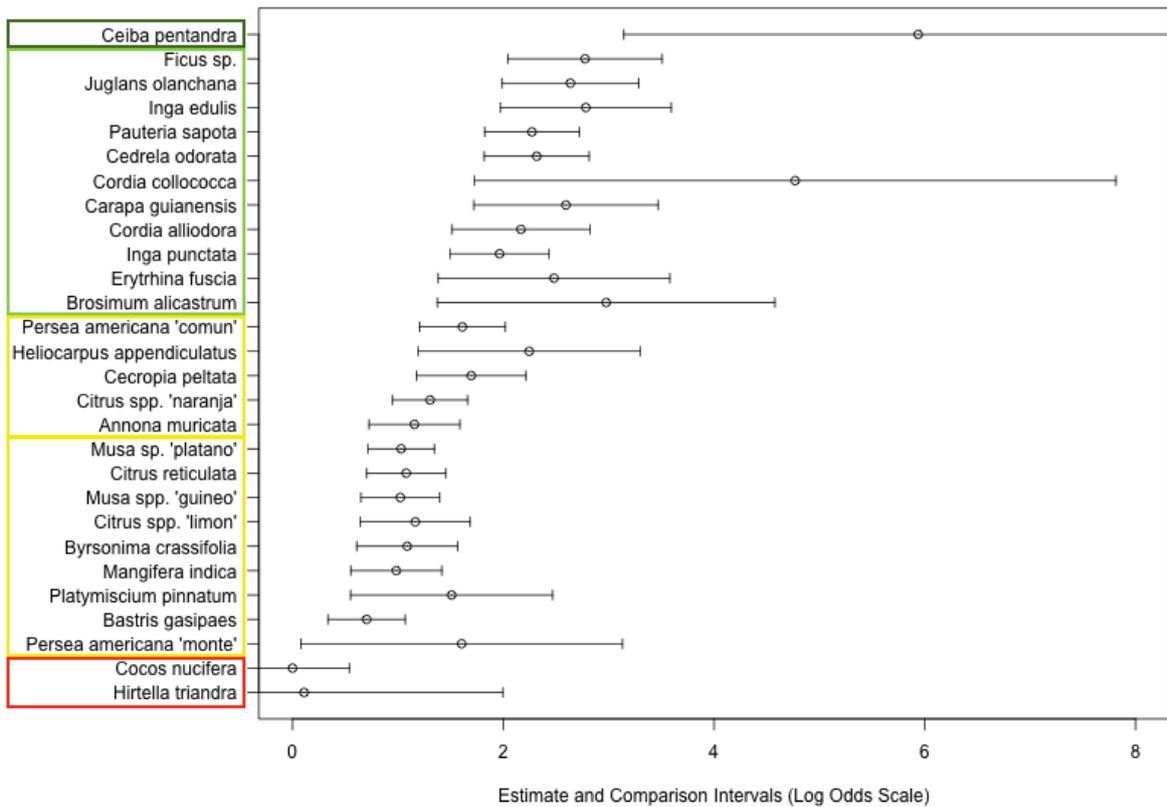
**La Estrellita - 08\_Management - Ranking scores**



**La Inmaculada - 08\_Management - Ranking scores**

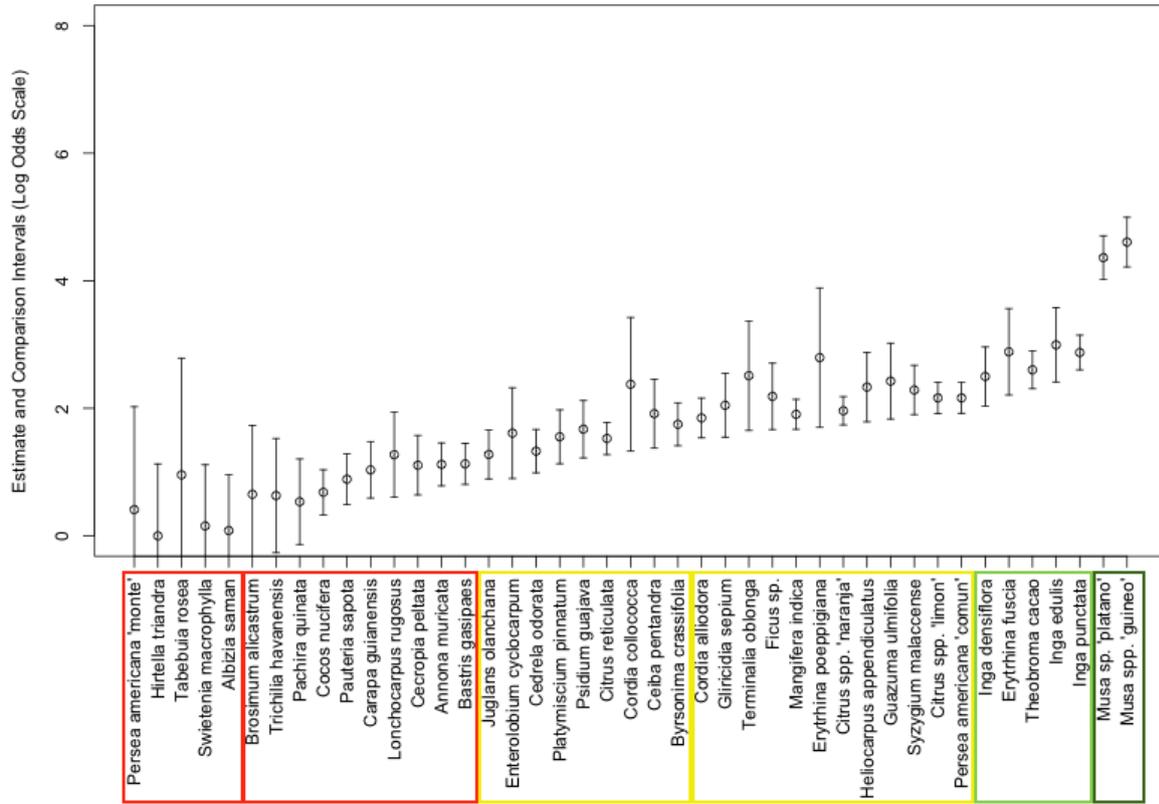


**Cerro Grande - 08\_Management - Ranking scores**

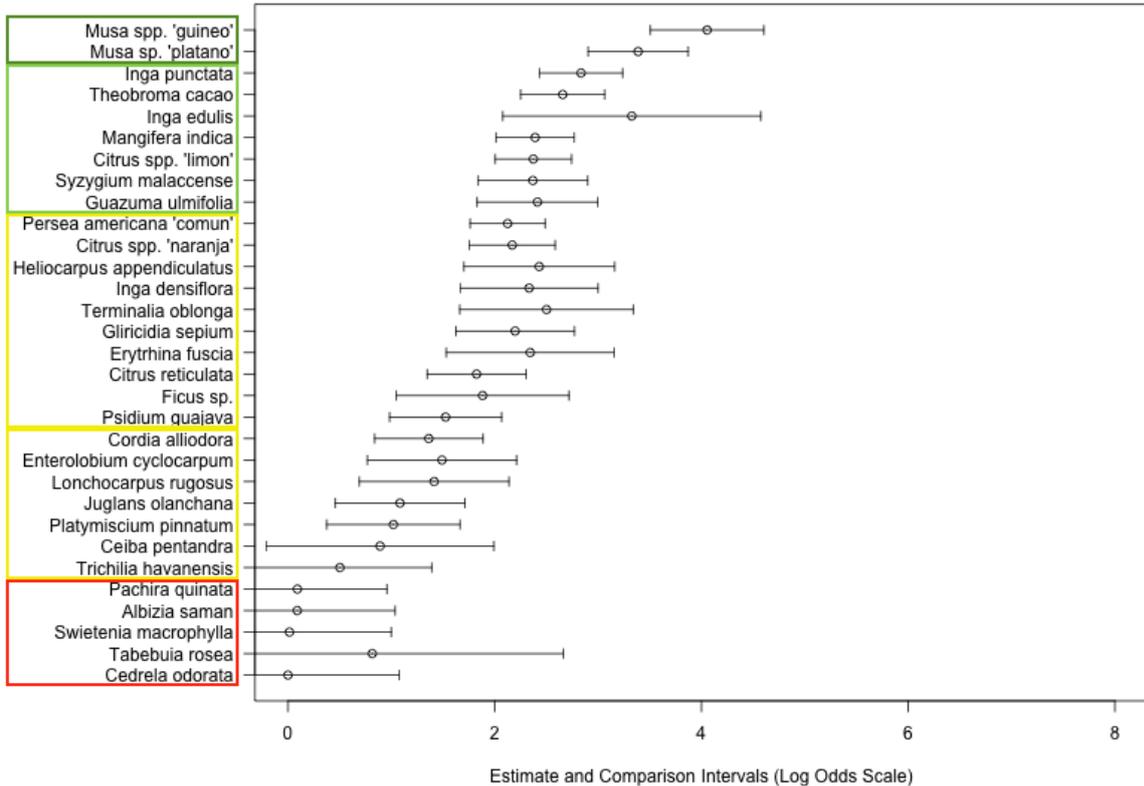


## RAPIDITY OF GROWTH

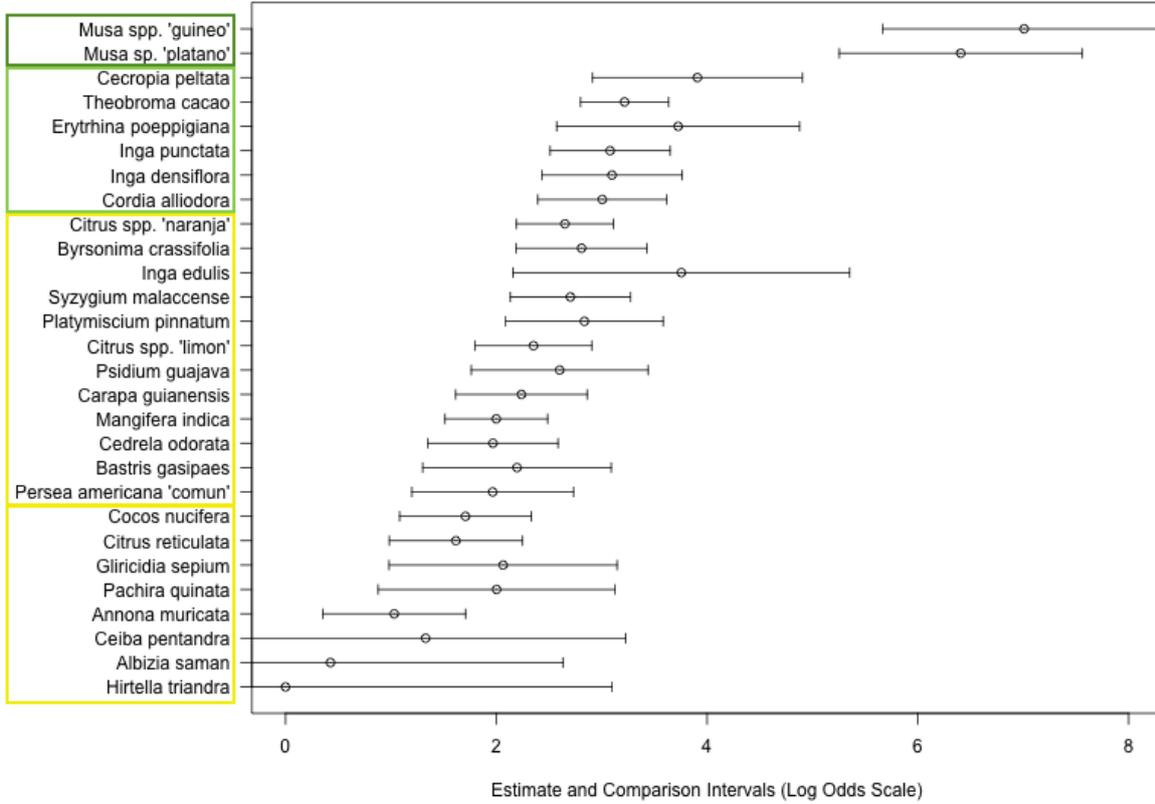
**Study area - 09\_Growth speed - Ranking scores**



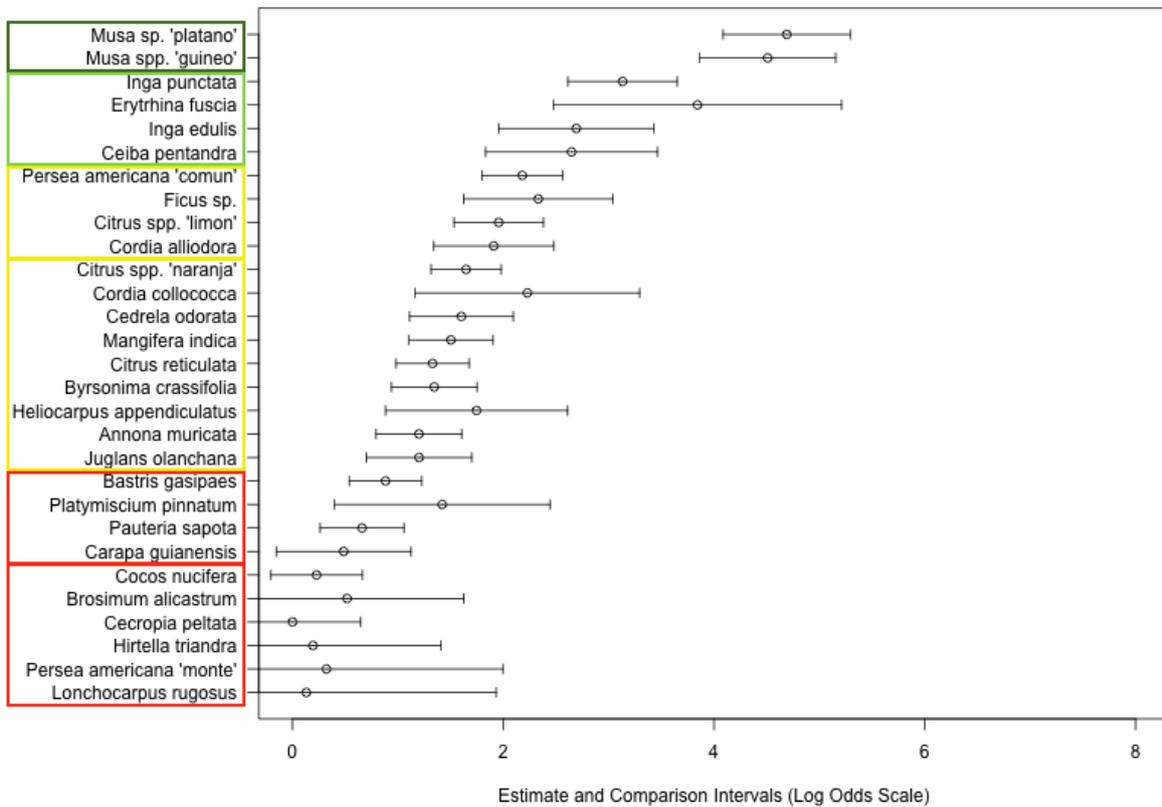
**La Estrellita - 09\_Growth speed - Ranking scores**



La Inmaculada - 09\_Growth speed - Ranking scores

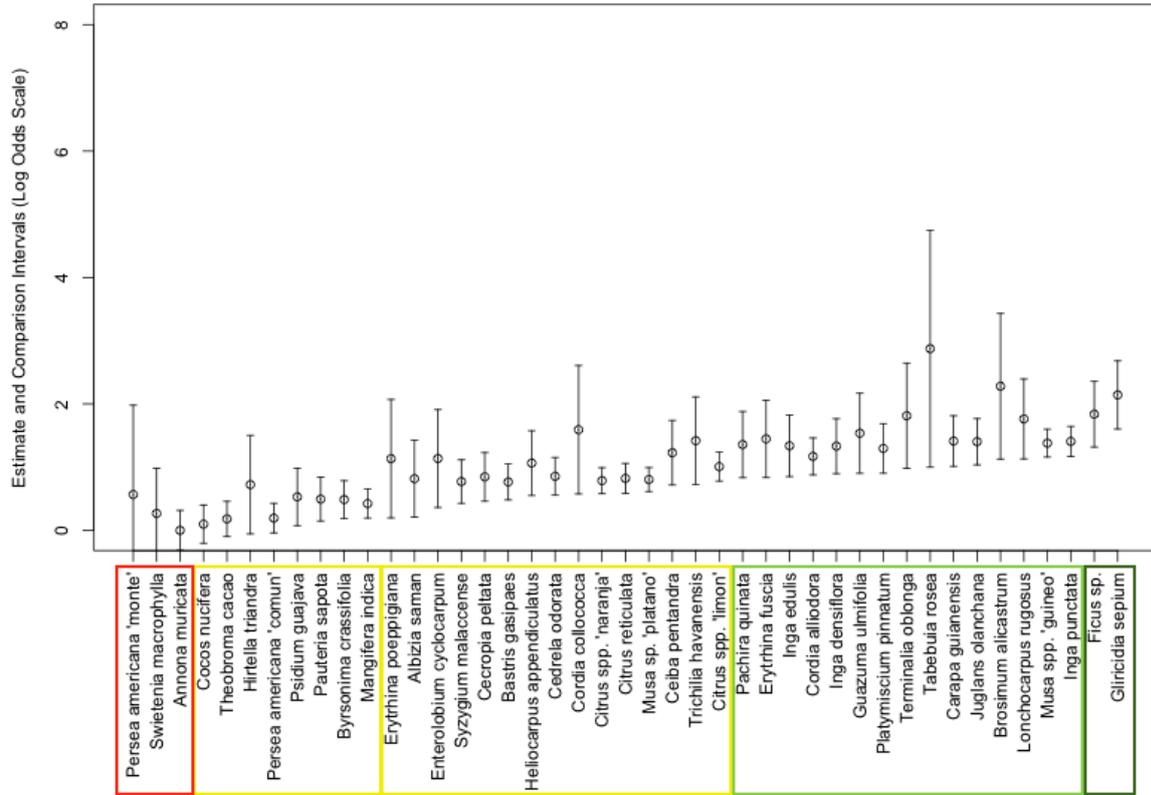


Cerro Grande - 09\_Growth speed - Ranking scores

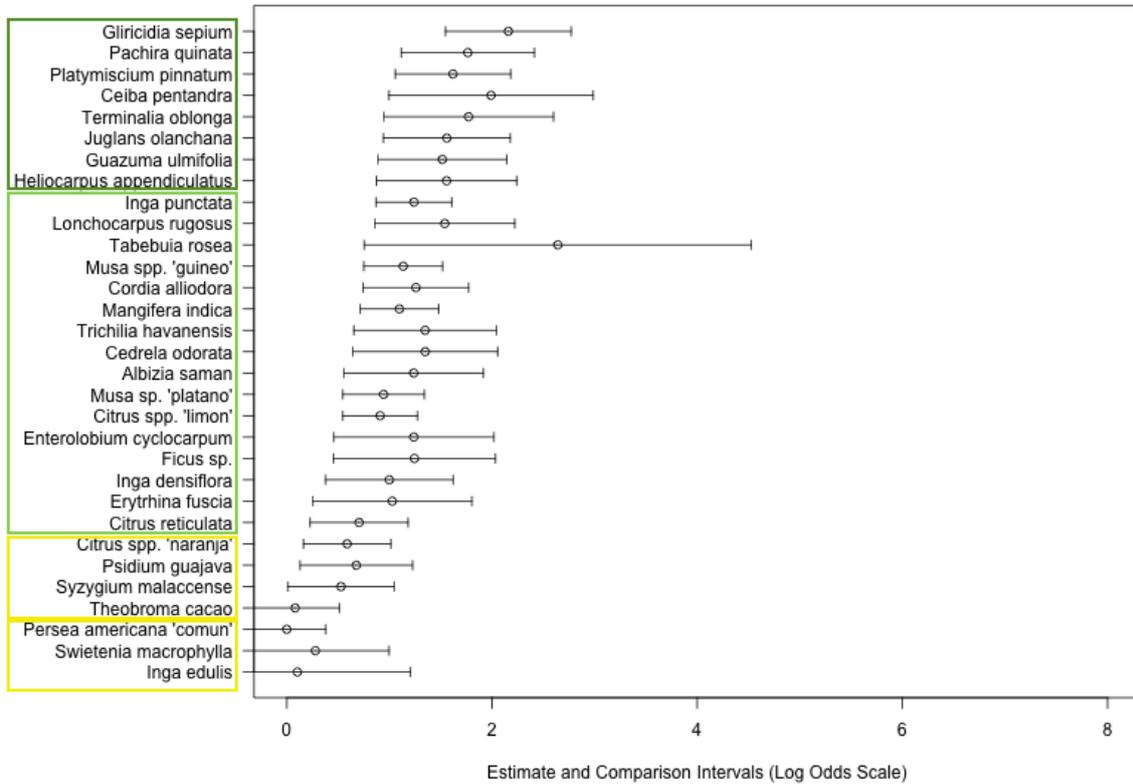


ADAPTED TO THE LOCAL CONDITIONS

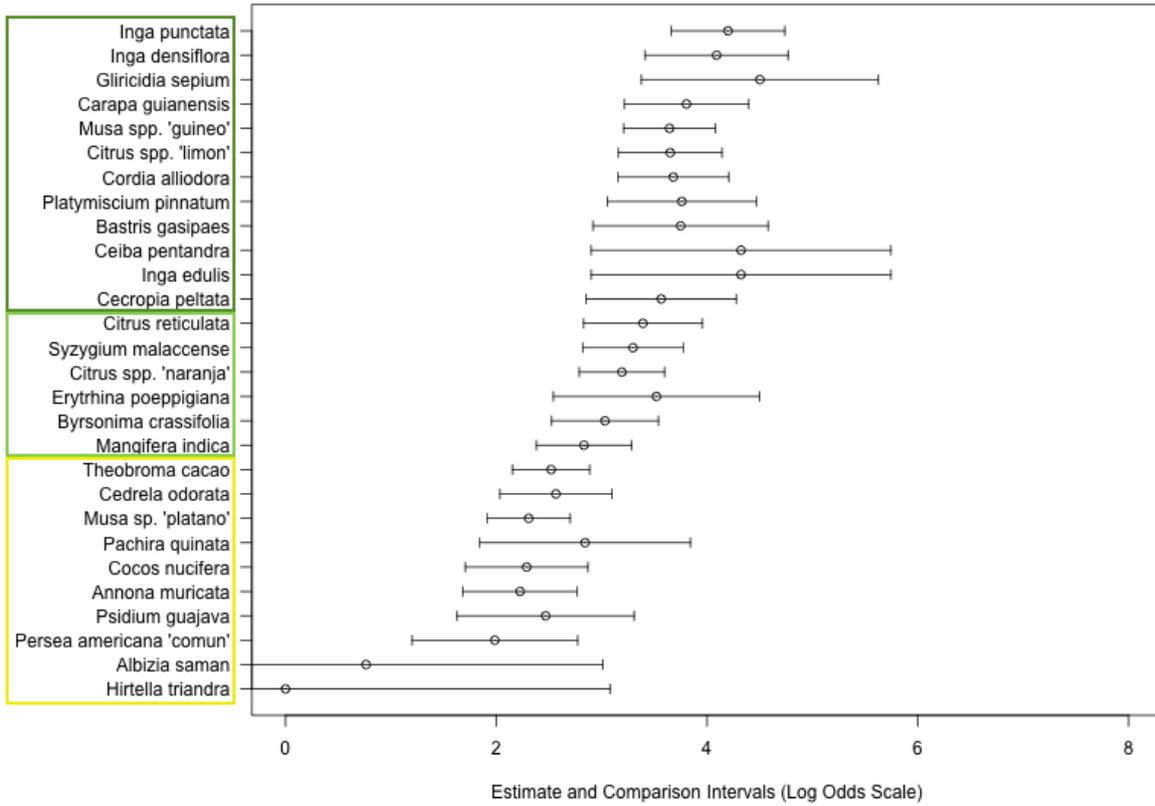
Study area - 10\_Adapted - Ranking scores



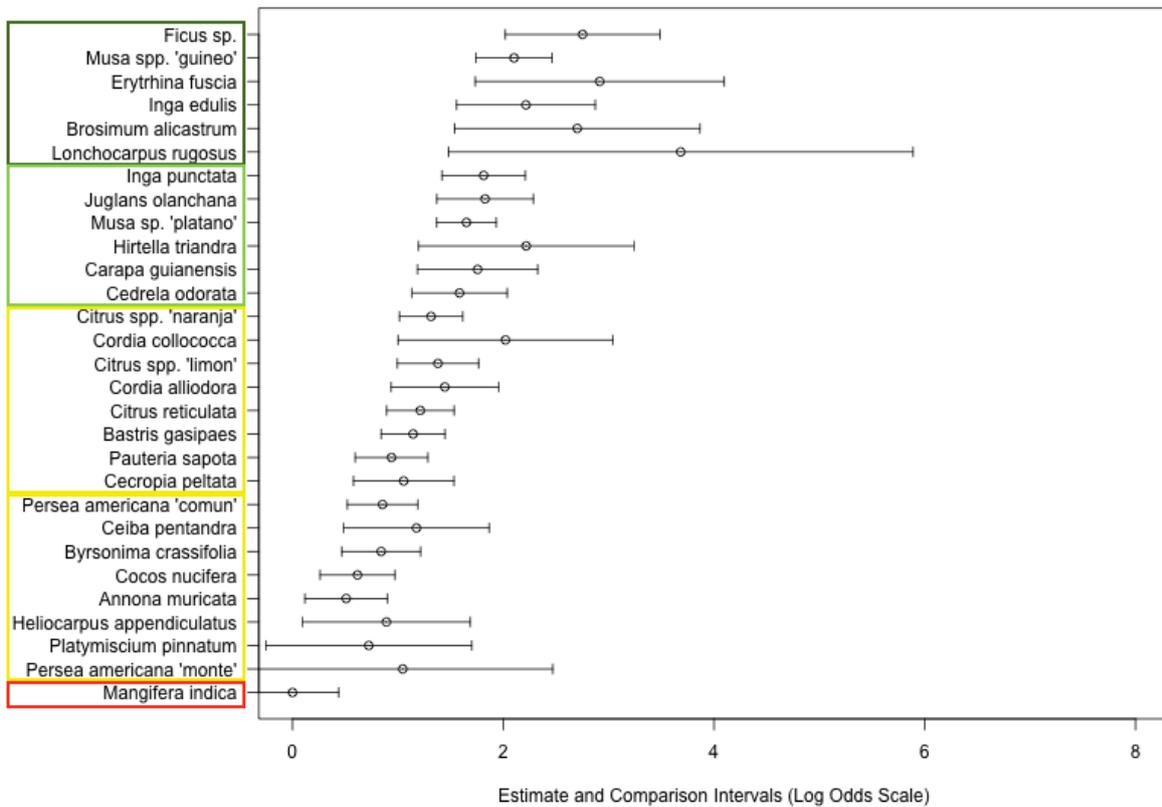
La Estrellita - 10\_Adapted - Ranking scores



La Inmaculada - 10\_Adapted - Ranking scores

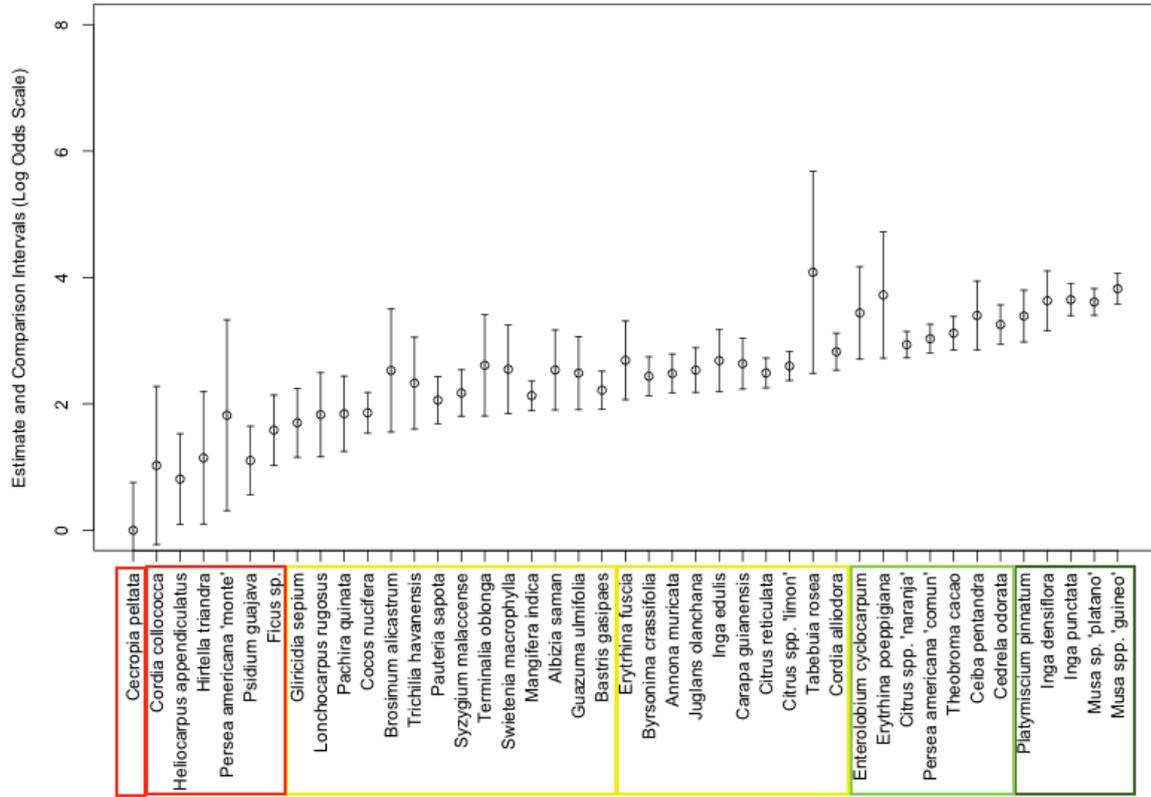


Cerro Grande - 10\_Adapted - Ranking scores

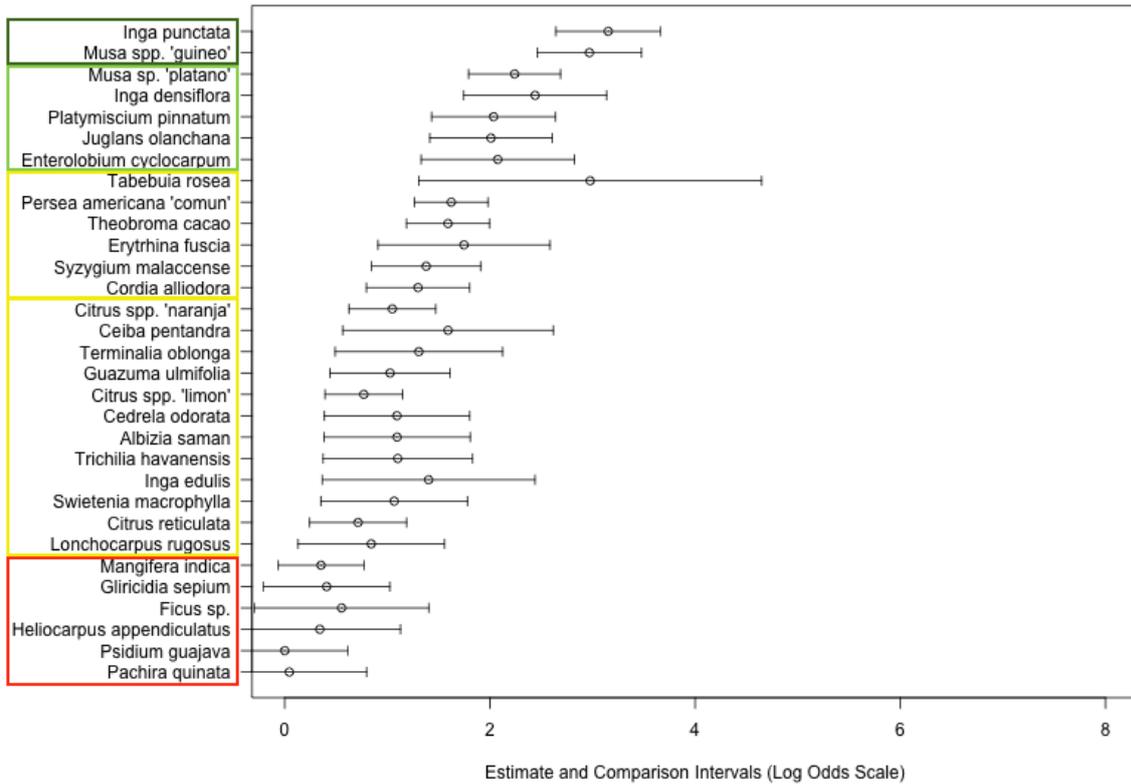


## PREFERENCES

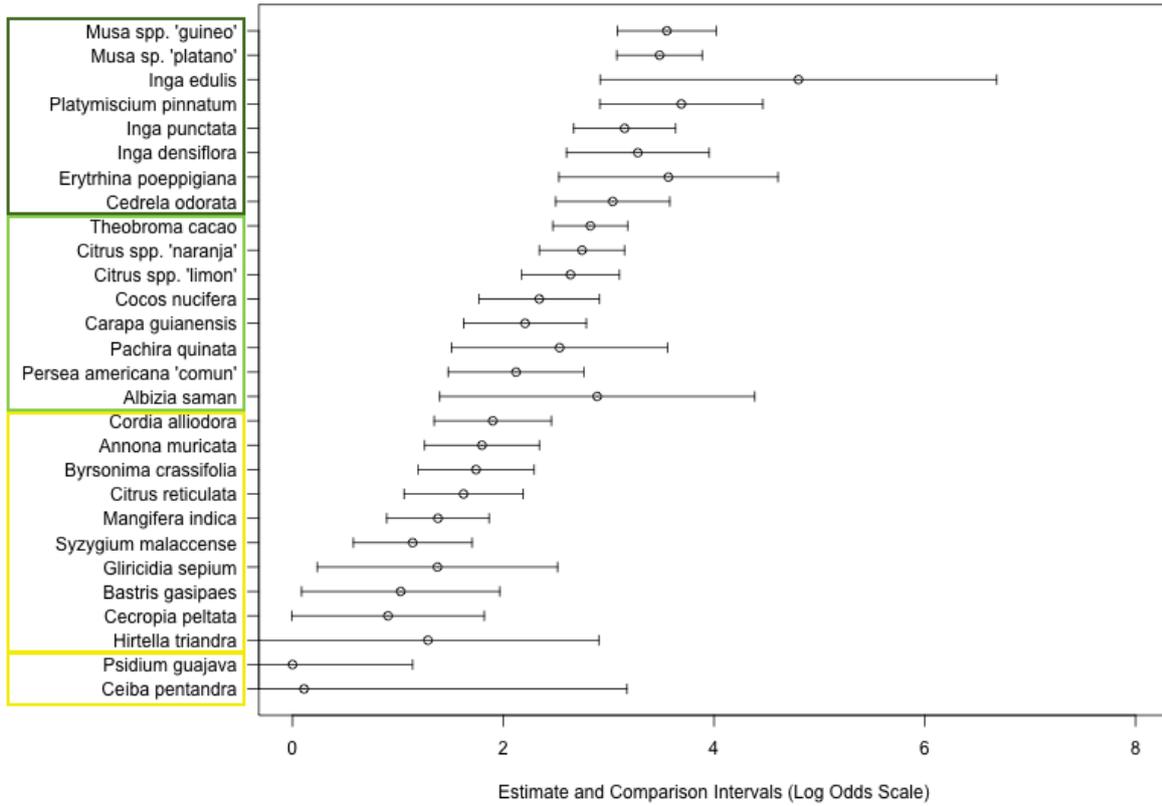
**Study area - Preference ranking**



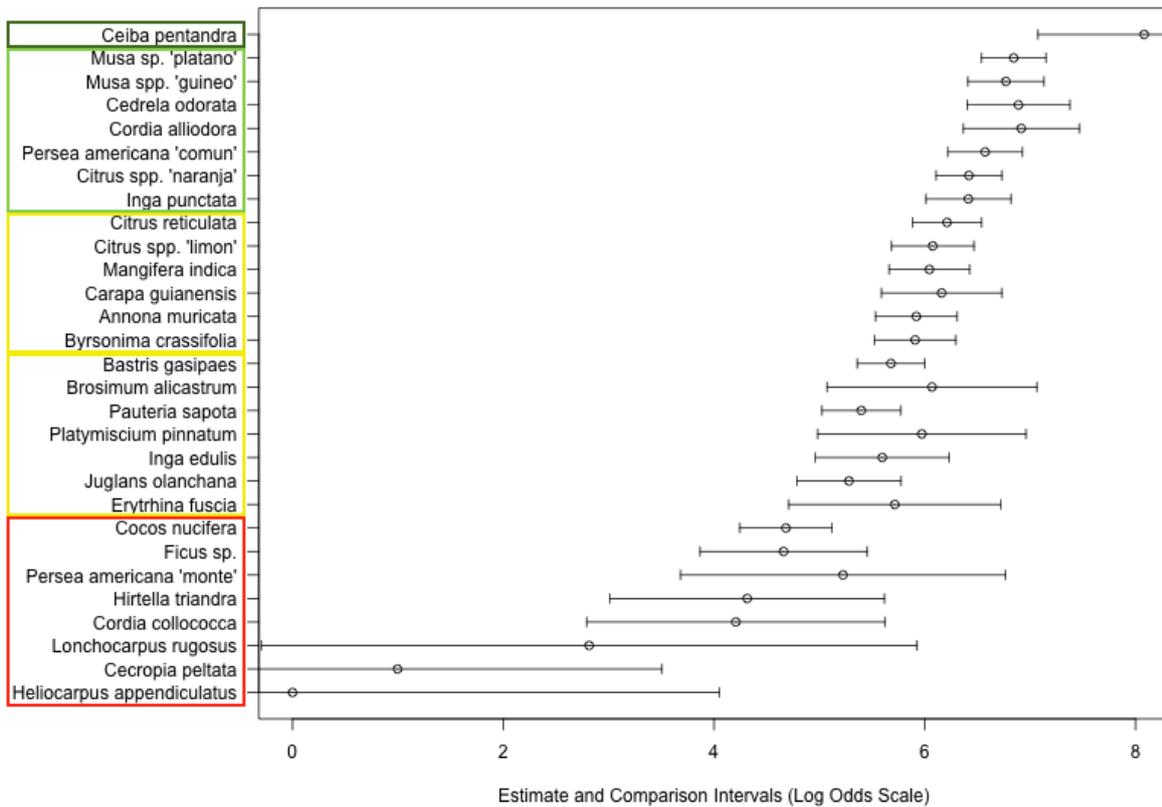
**La Estrellita - Preferences ranking**



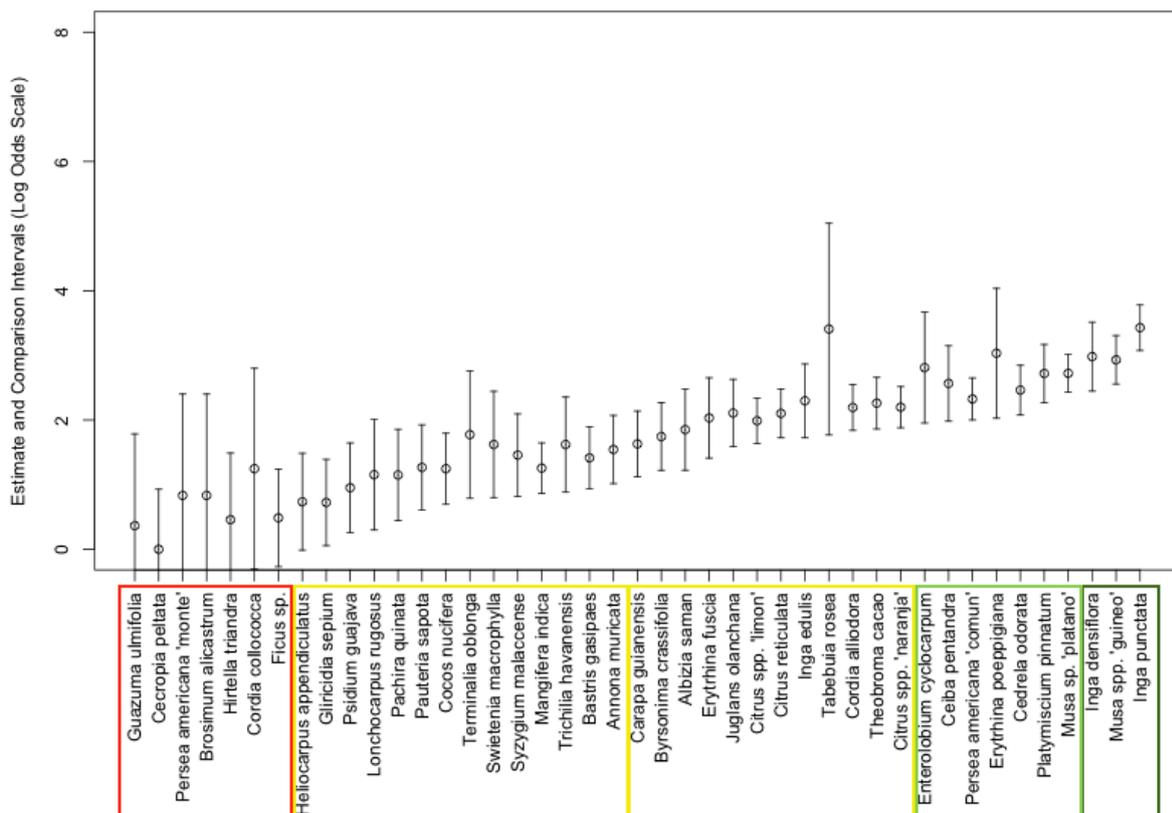
### La Inmaculada - Preferences ranking



### Cerro Grande - Preferences ranking



### Male respondents - Preference ranking



### Female respondents - Preference ranking

