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Tropical Dry Forest Leaf Composition and Hyperspectral Reflectance

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TROPICAL DRY FOREST LEAF COMPOSITION AND HYPERSPECTRAL REFLECTANCE

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by
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ABSTRACT

The use of hyperspectral imagers provides the capability to obtain quantitative and qualitative information on vegetation by remotely collecting reflectance over broad ranges of the ultraviolet and infrared spectrum. Reflectances are determined by the chemical composition and three-dimensional structure of leaves. However, the success of this approach depends on our ability to understand how factors affecting trees influences our ability to interpret reflectance data. The primary objectives of this study were to: 1) Understand the relationship between specific leaf constituents and spectral reflectance patterns of trees in a tropical dry forest, and 2) understand the effects that seasonality has on leaf reflectance and other leaf characteristics of tropical tree species in the reserve.

To answer these questions, leaves and hyperspectral data were collected from 83 individuals of 30 species in the Guánica Dry Forest in two missions representing two different seasonal periods (dry and wet). Leaf constituents (Chl-A, Chl-B, carotenoids, leaf water content, and nitrogen) were measured. Reflectance data were obtained from a hyperspectral sensor. The exotic legume species *Leucaena leucocephala* and *Prosopis juliflora* and the grasses *Uniola virgata* and *Urochloa maxima* tended to be the most distinct from the other species selected for this study. We found seasonal differences for Chl-A, total chlorophyll, and nitrogen concentrations, but not for reflectance at various wavelengths.

Among wavelengths recommended in the literature for having strong correlations between water concentration and reflectance, only the wavelengths 1180 and 1190 nm

differed among species in this study. Moreover, among the recommended wavelengths for nitrogen, only the 1191 and 1225 nm varied among species. Our results showed no correlation between leaf pigments and spectral reflectance data suggesting that these remotely sensed data will be insufficient for classifying trees species based on their pigment concentrations. Based on our results, the interval (1180-1225 nm) from the electromagnetic spectrum was the most sensitive for the use of reflectance to differentiate among tropical tree species from the Guánica Dry Forest.

DEDICATION

I want to dedicate my research and all my work to my family: my father Salvador Acevedo Jimenez, my mother Nilda L. Morales Rivera, and my sister Gisela Acevedo Morales, for all the support that they give me all my life.

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CHAPTER ONE

LITERATURE REVIEW

Tropical forests are considered one of the most biologically rich and complex ecosystems on earth (Gillman et al., 2014; Laurance et al., 2012). Lugo (1988) and Murphy & Lugo (1986a) indicated that only 40% of tropics are covered by forest, but within that proportion are 47% of the world's mature forests. Each year, more than 2,101 km^2 of tropical forests are lost due to anthropogenic pressures like agriculture and urban spread (Hansen et al., 2013; Kumar et al., 2015; Newbold et al., 2014). Recently, new technology including hyperspectral sensors has been used to develop species classification methods using variation in leaf constituents to identify unique reflectance patterns for each species.

As Laurance et al. (2012) reported, most of the tropical forest reserves around the world are being degraded, even though they have some level of protection. One problem with understanding tropical forest degradation is that much of the biodiversity in protected tropical forests is unknown, mostly due to difficult accessibility. The main causes of degradation are anthropogenic effects on reserve boundaries. Some of the anthropogenic perturbations are timber extraction, fires, the introduction of exotic species, reduced habitat area, and increased habitat isolation (Canale et al., 2012; Hanski, 2015; Miles et al., 2006; Sanchez-Azofeifa et al., 2005). Deforestation on forest margins causes the restriction of species into smaller, more confined areas. This limitation increases the competition for natural resources, leading to displacement and extinction of native and endemic tree species. These species occupy specific niches that are easily disturbed by anthropogenic effects or occupied by invasive species (Bussotti et al., 2015; Rodríguez et al., 2006). As a result, 34 of the world's biodiversity hotspots are at risk, including

Caribbean forests (Bellard et al., 2014; Myers et al., 2000; Rojas-Sandoval & Acevedo-Rodríguez, 2015).

The Caribbean hotspot includes a variety of tropical ecosystems, among which are rainforests, wet forests, and dry forests. According to Hoekstra et al. (2005), tropical dry forests have been reduced to 51% of their global extent since 2004. Of the 51%, only 7.6% is protected. Tropical dry forests are characterized by having only 500-2000 mm annual precipitation and a mean annual temperature greater than 17˚C (Kalacska et al., 2004; Murphy et al.,1995). These environmental conditions create higher structural density, higher floristic endemism, and higher physiological diversity than tropical rainforests (Gillespie et al., 2000; Kalacska et al., 2004). Fragmented dry forests are the main remnants of the genetic reservoir for tropical dry forest tree species in regions like the Caribbean (Gould et al., 2006).

In 2004, the Caribbean had 46,839 km² of dry forests, of which only 10.2% was protected (Portillo-Quintero & Sánchez-Azofeifa, 2010). Even though 10.2% seems low, within the Neotropics the Caribbean region has a relatively high rate of protected dry forest (Portillo-Quintero & Sánchez-Azofeifa, 2010). Since 2001, 72% of tropical dry forests in North and Central America have been converted to other land uses, South America has lost 60% of its tropical dry forests, and the Caribbean Islands have lost 66% of their tropical dry forests (Hoekstra et al., 2005; Portillo-Quintero & Sánchez-Azofeifa, 2010). These reductions are mostly due to urban expansion, tourism development and agriculture (Portillo-Quintero & Sánchez-Azofeifa, 2010). In North America, only 0.04% (804 km²) of the 203,884 km² of tropical dry forest cover has some level of protection (Kalacska et al., 2004; Portillo-Quintero & Sánchez-Azofeifa, 2010; Sánchez-Azofeifa et al., 2003). Meanwhile, in South America, 6.6% (17,816 km²) of 268,875 km² of tropical dry forests are protected (Portillo-Quintero & Sánchez-Azofeifa, 2010).

Due to the prolonged dry season, tropical dry forests are classified as a stressed ecosystem, a characteristic that has a relationship with high physiological diversity in life forms (Kalacska et al., 2004; Meinzer et al., 1999; Murphy & Lugo, 1986a). The high physiological diversity in tree species leads to phenological events associated with rainfall seasonality that can help differentiate tree species in a forest – a desirable goal for forest conservation (Castro-Esau & Kalacska, 2008). Mapping biodiversity is a fundamental conservation priority that includes vegetation surveys. However, vegetation surveys in tropical dry forests are challenging and time-consuming because plant species diversity is high, there are few taxonomic specialists, and remote areas are logistically difficult to access (Alvarez-Anorve et al., 2008; Kumar et al., 2015). Alvarez-Anorve et al. (2008) argued that vegetation surveys are necessary for biodiversity assessment techniques. However, prior biodiversity assessment techniques for ecosystems at risk such as the 'hotspot' approach developed and implemented by Conservation International and the FAO Forest Resources Assessment (2001) have failed when applied in tropical dry forests due to their challenging structural and physiological characteristics (Miles et al., 2006).

For this reason, it is important to develop a biodiversity assessment technique that fits the environment of tropical dry forests, but it is unclear if we have a method adapted to the conditions of Caribbean dry forests. Technology like multispectral imaging improves the capacity to study forest biodiversity by measuring spectral information not possible with previous techniques. This technology provides accurate spatially distributed spectral data about trees without needing to enter the forest, as long as the technology is calibrated with ground-truth data. Nonetheless, multispectral imagers like Landsat and MODIS only process ten spectral bands in each pixel, providing limited information compared to hyperspectral imagers (Blackburn, 2007; Lang et al., 2015). Hyperspectral imagers have the capability to obtain the most sensitive quantitative or qualitative information on vegetation (Clark et al., 2005; Feng et al., 2008; Papeş et al., 2010; Ustin et al., 2004). Nonetheless, using this approach depends on understanding the factors affecting plants in order to interpret reflectance data (Ollinger, 2011).

Hyperspectral imagers can measure the reflectance of the solar spectrum from 350 to 2510 nanometers (nm) with 150 to 500 contiguous bands of 5 to 10 nm bandwidths (Clark et al., 2005; Feret et al., 2011; Papeş et al., 2010; Ustin et al., 2009, 2004). Hyperspectral imaging is the most powerful and versatile technology available today and concurrently collects wide intervals of the spectrum, created by "atmospheric windows" comprised of wavelength ranges in which the atmosphere is transparent allowing the electromagnetic radiation to enter the stratosphere (Papp & Cudahy, 2002). The ability of hyperspectral imagers to detect 50 narrow bands within these intervals can be used to identify the chemical characteristics and the anatomical properties of vegetative and reproductive tissues of the plant such as leaf water, nitrogen, and concentrations of various pigments (Alvarez-Anorve et al., 2008; Asner & Martin, 2008; Cochrane, 2000; Ustin et al., 2009, 2004). With this technology, plants can be studied from space, or in the field with the use of a handheld device (Alvarez-Anorve et al., 2008; Clark et al., 2005).

Hyperspectral regions can be divided into the following three categories: visible to shortwave infrared, thermal infrared, and radar. From 350-700 nm is considered the visible spectrum, and 700-1327 nm is considered near infrared (NIR) (Asner et al., 2009; Clark et al., 2005; Cochrane, 2000; Roberts et al., 1998; Ustin et al., 2004). Meanwhile, the range of 1467-1771 nm is classified shortwave infrared 1 (SWIRI), and the range of 1994-2435 nm shortwave infrared 2 (SWIRII) (Clark et al., 2005). The visible to the shortwave infrared region is the most useful detecting vegetation information like plant pigments (Ceccato et al., 2001; Ollinger, 2011). The wavelength ranges between these categories are areas where the atmosphere absorbs all solar radiation. Previous research has shown that pigments absorb strongly in the visible spectrum (350-700 nm) and that wavelengths greater than 700 nm are reflected by non-pigment leaf constituents (Alvarez-Anorve et al., 2008; Kokaly et al.,2009).

Variability in the reflectance and absorbance of the spectral ranges has been under research for years with various researchers analyzing different ranges of the spectrum. The visible range of 690-720 nm and the SIR range of 1467-2435 nm are affected by plant aging and stress, which causes an increase in reflectance (Carter et al., 2001; Ustin et al., 2004). Various researchers have different recommendations on which wavelength ranges to use for hyperspectral analyses of forests. Asner et al. (2009) recommend the use of the NIR (700-1300 nm) spectral range to study leaves due to the high variability in reflectance caused by leaf water concentration. The NIR (700-1300 nm) region has proven to be affected by air spaces located inside the leaf structure (Ceccato et al., 2001; Clark et al., 2005; Grant, 1987; Knipling, 1970; Ustin et al., 2004). On the other hand, others have reported that reflectance of the spectral range 1300-2500 nm was reduced by high water absorbance, which would limit the capacity to find variability between species (Ceccato et al., 2001; Clark et al., 2005; Grant, 1987; Knipling, 1970; Ustin et al., 2004). Martin et al. (2008) stated that ranges of 760-1000 nm and 1180-1750 nm had positive correlations between N concentration and reflectance, which makes them useful wavelengths for N analysis. In summary, the optimal wavelength ranges within NIR and SWIR for tree-level analyses are still debated.

The use of high-resolution data at the leaf level allows the evaluation of spectral elements of leaf properties and their variations within and among species (Hesketh & Sánchez-Azofeifa, 2012). A better ecological understanding of this technology can give us the correct tools to classify, study, and protect highly biodiverse places like Caribbean dry forests (Alvarez et al., 2008). Asner et al. (2009) and Castro-Esau et al. (2006) pointed out that variation in leaf traits are the justification for using differences in leaf optical properties to allow species discrimination. Photosynthetic capacity of species at regional, continental, and global scales is an attribute that potentially influences the establishment, survival, and fitness of the trees (Castro-Esau et al., 2006; Cochrane, 2000; Foley et al., 2006; Grant, 1987; Reich et al., 2003; Reich et al. 2007). Researchers have reported the lack of information on leaf chemistry, physiology, and life span of global vegetation models designed for tropical forests (Asner et al., 2008; Asner et al., 2009; Reich et al., 2007) and that the understanding of the ecological variation of plant species leads to new, cleaner, and more efficient vegetation analysis methods that can be used to study biodiversity in complex ecosystems. However, the full understanding of leaf components and their effects on spectral signatures remains a major challenge in remote sensing (Espírito-Santo et al. 2014).

Although the hyperspectral sensor gathers vast amounts of information relevant to ecosystem functions (Blackburn, 2007), knowing which factors affect plant spectral properties would improve our ability to interpret reflectance data by (Ollinger, 2011). The variability of functional traits can be high, reflecting both genetic richness and environmental acclimatization, and this is fundamental for adaptive processes (Bussotti et al., 2015). The "principle of persistence" is based on adjustments occurring on functional traits at morphological and physiological levels (i.e. phenotypic plasticity). Phenotypic plasticity is defined as the range of phenotypes a single genotype can express as a function of its environments and is a requirement for plant acclimation because it increases a population's chance to survive in the ecosystem. Depending on species and population, some traits have higher plasticity than others. Plasticity may have a direct impact on the concentration of leaf constituents by increasing their variation among and within species, the desired trait for the development of biodiversity assessment techniques. Conversely, many highly plastic species within a community may be hard to resolve spatially with hyperspectral data if they all have similar optical responses to environmental stress.

Pigments are essential components in physiological and chemical functions of plants (Asner et al., 2008; Kira et al., 2015). Pigments like chlorophyll A and B (Chl-A and Chl-B), and carotenoids are the main pigments of green leaves and can provide detailed information on the physiological characteristics of vegetation (Blackburn, 1999; Blackburn, 2007; Gitelson et al., 2002; Goekkaya et al., 2014; Kira et al., 2015). Carotenoids play an important role in plant functions and leaf protection. Carotenoids are the second major group of plant pigments (after chlorophyll). Carotenoids are subdivided into two categories: carotenes (α- and β-) and xanthophylls (lutein, zeaxanthin, violaxanthin, antheraxanthin and neoxanthin) (Blackburn, 2007; Gitelson et al., 2002).

The role of carotenoids on physicochemical and photophysical functions of plants has been widely discussed in the literature (Demmig-Adams & Adams, 2006; Gitelson et al., 2002; Kira et al., 2015; Rascher et al., 2007; Ruban et al., 2011). Two important roles of carotenoids are the harvesting energy from light and photoprotection of leaf cells, forming part of the xanthophyll cycle (Demmig-Adams & Adams, 2006; Gitelson et al., 2002; Jahns et al., 2012; Kira et al., 2015; Niyogi et al., 1997; Rascher et al., 2007; Ruban et al., 2011; Sims & Gamon, 2002). The photoprotection effects of carotenoids are of particular importance when the leaf suffers stress. Some stress factors common to the dry tropics are insect and herbivore damage, drought stress, and light damage (Asner & Martin, 2008; Ramel et al., 2012; Rascher et al., 2007).

Drought is one of the most important environmental stress factors that influences physiological diversity in tropical dry forests (Ceccato et al., 2001). Water is the most abundant chemical in the leaf, and it plays a central role regulating tree growth, photosynthesis, and stress caused by temperature and moisture in the leaf (Asner & Martin, 2008; Kokaly et al., 2009; Ollinger, 2011). Leaf water content influences the leaf reflectance in a direct way, caused by the absorption properties of water itself, and indirectly in association with other leaf properties that change with hydration (Ollinger, 2011). The reflectance in the NIR and SWIR regions of the spectrum is mostly dominated by water absorption (Asner & Martin, 2008; Ceccato et al., 2001; Cheng et al., 2006; Kokaly et al., 2009; Peñuelas et al., 1997; Serrano et al., 2000; Sims & Gamon, 2003; Zarco-Tejada et al., 2003). Ceccato et al. (2001) and Kokaly et al. (2009) reported an increase in reflectance variability with lower leaf water content that can be used to study species distribution in dry ecosystems. Spectroscopic water features have been quantified and used to map vegetation water concentration and canopy water stress in a variety of ecosystems like chaparral and tropical forests (Asner & Martin, 2008; Sánchez-Azofeifa et al., 2009).

Leaf constituents such as Chl-A, Chl-B, carotenoids, and leaf water are central to understanding plants and whole ecosystems function, but so are other components like nitrogen (Asner & Martin, 2008). Even though nitrogen is a relatively small component of leaf dry weight, with a range of 0.26% in grasses to 3.5% in broadleaf deciduous trees, it has a strong link to ecosystem functions such as photosynthesis and net primary production (Asner et al., 2009; Kokaly et al., 2009; Martin et al., 2008; Ollinger, 2011). Nitrogen occurs primarily in proteins like rubisco, which accounts for 30% to 50% of the nitrogen in green leaves (Kokaly et al., 2009; Ollinger, 2011) and has therefore been correlated with chlorophyll in ecosystem analysis (Kokaly et al., 2009). Nitrogen has an indirect influence on leaf spectral properties due to its relationship with leaf structural and biochemical attributes. Nitrogen has been quantified at leaf and canopy scales using reflectance measurements, showing spatial variation caused by species composition and soil type (Kokaly et al., 2009; Martin et al., 2008).

Although nitrogen clearly influences the spectral properties of plants, some uncertainty remains surrounding the effects of nitrogen on leaf spectra and the ability to detect nitrogen using hyperspectral imagers. Other leaf components can mask the low overall proportion of nitrogen in leaves. Environmental conditions such as nitrogen transformation in soils, invasion of exotic trees species, and forest responses to atmospheric nitrogen deposition can influence nitrogen concentration in leaves (Ollinger, 2011).

This research was designed to understand the relationship between leaf constituents (pigments, water, and nitrogen) and leaf reflectance for trees from the Guánica Dry Forest. The principal objective of this research was to focus on physical and spectral differences between native, exotic, endangered and common tree species from the forest. In addition, this research also assessed the effects of seasonality on leaf reflectance and other leaf characteristics of dominant species in the forest. To our knowledge, this research is the first effort to measures the effects of pigments, water, and nitrogen concentration on leaf reflectance in Caribbean dry forests.

Study sites:

This research was conducted in the Guánica Dry Forest (GDF) in the Commonwealth of Puerto Rico (Figure 1). The forest (17˚58'N, 66˚55'w) consists of 4,500 ha located in the southwest part of the island. Four key elements influence the reserve: climatic gradients, substrate difference, topography, and human and natural disturbances (Gould et al., 2008). The forest is considered to be the best preserved tropical dry forest in the Caribbean (Lugo, 1996) and consists of a mosaic of a primary and secondary forest. The temperature fluctuates throughout the year with an average of 25.1°C (Wolfe et al., 2014). This forest has bimodal dry season from December to early April and late May to August with wet seasons in between. The Guánica Dry Forest has an average annual precipitation of 816 mm since 1931 (computed from National Weather Service data). Caribbean tropical dry forest structure is different from other tropical dry forests because hurricanes frequently impact this region. This situation creates a forest structure in which short-statured trees produce multiple stems that help limit hurricane effects (Murphy & Lugo, 1986b; Van Bloem et al., 2006). Trees from the Guánica Dry Forest have adaptations that let them survive drought stress including the production of small and thick leaves to reduce evapotranspiration, slow growth rate, and low height. Guánica Forest soils consist of shallow organic soils with limestone rocks in a dry karstic landscape (Lugo et al., 1996; Murphy & Lugo , 1986b).

The archipelago of Puerto Rico has over 2,800 species of native and exotic flowering plants throughout the various forest types; 9% of these species are endemic to the islands (Gould et al., 2006). Previous studies about the Guánica Forest flora identified a total of 460 plant species, including approximately 137 tree species (Monsegur, 2009). The Guánica Dry Forest has a tree species composition that is characterized by high endemism, but which shares species with dry forests of the Florida Keys and other Caribbean islands (Acevedo-Rodriguez, 1996; Kalacska et al., 2004; Little and Wadsworth 1974; Little et al., 1974; Ross et al., 2016).

In 1981, the Guánica Dry Forest was designated as an international biosphere reserve, due to the complexity, natural richness, and importance to the scientific community (Lugo et al., 1996). Recently, the Guánica Dry Forest was designated as the core site of the Atlantic Neo-tropical Domain of the US National Ecological Observatory Network (NEON) (www.neonscience.org). The NEON Network uses hyperspectral imagers as part of their data collection, making the results of this research applicable to future interpretation of NEON data.

CHAPTER TWO

RELATIONSHIPS BETWEEN LEAF CONSTITUENTS AND SPECTRAL REFLECTANCE OF CARIBBEAN TROPICAL DRY FOREST TREE SPECIES

1.0 Introduction

Use of advanced technology such as hyperspectral imagers may improve our understanding of the physiological, ecological, and spectral components of tropical dry forests by enhancing spatial analysis of leaf pigments, nitrogen, and water concentration (Blackburn, 2007; Hesketh et al. 2014; Sánchez-Azofeifa et al., 2009). The variation within these components may help us identify spectral differences between native and exotic species or common and endangered species. In tropical dry forests, seasonality in spectral characteristics of leaf reflectance and other leaf characteristics may provide additional utility in identifying patterns of tree species distribution.

Hyperspectral sensors have the capacity to capture high spectral resolution at a relatively low cost within a range of wavelengths from 348 to 2514 nm. Spectral data can be collected from the forest canopy or at the leaf level if a handheld device is used (Asner & Martin, 2008). Handheld devices generate to more precise and accurate results than canopy-level results because there are less atmospheric interference and less geospatial error, but handheld results are limited in spatial scale (Asner & Martin, 2008). New remotely sensed hyperspectral data provides the opportunity to study patterns of biodiversity that were previously tough to survey due to difficulty of accessing remote locations and the lack of accuracy and complexity in older remote-sensing technology (Clark et al., 2005).

Some researchers have successfully identified tree species without needing to enter and disturb the forests by using hyperspectral imagers to assess reflectance in complex ecosystems (Cochrane, 2000; Feret & Asner, 2011; Ferreira et al., 2013). Leaf-scale reflectance spectra have been studied for photosynthetic constituents such as total chlorophyll, chlorophyll A, chlorophyll B and carotenoids (Asner et al., 2008; Clark et al., 2005; Kira et al., 2015; Kokaly et al., 2009; Sims & Gamon, 2002; Ustin et al., 2009). Total chlorophyll (Chl-A plus Chl-B) tends to be the most studied because of chlorophyll's high concentration in the leaf and no spectral overlap with other constituents (Ollinger, 2011; Blackburn, 2007). Other leaf components like carotenoids, leaf water, and nitrogen are harder to study because they are present in lower concentrations or they have high interrelationships with other constituents (Blackburn, 2007; Kokaly et al., 2009; Ollinger, 2011). The non-pigment leaf components reflect wavelengths in the near infrared (NIR) and shortwave infrared (SWIR) regions of the electromagnetic spectrum (> 0.70 μm) (Kokaly et al., 2009).

As Kira et al. (2015) pointed out, some of the problems with the use of hyperspectral imagers include different recommendations to select the optimal bands for analysis and the appropriate processing approach for pigment estimation among the array of those available. Strong correlations have been found between pigment concentration and pigment absorbance or reflectance (Ball et al., 2015; Blackburn, 1999; Carter et al., 2001; Chen et al., 2013; Gitelson et al., 2002; Mariotti et al., 1996; Minocha et al., 2009; Ritchie, 2006; Torres et al., 2014; Warren, 2008; Wellburn, 1994). From these correlations, Wellburn (1994) and Warren (2008) developed Chl-A, Chl-B, and carotenoid estimation formulas using pigment concentrations (see below).

Several studies have found that nitrogen has a strong link with ecosystem functions such as photosynthesis, leaf respiration, light use efficiency, wood growth, net primary production, and canopy species diversity although nitrogen is a small component of leaves (Asner et al., 2009; Kokaly et al., 2009; Martin et al., 2008). As Feng et al. (2008) and Ollinger (2011) pointed out, nitrogen concentrations have a positive correlation with leaf reflectance in the NIR region (700-1250 nm).

Previous studies have shown the effects of water limitation in arid or semi-arid plants, where water deficiency induces physiological adaptations that help the plant conserve water and maintain leaf structure, shape, thermal regulation and photosynthesis (Asner et al., 2008; Kokaly et al., 2009). Water is the most abundant chemical in leaves and has been positively correlated with NIR and SWIR spectral ranges (Asner & Martin, 2008; Ceccato et al., 2001; Ceccato et al., 2002). The spectral regions from 950-970, 1150-1260, 1520-1540 nm have the best overall correlations with leaf water concentration (Ceccato et al., 2001; Ceccato et al., 2002; Peñuelas et al., 1993; Sims & Gamon, 2003; Ustin et al., 2004).

This research was designed to understand the relationship between leaf constituents (pigments, water, and nitrogen) and leaf reflectance for tropical trees from the Guánica Dry Forest. The principal objective of this research is to focus on physical and spectral differences between native, exotic, and endangered and common tree species from the Guánica Dry Forest. In addition, this research will assess the effects that seasonality has on leaf reflectance and other leaf characteristics of tree species from the Guánica Dry Forest Reserve. This research is the first effort to understand the effects of pigment, water, and nitrogen concentrations on leaf reflectance in Caribbean dry forests.

2.0 Material and methods

2.1 Study site

This research was carried in the Guánica Dry Forest (GDF) in the Commonwealth of Puerto Rico (Figure 1). The forest consists of 4,500 ha of protected tropical dry forest (Martinuzzi et al., 2013). Annual rainfall averages 816 mm/year since 1931 (computed from National Weather Service data), bimodally distributed into two wet seasons from April-May and August-November (Murphy & Lugo, 1986b; Wolfe & Van Bloem, 2012). Plants were sampled along forest roads in the eastern part of the forest (Figure 1) where the forest type and species composition were representatives of a mature native forest.Additional samples were collected in areas along the coastal road (PR-333). Coastal sites contained species common to grasslands and secondary non-native forests. All sampled plants were located close to the trails and roads so that crowns could be accessed by a bucket truck or by hand. Samples were collected in the Guánica Dry Forest in two different missions: January 27 - February 4, 2010, which was a wet period due to an extended rainy season (Figure 2), and April 8 - 15, 2013, which was dry (Figure 3).

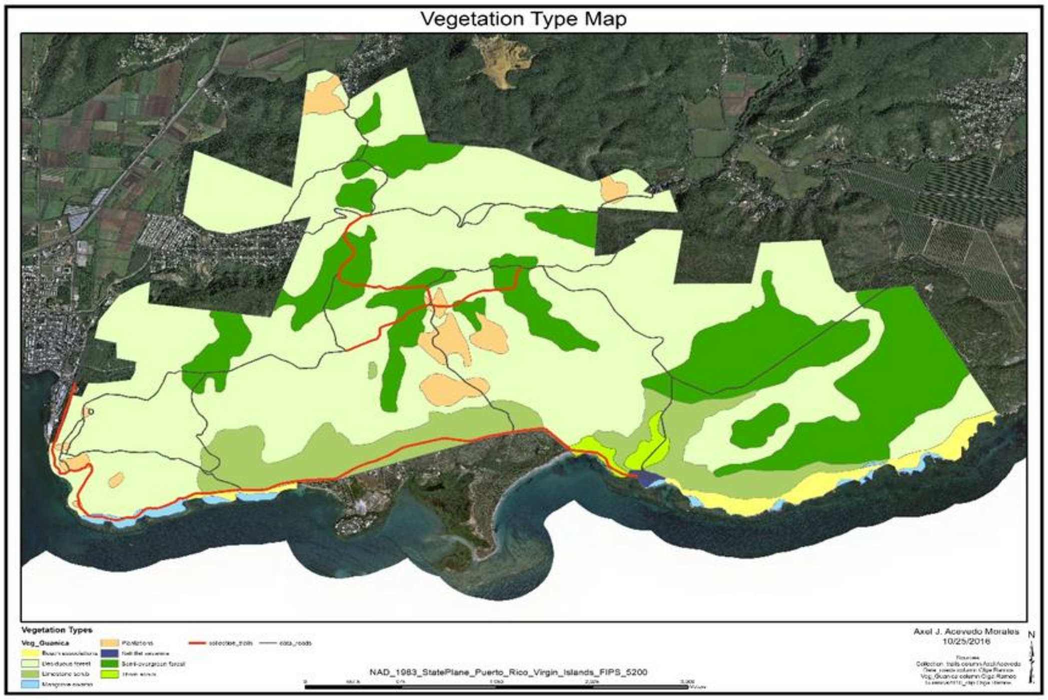

Figure 1: The eastern section of Guánica Dry Forest reserve vegetation map. Red lines show the roads where samples were collected. Sampling areas spanned vegetation types to collect data on dominant species related to land use and forest age.

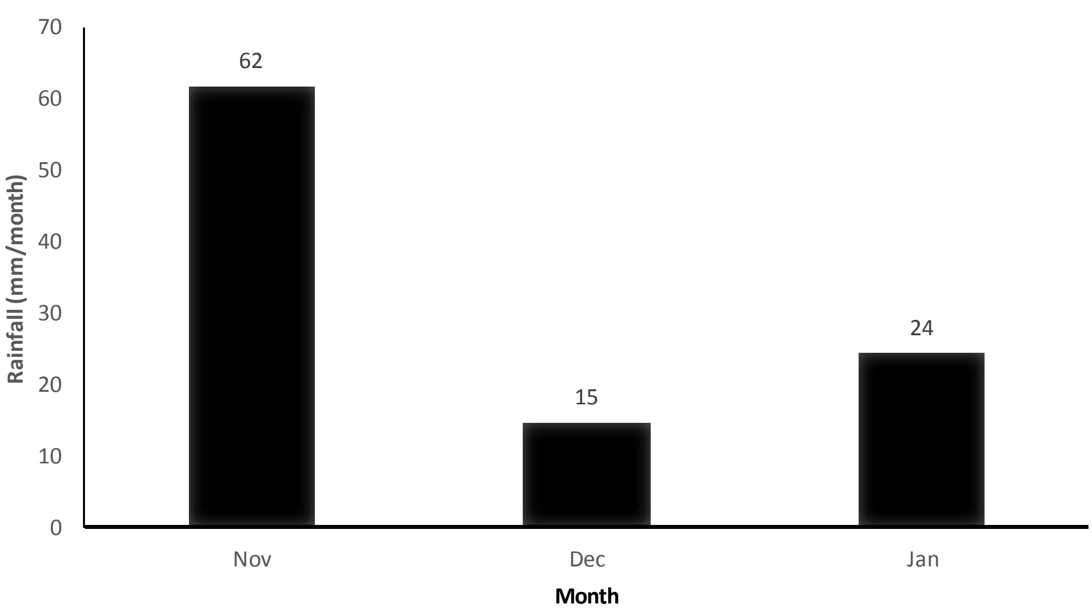

Figure 2: Total monthly rainfall of the previous 3 months for the 2010 mission representing a relatively wet period. Total rainfall for the period was 101 mm.

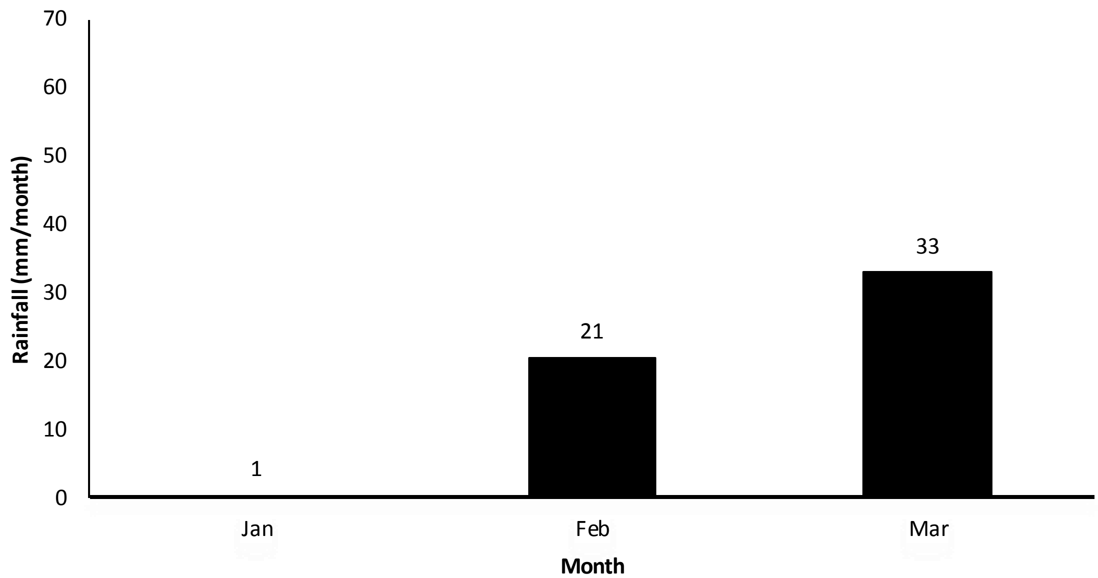

Figure 3: Total monthly rainfall of the previous 3 months for the 2013 mission representing a relatively dry period. Total rainfall for the period was 54 mm.

2.2 Tree selection and leaf sample collection:

For leaf sample collection, species were selected based on their functional type and their community dominance (Murphy & Lugo, 1986b). Overall, 83 individuals of 30 species from 20 families were sampled, reflecting a mix of native and exotic species of trees and grasses (Table 1). For most species, three individuals were sampled in wet season and again in dry season. Individuals from the wet season that were dead or lost in dry season were replaced by new individuals of the same species adjacent to the missing or dead tree. In some cases, we sampled fewer than three individuals from target species because we could not locate enough individuals that were accessible by the bucket truck. Those are not included in the analyses due to small sample sizes but are listed in appendices.

Common species were selected because they have a greater spectral presence in remote sensing data. The trees had coordinates taken on the wet season using a handheld GPS. Leaf samples and spectral images were collected from the crown of the tree using a bucket truck. Approximately ten shots were taken for each individual with a field spectrometer, (HR 1024 Spectra Vista Corporation; 0.4 µm to 2.5 µm) while the leaves were still attached to the branch. The samples were taken from 10:00- 2:00 pm on cloud free days to avoid any spectral contamination. From the visible range, we picked wavelengths 470, 652, and 665 nm (Figure 4) to analyze the reflectance of carotenoids, Chl-B, and Chl-A, respectively. Wavelengths 762, 813, 817, 984, 1192, 1225, 1497, and 1730 nm (Figure 5) were selected to analyze N reflectance, and wavelengths 960, 980, 1180, 1190, 1530, 1600, and 1720nm (Figure 5) were chosen to study leaf water concentration. From the same individuals, six leaves were collected for chlorophyll analysis, six leaves for carotenoid analysis, and twelve leaves for nutrient analysis. Therefore, a total of 24 leaves were collected from each individual.

Field chlorophyll concentrations were taken using an Apogee CCM-200 Chlorophyll Content Meter, whose calculations were based on a mix of both Chl-A and Chl-B in a 3 to 1 ratio using equation 1 (Parry et al., 2014).

$$CCI = \%T \text{ at } 931 \text{ nm} / \%T \text{ at } 653 \text{ nm} \qquad \text{Eq.1}$$

Where CCI is the chlorophyll concentration index and T is transmittance

Three chlorophyll meter measurements for each leaf were taken for each of the six leaves that were also analyzed for pigment concentrations (n=18). Chlorophyll measurements were taken from the left side of palmate or pinnate leaves. Leaf samples were packed in labeled, sealed plastic bags. Leaves for chlorophyll and carotenoid analyses were weighed and stored inside a cooler with ice under dark conditions to avoid degradation (Garcia & Nicolas, 1998; Lashbrooke et al., 2010; Minocha et al.,2009; Ritchie, 2006; Schumann et al., 2005; Xueyun et al.,2013). The samples were subsequently stored in a conventional freezer for two weeks with a temperature of -18˚C and then transferred to an ultra-freezer with a temperature of -80˚C, stopping biochemical reactions inside the leaves.

Table 1: List of species selected with the common name and family. # =Endemic and * =Exotic. Nomenclature (including common names) and status follow Little and Wadsworth (1974). Common names are based on usage in Puerto Rico and the US Virgin Islands

Scientific name:	Family	Common names (Spanish)	Common name (English)
*Agave sisalana**	Agavaceae	Maguey	Agave
Amyris elemifera	Rutaceae	Cuabilla	Candle wood
Avicennia germinans	Acanthaceae	Mangle negro	Black mangrove
Bourreria succulenta	Boraginaceae	Palo de vaca	Pigeon berry
Bucida buceras	Combretaceae	Ucar	Bullet tree
Bursera simaruba	Burseraceae	Almacigo	Gumbo limbo
Capparis cynophallophora	Capparaceae	Burro prieto	Jamaican caper
*Cenchrus ciliaris**	Poaceae	Yerba buffel	Buffel grass
Coccoloba diversifolia	Polygonaceae	Uvilla	Dove plum
Coccoloba microstachya	Polygonaceae	Uverillo	Puckhout
Conocarpus erectus	Combretaceae	Mangle boton	Button mangrove
Erithalis fructicosa	Rubiaceae	Téa	Blacktorch
Eugenia foetida	Myrtaceae	Hoja menuda	Boxleaf eugenia
Exostema caribaeum	Rubiaceae	Albarrillo	Caribbean princewood
Guaiacum officinale	Zygophyllaceae	Guayacan	Lignumvitae
Gymnanthes lucida	Euphorbiaceae	Yaití	Crabwood
*Haematoxylum campechianum**	Fabaceae	Campeche	Logwood
Jacquinia berteroi	Theophrastaceae	Espuela de caballero	Unknown
Krugiodendron ferreum	Ramnaceae	Bariaco	Lead wood
*Leucaena Leucocephala**	Fabaceae	Zarcilla	White lead tree
Pictetia aculeata #	Fabaceae	Tachuelo	Fustic
Pisonia albida	Nyctaginaceae	Corcho bobo	Unknown
Pithecellobium unguis-cati	Fabaceae	Uña de gato	Cat claw blackbead
Plumeria alba	Apocinaceae	Alelí	White frangipani
*Prosopis juliflora**	Fabaceae	Bayahonda blanca	Mesquite
*Swietenia mahogany**	Meliaceae	Caoba	West Indian mahogany
Tabebuia heterophylla	Bignoniacae	Roble nativo	Pink trumpet tree
Thouinia portoricensis#	Sapindaceae	Serrasuela	Puerto Rico ceboruquillo
Uniola virgata	Poaceae	Lagrimas de san pedro	Uniola grass
*Urochloa maxima**	Poaceae	Yerba guinea	Guinea grass
Zanthoxylum flavum	Rutaceae	Aceitillo	West Indian satin wood

2.3 Pigment extraction and conversion:

Three leaf disks of 11.11 mm of diameter were weighed and placed in separate centrifuge tubes, with three centrifuge tubes per individual. To avoid thawing damage, dry ice was used to keep samples frozen during the extraction process (Goekkaya et al., 2014; John et al., 2009). The samples were macerated in the centrifuge tubes with the help of liquid nitrogen using melted pipette tips as a micro-mortar. The ground samples were returned to the ultra-freezer to keep them frozen and avoid degradation. After all the samples were preprocessed, 0.5 ml of methanol (lab grade, S25426A) was added to the centrifuge tubes.

The samples were shaken for 1 minute in a shaker and centrifuged for 2 minutes at 14,000 g in an Eppendorf 5417C centrifuge. The supernatant was transferred to a second microcentrifuge tube (Warren, 2008). These steps were repeated by adding 0.5 ml of methanol to the remnant leaf material in the centrifuge tube, yielding a total of 1 ml of solution. Next, 200 µl of supernatant was transferred to each well ofa 96-wellplate. This procedure was repeated three times, using a total of 600 µl per tube. The samples in the wellplate were analyzed using a Spectramax M2E plate reader, which calculated the absorbance values of each sample. To obtain the pigment absorbance and reflectance values, we used the following wavelengths: 652 nm for Chl-B, 665 nm for Chl-A and 470 nm for carotenoids (Figure 4).

The Ch-A, Chl-B, and carotenoid concentrations were determined for each individual by averaging the absorbance values obtained from the plate reader. These values were then converted into pigment concentration values as recommended by Warren, (2008). Data on pigment absorbance for Chl-A and Chl-B were transformed to Chl-A and Chl-B concentration (µg/ml) using equations 2 and 3 (Ritchie, 2006; Warren, 2008). Similar to Chl-A and Chl-B, the carotenoid concentration was calculated using equation 4 (Chen & Vaidyanathan, 2013; Nordey et al., 2014; Saeed et al., 2014; Torres et al., 2014; Wellburn, 1994).

$$\text{Chl-A } (\mu g/ml) = -8.0962\ (A\ 652) + 16.5169\ (A\ 665) \qquad \text{Eq.2}$$

$$\text{Chl-B } (\mu g/ml) = 27.4405\ (A\ 652) - 12.1688\ (A\ 665) \qquad \text{Eq.3}$$

$$\text{Carotenoids } (\mu g/ml) = (1000\ A470 - 2.86\ Ca - 129.2\ Cb)/\ 221 \qquad \text{Eq.4}$$

Where A is absorbance at the associated wavelength, Ca is Chl-A concentration and Cb is Chl-B concentration. The Chl-A and Chl-B formulas assume a 1 cm pathlength (Warren, 2008).

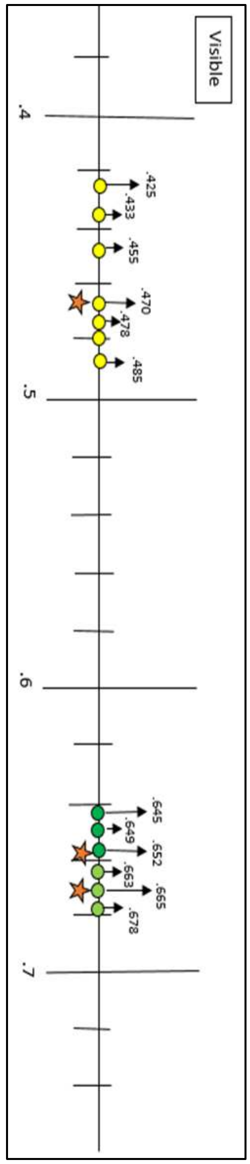

Figure 4: Visible region of the electromagnetic spectrum. Yellow represents the carotenoid absorbance wavelength peaks, dark green represents the absorbance peaks for chlorophyll B, and light green represents the recommended absorbance peaks for chlorophyll A used in other studies (see text). The stars mark the wavelengths used in this study. The values on the x axis are in micrometer (µm).

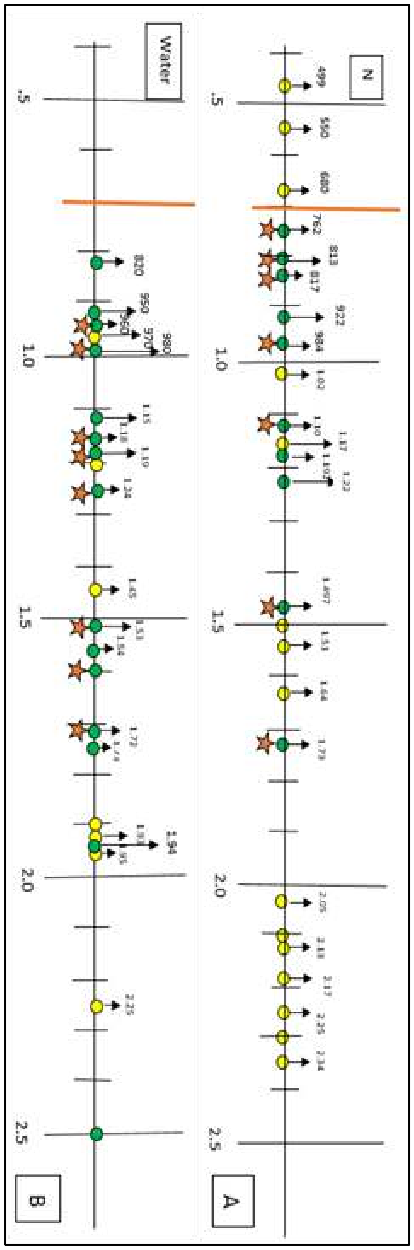

Figure 5: Electromagnetic spectrum from the visible to short wave infrared. The values on the x axis are in micrometer (µm). Yellow dots represent recommended absorbance peaks, and green dots represent recommended reflectance peaks from previous research (Kokaly et al. 2009; Martin et al, 2008; Ollinger et al., 2011; Warren et al. 2008). A) Nitrogen absorbance and reflectance peaks with the peaks selected for this study are marked with an orange star. B) Water concentration absorbance and reflectance peaks with the orange stars indicate peaks used in this study. The orange line represents 700 nm or .7µm where the NIR range starts.

2.4 Water concentration

We analyzed water concentration for the wet season samples. The leaf samples collected for nutrients were weighed fresh using a portable electronic balance in the field and then dried in an oven at 40˚C. The samples were re-weighted to obtain the dry weight to compute leaf moisture concentration.

We calculated the leaf water concentration using the equation 5:

$$\text{Leaf water concentration (\%)} = \frac{(\text{leaf fresh weight} - \text{leaf dry weight})}{\text{leaf fresh weight}} \times 100 \qquad \text{Eq.5}$$

2.5 Nitrogen concentration

To obtain nitrogen concentration, the dried leaf samples were ground and passed through a sieve (40 mesh). N concentrations were determined from 2-3 mg of each sample wrapped inside a tin foil capsule and analyzed in an elemental analyzer (EA2000 CHN-O Analyzer). To calibrate the elemental analyzer, we created a calibration curve using a 2, 5-Bis (5-tert-butyl-benzo-oxazol-2-yl) thiophene (BBOT) standard.

2.6 Statistical analysis

The reflectance measured by the handheld HR2024 spectrometer did not always correspond exactly to the recommended reflectance wavelengths. In these cases, a reflectance value was interpolated from the measured wavelengths on either side of the recommended wavelength with the use of the equation 6.

$$Rd = (W1)\,(1-|D1-Rd|/Dt) + (W2)\,(1-|D2-Rd|/Dt) \qquad \text{Eq. 6}$$

Where Rd is the recommended reflectance wavelength from the literature. W1 and W2 are the wavelengths measured by the spectrometer. D1 and D2 are the differences between the measured reflectance and the recommended reflectance, and Dt is the sum of the two distances. For example, for the recommended reflectance wavelength Rd = 762 nm, the handheld spectrometer measured the wavelengths W1 = 761.3 nm and W2 = 762.3 nm. The interpolated value for Rd should contain more of the reflectance from W2 because it is closer to the desired wavelength than W1. To obtain the reflectance value of 762nm, I interpolated the values by calculating the fractional differences between the measured wavelengths and the desired wavelength, D1= |761.3-762.0| = 0.7 nm, and D2= |762.3 – 762.0| = 0.3 nm. The total difference was Dt = 0.7 + 0.3= 1 nm. The total difference did not always equal 1.0 for each recommended wavelength interpolation because the distances between measured wavelengths varied in different parts of the spectrum. Therefore, a smaller fraction of reflectance from W1, which in this example was further from Rd than W2, was used to interpolate Rd. An average of the pigment concentration values were obtained for each tree individual. To test the assumption of normality of residuals we used the Shapiro-Wilks test. Vegetation and spectral data that did not meet ANOVA assumptions of normality and homogeneity of the residuals were log10 transformed. All data analysis was performed with Infostat (2006 Infostat group, FCA, Universidad Nacional Cordoba, Argentina).

Transformed data were analyzed using ANOVA, and posthoc comparisons were made with Tukey tests to identify differences between species and season. Comparison between exotic and native legumes were made with a nested ANOVA. Spearman correlation tests were used to analyze the correlations between leaf constituent concentrations and wavelength reflectances. The data collectes in each season were analyzed separately to determine differences among species leaf components. To determine seasonal differences, we used a subset of the data that included only the trees measured in both seasons. Interactions between seasons and species were eliminated from the seasonal analysis because the initial statistical analysis showed no significant interaction terms.

3.0 Results

3.1 Pigments

There were differences among species pigment concentrations in both seasons. Values for Chl-A, Chl-B, and carotenoid concentrations ranged from 5.32-26.13 µg/ml, 2.61-16.38 µg/ml and 2.63-12.35 µg/ml, respectively. The concentration of Chl-A, Chl-B, and carotenoids differed among species in both seasons ($P<0.05$). In the wet season, *Leucaena leucocephala* and *Prosopis juliflora* had greater average concentrations of Chl-A, Chl-B, and carotenoids (Figures 6, 7, 8 and Appendix B, C, D). For the dry season, *Prosopis juliflora* had the highest average concentration of Chl-A and Chl-B, while *Zanthoxylum flavum* had the highest average carotenoid concentration ($P=0.03$). The species *Haematoxylum campechianum* and *Krugiodendrum ferreum* had the lowest average for Chl-A and Chl-B while *Avicennia germinans* had the lowest average carotenoid concentration. In contrast to pigment concentrations measured in the lab, the chlorophyll meter measurements showed no differences among species for both seasons (2010: $P=0.11$; and 2013: $P=0.05$) (Figure 9 and Appendix W).

Among pigment concentrations, only Chl-A showed a seasonal difference. Average Chl-A concentration in the wet season was 1.32 µg/ml (17%) higher than the dry season ($P=0.03$). In contrast, there was no seasonal effect for Chl-B and carotenoids. The average chlorophyll meter concentration in wet season was 0.13 units higher than the dry season; $P=0.002$). For the wet season, average Chl-A, Chl-B and carotenoid concentrations for the exotic legumes were 7.30 µg/ml, 0.27 µg/ml and 4.16 µg/ml higher than native legumes species ($P=0.04$; $P=0.05$; $P=0.02$;

P=0.01). However, exotic and native legumes do not differ in the dry season. Average chlorophyll meter concentration for the native legumes was 0.27 µg/ml higher than exotic legumes species.

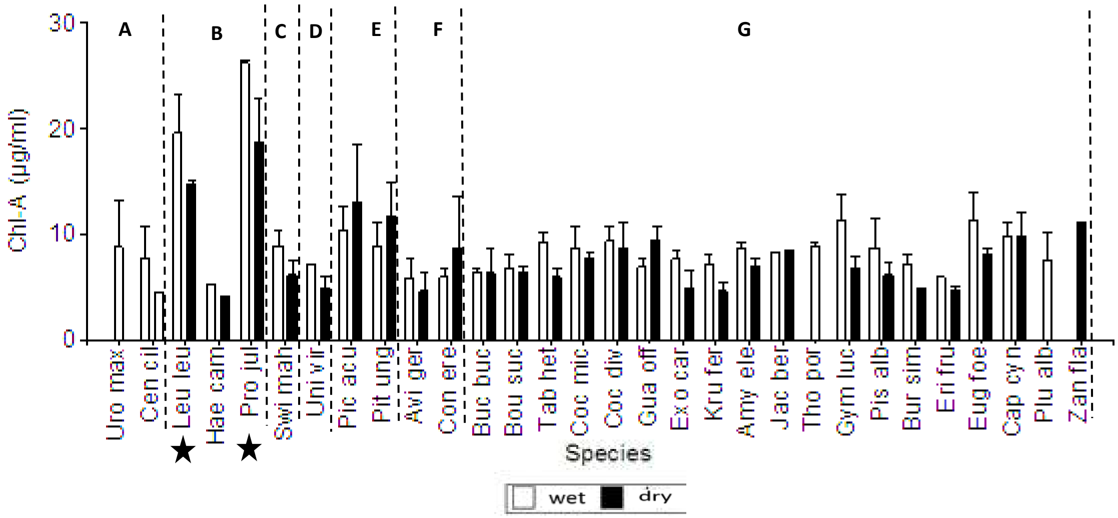

Figure 6: Average Chl-A concentration by species, for both seasons. Error bars represent the standard error. Stars represent significantly different species. A= exotic grasses, B= exotic legume trees, C= other exotic tree species, D= native grass, E= native legumes, F= mangrove, G= native tree species. Chl-A concentrations were 17% higher across species in the wet season.

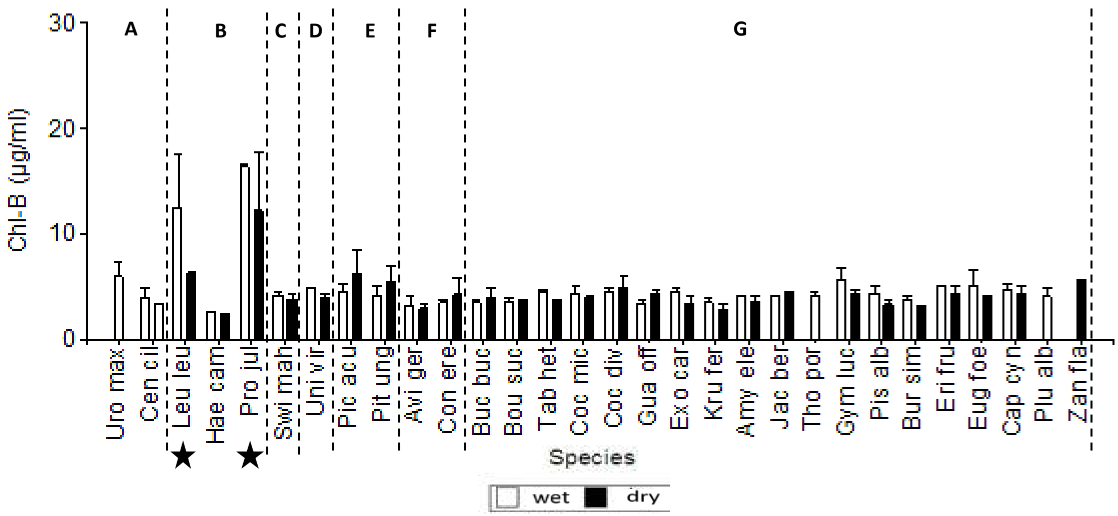

Figure 7: Average Chl-B concentration by species, for both seasons. Error bars represent the standard error. Star represent significantly different species. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

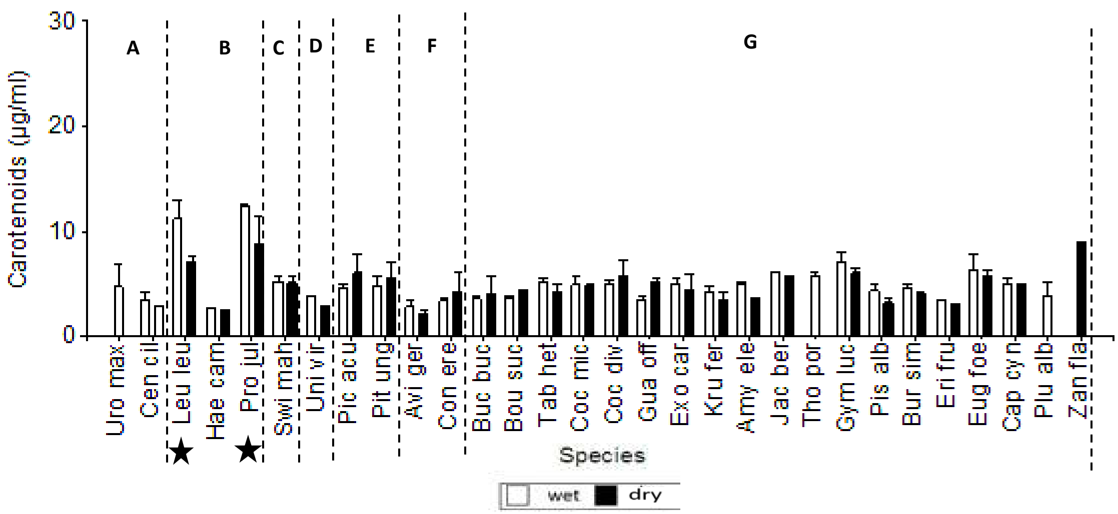

Figure 8: Average carotenoid concentration by species, for both seasons. The error barsrepresent the standard error. Star represent significantly different species. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

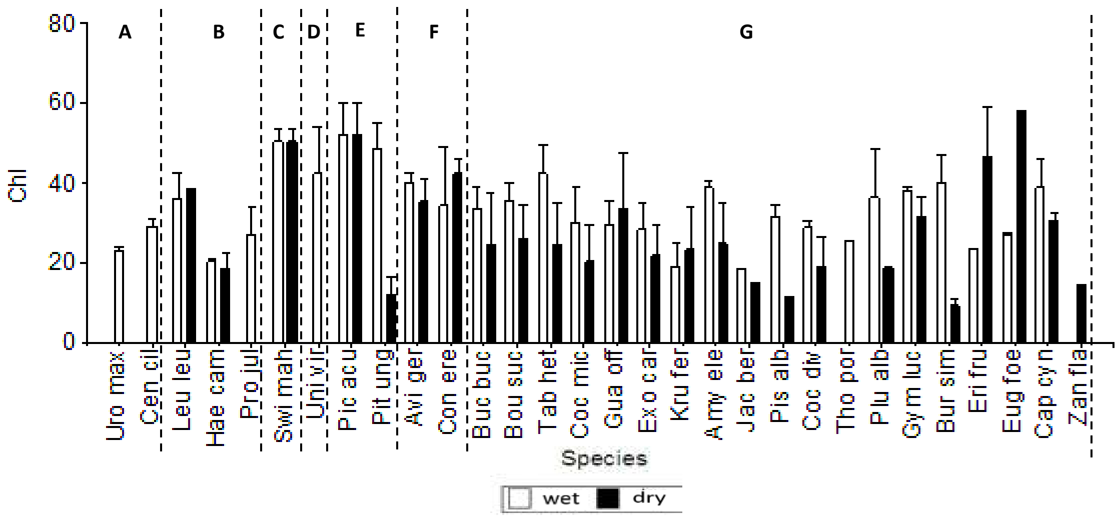

Figure 9: Average total chlorophyll concentration by species obtained from field measurements using a chlorophyll meter, for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

3.2 Water Concentration

The leaf water concentration of the analyzed species ranged from 25-84% with an average of 49% (Figure 10 and Appendix X). Water concentration differed between species in the wet season ($P<0.0001$). Among the species analyzed, the exotic species *Urochloa maxima* (83.65%) is the species that differ from the majority of the species (Figure 10 and Appendix X).

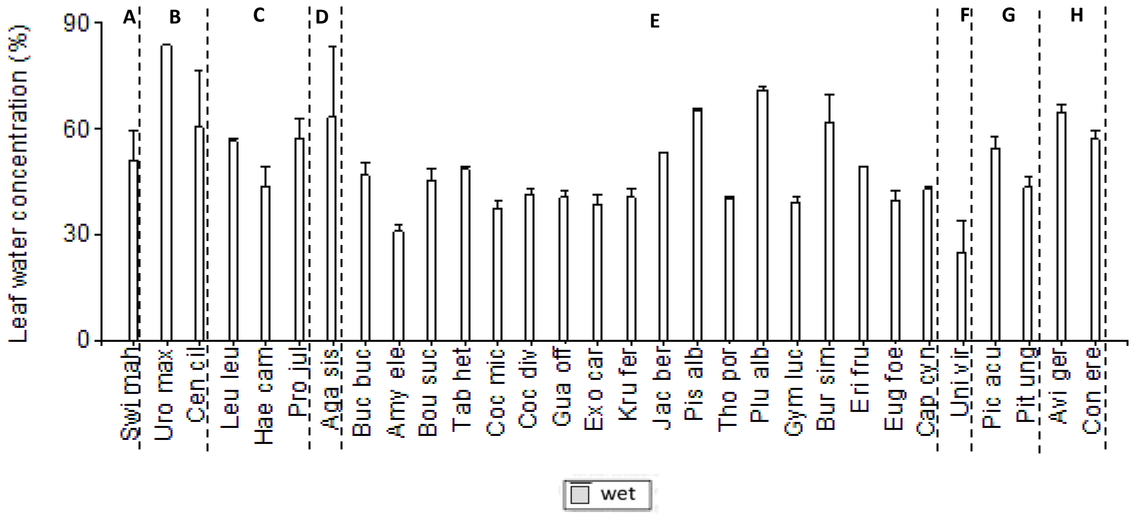

Figure 10: Average water concentration by species for the wet season. The error bars represent the standard error. Star represent significantly different species. A= exotic species, B= exotic grassess, C= exotic legumes, D= exotic legume, E= native species, F= native grass, G= native legumes, H= native mangrove.

3.3 Nitrogen concentration

Mean nitrogen concentrations ranged from 0.36-2.54 µmol/m² for the wet season, and 0.41-3.34 µmol/m² for the dry season (Figure 11 and and Appendix Y). Nitrogen concentration differed among species in both seasons (P<0.0001). In both seasons, the exotic N-fixing species *Prosopis juliflora* and *Leucaena leucocephala* had greater N concentration than all other species (P =<0.001). Average N concentration in dry season was 0.36 µmol/m² higher than the wet season (P < 0.001) (Figure 11 and Appendix Y). Exotic legumes averaged 0.17 µmol/m² higher N concentrations than native legumes (P=0.008).

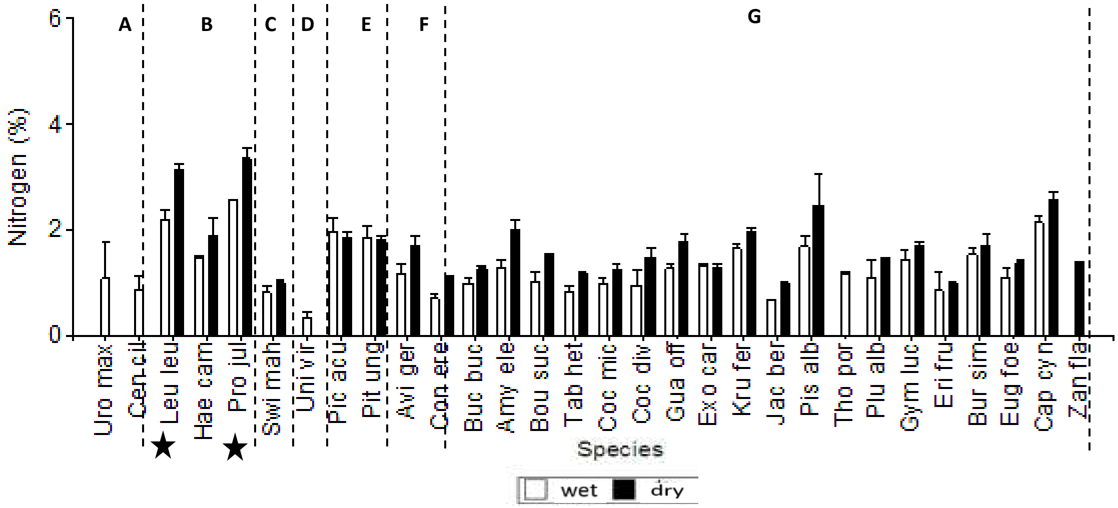

Figure 11: Average total nitrogen concentration by species for both seasons. The error bars represent the standard error. Star represent significantly different species. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

3.4 Reflectance

3.4.1 Reflectance of Wavelengths Associated with Pigments

The wavelengths selected for pigments, 470nm (Carotenoids), 652 nm (Chl-B), and 665 nm (Chl-A), did not differ in reflectance among species ($P > 0.05$ for all comparisons; Figures 12, 13, 14 and Appendix E, F, G). Average 470 nm reflectance in wet season was 4.49% higher than dry season ($P < 0.04$). In contrast, there was no seasonal effect for the wavelengths 652nm and 665nm.

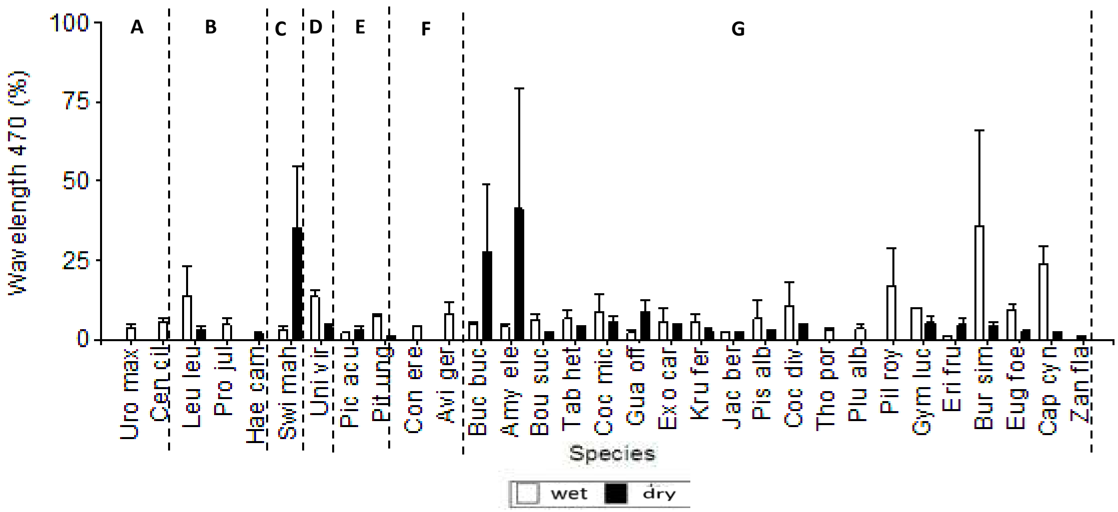

Figure 12: Average reflectance for wavelength 470 (Carotenoids) for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species. Wet season reflectance was 4.49% higher than in the dry season.

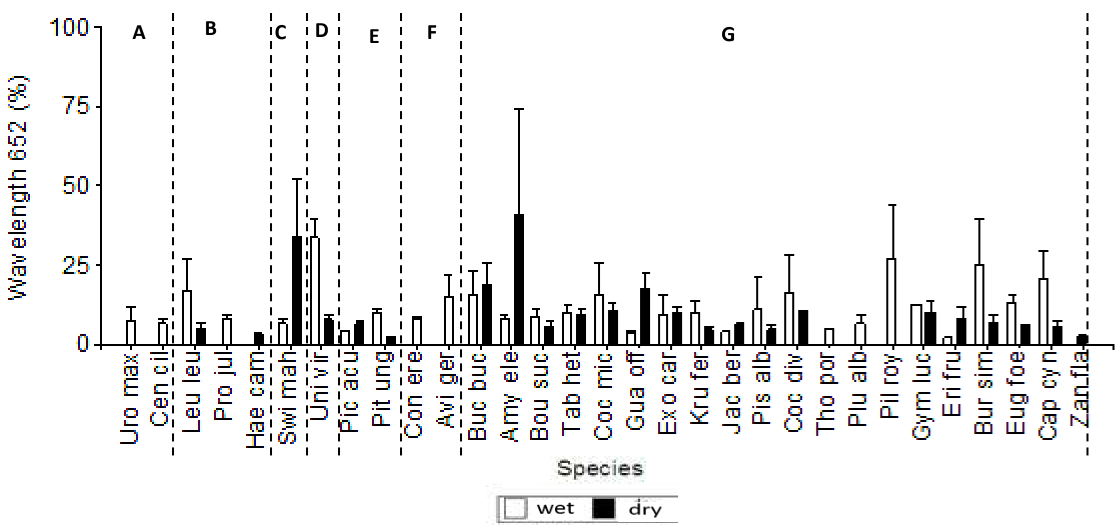

Figure 13: Average reflectance for wavelength 652 (Chl-B), for both seasons. The error bars represent the standard error. A= exotic grasses, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

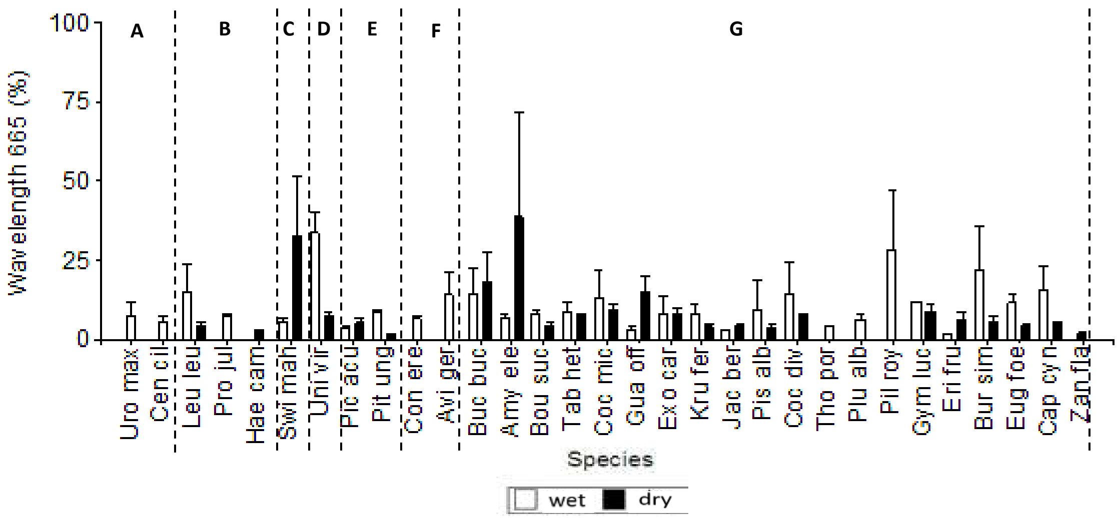

Figure 14: Average reflectance for wavelength 665 (Chl-A), for both seasons. The error bars represent the standard error. A= exotic grasses, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

3.4.2 Water reflectance

Among the seven wavelengths recommended in the literature (see Methods) for the analysis of leaf water concentration, only 1180 and 1190nm varied among species (Figure 15, 16 and Appendix N, O), and only in the wet season (P = 0.0421) (Table 2). Reflectance values ranged from 23.6-86.05% at 1180 nm and 23.6- 88.1% at 1190 nm. *Gymnanthes lucida* and *Capparis cynophallophora* had the highest average water reflectances and *Urochloa maxima* and *Thouinia portoricensis* had the lowest reflectances for both wavelengths. There was no seasonal effect on any of the water reflectance wavelengths studied. There was no difference between exotic and native legumes for wavelength 1180 or 1190 nm in either season.

Table 2: P-values for water reflectance wavelength selected for the wet and dry season. The (*) indicates wavelengths with statistically significant variability.

Wavelength (nm)	year	P-value
960	2010	0.2382
980	2010	0.0804
1180*	**2010**	**0.0478**
1190*	**2010**	**0.0421**
1530	2010	0.3396
1600	2010	0.2233
1720	2010	0.4550
960	2013	0.6657
980	2013	0.6194
1180	2013	0.7422
1190	2013	0.7615
1530	2013	0.5621
1600	2013	0.7360
1720	2013	0.8596

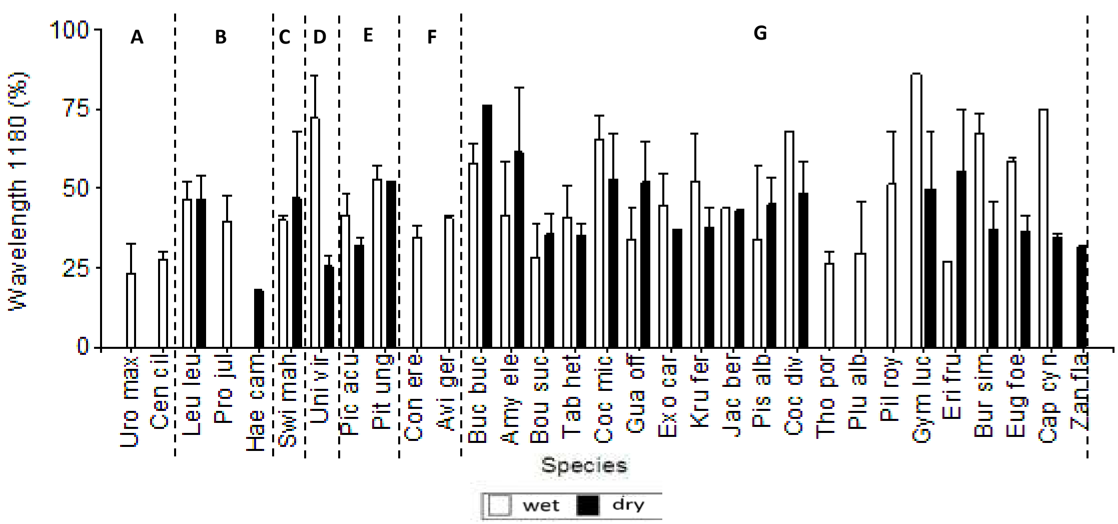

Figure 15: Average of the reflectance values of the wavelength 1180 nm per species, for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

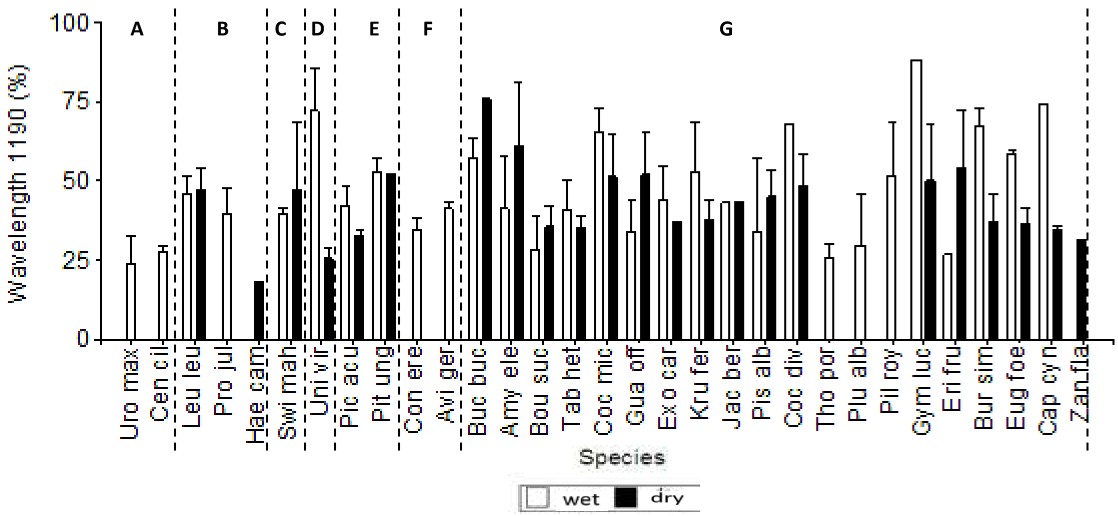

Figure 16: Average of the reflectance values of the wavelength 1190 nm per species, for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

3.4.3 Nitrogen Reflectance

Similar to the results above for water, only two of eight wavelengths recommended to study reflectance related to leaf N concentration showed any differences among species and only in the wet season (Figure 17, 18 and Appendix P, Q). These were the wavelengths 1192 nm and 1225 nm where reflectance ranged from 21.02-78.70% and 24.58-93.92% (P=0.04 and P=0.04). *Gymnanthes lucida* had the highest reflectance at both wavelengths (78.7 and 93.9%), and *Urochloa maxima* had the lowest (21.02 and 24.58%). There was no seasonal effect on any of the nitrogen reflectance wavelengths studied (P >0.20). There was no differences between exotic and native legumes for the wavelength 1192nm and 1225nm in either seasons.

Table 3: P-values for nitrogen reflectance wavelength selected for the wet and dry season. The (*) indicates wavelengths with statistically significant variability.

Wavelength	Year	P-value
762	2010	0.4939
813	2010	0.4196
817	2010	0.4186
984	2010	0.1743
1192*	**2010**	**0.0424**
1225*	**2010**	**0.0436**
1497	2010	0.2692
1730	2010	0.3385
762	2013	0.6292
813	2013	0.6337
817	2013	0.6230
984	2013	0.7542
1192	2013	0.6933
1225	2013	0.7140
1497	2013	0.6339
1730	2013	0.7881

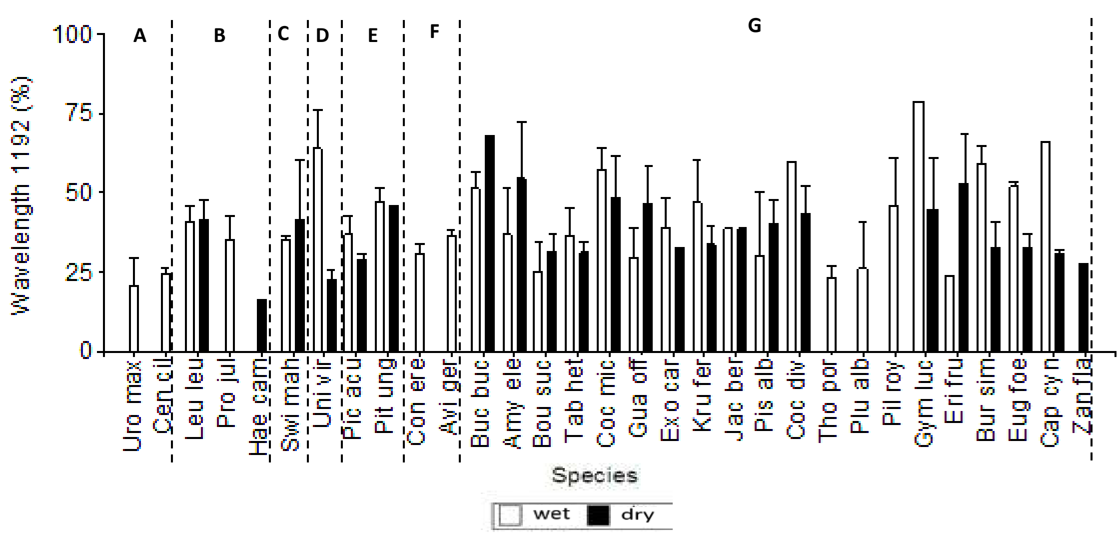

Figure 17. Average reflectance at 1192 nm by species for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

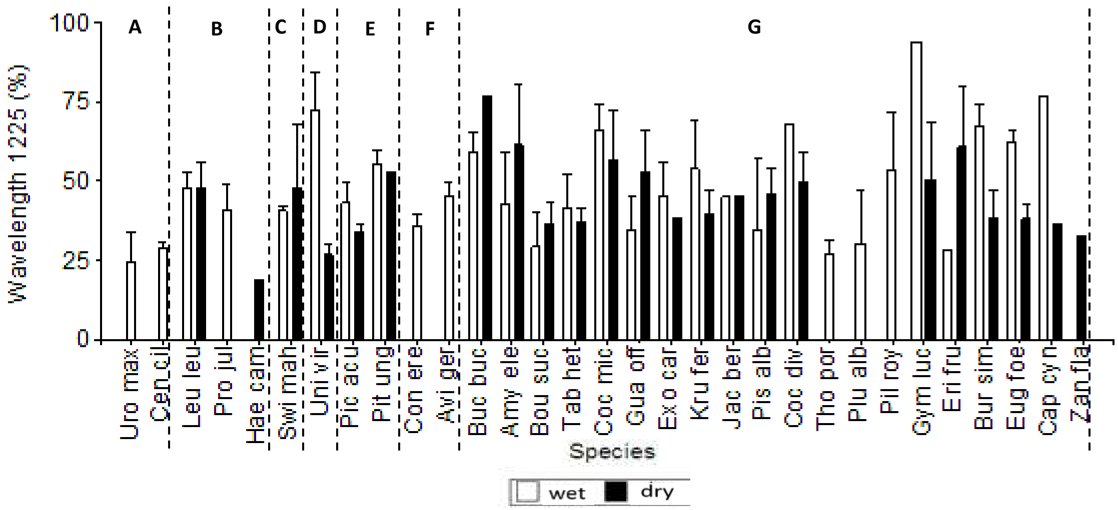

Figure 18. Average reflectance of wavelength 1225 nm by species for both seasons. The error bars represent the standard error. A= exotic grassess, B= exotic legumes, C= exotic species, D= native grass, E= native legumes, F= native mangrove, G= native species.

3.5 Correlations Between Leaf Constituents and Reflectance Wavelengths

3.5.1 Leaf Pigments Correlations

There were very strong positive correlations between the concentrations of Chl-A, Chl-B, and carotenoids measured in the lab (Table 4 and Appendix Z). There were also strong correlations in reflectance among wavelengths associated with these pigments (470, 652, and 665 nm). However, there were no correlations between either Chl-A or Chl-B concentrations and reflectance of wavelengths associated with chlorophyll (652 and 665 nm) or with total chlorophyll measured in the field with the chlorophyll meter (Table 4 and Appendix Z). Similarly, carotenoid concentrations were not correlated with reflectance at 470 nm (Table 4 and Appendix Z). Chlorophyll meter measurements also did not correlate with chlorophyll wavelength reflectance.

Table 4. P-values and r-values of Spearman correlation tests among leaf pigments (Chl-A, Chl-B, carotenoids and total Chl) and the selected wavelengths.

Variables	r-value	P-value
Chl-A vs Chl-B	0.88	<0.001
Chl-A vs Carotenoids	0.85	<0.001
Chl-A vs Total Chl	0.09	0.32
Chl-A vs W665	<0.001	0.52
Chl-B vs Carotenoids	0.81	<0.001
Chl-B vs Total Chl	0.09	0.33
Chl-B vs W 652	<0.001	0.39
Carotenoids vs W470	<0.001	0.75
Total Chl vs W652	0.02	0.38
Total Chl vs W665	0.02	0.48

3.5.2 Leaf Water correlations

Leaf water concentration was weakly negatively correlated with the reflectance of the wavelengths 1180 and 1190 nm (Table 5 and Appendix Z) but was not correlated with the other wavelengths associated with leaf water concentration. However, the reflectance of all the wavelengths proposed to be related to leaf water concentration was strongly correlated with each other.

Table 5. P-values and r-values of the Spearman correlation tests among leaf water concentration and reflectance of the selected wavelengths associated with leaf water concentration.

Variable	r-value	P-value
Water cont. vs W960	-0.21	0.07
Water cont. vs W980	-0.18	0.13
Water cont. vs W1180	**-0.24**	**0.04**
Water cont. vs W1190	**-0.24**	**0.04**
Water cont. vs W1530	-0.18	0.14
Water cont. vs W1600	-0.17	0.14
Water cont. vs W1720	-0.12	0.30

3.5.3 Leaf Nitrogen correlations

Leaf N concentration had no correlation with the wavelengths 762, 813, 817, 984, 1192, 1497, 1730, and 1225nm (Table 6 and Appendix Z). All the N wavelengths had a strong positive correlation among each other.

Table 6. Shows P-values and r-values of the Spearman correlation test for among leaf N concentration and the reflectance of selected wavelengths associated with N concentration.

Variable	r-value	P-value
N vs W762	0.03	0.78
N vs W813	0.01	0.95
N vs W817	0.01	0.95
N vs W984	<0.001	0.88
N vs W1192	<0.001	0.99
N vs W1497	0.03	0.74
N vs W1730	0.02	0.83
N vs W1225	<0.0001	0.98

4.0 Discussion

4.1 Pigment patterns

Our results demonstrated that the exotic legumes *Leucaena leucocephala* and *Prosopis juliflora* were the species most likely to be differentiated from others in terms of leaf constituents, having the greatest average concentrations of Chl-A, Chl-B, carotenoids, and leaf N (Figures 6-8, 11 and Appendix B, C, D, Y). However, these distinctions did not hold for hyperspectral reflectance patterns. These species differ from native species by being nitrogen fixers and are dominant in degraded areas (Wolfe & Van Bloem, 2012). Based on Pellegrini et al., (2016), these characteristics give them an advantage against non-legume species in disturbed areas where nitrogen is the major limitation in plant productivity. Guánica Dry Forest has a high total amount of nitrogen (9100 kg/ha) when compared with wet forests in Puerto Rico and Costa Rica. However, it has been reported that post-agricultural successional forests where legume species like *Leucaena leucocephala* were present in the area have higher soil nitrogen concentrations than primary forest where there is no *Leucaena leucocephala* (Erickson et al., 2002; Murphy and Lugo, 1986b).

Our results demonstrated that not all the legume species had higher values of pigment concentration. In the wet season, which showed some differences among species for Chl-A concentration and among exotic and native legumes, the exotic legume species *Haematoxylum campechianum* had the lowest median value of 5.32 µg/m, followed by native legume species *Pithecellobium unguis-cati* with mean value of 8.91 µg/m and *Pictetia aculeata* with a mean value of 10.47 µg/m. In the dry season, which showed no difference among exotic and native legume, the exotic legume species *Haematoxylum campechianum* had the lowest median value of 4.13 µg/m, followed by native legume species *Pithecellobium unguis cati* with a mean value of 11.61 µg/m, and *Pictetia aculeata* with a mean value of 13.10 µg/m. As Herridge et al (2008) reported, not all legumes have the same N-fixing efficiency, and so those may be species that are less efficient. Our results indicate similar Chl-A, Chl-B, and carotenoid concentrations for native legume and non-legume species. This pattern may be related to the principle of persistence, whereby the dry forest tree species all respond to common stress factors present.

The radiance in the visible range is mostly absorbed by vegetation, which thereby reduces reflectance. Due to the high absorbance by pigments in the visible spectrum, the pigment reflectance analysis had no differences between species and no seasonal effect. Similar results were reported by Clark et al. (2005) and Ollinger (2011). Blackburn (1999) demonstrated positive correlations between carotenoids concentrations and reflectance in wavelength 470nm. However, our results indicate no correlation between pigment concentration and reflectance, mostly because our carotenoids concentrations when converted to mg m^{-2} (2.63-12.35 mg m^{-2}) were lower than the concentrations (80-1447 mg m^{-2}) reported in his research. As Asner, et al., (2008) emphasized, low concentrations of leaf constituents reduce the ability to find correlations with reflectance data. This effect may preclude the use of the visible range reflectance for future species assessment techniques.

4.2 Water patterns

Tropical dry forests are known for having low average annual rainfall and in some cases high variability in the timing and amount of seasonal rainfall (Murphy and Lugo, 1986a). Drought stress promotes adaptation in plants including succulent and different photosynthetic pathways that conserve water (CAM, C4). The exotic grass species *Urochloa maxima* and *Cenchrus ciliaris* both had higher leaf water concentrations that were higher than the native grass species *Uniola virgata*. Our results were consistent with the results of Sims & Gamon (2002), who mentioned that plants with high leaf water concentration do not seem to have high pigment concentrations. Similarly, species with high leaf water concentration did not have high values of leaf N concentration. Water is the most abundant chemical in leaf and therefore has both direct and indirect effects on leaf reflectance, but in our case the negative relationship between reflectance at some water-sensitive wavelengths and leaf water concentration appears to be related to water conservation strategies at the leaf level.

Our data showed that from the selected wavelengths for water concentration, only 1180 and 1190 nm are sensitive to patterns in reflectance among species. These wavelengths are in the NIR region proposed for species separability at leaf scales (Clark et al., 2005). Asner & Vitousek (2005) and Kokaly et al. (2009) demonstrated positive correlations between leaf water concentration and reflectance for species of trees in tropical, deciduous and coniferous forests but there is great deal more variation in functional groups and leaf physiology from conifers to tropical evergreens than within a single dry forest. We also found that leaf water concentration had weak negative correlations with the reflectance of two of the recommended wavelengths sensitive to water (1180, and 1190). It is possible that stronger correlations were not found because many of our species had low leaf water concentration, where studies from other systems contained a much broader range of leaf water concentration (Asner & Vitousek, 2005; Asner & Martin, 2008; Blackburn, 1999; Castro-Esau et al., 2006; Kokaly et al., 2009).

4.3 Nitrogen patterns

For both seasons, the exotic legume species *Prosopis juliflora* and *Leucaena leucocephala* had higher leaf N concentrations than native legume and non-legume species as result of their ability to fix atmospheric nitrogen as ammonia (NH_3) (Asner & Vitousek, 2005; Herridge et al., 2008; Hietz et al., 2011). There was a seasonal effect on leaf N concentrations, where the wet season had greater leaf nitrogen concentrations (Figure 11). Our results indicate that the wavelengths 1192 and 1225 nm were best suited to distinguish variability between species during the wet season. These two wavelengths were in the same spectral region as the most discriminatory wavelengths for water reflectance (1180 and 1190 nm). It is notable that both sets of wavelength were only useful to identify species differences in the wet season and that neither correlated well with leaf N content.

One issue that must be resolved when using hyperspectral data to attempt to identify species in the field is to determine which wavelengths will provide the best ability to discriminate among trees of various species. Based on our results the wavelength range of 1180-1225 nm is the region that has the most variability of nitrogen and leaf water concentration for plant species of the Caribbean tropical dry forest. Wavelengths associated with pigments appear to provide little ability to discern trees of various species.

CHAPTER THREE

1.1 Relevance

Hyperspectral imagers are instruments that measure the complete spectrum of reflected solar energy for each pixel of spatial coverage. These technologies have demonstrated the power to provide ecological information that is unavailable with other technologies (Ustin et al., 2004). Previous studies have shown positive correlations between leaf reflectance and leaf constituents like pigments, water, and nitrogen for tropical and temperate forest ecosystems (Asner & Vitousek, 2005; Asner & Martin, 2008; Blackburn, 1999; Castro-Esau et al., 2006; Kokaly et al., 2009). Nonetheless, these hyperspectral data do not reflect the leaf constituent concentrations obtained from the species of the Guánica Dry Forest. Although we did not find any correlation between reflectance data and leaf pigment concentrations, we find a reflectance region that had high variability among species related to leaf water and nitrogen concentrations.

These results open new opportunities to classify exotic legume species. Based on previous research in the forest, one result of past human disturbance is the introduction of *Leucaena leucocephala* and *Prosopis juliflora* into disturbed areas (Molina Colon & Lugo et al., 2006; Wolfe & Van Bloem et al., 2012). These species have important qualities that can be used to restore the native dry forest, such as the ability to incorporate nitrogen into the soil, to serve as nurse trees, and to suppress the growth of exotic grasses (Wolfe & Van Bloem, 2012). According to our results, *Leucaena leucocephala* is one of the species with a high concentration of pigments and nitrogen. While our results suggest that hyperspectral imaging may have difficulty in identifying among native species, the instruments would be useful to classify species like *Leucaena leucocephala* in tropical dry forests, as well as a way to identify disturbed areas in dry forests.

This study would have been strengthened by increasing the number of individuals sampled in both seasons to improve seasonal analyses and statistical power. During our field work, one of the major concerns was the preservation of vegetative material in the field. The use of liquid nitrogen in the field would improve vegetation sample preservation during the data collection, but there were no sources for liquid N within a logistically feasible distance. Liquid nitrogen is better at stopping any possible degradation in the vegetation samples than ice and thereby obtains better pigment preservation.

I would increase the selection of wavelength peaks selected for each of the leaf constituents as a means to get more information about the correlations between leaf components and wavelengths from the entire electromagnetic spectrum. The increase in the number of wavelengths recommended for each of the leaf constituents would help identify more intervals with high variability among tree species. The results obtained in this research can be used to improve the understanding and forecasting of climate change, land use change and invasive species impacts of the Guánica Dry Forest. Projects like the NEON network will gather hyperspectral data to achieve their primary goal to understand climate change across the nation. The Guánica Dry Forest hosts one of the NEON network stations.

Future studies on hyperspectral data in dry forests should collect spectral and vegetative data from all of the exotic species present in the forests. This would increase the spectral library of the forest and improve our knowledge on the differences between exotic and native species. We did not have the opportunity to collect samples from the majority of the exotic tree species present in the forest reserve, although the three species we did sample comprised roughly 80% of all exotic stems. Obtaining spectral information from those un-sampled exotic species would be worthwhile. To understand the effects of drought stress on the spectral reflectance of Guánica Dry Forest native and exotic tree species, we should replicate our research in other forest reserves that share similar tree species composition.

The Maricao and Susúa Forest reserves are in the same geographic region as the Guánica Dry Forest and share trees species composition. However, they have differences in precipitation and soil types that create different forest structures. These characteristics might make the detection of drought stress effects on trees species reflectance possible. Using reserves with similar tree species compositions and different soil types and rainfall, we could deepen our study of the effects of other leaf constituents like nitrogen and phosphorous on reflectance. I would be interested to know the effects of leaf phosphorous concentration because the lack of this element causes strong nutritional deficiencies in trees from the Guánica Dry Forest Reserve, and it is has been identified as a major limiting factor (Murphy and Lugo, 1986b) that can have a significant influence on leaf reflectance (Asner & Martin et al., 2008; Kokaly et al. 2009; Porder et al., 2005; Sánchez-Azofeifa et al., 2009).

Another interesting topic to study in the future is the effect of exotic legume species like *Leucaena leucocephala* and *Prosopis juliflora* on native species reflectance. For this, we would need to collect data from tree species in mature forests and secondary forests where we find a mix of native and exotic legume species. We may subsequently discover how much exotic legume species alter the development of native species. We can also learn how native species from the Guánica Dry Forest react to the addition of N into the soil. If some native species respond better than others, then we can predict what the species composition of a disturbed forest would be if it were restored with exotic legume species like *Leucaena leucocephala* and *Prosopis juliflora*, as is ongoing in the Guánica Dry Forest Reserve.

2.1 Conclusion

The results from this study demonstrated that there were no correlations between leaf constituents (Chl-A, Chl-B, carotenoids, and leaf nitrogen concentration) and leaf reflectance of the tropical tree species selected for this study. This outcome is attributed to low concentrations of pigments and nitrogen in leaf samples. Also, the high absorbance in the visible region affects the reflectance, precluding the use of the visible range reflectance for species assessment techniques. For Chl-A, Chl-B, and carotenoid concentrations only the exotic legume species *Leucaena leucocephala* and *Prosopis juliflora* stood apart from non-legume species in both seasons and native legume in the wet season. The remarkable difference of the exotic species is likely due to their ability to fix nitrogen. The small variations between pigment concentrations among native species hindered the classification of these native species with a hyperspectral imager using the visible range.

Out of all of the tree species collected for this research, only grass species displayed a marked difference in leaf water concentration. This effect was attributed to major physiological differences that fibrous plants had compared to non-fibrous plants. Based on our results, we conclude that leaf reflectance variability for nitrogen and water wavelengths was more distinct during the wet season. The results from the analysis of nitrogen and water reflectance showed that the wavelength range of 1180 to 1225nm was the interval that has the highest variability for nitrogen and leaf water reflectance in the tree species of the forests.

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Appendix A

Normality test

Shapiro-Wilks

Variable	n	Median	S.D.	W*	p-value
RDUO_ChlA Concentration	144	0.00	2.85	0.98	0.3187
RDUO_ChlB Concentration	144	0.00	1.91	0.77	<0.0001
RDUO_Car. Concentration	144	0.00	1.32	0.98	0.2049
RDUO_Inter 470	137	0.00	11.87	0.72	<0.0001
RDUO_Inter 652	137	0.00	11.38	0.82	<0.0001
RDUO_Inter 665	137	0.00	11.24	0.81	<0.0001
RDUO_Inter 762	133	0.00	16.92	0.98	0.1729
RDUO_Inter 813	133	0.00	17.03	0.98	0.2142
RDUO_Inter 817	133	0.00	17.21	0.98	0.1748
RDUO_Inter 960	133	0.00	16.70	0.98	0.4050
RDUO_Inter 980	133	0.00	15.57	0.98	0.2941
RDUO_Inter 984	133	0.00	16.57	0.99	0.7125
RDUO_Inter 1180	132	0.00	15.82	0.99	0.8212
RDUO_Inter 1190	132	0.00	15.89	0.99	0.8270
RDUO_Inter 1192	132	0.00	14.22	0.99	0.8311
RDUO_Inter 1225	132	0.00	16.15	0.99	0.8145
RDUO_Inter 1600	133	0.00	14.44	0.95	<0.0001
RDUO_Inter 1730	132	0.00	14.24	0.95	0.0010
RDUO_Inter 1497	132	0.00	13.53	0.88	<0.0001
RDUO_Inter 1530	127	-0.79	17.53	0.98	0.2788
RDUO_Inter 1720	132	0.00	13.44	0.94	<0.0001
RDUO_Chl meter	145	0.00	11.83	0.96	0.0032
RDUO_Leaf water con.	88	0.00	7.73	0.91	<0.0001
RDUO_Nitrogen	161	0.00	0.60	0.94	<0.0001

Shapiro-Wilks

Variable	n	Median	S.D.	W*	p-value
RDUO_LOG10_ChlA Concentrat..	144	0.00	0.15	0.99	0.8796
RDUO_LOG10_ChlB Concentrat..	144	0.00	0.11	0.98	0.5318
RDUO_LOG10_Car. Concentrat..	144	0.00	0.11	0.99	0.8167
RDUO_LOG10_Inter 470	137	0.00	0.35	0.94	<0.0001
RDUO_LOG10_Inter 652	137	0.00	0.30	0.97	0.0791
RDUO_LOG10_Inter 665	137	0.00	0.31	0.97	0.0274
RDUO_LOG10_Inter 762	133	0.00	0.19	0.98	0.3679
RDUO_LOG10_Inter 813	133	0.00	0.19	0.97	0.1418
RDUO_LOG10_Inter 817	133	0.00	0.19	0.97	0.1517
RDUO_LOG10_Inter 960	133	0.00	0.18	0.97	0.0600
RDUO_LOG10_Inter 980	133	0.00	0.18	0.97	0.0381
RDUO_LOG10_Inter 984	133	0.00	0.17	0.97	0.0730
RDUO_LOG10_Inter 1180	132	0.00	0.18	0.96	0.0081
RDUO_LOG10_Inter 1190	132	0.00	0.18	0.96	0.0100
RDUO_LOG10_Inter 1192	132	0.00	0.18	0.96	0.0076
RDUO_LOG10_Inter 1225	132	0.00	0.18	0.96	0.0081
RDUO_LOG10_Inter 1497	132	0.00	0.25	0.98	0.3269
RDUO_LOG10_Inter 1530	127	0.00	0.20	0.98	0.4401
RDUO_LOG10_Inter 1600	133	0.00	0.22	0.98	0.6217
RDUO_LOG10_Inter 1720	132	0.00	0.21	0.97	0.1221
RDUO_LOG10_Inter 1730	132	0.00	0.22	0.98	0.6567
RDUO_LOG10_Chl meter	145	0.00	0.19	0.98	0.2627
RDUO_LOG10_Leaf water con...	88	0.00	0.08	0.84	<0.0001
RDUO_LOG10_Nitrogen	161	0.00	0.10	0.93	<0.0001

Appendix B

ANOVA table for Chl-A, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
ChlA Concentration	79	0.72	0.56	33.96

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1168.96	28	41.75	4.52	<0.0001
Species	1168.96	28	41.75	4.52	<0.0001
Error	461.32	50	9.23		
Total	1630.29	78			

Test:Tukey Alpha=0.05 MSD=11.35132

Error: 9.2265 DF: 50

Species	Medians	n	S.E.			
Haematoxylum campechianum	5.32	1	3.04	A		
Avicennia germinans	5.82	4	1.52	A		
Conocarpus erectus	5.89	3	1.75	A		
Erithalis fructicosa	5.96	1	3.04	A		
Bucida buceras	6.52	5	1.36	A		
Cenchrus ciliaris	6.66	3	1.75	A		
Bourreria succulenta	6.76	4	1.52	A		
Guaiacum officinale	6.91	4	1.52	A		
Krugiodendrum ferreum	7.12	3	1.75	A		
Uniola virgata	7.19	1	3.04	A		
Bursera simaruba	7.20	3	1.75	A		
Plumeria alba	7.63	2	2.15	A		
Exostema caribaeum	7.68	4	1.52	A		
Jacquinia berteroi	8.20	1	3.04	A	B	
Coccoloba microstachia	8.65	3	1.75	A	B	
Amyris elemifera	8.67	2	2.15	A	B	
Pisonia albida	8.71	2	2.15	A	B	
Urochloa maxima	8.82	2	2.15	A	B	
Swietenia mahogany	8.89	4	1.52	A	B	
Pithecellobium unguis cati..	8.91	3	1.75	A	B	
Thouinia portoricensis	8.94	2	2.15	A	B	
Tabebuia heterophylla	9.18	3	1.75	A	B	
Coccoloba diversifolia	9.35	3	1.75	A	B	
Capparis cynophallophora	9.93	3	1.75	A	B	
Pictetia aculeata	10.47	3	1.75	A	B	
Eugenia foetida	11.31	2	2.15	A	B	
Gymnanthes lucifera	11.32	3	1.75	A	B	
Leucaena leucocephala	19.53	3	1.75		B	C
Prosopis juliflora	26.13	2	2.15			C

($p > 0.05$)

Nested ANOVA table, Chl-A, exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
ChlA Concentration	12	0.80	0.69	31.12

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	573.17	4	143.29	7.01	0.0135
species/species>status	280.62	1	280.62	13.73	0.0076
species>status	292.54	3	97.51	4.77	0.0407
Error	143.05	7	20.44		
Total	716.22	11			

Test:Tukey Alfa=0.05 DMS=6.17163

Error: 20.4360 df: 7

status	Mean	n	S.E		
native legume	9.69	6	1.85	A	
exotic legume	16.99	6	2.04		B

ANOVA table for Chl-A, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
ChlA Concentration	65	0.61	0.36	44.62

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	790.77	25	31.63	2.47	0.0055
Species	790.77	25	31.63	2.47	0.0055
Error	499.59	39	12.81		
Total	1290.36	64			

Test:Tukey Alpha=0.05 MSD=13.96525

Error: 12.8099 DF: 39

Species	Medians	n	S.E.		
Haematoxylum campechianum	4.13	1	3.58	A	
Krugiodendrum ferreum	4.57	4	1.79	A	
Avicennia germinans	4.67	2	2.53	A	
Erithalis fructicosa	4.68	2	2.53	A	
Bursera simaruba	4.90	1	3.58	A	B
Exostema caribaeum	4.95	2	2.53	A	B
Uniola virgata	4.96	3	2.07	A	B
Tabebuia heterophylla	5.93	4	1.79	A	B
Swietenia mahogany	6.14	4	1.79	A	B
Pisonia albida	6.18	2	2.53	A	B
Bourreria succulenta	6.35	4	1.79	A	B
Bucida buceras	6.36	2	2.53	A	B
Gymnanthes lucifera	6.85	3	2.07	A	B
Amyris elemifera	7.08	2	2.53	A	B
Coccoloba microstachia	7.82	2	2.53	A	B
Eugenia foetida	8.12	4	1.79	A	B
Jacquinia berteroi	8.58	1	3.58	A	B
Coccoloba diversifolia	8.70	3	2.07	A	B
Conocarpus erectus	8.73	2	2.53	A	B
Guaiacum officinale	9.48	4	1.79	A	B
Capparis cynophallophora	9.86	2	2.53	A	B
Zanthoxylum flavum	11.11	1	3.58	A	B
Pithecellobium unguis cati..	11.61	2	2.53	A	B
Pictetia aculeata	13.10	3	2.07	A	B
Leucaena leucocephala	14.77	2	2.53	A	B
Prosopis juliflora	18.72	3	2.07		B

($p > 0.05$)

Nested ANOVA table, Chl-A, exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
ChlA Concentration	11	0.38	0.00	50.81

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	179.10	4	44.78	0.90	0.5168
species/species>status	16.66	1	16.66	0.34	0.5830
species>status	162.44	3	54.15	1.09	0.4213
Error	297.07	6	49.51		
Total	476.18	10			

Test:Tukey Alfa=0.05 DMS=10.42580

Error: 49.5121 df: 6

status	Mean	n	S.E	
native legume	12.35	5	3.21	A
exotic legume	12.54	6	3.18	A

ANOVA table, Seasonal, Chl-A

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
ChlA Concentration	58	0.69	0.54	27.26

ANOVA table (SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	397.53	19	20.92	4.47	<0.0001
Species	372.93	18	20.72	4.43	0.0001
year	24.61	1	24.61	5.26	0.0275
Error	177.90	38	4.68		
Total	575.43	57			

Test:Tukey Alpha=0.05 MSD=7.60113

Error: 4.6815 DF: 38

Species	Medians	n	S.E.			
Krugiodendrum ferreum	4.69	4	1.08	A		
Pictetia aculeata	4.99	2	1.53	A		
Erithalis fructicosa	5.14	2	1.53	A		
Uniola virgata	5.68	2	1.53	A		
Exostema caribaeum	5.87	4	1.08	A		
Bourreria succulenta	6.65	6	0.88	A	B	
Swietenia mahogany	6.84	6	0.88	A	B	
Guaiacum officinale	6.84	4	1.08	A	B	
Bucida buceras	7.44	2	1.53	A	B	C
Tabebuia heterophylla	7.93	6	0.88	A	B	C
Pisonia albida	8.19	2	1.53	A	B	C
Bursera simaruba	8.29	1	2.18	A	B	C
Jacquinia berteroi	8.39	2	1.53	A	B	C
Eugenia foetida	9.71	4	1.08	A	B	C
Coccoloba diversifolia	10.78	4	1.08	A	B	C
Capparis cynophallophora	11.16	2	1.53	A	B	C
Coccoloba microstachia	11.82	1	2.18	A	B	C
Pithecellobium unguis cati..	14.02	2	1.53		B	C
Leucaena leucocephala	14.49	2	1.53			C

(p > 0.05)

Test:Tukey Alpha=0.05 MSD=1.15096

Error: 4.6815 DF: 38

year	Medians	n	S.E.		
2013	7.70	28	0.46	A	
2010	9.02	30	0.42		B

Appendix C

ANOVA table for Chl-B, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 ChlB Concentration	79	0.68	0.50	19.47

ANOVA Table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1.60	28	0.06	3.75	<0.0001
Species	1.60	28	0.06	3.75	<0.0001
Error	0.76	50	0.02		
Total	2.36	78			

Test:Tukey Alpha=0.05 MSD=0.46159

Error: 0.0153 DF: 50

Species	Medians	n	S.E.			
Haematoxylum campechianum	0.42	1	0.12	A		
Avicennia germinans	0.47	4	0.06	A		
Krugiodendrum ferreum	0.53	3	0.07	A		
Guaiacum officinale	0.54	4	0.06	A		
Conocarpus erectus	0.54	3	0.07	A		
Bourreria succulenta	0.54	4	0.06	A		
Bucida buceras	0.55	5	0.06	A		
Cenchrus ciliaris	0.57	3	0.07	A		
Bursera simaruba	0.59	3	0.07	A	B	
Plumeria alba	0.59	2	0.09	A	B	
Pithecellobium unguis cati..	0.60	3	0.07	A	B	
Amyris elemifera	0.61	2	0.09	A	B	
Jacquinia berteroi	0.61	1	0.12	A	B	
Coccoloba microstachia	0.62	3	0.07	A	B	
Swietenia mahogany	0.62	4	0.06	A	B	
Thouinia portoricensis	0.62	2	0.09	A	B	
Pisonia albida	0.64	2	0.09	A	B	
Pictetia aculeata	0.64	3	0.07	A	B	
Exostema caribaeum	0.65	4	0.06	A	B	
Tabebuia heterophylla	0.65	3	0.07	A	B	
Coccoloba diversifolia	0.65	3	0.07	A	B	
Capparis cynophallophora	0.66	3	0.07	A	B	
Uniola virgata	0.69	1	0.12	A	B	
Eugenia foetida	0.70	2	0.09	A	B	
Erithalis fructicosa	0.71	1	0.12	A	B	
Gymnanthes lucifera	0.74	3	0.07	A	B	
Urochloa maxima	0.76	2	0.09	A	B	C
Leucaena leucocephala	1.03	3	0.07		B	C
Prosopis juliflora	1.21	2	0.09			C

($p > 0.05$)

Nested ANOVA table, exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
LOG10 ChlB Concentration	12	0.77	0.65	23.36

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.85	4	0.21	6.02	0.0201
species/species>status	0.41	1	0.41	11.68	0.0112
species>status	0.44	3	0.15	4.13	0.0558
Error	0.25	7	0.04		
Total	1.10	11			

Test:Tukey Alfa=0.05 DMS=0.25696

Error: 0.0354 df: 7

status	Mean	n	S.E		
native legume	0.62	6	0.08	A	
exotic legume	0.89	6	0.08		B

ANOVA table for Chl-B, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 ChlB Concentration	65	0.55	0.27	22.68

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.94	25	0.04	1.94	0.0304
Species	0.94	25	0.04	1.94	0.0304
Error	0.76	39	0.02		
Total	1.70	64			

Test:Tukey Alpha=0.05 MSD=0.54323

Error: 0.0194 gl: 39

Species	Medians	n	S.E.		
Haematoxylum campechianum	0.39	1	0.14	A	
Krugiodendrum ferreum	0.45	4	0.07	A	
Avicennia germinans	0.47	2	0.10	A	B
Bursera simaruba	0.50	1	0.14	A	B
Exostema caribaeum	0.52	2	0.10	A	B
Pisonia albida	0.52	2	0.10	A	B
Tabebuia heterophylla	0.53	4	0.07	A	B
Amyris elemifera	0.56	2	0.10	A	B
Bourreria succulenta	0.56	4	0.07	A	B
Swietenia mahogany	0.57	4	0.07	A	B
Bucida buceras	0.58	2	0.10	A	B
Eugenia foetida	0.59	4	0.07	A	B
Uniola virgata	0.59	3	0.08	A	B
Conocarpus erectus	0.60	2	0.10	A	B
Coccoloba microstachia	0.61	2	0.10	A	B
Capparis cynophallophora	0.63	2	0.10	A	B
Erithalis fructicosa	0.63	2	0.10	A	B
Guaiacum officinale	0.64	4	0.07	A	B
Gymnanthes lucifera	0.65	3	0.08	A	B
Jacquinia berteroi	0.66	1	0.14	A	B
Coccoloba diversifolia	0.67	3	0.08	A	B
Pithecellobium unguis cati..	0.72	2	0.10	A	B
Pictetia aculeata	0.73	3	0.08	A	B
Zanthoxylum flavum	0.76	1	0.14	A	B
Leucaena leucocephala	0.80	2	0.10	A	B
Prosopis juliflora	1.00	3	0.08		B

($p > 0.05$)

Nested ANOVA table, Chl-B, exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
LOG10 ChlB Concentration	11	0.44	0.07	33.38

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.32	4	0.08	1.17	0.4087
species/species>status	0.03	1	0.03	0.47	0.5200
species>status	0.29	3	0.10	1.41	0.3285
Error	0.41	6	0.07		
Total	0.73	10			

Test:Tukey Alfa=0.05 DMS=0.38829

Error: 0.0687 df: 6

status	Mean	n	S.E	
native legume	0.72	5	0.12	A
exotic legume	0.73	6	0.12	A

ANOVA table, Seasonal, Chl-B

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 ChlB Concentration	58	0.64	0.45	14.77

ANOVA table (SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.53	19	0.03	3.48	0.0005
Species	0.52	18	0.03	3.60	0.0004
year	0.01	1	0.01	1.41	0.2417
Error	0.31	38	0.01		
Total	0.84	57			

Test:Tukey Alpha=0.05 MSD=0.31566

Error: 0.0081 DF: 38

Species	Medians	n	S.E.			
Krugiodendrum ferreum	0.41	4	0.04	A		
Pictetia aculeata	0.46	2	0.06	A	B	
Bourreria succulenta	0.55	6	0.04	A	B	C
Guaiacum officinale	0.55	4	0.04	A	B	C
Exostema caribaeum	0.57	4	0.04	A	B	C
Swietenia mahogany	0.58	6	0.04	A	B	C
Pisonia albida	0.59	2	0.06	A	B	C
Tabebuia heterophylla	0.61	6	0.04	A	B	C
Bucida buceras	0.62	2	0.06	A	B	C
Bursera simaruba	0.62	1	0.09	A	B	C
Uniola virgata	0.62	2	0.06	A	B	C
Jacquinia berteroi	0.63	2	0.06	A	B	C
Eugenia foetida	0.64	4	0.04	A	B	C
Capparis cynophallophora	0.70	2	0.06	A	B	C
Erithalis fructicosa	0.71	2	0.06	A	B	C
Coccoloba diversifolia	0.73	4	0.04	A	B	C
Coccoloba microstachia	0.77	1	0.09		B	C
Leucaena leucocephala	0.80	2	0.06			C
Pithecellobium unguis cati..	0.80	2	0.06			C

(p > 0.05)

Test:Tukey Alpha=0.05 MSD=0.04780

Error: 0.0081 DF: 38

year	Medians	n	S.E.	
2013	0.61	28	0.02	A
2010	0.64	30	0.02	A

(p > 0.05)

Appendix D

ANOVA table for carotenoids, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Car. Concentration	79	0.81	0.70	25.57

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	321.55	28	11.48	7.40	<0.0001
Species	321.55	28	11.48	7.40	<0.0001
Error	77.61	50	1.55		
Total	399.16	78			

Test:Tukey Alpha=0.05 MSD=4.65601

Error: 1.5523 DF: 50

Species	Medians	n	S.E.			
Haematoxylum campechianum	2.63	1	1.25	A		
Avicennia germinans	2.77	4	0.62	A		
Cenchrus ciliaris	3.17	3	0.72	A		
Conocarpus erectus	3.34	3	0.72	A		
Guaiacum officinale	3.40	4	0.62	A		
Erithalis fructicosa	3.47	1	1.25	A		
Bourreria succulenta	3.57	4	0.62	A		
Bucida buceras	3.59	5	0.56	A		
Uniola virgata	3.79	1	1.25	A		
Plumeria alba	3.85	2	0.88	A		
Krugiodendrum ferreum	4.16	3	0.72	A		
Pisonia albida	4.33	2	0.88	A		
Pictetia aculeata	4.49	3	0.72	A		
Bursera simaruba	4.52	3	0.72	A		
Pithecellobium unguis cati..	4.63	3	0.72	A		
Urochloa maxima	4.67	2	0.88	A		
Amyris elemifera	4.91	2	0.88	A		
Coccoloba microstachia	4.92	3	0.72	A		
Coccoloba diversifolia	4.93	3	0.72	A		
Capparis cynophallophora	4.99	3	0.72	A		
Exostema caribaeum	5.02	4	0.62	A		
Swietenia mahogany	5.16	4	0.62	A		
Tabebuia heterophylla	5.19	3	0.72	A		
Thouinia portoricensis	5.71	2	0.88	A		
Jacquinia berteroi	5.94	1	1.25	A		
Eugenia foetida	6.26	2	0.88	A		
Gymnanthes lucifera	6.95	3	0.72	A	B	
Leucaena leucocephala	11.18	3	0.72		B	C
Prosopis juliflora	12.35	2	0.88			C

($p > 0.05$)

Nested ANOVA table, carotenoids, exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Car. Concentration	12	0.85	0.77	27.13

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	162.84	4	40.71	10.24	0.0047
species/species>status	93.47	1	93.47	23.50	0.0019
species>status	69.37	3	23.12	5.81	0.0258
Error	27.84	7	3.98		
Total	190.68	11			

Test:Tukey Alfa=0.05 DMS=2.72273

Error: 3.9775 df: 7

status	Mean	n	S.E		
native legume	4.56	6	0.81	A	
exotic legume	8.72	6	0.90		B

ANOVA table for carotenoids, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Car. Concentration	65	0.57	0.29	36.07

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	154.45	25	6.18	2.05	0.0218
Species	154.45	25	6.18	2.05	0.0218
Error	117.73	39	3.02		
Total	272.18	64			

Test:Tukey Alpha=0.05 MSD=6.77926

Error: 3.0186 DF: 39

Species	Medians	n	S.E.		
Avicennia germinans	2.14	2	1.23	A	
Haematoxylum campechianum	2.39	1	1.74	A	B
Uniola virgata	2.61	3	1.00	A	B
Erithalis fructicosa	2.93	2	1.23	A	B
Pisonia albida	3.21	2	1.23	A	B
Krugiodendrum ferreum	3.48	4	0.87	A	B
Amyris elemifera	3.63	2	1.23	A	B
Bucida buceras	3.99	2	1.23	A	B
Bursera simaruba	4.07	1	1.74	A	B
Bourreria succulenta	4.09	4	0.87	A	B
Conocarpus erectus	4.20	2	1.23	A	B
Tabebuia heterophylla	4.25	4	0.87	A	B
Exostema caribaeum	4.47	2	1.23	A	B
Capparis cynophallophora	4.66	2	1.23	A	B
Coccoloba microstachia	4.86	2	1.23	A	B
Swietenia mahogany	5.12	4	0.87	A	B
Guaiacum officinale	5.19	4	0.87	A	B
Pithecellobium unguis cati..	5.40	2	1.23	A	B
Coccoloba diversifolia	5.65	3	1.00	A	B
Jacquinia berteroi	5.77	1	1.74	A	B
Eugenia foetida	5.77	4	0.87	A	B
Gymnanthes lucifera	6.00	3	1.00	A	B
Pictetia aculeata	6.00	3	1.00	A	B
Leucaena leucocephala	7.12	2	1.23	A	B
Prosopis juliflora	8.76	3	1.00	A	B
Zanthoxylum flavum	8.95	1	1.74		B

($p > 0.05$)

Nested ANOVA table, carotenoids, exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Car. Concentration	11	0.35	0.00	51.01

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	36.14	4	9.03	0.82	0.5584
species/species>status	5.27	1	5.27	0.48	0.5159
species>status	30.87	3	10.29	0.93	0.4817
Error	66.36	6	11.06		
Total	102.50	10			

Test:Tukey Alfa=0.05 DMS=4.92741

Error: 11.0593 df: 6

status	Mean	n	S.E	
native legume	5.70	5	1.52	A
exotic legume	6.09	6	1.50	A

ANOVA table, Seasonal, Chl-B

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Car. Concentration	58	0.65	0.48	22.50

ANOVA table (SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	82.25	19	4.33	3.79	0.0002
Species	82.22	18	4.57	4.00	0.0002
year	0.03	1	0.03	0.02	0.8805
Error	43.37	38	1.14		
Total	125.62	57			

Test:Tukey Alpha=0.05 MSD=3.75288

Error: 1.1412 DF: 38

Species	Medians	n	S.E.			
Uniola virgata	3.06	2	0.76	A		
Krugiodendrum ferreum	3.12	4	0.53	A		
Erithalis fructicosa	3.25	2	0.76	A	B	
Pictetia aculeata	3.30	2	0.76	A	B	
Bourreria succulenta	3.78	6	0.44	A	B	
Pisonia albida	3.82	2	0.76	A	B	
Guaiacum officinale	4.04	4	0.53	A	B	C
Exostema caribaeum	4.50	4	0.53	A	B	C
Bucida buceras	4.58	2	0.76	A	B	C
Swietenia mahogany	4.83	6	0.44	A	B	C
Tabebuia heterophylla	4.91	6	0.44	A	B	C
Capparis cynophallophora	5.00	2	0.76	A	B	C
Bursera simaruba	5.38	1	1.08	A	B	C
Jacquinia berteroi	5.86	2	0.76	A	B	C
Eugenia foetida	6.03	4	0.53	A	B	C
Coccoloba diversifolia	6.16	4	0.53	A	B	C
Coccoloba microstachia	6.58	1	1.08	A	B	C
Pithecellobium unguis cati..	6.99	2	0.76		B	C
Leucaena leucocephala	7.60	2	0.76			C

(p > 0.05)

Test:Tukey Alpha=0.05 MSD=0.56826

Error: 1.1412 DF: 38

year	Medians	n	S.E.	
2013	4.86	28	0.23	A
2010	4.90	30	0.21	A

(p > 0.05)

Appendix E

ANOVA table for W470, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 470	80	0.43	0.10	120.30

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model	3210.56	29	110.71	1.31	0.1951
species	3210.56	29	110.71	1.31	0.1951
Error	4213.90	50	84.28		
Total	7424.46	79			

Test:Tukey Alfa=0.05 DMS=34.11223

Error: 84.2780 df: 50

species	Medians	n	S.E.		
Erithalis fructicosa	1.50	1	9.18	A	
Pictetia aculeata	2.15	3	5.30	A	B
Guaiacum officinale	2.28	3	5.30	A	B
Jacquinia berteroi	2.45	1	9.18	A	B
Thouinia portoricensis	3.15	2	6.49	A	B
Swietenia mahogany	3.36	3	5.30	A	B
Urochloa maxima	3.49	3	5.30	A	B
Plumeria alba	3.57	3	5.30	A	B
Conocarpus erectus	4.01	3	5.30	A	B
Amyris elemifera	4.15	3	5.30	A	B
Prosopis juliflora	4.67	2	6.49	A	B
Bucida buceras	4.82	5	4.11	A	B
Cenchrus ciliaris	5.32	3	5.30	A	B
Exostema caribaeum	5.91	4	4.59	A	B
Krugiodendrum ferreum	5.97	3	5.30	A	B
Bourreria succulenta	6.41	4	4.59	A	B
Pisonia albida	6.45	2	6.49	A	B
Tabebuia heterophylla	6.53	4	4.59	A	B
Pithecellobium unguis cati..	7.31	3	5.30	A	B
Agave sisalana	7.70	2	6.49	A	B
Avicennia germinans	8.05	3	5.30	A	B
Coccoloba microstachia	8.66	3	5.30	A	B
Eugenia foetida	9.38	2	6.49	A	B
Gymnanthes lucifera	10.19	1	9.18	A	B
Coccoloba diversifolia	10.80	2	6.49	A	B
Leucaena leucocephala	13.45	3	5.30	A	B
Uniola virgata	13.49	2	6.49	A	B
Pilosocereus royeni	16.98	3	5.30	A	B
Capparis cynophallophora	23.68	2	6.49	A	B
Bursera simaruba	35.99	2	6.49		B

($p > 0.05$)

ANOVA table for W470, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 470	57	0.45	0.07	196.45

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6931.95	23	301.39	1.17	0.3332
Species	6931.95	23	301.39	1.17	0.3332
Error	8496.01	33	257.45		
Total	15427.96	56			

Test:Tukey Alpha=0.05 MSD=64.32543

Error: 257.4549 DF: 33

Species	Medians	n	S.E.	
Zanthoxylum flavum	1.18	1	16.05	A
Pithecellobium unguis cati..	1.57	1	16.05	A
Bourreria succulenta	2.06	3	9.26	A
Haematoxylum campechianum	2.34	1	16.05	A
Agave sisalana	2.39	1	16.05	A
Capparis cynophallophora	2.43	2	11.35	A
Pisonia albida	2.47	3	9.26	A
Jacquinia berteroi	2.60	1	16.05	A
Krugiodendrum ferreum	2.83	3	9.26	A
Eugenia foetida	3.04	3	9.26	A
Leucaena leucocephala	3.10	2	11.35	A
Pictetia aculeata	3.13	3	9.26	A
Tabebuia heterophylla	3.93	3	9.26	A
Uniola virgata	4.12	3	9.26	A
Exostema caribaeum	4.27	3	9.26	A
Bursera simaruba	4.48	4	8.02	A
Coccoloba diversifolia	4.61	2	11.35	A
Erithalis fructicosa	4.79	2	11.35	A
Gymnanthes lucifera	5.52	3	9.26	A
Coccoloba microstachia	5.82	3	9.26	A
Guaiacum officinale	8.78	2	11.35	A
Bucida buceras	27.32	2	11.35	A
Swietenia mahogany	35.28	4	8.02	A
Amyris elemifera	41.42	2	11.35	A

($p > 0.05$)

ANOVA table for W470, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 470	60	0.48	0.19	139.49

Cuadro de Análisis de la Varianza (SC tipo III)

F.V.	SS	DF	MS	F	p-value
Modelo.	2434.63	21	115.93	1.66	0.0855
species	2132.28	20	106.61	1.53	0.1285
year	302.36	1	302.36	4.33	0.0443
Error	2654.09	38	69.84		
Total	5088.72	59			

Test:Tukey Alfa=0.05 DMS=28.94945

Error: 69.8444 df: 38

species	Medians	n	S.E.		
Pictetia aculeata	2.13	2	5.91	A	
Pisonia albida	2.19	2	5.91	A	
Erithalis fructicosa	2.21	2	5.91	A	
Jacquinia berteroi	2.53	2	5.91	A	
Amyris elemifera	3.24	2	5.91	A	
Bourreria succulenta	3.27	4	4.18	A	
Swietenia mahogany	3.33	4	4.18	A	
Coccoloba microstachia	3.60	2	5.91	A	
Bucida buceras	3.83	2	5.91	A	
Tabebuia heterophylla	3.91	6	3.41	A	
Leucaena leucocephala	4.14	2	5.91	A	
Krugiodendrum ferreum	4.70	4	4.18	A	
Guaiacum officinale	5.16	4	4.18	A	
Pithecellobium unguis cati..	5.62	2	5.91	A	B
Exostema caribaeum	5.78	6	3.41	A	B
Agave sisalana	5.86	2	5.91	A	B
Eugenia foetida	6.25	4	4.18	A	B
Uniola virgata	8.38	2	5.91	A	B
Coccoloba diversifolia	11.07	2	5.91	A	B
Capparis cynophallophora	16.08	2	5.91	A	B
Bursera simaruba	34.43	2	5.91		B

(p > 0.05)

Test:Tukey Alfa=0.05 DMS=4.36833

Error: 69.8444 df: 38

year	Medians	n	S.E.		
2013	4.31	30	1.59	A	
2010	8.80	30	1.59		B

(p > 0.05)

Appendix F

ANOVA table for W652, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 652	80	0.40	0.06	35.61

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	3.73	29	0.13	1.17	0.3074
Species	3.73	29	0.13	1.17	0.3074
Error	5.49	50	0.11		
Total	9.22	79			

Test:Tukey Alpha=0.05 MSD=1.23165

Error: 0.1099 DF: 50

Species	Medians	n	S.E.	
Erithalis fructicosa	0.37	1	0.33	A
Guaiacum officinale	0.55	3	0.19	A
Jacquinia berteroi	0.61	1	0.33	A
Pisonia albida	0.61	2	0.23	A
Pictetia aculeata	0.65	3	0.19	A
Thouinia portoricensis	0.69	2	0.23	A
Urochloa maxima	0.77	3	0.19	A
Plumeria alba	0.77	3	0.19	A
Exostema caribaeum	0.77	4	0.17	A
Swietenia mahogany	0.79	3	0.19	A
Cenchrus ciliaris	0.79	3	0.19	A
Amyris elemifera	0.90	3	0.19	A
Conocarpus erectus	0.90	3	0.19	A
Prosopis juliflora	0.91	2	0.23	A
Bourreria succulenta	0.93	4	0.17	A
Krugiodendrum ferreum	0.93	3	0.19	A
Tabebuia heterophylla	0.96	4	0.17	A
Pithecellobium unguis cati..	1.01	3	0.19	A
Coccoloba microstachia	1.02	3	0.19	A
Agave sisalana	1.03	2	0.23	A
Bucida buceras	1.05	5	0.15	A
Coccoloba diversifolia	1.05	2	0.23	A
Leucaena leucocephala	1.07	3	0.19	A
Avicennia germinans	1.09	3	0.19	A
Gymnanthes lucifera	1.11	1	0.33	A
Eugenia foetida	1.11	2	0.23	A
Pilosocereus royeni	1.26	3	0.19	A
Capparis cynophallophora	1.27	2	0.23	A
Bursera simaruba	1.30	2	0.23	A
Uniola virgata	1.52	2	0.23	A

($p > 0.05$)

ANOVA table for W652, Dry season

Analysis of variance

Variable	N	R²	R² Aj	VC
LOG10 Inter 652	57	0.49	0.13	33.63

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.77	23	0.12	1.35	0.2092
Species	2.77	23	0.12	1.35	0.2092
Error	2.93	33	0.09		
Total	5.70	56			

Test:Tukey Alpha=0.05 MSD=1.19503

Error: 0.0889 DF: 33

Species	Medians	n	S.E.	
Pithecellobium unguis cati..	0.42	1	0.30	A
Zanthoxylum flavum	0.47	1	0.30	A
Haematoxylum campechianum	0.58	1	0.30	A
Pisonia albida	0.64	3	0.17	A
Krugiodendrum ferreum	0.66	3	0.17	A
Bourreria succulenta	0.71	3	0.17	A
Leucaena leucocephala	0.71	2	0.21	A
Agave sisalana	0.74	1	0.30	A
Eugenia foetida	0.75	3	0.17	A
Bursera simaruba	0.75	4	0.15	A
Capparis cynophallophora	0.76	2	0.21	A
Pictetia aculeata	0.80	3	0.17	A
Jacquinia berteroi	0.81	1	0.30	A
Erithalis fructicosa	0.88	2	0.21	A
Uniola virgata	0.90	3	0.17	A
Gymnanthes lucifera	0.96	3	0.17	A
Tabebuia heterophylla	0.98	3	0.17	A
Exostema caribaeum	0.99	3	0.17	A
Coccoloba microstachia	1.00	3	0.17	A
Coccoloba diversifolia	1.01	2	0.21	A
Swietenia mahogany	1.22	4	0.15	A
Guaiacum officinale	1.22	2	0.21	A
Bucida buceras	1.25	2	0.21	A
Amyris elemifera	1.38	2	0.21	A

ANOVA table for W652, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 652	62	0.31	0.00	36.83

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1.78	21	0.08	0.85	0.6426
Species	1.77	20	0.09	0.89	0.5958
year	0.02	1	0.02	0.25	0.6217
Error	3.97	40	0.10		
Total	5.75	61			

Test:Tukey Alpha=0.05 MSD=1.06593

Error: 0.0992 DF: 40

Species	Medians	n	S.E.	
Pisonia albida	0.38	2	0.22	A
Erithalis fructicosa	0.52	2	0.22	A
Pictetia aculeata	0.68	2	0.22	A
Bourreria succulenta	0.70	4	0.16	A
Jacquinia berteroi	0.71	2	0.22	A
Pithecellobium unguis cati..	0.72	2	0.22	A
Swietenia mahogany	0.76	4	0.16	A
Coccoloba microstachia	0.78	2	0.22	A
Amyris elemifera	0.82	2	0.22	A
Leucaena leucocephala	0.84	2	0.22	A
Krugiodendrum ferreum	0.84	4	0.16	A
Bucida buceras	0.84	2	0.22	A
Guaiacum officinale	0.85	4	0.16	A
Agave sisalana	0.91	2	0.22	A
Tabebuia heterophylla	0.92	6	0.13	A
Eugenia foetida	0.93	4	0.16	A
Exostema caribaeum	0.93	6	0.13	A
Capparis cynophallophora	1.06	2	0.22	A
Uniola virgata	1.12	3	0.18	A
Bursera simaruba	1.13	2	0.22	A
Coccoloba diversifolia	1.16	3	0.18	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=0.16177

Error: 0.0992 DF: 40

year	Medians	n	S.E.	
2013	0.82	32	0.06	A
2010	0.86	30	0.06	A

($p > 0.05$)

Appendix G

ANOVA table for W665, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 665	80	0.36	0.00	104.88

ANOVA table (SC type III)

F.V.	SS	DF	MS	F	p-value
Modelo.	3462.45	29	119.39	0.96	0.5417
species	3462.45	29	119.39	0.96	0.5417
Error	6242.35	50	124.85		
Total	9704.80	79			

Test:Tukey Alfa=0.05 DMS=41.51853

Error: 124.8471 df: 50

species	Medians	n	S.E.	
Erithalis fructicosa	1.95	1	11.17	A
Jacquinia berteroi	3.27	1	11.17	A
Guaiacum officinale	3.31	3	6.45	A
Pictetia aculeata	3.73	3	6.45	A
Thouinia portoricensis	4.05	2	7.90	A
Swietenia mahogany	5.66	3	6.45	A
Cenchrus ciliaris	5.85	3	6.45	A
Plumeria alba	6.20	3	6.45	A
Conocarpus erectus	6.76	3	6.45	A
Amyris elemifera	6.81	3	6.45	A
Prosopis juliflora	7.82	2	7.90	A
Urochloa maxima	7.83	3	6.45	A
Bourreria succulenta	7.90	4	5.59	A
Krugiodendrum ferreum	8.38	3	6.45	A
Exostema caribaeum	8.45	4	5.59	A
Pithecellobium unguis cati..	8.82	3	6.45	A
Tabebuia heterophylla	8.92	4	5.59	A
Pisonia albida	9.68	2	7.90	A
Agave sisalana	10.08	2	7.90	A
Eugenia foetida	11.66	2	7.90	A
Gymnanthes lucifera	12.04	1	11.17	A
Coccoloba microstachia	13.36	3	6.45	A
Coccoloba diversifolia	14.18	2	7.90	A
Avicennia germinans	14.27	3	6.45	A
Bucida buceras	14.66	5	5.00	A
Leucaena leucocephala	15.13	3	6.45	A
Capparis cynophallophora	15.85	2	7.90	A
Bursera simaruba	22.06	2	7.90	A
Pilosocereus royeni	28.10	3	6.45	A
Uniola virgata	33.66	2	7.90	A

($p > 0.05$)

ANOVA table for W665, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 665	57	0.43	0.04	144.82

ANOVA table(SC type III)

F.V.	SS	DF	MS	F	p-value
Modelo.	4947.36	23	215.10	1.09	0.4041
species	4947.36	23	215.10	1.09	0.4041
Error	6519.87	33	197.57		
Total	11467.24	56			

Test:Tukey Alfa=0.05 DMS=56.35010

Error: 197.5719 gl: 33

species	Medians	n	S.E.	
Pithecellobium unguis cati..	1.96	1	14.06	A
Zanthoxylum flavum	2.11	1	14.06	A
Haematoxylum campechianum	3.40	1	14.06	A
Pisonia albida	3.74	3	8.12	A
Krugiodendrum ferreum	3.91	3	8.12	A
Bourreria succulenta	4.31	3	8.12	A
Leucaena leucocephala	4.35	2	9.94	A
Capparis cynophallophora	4.60	2	9.94	A
Eugenia foetida	4.68	3	8.12	A
Agave sisalana	4.71	1	14.06	A
Jacquinia berteroi	4.74	1	14.06	A
Pictetia aculeata	5.45	3	8.12	A
Bursera simaruba	5.48	4	7.03	A
Erithalis fructicosa	6.31	2	9.94	A
Uniola virgata	7.65	3	8.12	A
Coccoloba diversifolia	7.87	2	9.94	A
Tabebuia heterophylla	7.94	3	8.12	A
Exostema caribaeum	8.43	3	8.12	A
Gymnanthes lucifera	8.73	3	8.12	A
Coccoloba microstachia	9.08	3	8.12	A
Guaiacum officinale	15.00	2	9.94	A
Bucida buceras	18.37	2	9.94	A
Swietenia mahogany	33.03	4	7.03	A
Amyris elemifera	38.79	2	9.94	A

($p > 0.05$)

ANOVA table for W665, Seasonal

Anylisis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 665	60	0.39	0.06	85.63

ANOVA table(SC type III)

F.V.	SS	DF	MS	F	p-value
Modelo.	1098.61	21	52.31	1.18	0.3198
species	962.20	20	48.11	1.09	0.4013
year	136.41	1	136.41	3.08	0.0874
Error	1683.85	38	44.31		
Total	2782.46	59			

Test:Tukey Alfa=0.05 DMS=23.05867

Error: 44.3118 df: 38

species	Medians	n	S.E.	
Erithalis fructicosa	2.87	2	4.71	A
Pisonia albida	3.12	2	4.71	A
Pictetia aculeata	3.82	2	4.71	A
Jacquinia berteroi	4.01	2	4.71	A
Bourreria succulenta	4.55	4	3.33	A
Pithecellobium unguis cati..	5.02	2	4.71	A
Amyris elemifera	5.37	2	4.71	A
Coccoloba microstachia	5.37	2	4.71	A
Swietenia mahogany	5.46	4	3.33	A
Leucaena leucocephala	5.90	2	4.71	A
Bucida buceras	6.16	2	4.71	A
Krugiodendrum ferreum	6.88	4	3.33	A
Tabebuia heterophylla	7.12	6	2.72	A
Agave sisalana	7.67	2	4.71	A
Eugenia foetida	8.15	4	3.33	A
Guaiacum officinale	8.80	4	3.33	A
Exostema caribaeum	9.44	6	2.72	A
Capparis cynophallophora	13.37	2	4.71	A
Coccoloba diversifolia	16.32	2	4.71	A
Uniola virgata	17.19	2	4.71	A
Bursera simaruba	19.70	2	4.71	A

Medias con una letra común no son significativamente diferentes ($p > 0.05$)

Test:Tukey Alfa=0.05 DMS=3.47944

Error: 44.3118 df: 38

year	Medians	n	S.E.	
2013	6.41	30	1.27	A
2010	9.42	30	1.27	A

($p > 0.05$)

Appendix H

ANOVA table for W762, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 762	79	0.37	0.00	45.20

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	11427.25	29	394.04	1.00	0.4939
Species	11427.25	29	394.04	1.00	0.4939
Error	19392.32	49	395.76		
Total	30819.57	78			

Test:Tukey Alpha=0.05 MSD=75.40448

Error: 395.7616 DF: 49

Species	Medians	n	S.E.	
Urochloa maxima	16.75	3	11.49	A
Thouinia portoricensis	25.26	2	14.07	A
Plumeria alba	27.20	3	11.49	A
Pisonia albida	29.13	2	14.07	A
Erithalis fructicosa	29.82	1	19.89	A
Prosopis juliflora	33.25	2	14.07	A
Swietenia mahogany	36.34	3	11.49	A
Avicennia germinans	37.95	3	11.49	A
Conocarpus erectus	38.27	3	11.49	A
Guaiacum officinale	38.74	3	11.49	A
Exostema caribaeum	39.27	4	9.95	A
Pictetia aculeata	39.86	3	11.49	A
Bourreria succulenta	40.64	4	9.95	A
Leucaena leucocephala	40.76	3	11.49	A
Pilosocereus royeni	41.04	3	11.49	A
Coccoloba diversifolia	42.18	2	14.07	A
Jacquinia berteroi	43.34	1	19.89	A
Krugiodendrum ferreum	43.90	3	11.49	A
Tabebuia heterophylla	47.76	4	9.95	A
Amyris elemifera	48.62	3	11.49	A
Cenchrus ciliaris	48.84	3	11.49	A
Pithecellobium unguis cati..	54.44	3	11.49	A
Agave sisalana	57.30	2	14.07	A
Uniola virgata	57.57	2	14.07	A
Eugenia foetida	58.53	2	14.07	A
Bucida buceras	58.70	5	8.90	A
Coccoloba microstachia	61.65	3	11.49	A
Bursera simaruba	63.38	2	14.07	A
Gymnanthes lucifera	65.63	1	19.89	A
Capparis cynophallophora	78.07	1	19.89	A

($p > 0.05$)

ANOVA table for W762, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 762	54	0.40	0.00	45.58

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	7443.95	23	323.65	0.87	0.6292
Species	7443.95	23	323.65	0.87	0.6292
Error	11143.61	30	371.45		
Total	18587.57	53			

Test:Tukey Alpha=0.05 MSD=80.22758

Error: 371.4537 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	14.98	1	19.27	A
Uniola virgata	24.90	3	11.13	A
Pictetia aculeata	26.70	3	11.13	A
Agave sisalana	28.34	1	19.27	A
Bourreria succulenta	34.41	3	11.13	A
Capparis cynophallophora	34.88	2	13.63	A
Tabebuia heterophylla	35.48	3	11.13	A
Exostema caribaeum	35.99	3	11.13	A
Zanthoxylum flavum	36.80	1	19.27	A
Eugenia foetida	36.82	3	11.13	A
Bursera simaruba	39.06	4	9.64	A
Krugiodendrum ferreum	42.20	3	11.13	A
Swietenia mahogany	43.60	3	11.13	A
Jacquinia berteroi	46.70	1	19.27	A
Leucaena leucocephala	46.89	2	13.63	A
Gymnanthes lucifera	50.17	3	11.13	A
Coccoloba microstachia	50.42	3	11.13	A
Coccoloba diversifolia	52.54	2	13.63	A
Guaiacum officinale	52.93	2	13.63	A
Erithalis fructicosa	53.19	2	13.63	A
Pisonia albida	56.17	2	13.63	A
Pithecellobium unguis cati..	60.21	1	19.27	A
Amyris elemifera	61.37	2	13.63	A
Bucida buceras	82.18	1	19.27	A

($p > 0.05$)

ANOVA table for W762, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 762	62	0.37	0.05	39.17

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6459.93	21	307.62	1.14	0.3494
Species	6440.92	20	322.05	1.20	0.3071
year	24.04	1	24.04	0.09	0.7667
Error	10777.13	40	269.43		
Total	17237.06	61			

Test:Tukey Alpha=0.05 MSD=55.55039

Error: 269.4283 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	25.32	4	8.21	A
Pictetia aculeata	27.97	2	11.61	A
Swietenia mahogany	28.47	4	8.21	A
Erithalis fructicosa	32.30	2	11.61	A
Uniola virgata	34.38	3	9.50	A
Leucaena leucocephala	37.36	2	11.61	A
Tabebuia heterophylla	37.63	6	6.70	A
Krugiodendrum ferreum	38.07	4	8.21	A
Exostema caribaeum	39.33	6	6.70	A
Amyris elemifera	40.21	2	11.61	A
Pisonia albida	41.64	2	11.61	A
Bursera simaruba	44.16	2	11.61	A
Jacquinia berteroi	45.02	2	11.61	A
Guaiacum officinale	47.40	4	8.21	A
Eugenia foetida	48.52	4	8.21	A
Agave sisalana	52.78	2	11.61	A
Coccoloba diversifolia	53.94	3	9.50	A
Capparis cynophallophora	56.85	2	11.61	A
Bucida buceras	58.90	2	11.61	A
Coccoloba microstachia	60.63	2	11.61	A
Pithecellobium unguis cati..	63.11	2	11.61	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=8.43071

Error: 269.4283 DF: 40

year	Medians	n	S.E.	
2013	42.90	32	3.03	A
2010	44.15	30	3.12	A

($p > 0.05$)

Appendix I

ANOVA table for W813, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 813	79	0.39	0.02	43.29

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	12419.11	29	428.25	1.06	0.4196
Species	12419.11	29	428.25	1.06	0.4196
Error	19800.32	49	404.09		
Total	32219.43	78			

Test:Tukey Alpha=0.05 MSD=76.19359

Error: 404.0882 DF: 49

Species	Medians	n	S.E.	
Urochloa maxima	18.28	3	11.61	A
Thouinia portoricensis	26.52	2	14.21	A
Plumeria alba	28.67	3	11.61	A
Pisonia albida	29.79	2	14.21	A
Erithalis fructicosa	31.41	1	20.10	A
Prosopis juliflora	35.16	2	14.21	A
Swietenia mahogany	38.19	3	11.61	A
Conocarpus erectus	40.42	3	11.61	A
Avicennia germinans	40.82	3	11.61	A
Exostema caribaeum	41.54	4	10.05	A
Guaiacum officinale	41.90	3	11.61	A
Pictetia aculeata	42.23	3	11.61	A
Leucaena leucocephala	42.59	3	11.61	A
Bourreria succulenta	42.98	4	10.05	A
Pilosocereus royeni	43.77	3	11.61	A
Coccoloba diversifolia	44.69	2	14.21	A
Krugiodendrum ferreum	45.73	3	11.61	A
Jacquinia berteroi	45.80	1	20.10	A
Tabebuia heterophylla	50.25	4	10.05	A
Amyris elemifera	51.10	3	11.61	A
Cenchrus ciliaris	52.36	3	11.61	A
Pithecellobium unguis cati..	56.87	3	11.61	A
Agave sisalana	59.84	2	14.21	A
Eugenia foetida	61.23	2	14.21	A
Bucida buceras	61.31	5	8.99	A
Uniola virgata	62.63	2	14.21	A
Coccoloba microstachia	63.71	3	11.61	A
Bursera simaruba	65.70	2	14.21	A
Gymnanthes lucifera	74.63	1	20.10	A
Capparis cynophallophora	79.79	1	20.10	A

($p > 0.05$)

ANOVA table for W813, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 813	54	0.40	0.00	43.73

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	7329.21	23	318.66	0.87	0.6337
Species	7329.21	23	318.66	0.87	0.6337
Error	11024.46	30	367.48		
Total	18353.66	53			

Test:Tukey Alpha=0.05 MSD=79.79751

Error: 367.4819 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	16.18	1	19.17	A
Uniola virgata	26.55	3	11.07	A
Pictetia aculeata	28.18	3	11.07	A
Agave sisalana	30.54	1	19.17	A
Bourreria succulenta	36.09	3	11.07	A
Capparis cynophallophora	37.30	2	13.56	A
Tabebuia heterophylla	37.41	3	11.07	A
Exostema caribaeum	37.48	3	11.07	A
Eugenia foetida	38.22	3	11.07	A
Zanthoxylum flavum	38.56	1	19.17	A
Bursera simaruba	40.56	4	9.58	A
Krugiodendrum ferreum	43.50	3	11.07	A
Swietenia mahogany	44.48	3	11.07	A
Jacquinia berteroi	48.00	1	19.17	A
Leucaena leucocephala	49.03	2	13.56	A
Gymnanthes lucifera	52.54	3	11.07	A
Coccoloba microstachia	53.04	3	11.07	A
Coccoloba diversifolia	53.41	2	13.56	A
Guaiacum officinale	54.06	2	13.56	A
Erithalis fructicosa	54.39	2	13.56	A
Pisonia albida	58.12	2	13.56	A
Amyris elemifera	60.37	2	13.56	A
Pithecellobium unguis cati..	61.40	1	19.17	A
Bucida buceras	84.43	1	19.17	A

($p > 0.05$)

ANOVA table for W813, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 813	62	0.38	0.05	38.11

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6710.12	21	319.53	1.16	0.3378
Species	6676.99	20	333.85	1.21	0.2980
year	40.16	1	40.16	0.15	0.7052
Error	11060.83	40	276.52		
Total	17770.95	61			

Test:Tukey Alpha=0.05 MSD=56.27680

Error: 276.5208 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	26.35	4	8.31	A
Pictetia aculeata	29.20	2	11.76	A
Swietenia mahogany	30.08	4	8.31	A
Erithalis fructicosa	33.64	2	11.76	A
Uniola virgata	37.16	3	9.63	A
Leucaena leucocephala	38.83	2	11.76	A
Krugiodendrum ferreum	39.21	4	8.31	A
Tabebuia heterophylla	39.51	6	6.79	A
Exostema caribaeum	41.22	6	6.79	A
Amyris elemifera	42.19	2	11.76	A
Pisonia albida	42.95	2	11.76	A
Bursera simaruba	45.26	2	11.76	A
Jacquinia berteroi	46.90	2	11.76	A
Guaiacum officinale	49.59	4	8.31	A
Eugenia foetida	50.38	4	8.31	A
Agave sisalana	54.48	2	11.76	A
Coccoloba diversifolia	54.98	3	9.63	A
Capparis cynophallophora	59.03	2	11.76	A
Bucida buceras	60.81	2	11.76	A
Coccoloba microstachia	63.66	2	11.76	A
Pithecellobium unguis cati..	64.86	2	11.76	A

(p > 0.05)

Test:Tukey Alpha=0.05 MSD=8.54096

Error: 276.5208 DF: 40

year	Medians	n	S.E.	
2013	44.44	32	3.07	A
2010	46.06	30	3.16	A

(p > 0.05)

Appendix J

ANOVA table for W817, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 817	79	0.39	0.02	43.37

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	12579.90	29	433.79	1.06	0.4186
Species	12579.90	29	433.79	1.06	0.4186
Error	20040.05	49	408.98		
Total	32619.95	78			

Test:Tukey Alpha=0.05 MSD=76.65346

Error: 408.9807 DF: 49

Species	Medians	n	S.E.	
Urochloa maxima	18.32	3	11.68	A
Thouinia portoricensis	26.66	2	14.30	A
Plumeria alba	28.80	3	11.68	A
Pisonia albida	29.78	2	14.30	A
Erithalis fructicosa	31.57	1	20.22	A
Prosopis juliflora	35.37	2	14.30	A
Swietenia mahogany	38.38	3	11.68	A
Conocarpus erectus	40.68	3	11.68	A
Avicennia germinans	41.20	3	11.68	A
Exostema caribaeum	41.68	4	10.11	A
Guaiacum officinale	42.16	3	11.68	A
Pictetia aculeata	42.47	3	11.68	A
Leucaena leucocephala	42.95	3	11.68	A
Bourreria succulenta	43.33	4	10.11	A
Coccoloba diversifolia	43.33	2	14.30	A
Pilosocereus royeni	44.05	3	11.68	A
Krugiodendrum ferreum	45.75	3	11.68	A
Jacquinia berteroi	45.96	1	20.22	A
Tabebuia heterophylla	50.40	4	10.11	A
Amyris elemifera	51.48	3	11.68	A
Cenchrus ciliaris	52.18	3	11.68	A
Pithecellobium unguis cati..	56.90	3	11.68	A
Eugenia foetida	60.55	2	14.30	A
Agave sisalana	61.52	2	14.30	A
Bucida buceras	61.72	5	9.04	A
Uniola virgata	63.23	2	14.30	A
Coccoloba microstachia	63.87	3	11.68	A
Bursera simaruba	66.07	2	14.30	A
Gymnanthes lucifera	75.12	1	20.22	A
Capparis cynophallophora	80.15	1	20.22	A

($p > 0.05$)

ANOVA table for W817, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 817	54	0.40	0.00	44.14

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	7626.53	23	331.59	0.88	0.6230
Species	7626.53	23	331.59	0.88	0.6230
Error	11343.74	30	378.12		
Total	18970.27	53			

Test:Tukey Alpha=0.05 MSD=80.94478

Error: 378.1247 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	16.32	1	19.45	A
Uniola virgata	26.50	3	11.23	A
Pictetia aculeata	28.23	3	11.23	A
Agave sisalana	30.80	1	19.45	A
Bourreria succulenta	36.14	3	11.23	A
Tabebuia heterophylla	37.06	3	11.23	A
Exostema caribaeum	37.48	3	11.23	A
Capparis cynophallophora	37.51	2	13.75	A
Eugenia foetida	38.39	3	11.23	A
Zanthoxylum flavum	38.66	1	19.45	A
Bursera simaruba	40.95	4	9.72	A
Krugiodendrum ferreum	43.10	3	11.23	A
Swietenia mahogany	44.73	3	11.23	A
Jacquinia berteroi	47.41	1	19.45	A
Leucaena leucocephala	49.16	2	13.75	A
Coccoloba microstachia	53.27	3	11.23	A
Gymnanthes lucifera	53.40	3	11.23	A
Coccoloba diversifolia	54.33	2	13.75	A
Guaiacum officinale	54.62	2	13.75	A
Erithalis fructicosa	54.86	2	13.75	A
Pisonia albida	58.82	2	13.75	A
Amyris elemifera	60.59	2	13.75	A
Pithecellobium unguis cati..	61.64	1	19.45	A
Bucida buceras	85.86	1	19.45	A

(p > 0.05)

ANOVA table for W817, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 817	62	0.38	0.05	38.52

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6922.06	21	329.62	1.16	0.3347
Species	6885.22	20	344.26	1.21	0.2955
year	44.77	1	44.77	0.16	0.6936
Error	11373.84	40	284.35		
Total	18295.90	61			

Test:Tukey Alpha=0.05 MSD=57.06752

Error: 284.3459 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	26.40	4	8.43	A
Pictetia aculeata	29.17	2	11.92	A
Swietenia mahogany	30.23	4	8.43	A
Erithalis fructicosa	33.74	2	11.92	A
Uniola virgata	37.31	3	9.76	A
Krugiodendrum ferreum	38.69	4	8.43	A
Leucaena leucocephala	39.09	2	11.92	A
Tabebuia heterophylla	39.39	6	6.88	A
Exostema caribaeum	41.28	6	6.88	A
Amyris elemifera	42.30	2	11.92	A
Pisonia albida	43.60	2	11.92	A
Bursera simaruba	45.34	2	11.92	A
Jacquinia berteroi	46.69	2	11.92	A
Guaiacum officinale	50.04	4	8.43	A
Eugenia foetida	50.13	4	8.43	A
Coccoloba diversifolia	55.45	3	9.76	A
Agave sisalana	56.31	2	11.92	A
Capparis cynophallophora	59.27	2	11.92	A
Bucida buceras	61.65	2	11.92	A
Coccoloba microstachia	63.60	2	11.92	A
Pithecellobium unguis cati..	65.18	2	11.92	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=8.66096

Error: 284.3459 DF: 40

year	Medians	n	S.E.	
2013	44.61	32	3.11	A
2010	46.32	30	3.20	A

($p > 0.05$)

Appendix K

ANOVA table for W960, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 960	79	0.43	0.09	40.65

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	12636.80	29	435.75	1.25	0.2382
Species	12636.80	29	435.75	1.25	0.2382
Error	17031.93	49	347.59		
Total	29668.73	78			

Test:Tukey Alpha=0.05 MSD=70.66661

Error: 347.5904 DF: 49

Species	Medians	n	S.E.	
Urochloa maxima	20.49	3	10.76	A
Thouinia portoricensis	26.79	2	13.18	A
Plumeria alba	29.13	3	10.76	A
Pisonia albida	29.39	2	13.18	A
Erithalis fructicosa	31.79	1	18.64	A
Cenchrus ciliaris	35.76	3	10.76	A
Prosopis juliflora	36.90	2	13.18	A
Guaiacum officinale	38.01	3	10.76	A
Conocarpus erectus	39.25	3	10.76	A
Swietenia mahogany	39.79	3	10.76	A
Exostema caribaeum	41.91	4	9.32	A
Coccoloba diversifolia	41.93	2	13.18	A
Avicennia germinans	42.07	3	10.76	A
Pictetia aculeata	43.02	3	10.76	A
Agave sisalana	44.03	2	13.18	A
Tabebuia heterophylla	44.03	4	9.32	A
Krugiodendrum ferreum	44.57	3	10.76	A
Bourreria succulenta	45.60	4	9.32	A
Jacquinia berteroi	46.17	1	18.64	A
Leucaena leucocephala	46.27	3	10.76	A
Pilosocereus royeni	48.12	3	10.76	A
Amyris elemifera	53.32	3	10.76	A
Pithecellobium unguis cati..	56.57	3	10.76	A
Eugenia foetida	60.79	2	13.18	A
Bucida buceras	62.41	5	8.34	A
Coccoloba microstachia	62.83	3	10.76	A
Uniola virgata	68.05	2	13.18	A
Bursera simaruba	69.02	2	13.18	A
Capparis cynophallophora	76.64	1	18.64	A
Gymnanthes lucifera	79.15	1	18.64	A

($p > 0.05$)

ANOVA table for W960, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 960	54	0.39	0.00	45.37

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	7763.43	23	337.54	0.84	0.6657
Species	7763.43	23	337.54	0.84	0.6657
Error	12087.81	30	402.93		
Total	19851.24	53			

Test:Tukey Alpha=0.05 MSD=83.55731

Error: 402.9269 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	17.26	1	20.07	A
Uniola virgata	25.94	3	11.59	A
Pictetia aculeata	30.70	3	11.59	A
Agave sisalana	34.12	1	20.07	A
Tabebuia heterophylla	34.98	3	11.59	A
Zanthoxylum flavum	36.53	1	20.07	A
Exostema caribaeum	37.22	3	11.59	A
Bourreria succulenta	37.57	3	11.59	A
Eugenia foetida	38.39	3	11.59	A
Capparis cynophallophora	38.60	2	14.19	A
Krugiodendrum ferreum	39.66	3	11.59	A
Bursera simaruba	41.77	4	10.04	A
Jacquinia berteroi	43.49	1	20.07	A
Swietenia mahogany	46.19	3	11.59	A
Leucaena leucocephala	49.75	2	14.19	A
Coccoloba diversifolia	52.92	2	14.19	A
Coccoloba microstachia	54.31	3	11.59	A
Erithalis fructicosa	55.48	2	14.19	A
Gymnanthes lucifera	55.92	3	11.59	A
Guaiacum officinale	56.32	2	14.19	A
Pisonia albida	58.09	2	14.19	A
Pithecellobium unguis cati..	58.54	1	20.07	A
Amyris elemifera	58.95	2	14.19	A
Bucida buceras	89.24	1	20.07	A

($p > 0.05$)

ANOVA table for W960, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 960	62	0.38	0.05	37.35

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6362.89	21	302.99	1.17	0.3290
Species	6340.31	20	317.02	1.22	0.2885
year	27.62	1	27.62	0.11	0.7461
Error	10393.14	40	259.83		
Total	16756.03	61			

Test:Tukey Alpha=0.05 MSD=54.55178

Error: 259.8286 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	26.26	4	8.06	A
Pictetia aculeata	30.11	2	11.40	A
Swietenia mahogany	31.94	4	8.06	A
Erithalis fructicosa	33.97	2	11.40	A
Krugiodendrum ferreum	35.25	4	8.06	A
Uniola virgata	37.39	3	9.33	A
Tabebuia heterophylla	38.43	6	6.58	A
Leucaena leucocephala	40.28	2	11.40	A
Amyris elemifera	41.21	2	11.40	A
Exostema caribaeum	41.22	6	6.58	A
Pisonia albida	43.91	2	11.40	A
Jacquinia berteroi	44.83	2	11.40	A
Agave sisalana	45.12	2	11.40	A
Bursera simaruba	47.37	2	11.40	A
Eugenia foetida	49.91	4	8.06	A
Guaiacum officinale	51.48	4	8.06	A
Coccoloba diversifolia	53.13	3	9.33	A
Capparis cynophallophora	57.65	2	11.40	A
Pithecellobium unguis cati..	62.00	2	11.40	A
Bucida buceras	63.81	2	11.40	A
Coccoloba microstachia	63.96	2	11.40	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=8.27916

Error: 259.8286 DF: 40

year	Medians	n	S.E.	
2013	44.05	32	2.97	A
2010	45.40	30	3.06	A

($p > 0.05$)

Appendix L

ANOVA table for W980, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 980	78	0.49	0.18	38.62

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	13336.19	29	459.87	1.57	0.0804
Species	13336.19	29	459.87	1.57	0.0804
Error	14022.66	48	292.14		
Total	27358.85	77			

Test:Tukey Alpha=0.05 MSD=65.06151

Error: 292.1388 DF: 48

Species	Medians	n	S.E.	
Urochloa maxima	20.54	3	9.87	A
Thouinia portoricensis	26.13	2	12.09	A
Plumeria alba	28.52	3	9.87	A
Bourreria succulenta	29.25	3	9.87	A
Pisonia albida	29.67	2	12.09	A
Erithalis fructicosa	31.12	1	17.09	A
Cenchrus ciliaris	34.74	3	9.87	A
Agave sisalana	35.89	2	12.09	A
Guaiacum officinale	36.47	3	9.87	A
Prosopis juliflora	38.08	2	12.09	A
Swietenia mahogany	38.67	3	9.87	A
Conocarpus erectus	38.85	3	9.87	A
Avicennia germinans	41.19	3	9.87	A
Exostema caribaeum	41.29	4	8.55	A
Coccoloba diversifolia	42.06	2	12.09	A
Amyris elemifera	42.76	3	9.87	A
Pictetia aculeata	42.88	3	9.87	A
Krugiodendrum ferreum	44.17	3	9.87	A
Tabebuia heterophylla	44.39	4	8.55	A
Jacquinia berteroi	45.40	1	17.09	A
Pilosocereus royeni	47.95	3	9.87	A
Leucaena leucocephala	48.16	3	9.87	A
Pithecellobium unguis cati..	56.59	3	9.87	A
Eugenia foetida	59.17	2	12.09	A
Bucida buceras	60.31	5	7.64	A
Coccoloba microstachia	61.86	3	9.87	A
Bursera simaruba	66.54	2	12.09	A
Uniola virgata	69.05	2	12.09	A
Capparis cynophallophora	78.55	1	17.09	A
Gymnanthes lucifera	82.10	1	17.09	A

$(p > 0.05)$

ANOVA table for W980, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 980	55	0.40	0.00	41.73

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6598.66	23	286.90	0.88	0.6194
Species	6598.66	23	286.90	0.88	0.6194
Error	10102.80	31	325.90		
Total	16701.46	54			

Test:Tukey Alpha=0.05 MSD=74.45266

Error: 325.8967 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	16.74	1	18.05	A
Uniola virgata	26.63	3	10.42	A
Pictetia aculeata	29.89	3	10.42	A
Agave sisalana	33.71	1	18.05	A
Zanthoxylum flavum	35.88	1	18.05	A
Bourreria succulenta	36.80	3	10.42	A
Exostema caribaeum	37.07	3	10.42	A
Capparis cynophallophora	37.14	2	12.77	A
Tabebuia heterophylla	37.24	3	10.42	A
Eugenia foetida	37.57	3	10.42	A
Bursera simaruba	40.09	4	9.03	A
Krugiodendrum ferreum	40.33	3	10.42	A
Swietenia mahogany	43.30	3	10.42	A
Jacquinia berteroi	44.70	1	18.05	A
Leucaena leucocephala	49.03	2	12.77	A
Pisonia albida	50.11	3	10.42	A
Coccoloba microstachia	52.37	3	10.42	A
Coccoloba diversifolia	53.05	2	12.77	A
Erithalis fructicosa	53.19	2	12.77	A
Gymnanthes lucifera	53.78	3	10.42	A
Guaiacum officinale	55.45	2	12.77	A
Pithecellobium unguis cati..	55.77	1	18.05	A
Amyris elemifera	58.32	2	12.77	A
Bucida buceras	84.63	1	18.05	A

(p > 0.05)

ANOVA table for W980, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 980	62	0.37	0.04	36.57

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5603.76	21	266.85	1.11	0.3793
Species	5601.19	20	280.06	1.16	0.3329
year	6.31	1	6.31	0.03	0.8722
Error	9636.12	40	240.90		
Total	15239.88	61			

Test:Tukey Alpha=0.05 MSD=52.52749

Error: 240.9031 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	26.18	4	7.76	A
Pictetia aculeata	30.19	2	10.98	A
Swietenia mahogany	31.53	4	7.76	A
Erithalis fructicosa	32.95	2	10.98	A
Krugiodendrum ferreum	35.76	4	7.76	A
Agave sisalana	36.95	2	10.98	A
Uniola virgata	38.90	3	8.99	A
Tabebuia heterophylla	39.86	6	6.34	A
Amyris elemifera	40.46	2	10.98	A
Leucaena leucocephala	40.51	2	10.98	A
Exostema caribaeum	40.77	6	6.34	A
Pisonia albida	41.31	2	10.98	A
Bursera simaruba	44.41	2	10.98	A
Jacquinia berteroi	45.05	2	10.98	A
Eugenia foetida	48.51	4	7.76	A
Guaiacum officinale	50.37	4	7.76	A
Coccoloba diversifolia	53.26	3	8.99	A
Capparis cynophallophora	58.15	2	10.98	A
Pithecellobium unguis cati..	58.24	2	10.98	A
Bucida buceras	60.85	2	10.98	A
Coccoloba microstachia	62.37	2	10.98	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=7.97194

Error: 240.9031 DF: 40

year	Medians	n	S.E.	
2013	43.32	32	2.86	A
2010	43.97	30	2.95	A

($p > 0.05$)

Appendix M

ANOVA table for W984, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 984	79	0.44	0.12	39.03

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	14222.68	29	490.44	1.35	0.1743
Species	14222.68	29	490.44	1.35	0.1743
Error	17806.05	49	363.39		
Total	32028.73	78			

Test:Tukey Alpha=0.05 MSD=72.25470

Error: 363.3888 DF: 49

Species	Medians	n	S.E.	
Urochloa maxima	22.07	3	11.01	A
Thouinia portoricensis	28.21	2	13.48	A
Plumeria alba	30.62	3	11.01	A
Erithalis fructicosa	31.64	1	19.06	A
Cenchrus ciliaris	35.69	3	11.01	A
Prosopis juliflora	38.18	2	13.48	A
Pisonia albida	39.29	2	13.48	A
Guaiacum officinale	39.74	3	11.01	A
Conocarpus erectus	39.98	3	11.01	A
Swietenia mahogany	41.17	3	11.01	A
Agave sisalana	42.21	2	13.48	A
Avicennia germinans	43.16	3	11.01	A
Bourreria succulenta	44.65	4	9.53	A
Leucaena leucocephala	44.88	3	11.01	A
Pictetia aculeata	44.98	3	11.01	A
Jacquinia berteroi	47.94	1	19.06	A
Tabebuia heterophylla	48.80	4	9.53	A
Pilosocereus royeni	49.07	3	11.01	A
Exostema caribaeum	49.28	4	9.53	A
Amyris elemifera	54.20	3	11.01	A
Krugiodendrum ferreum	58.63	3	11.01	A
Pithecellobium unguis cati..	58.96	3	11.01	A
Coccoloba diversifolia	59.84	2	13.48	A
Eugenia foetida	63.47	2	13.48	A
Bucida buceras	63.66	5	8.53	A
Bursera simaruba	69.91	2	13.48	A
Uniola virgata	70.08	2	13.48	A
Coccoloba microstachia	70.90	3	11.01	A
Capparis cynophallophora	81.75	1	19.06	A
Gymnanthes lucifera	83.61	1	19.06	A

ANOVA table for W984, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 984	54	0.37	0.00	43.00

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6442.72	23	280.12	0.75	0.7542
Species	6442.72	23	280.12	0.75	0.7542
Error	11132.15	30	371.07		
Total	17574.88	53			

Test:Tukey Alpha=0.05 MSD=80.18632

Error: 371.0717 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	18.80	1	19.26	A
Uniola virgata	27.36	3	11.12	A
Pictetia aculeata	31.65	3	11.12	A
Agave sisalana	35.15	1	19.26	A
Bourreria succulenta	37.69	3	11.12	A
Zanthoxylum flavum	37.70	1	19.26	A
Tabebuia heterophylla	38.22	3	11.12	A
Capparis cynophallophora	38.63	2	13.62	A
Exostema caribaeum	38.73	3	11.12	A
Eugenia foetida	39.52	3	11.12	A
Bursera simaruba	40.56	4	9.63	A
Krugiodendrum ferreum	42.97	3	11.12	A
Jacquinia berteroi	47.72	1	19.26	A
Swietenia mahogany	49.16	3	11.12	A
Leucaena leucocephala	50.97	2	13.62	A
Gymnanthes lucifera	52.21	3	11.12	A
Coccoloba diversifolia	52.72	2	13.62	A
Coccoloba microstachia	54.12	3	11.12	A
Erithalis fructicosa	54.39	2	13.62	A
Guaiacum officinale	54.53	2	13.62	A
Pisonia albida	55.65	2	13.62	A
Pithecellobium unguis cati..	60.82	1	19.26	A
Amyris elemifera	63.54	2	13.62	A
Bucida buceras	80.84	1	19.26	A

(p > 0.05)

ANOVA table for W984, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 984	62	0.38	0.06	35.65

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6618.32	21	315.16	1.18	0.3182
Species	6248.58	20	312.43	1.17	0.3275
year	410.36	1	410.36	1.54	0.2225
Error	10688.07	40	267.20		
Total	17306.39	61			

Test:Tukey Alpha=0.05 MSD=55.32039

Error: 267.2018 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	27.15	4	8.17	A
Pictetia aculeata	32.06	2	11.56	A
Swietenia mahogany	32.96	4	8.17	A
Erithalis fructicosa	33.75	2	11.56	A
Uniola virgata	40.05	3	9.46	A
Pisonia albida	40.74	2	11.56	A
Leucaena leucocephala	41.09	2	11.56	A
Agave sisalana	42.92	2	11.56	A
Amyris elemifera	43.29	2	11.56	A
Tabebuia heterophylla	43.40	6	6.67	A
Exostema caribaeum	46.78	6	6.67	A
Krugiodendrum ferreum	47.25	4	8.17	A
Jacquinia berteroi	47.83	2	11.56	A
Bursera simaruba	48.71	2	11.56	A
Eugenia foetida	51.69	4	8.17	A
Guaiacum officinale	52.00	4	8.17	A
Bucida buceras	59.96	2	11.56	A
Capparis cynophallophora	60.22	2	11.56	A
Coccoloba diversifolia	60.70	3	9.46	A
Pithecellobium unguis cati..	63.65	2	11.56	A
Coccoloba microstachia	66.08	2	11.56	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=8.39581

Error: 267.2018 DF: 40

year	Medians	n	S.E.	
2013	44.19	32	3.01	A
2010	49.36	30	3.10	A

($p > 0.05$)

Appendix N

ANOVA table for W1180, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1180	77	0.52	0.22	38.90

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	14917.74	29	514.40	1.72	0.0478
Species	14917.74	29	514.40	1.72	0.0478
Error	14047.01	47	298.87		
Total	28964.75	76			

Test:Tukey Alpha=0.05 MSD=67.08148

Error: 298.8726 DF: 47

Species	Medians	n	S.E.	
Urochloa maxima	23.58	3	9.98	A
Thouinia portoricensis	26.22	2	12.22	A
Erithalis fructicosa	27.12	1	17.29	A
Cenchrus ciliaris	27.85	3	9.98	A
Bourreria succulenta	28.43	3	9.98	A
Plumeria alba	29.57	3	9.98	A
Agave sisalana	31.04	2	12.22	A
Guaiacum officinale	33.96	3	9.98	A
Pisonia albida	34.16	2	12.22	A
Conocarpus erectus	34.90	3	9.98	A
Prosopis juliflora	39.51	2	12.22	A
Swietenia mahogany	39.78	3	9.98	A
Avicennia germinans	40.54	3	9.98	A
Tabebuia heterophylla	41.12	4	8.64	A
Amyris elemifera	41.80	3	9.98	A
Pictetia aculeata	41.90	3	9.98	A
Jacquinia berteroi	43.91	1	17.29	A
Exostema caribaeum	44.60	4	8.64	A
Leucaena leucocephala	46.37	3	9.98	A
Pilosocereus royeni	51.25	3	9.98	A
Krugiodendrum ferreum	52.45	3	9.98	A
Pithecellobium unguis cati..	53.05	3	9.98	A
Bucida buceras	57.93	5	7.73	A
Eugenia foetida	58.49	2	12.22	A
Coccoloba microstachia	65.33	3	9.98	A
Bursera simaruba	67.41	2	12.22	A
Coccoloba diversifolia	67.84	1	17.29	A
Uniola virgata	72.19	2	12.22	A
Capparis cynophallophora	74.77	1	17.29	A
Gymnanthes lucifera	86.05	1	17.29	A

($p > 0.05$)

Nested ANOVA table for W1180, exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1180	11	0.28	0.00	22.36

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	283.30	3	94.43	0.90	0.4862
species/species>status	40.40	1	40.40	0.39	0.5539
species>status	242.90	2	121.45	1.16	0.3668
Error	731.91	7	104.56		
Total	1015.21	10			

Test:Tukey Alfa=0.05 DMS=14.64126

Error: 104.5590 df: 7

status	Mean	n	S.E	
exotic legume	41.80	5	5.21	A
native legume	47.48	6	4.17	A

ANOVA table for W1180, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1180	55	0.36	0.00	43.33

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5818.54	23	252.98	0.77	0.7422
Species	5818.54	23	252.98	0.77	0.7422
Error	10222.29	31	329.75		
Total	16040.83	54			

Test:Tukey Alpha=0.05 MSD=74.89169

Error: 329.7514 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	18.03	1	18.16	A
Uniola virgata	25.80	3	10.48	A
Zanthoxylum flavum	31.84	1	18.16	A
Pictetia aculeata	32.36	3	10.48	A
Agave sisalana	34.29	1	18.16	A
Capparis cynophallophora	34.69	2	12.84	A
Tabebuia heterophylla	35.01	3	10.48	A
Bourreria succulenta	35.43	3	10.48	A
Eugenia foetida	36.62	3	10.48	A
Exostema caribaeum	36.68	3	10.48	A
Bursera simaruba	37.52	4	9.08	A
Krugiodendrum ferreum	37.77	3	10.48	A
Jacquinia berteroi	43.34	1	18.16	A
Pisonia albida	45.07	3	10.48	A
Leucaena leucocephala	46.48	2	12.84	A
Swietenia mahogany	46.89	3	10.48	A
Coccoloba diversifolia	48.40	2	12.84	A
Gymnanthes lucifera	49.97	3	10.48	A
Guaiacum officinale	51.95	2	12.84	A
Pithecellobium unguis cati..	52.00	1	18.16	A
Coccoloba microstachia	52.68	3	10.48	A
Erithalis fructicosa	55.48	2	12.84	A
Amyris elemifera	61.39	2	12.84	A
Bucida buceras	76.02	1	18.16	A

($p > 0.05$)

Nested ANOVA table for W1180, exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1180	7	0.86	0.72	18.16

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	829.12	3	276.37	6.07	0.0863
species/species>status	0.13	1	0.13	2.8E-03	0.9614
species>status	829.00	2	414.50	9.11	0.0532
Error	136.56	3	45.52		
Total	965.68	6			

Test:Tukey Alfa=0.05 DMS=16.39916

Error: 45.5202 df: 3

status	Mean	n	S.E	
exotic legume	37.00	3	3.90	A
native legume	42.18	4	3.90	A

ANOVA table for W1180, Seasonal

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1180	62	0.35	0.01	36.45

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5039.91	21	240.00	1.02	0.4654
Species	4842.41	20	242.12	1.03	0.4554
year	234.65	1	234.65	1.00	0.3244
Error	9428.12	40	235.70		
Total	14468.03	61			

Test:Tukey Alpha=0.05 MSD=51.95746

Error: 235.7029 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	25.41	4	7.68	A
Pictetia aculeata	31.26	2	10.86	A
Erithalis fructicosa	31.63	2	10.86	A
Swietenia mahogany	32.35	4	7.68	A
Agave sisalana	33.67	2	10.86	A
Pisonia albida	36.26	2	10.86	A
Tabebuia heterophylla	38.80	6	6.27	A
Amyris elemifera	39.33	2	10.86	A
Uniola virgata	39.37	3	8.89	A
Leucaena leucocephala	39.79	2	10.86	A
Krugiodendrum ferreum	42.12	4	7.68	A
Exostema caribaeum	43.16	6	6.27	A
Jacquinia berteroi	43.63	2	10.86	A
Bursera simaruba	47.30	2	10.86	A
Eugenia foetida	47.65	4	7.68	A
Guaiacum officinale	48.07	4	7.68	A
Pithecellobium unguis cati..	53.44	2	10.86	A
Capparis cynophallophora	54.18	2	10.86	A
Coccoloba diversifolia	55.53	3	8.89	A
Bucida buceras	56.08	2	10.86	A
Coccoloba microstachia	61.58	2	10.86	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=7.88543

Error: 235.7029 DF: 40

year	Medians	n	S.E.	
2013	40.93	32	2.83	A
2010	44.84	30	2.92	A

($p > 0.05$)

Appendix O

ANOVA table for W1190, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1190	77	0.52	0.22	39.15

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	15325.72	29	528.47	1.76	0.0421
Species	15325.72	29	528.47	1.76	0.0421
Error	14148.26	47	301.03		
Total	29473.97	76			

Test:Tukey Alpha=0.05 MSD=67.32278

Error: 301.0267 DF: 47

Species	Medians	n	S.E.	
Urochloa maxima	23.64	3	10.02	A
Thouinia portoricensis	26.11	2	12.27	A
Agave sisalana	26.61	2	12.27	A
Erithalis fructicosa	26.68	1	17.35	A
Cenchrus ciliaris	27.67	3	10.02	A
Bourreria succulenta	28.55	3	10.02	A
Plumeria alba	29.54	3	10.02	A
Pisonia albida	33.90	2	12.27	A
Guaiacum officinale	34.04	3	10.02	A
Conocarpus erectus	34.81	3	10.02	A
Prosopis juliflora	39.65	2	12.27	A
Swietenia mahogany	39.71	3	10.02	A
Tabebuia heterophylla	40.92	4	8.68	A
Avicennia germinans	41.24	3	10.02	A
Amyris elemifera	41.55	3	10.02	A
Pictetia aculeata	42.29	3	10.02	A
Jacquinia berteroi	43.16	1	17.35	A
Exostema caribaeum	44.25	4	8.68	A
Leucaena leucocephala	45.92	3	10.02	A
Pilosocereus royeni	51.57	3	10.02	A
Krugiodendrum ferreum	53.01	3	10.02	A
Pithecellobium unguis cati..	53.16	3	10.02	A
Bucida buceras	57.65	5	7.76	A
Eugenia foetida	58.43	2	12.27	A
Coccoloba microstachia	65.25	3	10.02	A
Bursera simaruba	67.06	2	12.27	A
Coccoloba diversifolia	67.65	1	17.35	A
Uniola virgata	72.27	2	12.27	A
Capparis cynophallophora	74.29	1	17.35	A
Gymnanthes lucifera	88.12	1	17.35	A

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1190	11	0.28	0.00	21.76

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	275.07	3	91.69	0.92	0.4771
species/species>status	50.82	1	50.82	0.51	0.4972
species>status	224.25	2	112.13	1.13	0.3753
Error	694.05	7	99.15		
Total	969.12	10			

Test:Tukey Alfa=0.05 DMS=14.25756

Error: 99.1504 df: 7

status	Mean	n	S.E	
exotic legume	41.74	5	5.07	A
native legume	47.73	6	4.07	A

ANOVA table for 1190nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1190	55	0.36	0.00	43.37

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5662.38	23	246.19	0.75	0.7615
Species	5662.38	23	246.19	0.75	0.7615
Error	10194.22	31	328.85		
Total	15856.60	54			

Test:Tukey Alpha=0.05 MSD=74.78879

Error: 328.8459 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	18.49	1	18.13	A
Uniola virgata	25.79	3	10.47	A
Zanthoxylum flavum	31.40	1	18.13	A
Pictetia aculeata	32.45	3	10.47	A
Agave sisalana	34.26	1	18.13	A
Capparis cynophallophora	34.75	2	12.82	A
Tabebuia heterophylla	35.08	3	10.47	A
Bourreria succulenta	35.36	3	10.47	A
Exostema caribaeum	36.56	3	10.47	A
Eugenia foetida	36.74	3	10.47	A
Bursera simaruba	37.28	4	9.07	A
Krugiodendrum ferreum	37.68	3	10.47	A
Jacquinia berteroi	43.54	1	18.13	A
Pisonia albida	45.14	3	10.47	A
Leucaena leucocephala	46.83	2	12.82	A
Swietenia mahogany	47.24	3	10.47	A
Coccoloba diversifolia	48.55	2	12.82	A
Gymnanthes lucifera	50.01	3	10.47	A
Coccoloba microstachia	51.16	3	10.47	A
Pithecellobium unguis cati..	51.99	1	18.13	A
Guaiacum officinale	52.18	2	12.82	A
Erithalis fructicosa	54.11	2	12.82	A
Amyris elemifera	61.19	2	12.82	A
Bucida buceras	75.94	1	18.13	A

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1190	7	0.86	0.72	17.83

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p value
Model.	821.90	3	273.97	6.18	0.0845
species/species>status	4.4E-03	1	4.4E-03	1.0E-04	0.9927
species>status	821.89	2	410.95	9.26	0.0520
Error	133.10	3	44.37		
Total	955.00	6			

Test:Tukey Alfa=0.05 DMS=16.19005

Error: 44.3668 df: 3

status	Mean	n	S.E	
exotic legume	37.38	3	3.85	A
native legume	42.22	4	3.85	A

ANOVA table for Seasonal 1190nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1190	62	0.35	0.01	36.78

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5200.36	21	247.64	1.04	0.4417
Species	5048.19	20	252.41	1.06	0.4217
year	186.94	1	186.94	0.79	0.3805
Error	9507.54	40	237.69		
Total	14707.90	61			

Test:Tukey Alpha=0.05 MSD=52.17585

Error: 237.6884 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	25.32	4	7.71	A
Agave sisalana	29.39	2	10.90	A
Erithalis fructicosa	31.12	2	10.90	A
Pictetia aculeata	31.19	2	10.90	A
Swietenia mahogany	32.32	4	7.71	A
Pisonia albida	36.38	2	10.90	A
Tabebuia heterophylla	38.75	6	6.29	A
Amyris elemifera	39.04	2	10.90	A
Uniola virgata	39.49	3	8.93	A
Leucaena leucocephala	39.84	2	10.90	A
Krugiodendrum ferreum	42.01	4	7.71	A
Exostema caribaeum	42.92	6	6.29	A
Jacquinia berteroi	43.35	2	10.90	A
Bursera simaruba	47.20	2	10.90	A
Eugenia foetida	47.69	4	7.71	A
Guaiacum officinale	48.29	4	7.71	A
Pithecellobium unguis cati..	53.46	2	10.90	A
Capparis cynophallophora	53.97	2	10.90	A
Coccoloba diversifolia	55.50	3	8.93	A
Bucida buceras	55.90	2	10.90	A
Coccoloba microstachia	61.61	2	10.90	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=7.91857

Error: 237.6884 DF: 40

year	Medians	n	S.E.	
2013	40.86	32	2.84	A
2010	44.35	30	2.93	A

($p > 0.05$)

Appendix P

ANOVA table for 1192nm Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1192	77	0.52	0.22	39.20

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	12065.57	29	416.05	1.75	0.0424
Species	12065.57	29	416.05	1.75	0.0424
Error	11152.16	47	237.28		
Total	23217.74	76			

Test:Tukey Alpha=0.05 MSD=59.77095

Error: 237.2800 DF: 47

Species	Medians	n	S.E.	
Urochloa maxima	21.02	3	8.89	A
Thouinia portoricensis	23.22	2	10.89	A
Agave sisalana	23.40	2	10.89	A
Erithalis fructicosa	23.71	1	15.40	A
Cenchrus ciliaris	24.59	3	8.89	A
Bourreria succulenta	25.37	3	8.89	A
Plumeria alba	26.26	3	8.89	A
Guaiacum officinale	29.85	3	8.89	A
Pisonia albida	29.93	2	10.89	A
Conocarpus erectus	30.90	3	8.89	A
Prosopis juliflora	35.28	2	10.89	A
Swietenia mahogany	35.32	3	8.89	A
Tabebuia heterophylla	36.22	4	7.70	A
Avicennia germinans	36.67	3	8.89	A
Amyris elemifera	36.93	3	8.89	A
Pictetia aculeata	37.09	3	8.89	A
Jacquinia berteroi	38.81	1	15.40	A
Exostema caribaeum	39.21	4	7.70	A
Leucaena leucocephala	40.80	3	8.89	A
Pilosocereus royeni	45.87	3	8.89	A
Krugiodendrum ferreum	46.97	3	8.89	A
Pithecellobium unguis cati..	47.32	3	8.89	A
Bucida buceras	51.22	5	6.89	A
Eugenia foetida	51.99	2	10.89	A
Coccoloba microstachia	57.15	3	8.89	A
Bursera simaruba	59.46	2	10.89	A
Coccoloba diversifolia	59.66	1	15.40	A
Uniola virgata	64.22	2	10.89	A
Capparis cynophallophora	66.09	1	15.40	A
Gymnanthes lucifera	78.70	1	15.40	A

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1192	11	0.30	0.00	21.61

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	229.01	3	76.34	0.99	0.4497
species/species>status	35.53	1	35.53	0.46	0.5184
species>status	193.49	2	96.74	1.26	0.3412
Error	538.04	7	76.86		
Total	767.05	10			

Test:Tukey Alfa=0.05 DMS=12.55324

Error: 76.8627 df: 7

status	Mean	n	S.E	
exotic legume	37.12	5	4.46	A
native legume	42.20	6	3.58	A

ANOVA table for 1192nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1192	55	0.38	0.00	43.44

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	4959.57	23	215.63	0.81	0.6933
Species	4959.57	23	215.63	0.81	0.6933
Error	8224.63	31	265.31		
Total	13184.20	54			

Test:Tukey Alpha=0.05 MSD=67.17653

Error: 265.3106 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	16.31	1	16.29	A
Uniola virgata	22.84	3	9.40	A
Zanthoxylum flavum	27.80	1	16.29	A
Pictetia aculeata	28.77	3	9.40	A
Agave sisalana	30.50	1	16.29	A
Capparis cynophallophora	30.85	2	11.52	A
Tabebuia heterophylla	31.22	3	9.40	A
Bourreria succulenta	31.36	3	9.40	A
Exostema caribaeum	32.40	3	9.40	A
Eugenia foetida	32.71	3	9.40	A
Bursera simaruba	33.10	4	8.14	A
Krugiodendrum ferreum	33.53	3	9.40	A
Jacquinia berteroi	38.72	1	16.29	A
Pisonia albida	40.17	3	9.40	A
Leucaena leucocephala	41.56	2	11.52	A
Swietenia mahogany	41.74	3	9.40	A
Coccoloba diversifolia	43.27	2	11.52	A
Gymnanthes lucifera	44.63	3	9.40	A
Pithecellobium unguis cati..	46.18	1	16.29	A
Guaiacum officinale	46.50	2	11.52	A
Coccoloba microstachia	48.17	3	9.40	A
Erithalis fructicosa	53.29	2	11.52	A
Amyris elemifera	54.47	2	11.52	A
Bucida buceras	67.83	1	16.29	A

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1192	7	0.86	0.72	17.82

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	652.29	3	217.43	6.23	0.0835
species/species>status	5.8E-04	1	5.8E-04	1.7E-05	0.9970
species>status	652.29	2	326.14	9.35	0.0514
Error	104.64	3	34.88		
Total	756.92	6			

Test:Tukey Alfa=0.05 DMS=14.35506

Error: 34.8796 df: 3

status	Mean	n	S.E	
exotic legume	33.14	3	3.41	A
native legume	37.48	4	3.41	A

ANOVA table for Seasonal 1192nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1192	62	0.34	0.00	37.05

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	3978.64	21	189.46	0.99	0.4925
Species	3881.74	20	194.09	1.02	0.4664
year	120.84	1	120.84	0.63	0.4311
Error	7639.67	40	190.99		
Total	11618.31	61			

Test:Tukey Alpha=0.05 MSD=46.77059

Error: 190.9918 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	22.48	4	6.91	A
Agave sisalana	25.91	2	9.77	A
Pictetia aculeata	27.71	2	9.77	A
Swietenia mahogany	28.71	4	6.91	A
Erithalis fructicosa	30.65	2	9.77	A
Pisonia albida	32.50	2	9.77	A
Tabebuia heterophylla	34.37	6	5.64	A
Amyris elemifera	34.66	2	9.77	A
Uniola virgata	34.96	3	8.00	A
Leucaena leucocephala	35.41	2	9.77	A
Krugiodendrum ferreum	37.27	4	6.91	A
Exostema caribaeum	38.03	6	5.64	A
Jacquinia berteroi	38.77	2	9.77	A
Bursera simaruba	41.70	2	9.77	A
Eugenia foetida	42.45	4	6.91	A
Guaiacum officinale	42.69	4	6.91	A
Pithecellobium unguis cati..	47.52	2	9.77	A
Capparis cynophallophora	48.03	2	9.77	A
Coccoloba diversifolia	49.20	3	8.00	A
Bucida buceras	49.84	2	9.77	A
Coccoloba microstachia	54.56	2	9.77	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=7.09823

Error: 190.9918 DF: 40

year	Medians	n	S.E.	
2013	36.57	32	2.55	A
2010	39.38	30	2.62	A

($p > 0.05$)

Appendix Q

ANOVA table for W1225, wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1225	77	0.52	0.22	38.93

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	15994.83	29	551.55	1.75	0.0436
Species	15994.83	29	551.55	1.75	0.0436
Error	14845.55	47	315.86		
Total	30840.37	76			

Test:Tukey Alpha=0.05 MSD=68.96182

Error: 315.8627 DF: 47

Species	Medians	n	S.E.		
Urochloa maxima	24.58	3	10.26	A	
Thouinia portoricensis	26.98	2	12.57	A	B
Agave sisalana	27.17	2	12.57	A	B
Erithalis fructicosa	28.05	1	17.77	A	B
Cenchrus ciliaris	28.82	3	10.26	A	B
Bourreria succulenta	29.37	3	10.26	A	B
Plumeria alba	30.45	3	10.26	A	B
Pisonia albida	34.34	2	12.57	A	B
Guaiacum officinale	34.83	3	10.26	A	B
Conocarpus erectus	36.00	3	10.26	A	B
Swietenia mahogany	40.81	3	10.26	A	B
Prosopis juliflora	40.93	2	12.57	A	B
Tabebuia heterophylla	41.94	4	8.89	A	B
Amyris elemifera	42.73	3	10.26	A	B
Pictetia aculeata	43.06	3	10.26	A	B
Jacquinia berteroi	45.15	1	17.77	A	B
Avicennia germinans	45.27	3	10.26	A	B
Exostema caribaeum	45.45	4	8.89	A	B
Leucaena leucocephala	47.51	3	10.26	A	B
Pilosocereus royeni	53.54	3	10.26	A	B
Krugiodendrum ferreum	53.83	3	10.26	A	B
Pithecellobium unguis cati..	55.34	3	10.26	A	B
Bucida buceras	58.87	5	7.95	A	B
Eugenia foetida	62.24	2	12.57	A	B
Coccoloba microstachia	65.87	3	10.26	A	B
Bursera simaruba	67.56	2	12.57	A	B
Coccoloba diversifolia	67.78	1	17.77	A	B
Uniola virgata	72.59	2	12.57	A	B
Capparis cynophallophora	76.80	1	17.77	A	B
Gymnanthes lucifera	93.92	1	17.77		B

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1225	11	0.32	0.03	21.15

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	328.93	3	109.64	1.10	0.4110
species/species>status	50.95	1	50.95	0.51	0.4980
species>status	277.98	2	138.99	1.39	0.3096
Error	698.53	7	99.79		
Total	1027.46	10			

Test:Tukey Alfa=0.05 DMS=14.30344

Error: 99.7896 df: 7

status	Mean	n	S.E	
exotic legume	43.12	5	5.09	A
native legume	49.20	6	4.08	A

ANOVA table for 1225nm Dry season

Analysis of variance

Variable	N	R²	R² Aj	VC
Inter 1225	55	0.37	0.00	41.89

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	6036.39	23	262.45	0.79	0.7140
Species	6036.39	23	262.45	0.79	0.7140
Error	10251.09	31	330.68		
Total	16287.47	54			

Test:Tukey Alpha=0.05 MSD=74.99709

Error: 330.6802 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	19.18	1	18.18	A
Uniola virgata	26.90	3	10.50	A
Zanthoxylum flavum	33.11	1	18.18	A
Pictetia aculeata	34.12	3	10.50	A
Agave sisalana	35.75	1	18.18	A
Capparis cynophallophora	35.92	2	12.86	A
Bourreria succulenta	36.60	3	10.50	A
Tabebuia heterophylla	36.93	3	10.50	A
Exostema caribaeum	37.71	3	10.50	A
Eugenia foetida	37.99	3	10.50	A
Bursera simaruba	38.54	4	9.09	A
Krugiodendrum ferreum	39.72	3	10.50	A
Jacquinia berteroi	45.49	1	18.18	A
Pisonia albida	45.97	3	10.50	A
Swietenia mahogany	47.61	3	10.50	A
Leucaena leucocephala	48.09	2	12.86	A
Coccoloba diversifolia	49.79	2	12.86	A
Gymnanthes lucifera	50.45	3	10.50	A
Guaiacum officinale	53.01	2	12.86	A
Pithecellobium unguis cati..	53.12	1	18.18	A
Coccoloba microstachia	56.75	3	10.50	A
Erithalis fructicosa	60.70	2	12.86	A
Amyris elemifera	61.48	2	12.86	A
Bucida buceras	76.52	1	18.18	A

($p > 0.05$)

<u>Nested ANOVA table for exotic vs native legumes, Dry season</u>

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Inter 1225	7	0.85	0.71	17.71

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	828.05	3	276.02	5.88	0.0899
species/species>status	0.30	1	0.30	0.01	0.9411
species>status	827.75	2	413.87	8.82	0.0554
Error	140.82	3	46.94		
Total	968.87	6			

Test:Tukey Alfa=0.05 DMS=16.65288

Error: 46.9396 df: 3

status	Mean	n	S.E	
exotic legume	38.45	3	3.96	A
native legume	43.62	4	3.96	A

ANOVA table for Seasonal 1225nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1225	62	0.35	3.0E-03	36.31

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5226.07	21	248.86	1.01	0.4751
Species	5100.19	20	255.01	1.03	0.4490
year	155.71	1	155.71	0.63	0.4316
Error	9868.25	40	246.71		
Total	15094.32	61			

Test:Tukey Alpha=0.05 MSD=53.15640

Error: 246.7062 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	26.21	4	7.85	A
Agave sisalana	29.91	2	11.11	A
Pictetia aculeata	32.80	2	11.11	A
Swietenia mahogany	33.61	4	7.85	A
Erithalis fructicosa	34.63	2	11.11	A
Pisonia albida	36.62	2	11.11	A
Tabebuia heterophylla	40.13	6	6.41	A
Amyris elemifera	40.33	2	11.11	A
Uniola virgata	40.68	3	9.09	A
Leucaena leucocephala	40.94	2	11.11	A
Krugiodendrum ferreum	43.50	4	7.85	A
Exostema caribaeum	44.10	6	6.41	A
Jacquinia berteroi	45.32	2	11.11	A
Bursera simaruba	47.68	2	11.11	A
Guaiacum officinale	49.11	4	7.85	A
Eugenia foetida	50.10	4	7.85	A
Pithecellobium unguis cati..	55.35	2	11.11	A
Capparis cynophallophora	55.94	2	11.11	A
Coccoloba diversifolia	56.32	3	9.09	A
Bucida buceras	56.60	2	11.11	A
Coccoloba microstachia	63.15	2	11.11	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=8.06738

Error: 246.7062 DF: 40

year	Medians	n	S.E.	
2013	42.36	32	2.90	A
2010	45.55	30	2.98	A

($p > 0.05$)

Appendix R

ANOVA table for W1497, wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1497	77	0.43	0.08	24.16

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	3.08	29	0.11	1.22	0.2692
Species	3.08	29	0.11	1.22	0.2692
Error	4.10	47	0.09		
Total	7.17	76			

Test:Tukey Alpha=0.05 MSD=1.14537

Error: 0.0871 DF: 47

Species	Medians	n	S.E.	
Erithalis fructicosa	0.76	1	0.30	A
Thouinia portoricensis	0.92	2	0.21	A
Cenchrus ciliaris	0.94	3	0.17	A
Guaiacum officinale	1.00	3	0.17	A
Pisonia albida	1.01	2	0.21	A
Conocarpus erectus	1.02	3	0.17	A
Amyris elemifera	1.05	3	0.17	A
Plumeria alba	1.06	3	0.17	A
Urochloa maxima	1.08	3	0.17	A
Bourreria succulenta	1.09	3	0.17	A
Jacquinia berteroi	1.10	1	0.30	A
Pictetia aculeata	1.11	3	0.17	A
Agave sisalana	1.16	2	0.21	A
Swietenia mahogany	1.16	3	0.17	A
Exostema caribaeum	1.17	4	0.15	A
Avicennia germinans	1.23	3	0.17	A
Tabebuia heterophylla	1.24	4	0.15	A
Bucida buceras	1.30	5	0.13	A
Prosopis juliflora	1.32	2	0.21	A
Pithecellobium unguis cati..	1.33	3	0.17	A
Krugiodendrum ferreum	1.36	3	0.17	A
Eugenia foetida	1.40	2	0.21	A
Coccoloba microstachia	1.42	3	0.17	A
Leucaena leucocephala	1.44	3	0.17	A
Pilosocereus royeni	1.49	3	0.17	A
Gymnanthes lucifera	1.50	1	0.30	A
Capparis cynophallophora	1.52	1	0.30	A
Bursera simaruba	1.55	2	0.21	A
Uniola virgata	1.66	2	0.21	A
Coccoloba diversifolia	1.74	1	0.30	A

($p > 0.05$)

ANOVA table for 1497nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1497	55	0.34	0.00	21.14

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.99	23	0.04	0.70	0.8081
Species	0.99	23	0.04	0.70	0.8081
Error	1.90	31	0.06		
Total	2.88	54			

Test:Tukey Alpha=0.05 MSD=1.02010

Error: 0.0612 DF: 31

Species	Medians	n	S.E.	
Zanthoxylum flavum	0.78	1	0.25	A
Haematoxylum campechianum	0.90	1	0.25	A
Krugiodendrum ferreum	1.04	3	0.14	A
Bourreria succulenta	1.06	3	0.14	A
Capparis cynophallophora	1.06	2	0.17	A
Uniola virgata	1.07	3	0.14	A
Bursera simaruba	1.08	4	0.12	A
Eugenia foetida	1.10	3	0.14	A
Pisonia albida	1.11	3	0.14	A
Tabebuia heterophylla	1.12	3	0.14	A
Agave sisalana	1.14	1	0.25	A
Pictetia aculeata	1.17	3	0.14	A
Pithecellobium unguis cati..	1.17	1	0.25	A
Jacquinia berteroi	1.19	1	0.25	A
Exostema caribaeum	1.19	3	0.14	A
Leucaena leucocephala	1.22	2	0.17	A
Gymnanthes lucifera	1.23	3	0.14	A
Coccoloba microstachia	1.25	3	0.14	A
Erithalis fructicosa	1.26	2	0.17	A
Coccoloba diversifolia	1.27	2	0.17	A
Swietenia mahogany	1.28	3	0.14	A
Guaiacum officinale	1.33	2	0.17	A
Bucida buceras	1.51	1	0.25	A
Amyris elemifera	1.55	2	0.17	A

($p > 0.05$)

ANOVA table for Seasonal 1497nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1497	62	0.30	0.00	21.14

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1.05	21	0.05	0.80	0.7043
Species	0.99	20	0.05	0.79	0.7070
year	0.08	1	0.08	1.31	0.2589
Error	2.50	40	0.06		
Total	3.55	61			

Test:Tukey Alpha=0.05 MSD=0.84683

Error: 0.0626 DF: 40

Species	Medians	n	S.E.	
Pisonia albida	0.84	2	0.18	A
Erithalis fructicosa	0.95	2	0.18	A
Bourreria succulenta	0.99	4	0.13	A
Pictetia aculeata	1.06	2	0.18	A
Swietenia mahogany	1.08	4	0.13	A
Amyris elemifera	1.12	2	0.18	A
Agave sisalana	1.12	2	0.18	A
Jacquinia berteroi	1.14	2	0.18	A
Krugiodendrum ferreum	1.19	4	0.13	A
Tabebuia heterophylla	1.20	6	0.10	A
Guaiacum officinale	1.22	4	0.13	A
Exostema caribaeum	1.22	6	0.10	A
Pithecellobium unguis cati..	1.23	2	0.18	A
Leucaena leucocephala	1.24	2	0.18	A
Eugenia foetida	1.25	4	0.13	A
Capparis cynophallophora	1.27	2	0.18	A
Coccoloba microstachia	1.28	2	0.18	A
Uniola virgata	1.29	3	0.14	A
Bucida buceras	1.32	2	0.18	A
Bursera simaruba	1.36	2	0.18	A
Coccoloba diversifolia	1.44	3	0.14	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=0.12852

Error: 0.0626 DF: 40

year	Medians	n	S.E.	
2013	1.14	32	0.05	A
2010	1.22	30	0.05	A

($p > 0.05$)

Appendix S

ANOVA table for 1530nm Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1530	74	0.43	0.05	53.31

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	14920.55	29	514.50	1.14	0.3396
Species	14920.55	29	514.50	1.14	0.3396
Error	19831.26	44	450.71		
Total	34751.81	73			

Test:Tukey Alpha=0.05 MSD=85.10893

Error: 450.7104 DF: 44

Species	Medians	n	S.E.	
Erithalis fructicosa	13.50	1	21.23	A
Thouinia portoricensis	19.53	2	15.01	A
Cenchrus ciliaris	19.79	3	12.26	A
Guaiacum officinale	23.23	3	12.26	A
Conocarpus erectus	27.30	3	12.26	A
Bourreria succulenta	27.58	3	12.26	A
Jacquinia berteroi	28.94	1	21.23	A
Pictetia aculeata	29.77	3	12.26	A
Plumeria alba	29.87	3	12.26	A
Agave sisalana	30.16	2	15.01	A
Urochloa maxima	32.46	3	12.26	A
Swietenia mahogany	33.08	3	12.26	A
Tabebuia heterophylla	35.84	4	10.61	A
Amyris elemifera	36.51	3	12.26	A
Pisonia albida	38.76	2	15.01	A
Exostema caribaeum	38.97	4	10.61	A
Leucaena leucocephala	39.76	2	15.01	A
Avicennia germinans	43.17	3	12.26	A
Prosopis juliflora	45.83	2	15.01	A
Pilosocereus royeni	46.49	2	15.01	A
Bucida buceras	46.60	5	9.49	A
Pithecellobium unguis cati..	47.52	3	12.26	A
Krugiodendrum ferreum	53.25	3	12.26	A
Eugenia foetida	54.62	2	15.01	A
Coccoloba microstachia	60.01	3	12.26	A
Bursera simaruba	67.46	2	15.01	A
Gymnanthes lucifera	67.82	1	21.23	A
Capparis cynophallophora	71.54	1	21.23	A
Uniola virgata	76.38	1	21.23	A
Coccoloba diversifolia	80.95	1	21.23	A

($p > 0.05$)

ANOVA table for 1530nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1530	53	0.43	0.00	41.66

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	4394.89	23	191.08	0.93	0.5621
Species	4394.89	23	191.08	0.93	0.5621
Error	5934.55	29	204.64		
Total	10329.44	52			

Test:Tukey Alpha=0.05 MSD=60.86127

Error: 204.6398 DF: 29

Species	Medians	n	S.E.	
Zanthoxylum flavum	15.76	1	14.31	A
Haematoxylum campechianum	17.79	1	14.31	A
Swietenia mahogany	23.47	2	10.12	A
Uniola virgata	25.86	3	8.26	A
Capparis cynophallophora	26.48	2	10.12	A
Bourreria succulenta	27.56	3	8.26	A
Krugiodendrum ferreum	28.40	3	8.26	A
Eugenia foetida	29.85	3	8.26	A
Agave sisalana	30.44	1	14.31	A
Tabebuia heterophylla	31.27	3	8.26	A
Bursera simaruba	31.51	4	7.15	A
Pictetia aculeata	33.20	3	8.26	A
Pisonia albida	33.33	3	8.26	A
Amyris elemifera	34.47	1	14.31	A
Exostema caribaeum	35.47	3	8.26	A
Jacquinia berteroi	35.72	1	14.31	A
Pithecellobium unguis cati..	37.11	1	14.31	A
Leucaena leucocephala	37.76	2	10.12	A
Coccoloba diversifolia	43.25	2	10.12	A
Erithalis fructicosa	43.25	2	10.12	A
Coccoloba microstachia	45.00	3	8.26	A
Gymnanthes lucifera	45.10	3	8.26	A
Guaiacum officinale	49.14	2	10.12	A
Bucida buceras	70.85	1	14.31	A

($p > 0.05$)

ANOVA table for Seasonal 1530nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
Inter 1530	62	0.29	0.00	49.58

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	5625.43	21	267.88	0.78	0.7254
Species	5111.76	20	255.59	0.74	0.7582
year	681.34	1	681.34	1.98	0.1668
Error	13743.53	40	343.59		
Total	19368.97	61			

Test:Tukey Alpha=0.05 MSD=62.73136

Error: 343.5883 DF: 40

Species	Medians	n	S.E.	
Bourreria succulenta	22.09	4	9.27	A
Erithalis fructicosa	22.65	2	13.11	A
Pictetia aculeata	25.64	2	13.11	A
Pisonia albida	27.03	2	13.11	A
Agave sisalana	27.82	2	13.11	A
Swietenia mahogany	28.85	4	9.27	A
Amyris elemifera	30.26	2	13.11	A
Jacquinia berteroi	32.33	2	13.11	A
Tabebuia heterophylla	34.89	6	7.57	A
Leucaena leucocephala	37.91	2	13.11	A
Guaiacum officinale	39.02	4	9.27	A
Krugiodendrum ferreum	39.52	4	9.27	A
Exostema caribaeum	40.60	6	7.57	A
Pithecellobium unguis cati..	40.78	2	13.11	A
Eugenia foetida	42.41	4	9.27	A
Coccoloba microstachia	44.49	2	13.11	A
Uniola virgata	46.13	3	10.73	A
Capparis cynophallophora	47.26	2	13.11	A
Bucida buceras	49.68	2	13.11	A
Bursera simaruba	51.73	2	13.11	A
Coccoloba diversifolia	56.93	3	10.73	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=9.52055

Error: 343.5883 DF: 40

year	Medians	n	S.E.	
2013	34.19	32	3.42	A
2010	40.86	30	3.52	A

($p > 0.05$)

Appendix T

ANOVA table for 1600nm Wet season

Analysis of variance

Variable	N	R²	R² Aj	VC
LOG10 Inter 1600	78	0.44	0.09	18.71

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.47	29	0.09	1.28	0.2233
Species	2.47	29	0.09	1.28	0.2233
Error	3.21	48	0.07		
Total	5.68	77			

Test:Tukey Alpha=0.05 MSD=0.98362

Error: 0.0668 DF: 48

Species	Medians	n	S.E.	
Erithalis fructicosa	1.03	1	0.26	A
Agave sisalana	1.07	2	0.18	A
Thouinia portoricensis	1.14	2	0.18	A
Cenchrus ciliaris	1.14	3	0.15	A
Pisonia albida	1.17	2	0.18	A
Guaiacum officinale	1.17	3	0.15	A
Plumeria alba	1.21	3	0.15	A
Bourreria succulenta	1.22	3	0.15	A
Urochloa maxima	1.23	3	0.15	A
Conocarpus erectus	1.25	3	0.15	A
Amyris elemifera	1.25	3	0.15	A
Jacquinia berteroi	1.32	1	0.26	A
Pictetia aculeata	1.33	3	0.15	A
Exostema caribaeum	1.34	4	0.13	A
Tabebuia heterophylla	1.36	4	0.13	A
Swietenia mahogany	1.36	3	0.15	A
Avicennia germinans	1.40	3	0.15	A
Krugiodendrum ferreum	1.48	3	0.15	A
Prosopis juliflora	1.48	2	0.18	A
Bucida buceras	1.49	5	0.12	A
Pithecellobium unguis cati..	1.52	3	0.15	A
Leucaena leucocephala	1.56	3	0.15	A
Eugenia foetida	1.56	2	0.18	A
Coccoloba microstachia	1.56	3	0.15	A
Pilosocereus royeni	1.57	3	0.15	A
Coccoloba diversifolia	1.62	2	0.18	A
Gymnanthes lucifera	1.67	1	0.26	A
Capparis cynophallophora	1.67	1	0.26	A
Bursera simaruba	1.69	2	0.18	A
Uniola virgata	1.75	2	0.18	A

(p > 0.05)

ANOVA table for 1600nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1600	55	0.36	0.00	15.73

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.83	23	0.04	0.77	0.7360
Species	0.83	23	0.04	0.77	0.7360
Error	1.45	31	0.05		
Total	2.28	54			

Test:Tukey Alpha=0.05 MSD=0.89171

Error: 0.0467 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	1.07	1	0.22	A
Zanthoxylum flavum	1.12	1	0.22	A
Uniola virgata	1.23	3	0.12	A
Capparis cynophallophora	1.25	2	0.15	A
Bourreria succulenta	1.27	3	0.12	A
Bursera simaruba	1.30	4	0.11	A
Krugiodendrum ferreum	1.31	3	0.12	A
Agave sisalana	1.31	1	0.22	A
Tabebuia heterophylla	1.32	3	0.12	A
Eugenia foetida	1.32	3	0.12	A
Pictetia aculeata	1.35	3	0.12	A
Pisonia albida	1.36	3	0.12	A
Exostema caribaeum	1.38	3	0.12	A
Gymnanthes lucifera	1.38	3	0.12	A
Jacquinia berteroi	1.40	1	0.22	A
Swietenia mahogany	1.43	3	0.12	A
Leucaena leucocephala	1.43	2	0.15	A
Pithecellobium unguis cati..	1.45	1	0.22	A
Coccoloba diversifolia	1.47	2	0.15	A
Coccoloba microstachia	1.48	3	0.12	A
Guaiacum officinale	1.51	2	0.15	A
Erithalis fructicosa	1.63	2	0.15	A
Bucida buceras	1.66	1	0.22	A
Amyris elemifera	1.67	2	0.15	A

($p > 0.05$)

ANOVA table for Seasonal 1600nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1600	62	0.32	0.00	16.07

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.90	21	0.04	0.89	0.5980
Species	0.90	20	0.05	0.94	0.5466
year	3.3E-04	1	3.3E-04	0.01	0.9340
Error	1.92	40	0.05		
Total	2.82	61			

Test:Tukey Alpha=0.05 MSD=0.74171

Error: 0.0480 DF: 40

Species	Medians	n	S.E.	
Agave sisalana	1.06	2	0.15	A
Pisonia albida	1.10	2	0.15	A
Bourreria succulenta	1.16	4	0.11	A
Pictetia aculeata	1.26	2	0.15	A
Erithalis fructicosa	1.26	2	0.15	A
Swietenia mahogany	1.27	4	0.11	A
Amyris elemifera	1.32	2	0.15	A
Tabebuia heterophylla	1.35	6	0.09	A
Jacquinia berteroi	1.36	2	0.15	A
Krugiodendrum ferreum	1.38	4	0.11	A
Exostema caribaeum	1.39	6	0.09	A
Leucaena leucocephala	1.41	2	0.15	A
Guaiacum officinale	1.42	4	0.11	A
Uniola virgata	1.43	3	0.13	A
Capparis cynophallophora	1.44	2	0.15	A
Eugenia foetida	1.45	4	0.11	A
Bucida buceras	1.47	2	0.15	A
Pithecellobium unguis cati..	1.48	2	0.15	A
Coccoloba microstachia	1.50	2	0.15	A
Bursera simaruba	1.51	2	0.15	A
Coccoloba diversifolia	1.57	3	0.13	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=0.11257

Error: 0.0480 DF: 40

year	Medians	n	S.E.	
2013	1.36	32	0.04	A
2010	1.36	30	0.04	A

($p > 0.05$)

Appendix U

ANOVA table for 1720nm Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1720	77	0.39	0.01	19.51

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.14	29	0.07	1.03	0.4550
Species	2.14	29	0.07	1.03	0.4550
Error	3.37	47	0.07		
Total	5.51	76			

Test:Tukey Alpha=0.05 MSD=1.03850

Error: 0.0716 DF: 47

Species	Medians	n	S.E.	
Erithalis fructicosa	1.02	1	0.27	A
Thouinia portoricensis	1.11	2	0.19	A
Cenchrus ciliaris	1.13	3	0.15	A
Guaiacum officinale	1.15	3	0.15	A
Pisonia albida	1.18	2	0.19	A
Plumeria alba	1.20	3	0.15	A
Amyris elemifera	1.22	3	0.15	A
Urochloa maxima	1.23	3	0.15	A
Bourreria succulenta	1.23	3	0.15	A
Conocarpus erectus	1.24	3	0.15	A
Agave sisalana	1.30	2	0.19	A
Jacquinia berteroi	1.31	1	0.27	A
Exostema caribaeum	1.32	4	0.13	A
Pictetia aculeata	1.32	3	0.15	A
Swietenia mahogany	1.34	3	0.15	A
Avicennia germinans	1.40	3	0.15	A
Tabebuia heterophylla	1.40	4	0.13	A
Bucida buceras	1.47	5	0.12	A
Krugiodendrum ferreum	1.48	3	0.15	A
Pithecellobium unguis cati..	1.48	3	0.15	A
Prosopis juliflora	1.49	2	0.19	A
Coccoloba diversifolia	1.50	2	0.19	A
Eugenia foetida	1.52	2	0.19	A
Leucaena leucocephala	1.54	3	0.15	A
Coccoloba microstachia	1.58	3	0.15	A
Pilosocereus royeni	1.58	3	0.15	A
Capparis cynophallophora	1.63	1	0.27	A
Bursera simaruba	1.66	2	0.19	A
Uniola virgata	1.68	1	0.27	A
Gymnanthes lucifera	1.84	1	0.27	A

($p > 0.05$)

ANOVA table for 1720nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1720	55	0.32	0.00	15.75

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.66	23	0.03	0.65	0.8596
Species	0.66	23	0.03	0.65	0.8596
Error	1.38	31	0.04		
Total	2.05	54			

Test:Tukey Alpha=0.05 MSD=0.87130

Error: 0.0446 DF: 31

Species	Medians	n	S.E.	
Haematoxylum campechianum	1.05	1	0.21	A
Zanthoxylum flavum	1.07	1	0.21	A
Capparis cynophallophora	1.22	2	0.15	A
Uniola virgata	1.22	3	0.12	A
Bourreria succulenta	1.26	3	0.12	A
Krugiodendrum ferreum	1.27	3	0.12	A
Agave sisalana	1.28	1	0.21	A
Bursera simaruba	1.28	4	0.11	A
Tabebuia heterophylla	1.29	3	0.12	A
Eugenia foetida	1.31	3	0.12	A
Pictetia aculeata	1.32	3	0.12	A
Exostema caribaeum	1.34	3	0.12	A
Pisonia albida	1.35	3	0.12	A
Swietenia mahogany	1.36	3	0.12	A
Jacquinia berteroi	1.37	1	0.21	A
Gymnanthes lucifera	1.39	3	0.12	A
Pithecellobium unguis cati..	1.41	1	0.21	A
Leucaena leucocephala	1.41	2	0.15	A
Erithalis fructicosa	1.43	2	0.15	A
Coccoloba microstachia	1.45	3	0.12	A
Coccoloba diversifolia	1.45	2	0.15	A
Guaiacum officinale	1.48	2	0.15	A
Amyris elemifera	1.61	2	0.15	A
Bucida buceras	1.63	1	0.21	A

($p > 0.05$)

ANOVA table for Seasonal 1720nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1720	62	0.28	0.00	16.11

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.73	21	0.03	0.73	0.7776
Species	0.71	20	0.04	0.75	0.7513
year	0.02	1	0.02	0.52	0.4737
Error	1.89	40	0.05		
Total	2.62	61			

Test:Tukey Alpha=0.05 MSD=0.73656

Error: 0.0474 DF: 40

Species	Medians	n	S.E.	
Pisonia albida	1.11	2	0.15	A
Bourreria succulenta	1.16	4	0.11	A
Erithalis fructicosa	1.18	2	0.15	A
Pictetia aculeata	1.23	2	0.15	A
Swietenia mahogany	1.25	4	0.11	A
Agave sisalana	1.28	2	0.15	A
Amyris elemifera	1.29	2	0.15	A
Jacquinia berteroi	1.34	2	0.15	A
Exostema caribaeum	1.36	6	0.09	A
Tabebuia heterophylla	1.37	6	0.09	A
Krugiodendrum ferreum	1.37	4	0.11	A
Guaiacum officinale	1.38	4	0.11	A
Leucaena leucocephala	1.40	2	0.15	A
Capparis cynophallophora	1.40	2	0.15	A
Uniola virgata	1.41	3	0.13	A
Pithecellobium unguis cati..	1.42	2	0.15	A
Eugenia foetida	1.42	4	0.11	A
Bucida buceras	1.45	2	0.15	A
Bursera simaruba	1.48	2	0.15	A
Coccoloba microstachia	1.49	2	0.15	A
Coccoloba diversifolia	1.56	3	0.13	A

(p > 0.05)

Test:Tukey Alpha=0.05 MSD=0.11179

Error: 0.0474 DF: 40

year	Medians	n	S.E.	
2013	1.33	32	0.04	A
2010	1.37	30	0.04	A

(p > 0.05)

Appendix V

ANOVA table for W1730, wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1730	78	0.41	0.05	20.05

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.49	29	0.09	1.14	0.3385
Species	2.49	29	0.09	1.14	0.3385
Error	3.62	48	0.08		
Total	6.12	77			

Test:Tukey Alpha=0.05 MSD=1.04583

Error: 0.0755 DF: 48

Species	Medians	n	S.E.	
Erithalis fructicosa	1.02	1	0.27	A
Agave sisalana	1.08	2	0.19	A
Thouinia portoricensis	1.12	2	0.19	A
Cenchrus ciliaris	1.13	3	0.16	A
Guaiacum officinale	1.16	3	0.16	A
Pisonia albida	1.19	2	0.19	A
Plumeria alba	1.19	3	0.16	A
Bourreria succulenta	1.22	3	0.16	A
Amyris elemifera	1.22	3	0.16	A
Urochloa maxima	1.23	3	0.16	A
Conocarpus erectus	1.24	3	0.16	A
Jacquinia berteroi	1.31	1	0.27	A
Exostema caribaeum	1.32	4	0.14	A
Pictetia aculeata	1.33	3	0.16	A
Swietenia mahogany	1.34	3	0.16	A
Tabebuia heterophylla	1.39	4	0.14	A
Avicennia germinans	1.40	3	0.16	A
Bucida buceras	1.48	5	0.12	A
Pithecellobium unguis cati..	1.48	3	0.16	A
Prosopis juliflora	1.49	2	0.19	A
Krugiodendrum ferreum	1.49	3	0.16	A
Coccoloba diversifolia	1.50	2	0.19	A
Eugenia foetida	1.52	2	0.19	A
Leucaena leucocephala	1.54	3	0.16	A
Pilosocereus royeni	1.56	3	0.16	A
Coccoloba microstachia	1.57	3	0.16	A
Capparis cynophallophora	1.63	1	0.27	A
Bursera simaruba	1.66	2	0.19	A
Uniola virgata	1.75	2	0.19	A
Gymnanthes lucifera	1.87	1	0.27	A

($p > 0.05$)

ANOVA table for 1730nm Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1730	54	0.36	0.00	15.98

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.77	23	0.03	0.72	0.7881
Species	0.77	23	0.03	0.72	0.7881
Error	1.38	30	0.05		
Total	2.15	53			

Test:Tukey Alpha=0.05 MSD=0.90509

Error: 0.0461 DF: 30

Species	Medians	n	S.E.	
Haematoxylum campechianum	1.06	1	0.21	A
Zanthoxylum flavum	1.08	1	0.21	A
Uniola virgata	1.22	3	0.12	A
Capparis cynophallophora	1.22	2	0.15	A
Bourreria succulenta	1.25	3	0.12	A
Krugiodendrum ferreum	1.26	3	0.12	A
Bursera simaruba	1.28	4	0.11	A
Tabebuia heterophylla	1.28	3	0.12	A
Agave sisalana	1.29	1	0.21	A
Eugenia foetida	1.31	3	0.12	A
Pictetia aculeata	1.31	3	0.12	A
Amyris elemifera	1.33	1	0.21	A
Pisonia albida	1.35	3	0.12	A
Exostema caribaeum	1.35	3	0.12	A
Jacquinia berteroi	1.36	1	0.21	A
Gymnanthes lucifera	1.38	3	0.12	A
Swietenia mahogany	1.39	3	0.12	A
Pithecellobium unguis cati..	1.40	1	0.21	A
Leucaena leucocephala	1.41	2	0.15	A
Coccoloba diversifolia	1.43	2	0.15	A
Guaiacum officinale	1.48	2	0.15	A
Coccoloba microstachia	1.49	3	0.12	A
Bucida buceras	1.63	1	0.21	A
Erithalis fructicosa	1.69	2	0.15	A

($p > 0.05$)

ANOVA table for Seasonal 1730nm

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Inter 1730	62	0.28	0.00	17.16

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	0.85	21	0.04	0.76	0.7502
Species	0.84	20	0.04	0.79	0.7070
year	0.01	1	0.01	0.13	0.7247
Error	2.13	40	0.05		
Total	2.98	61			

Test:Tukey Alpha=0.05 MSD=0.78097

Error: 0.0533 DF: 40

Species	Medians	n	S.E.	
Agave sisalana	1.07	2	0.16	A
Pisonia albida	1.09	2	0.16	A
Bourreria succulenta	1.14	4	0.12	A
Pictetia aculeata	1.23	2	0.16	A
Swietenia mahogany	1.24	4	0.12	A
Amyris elemifera	1.29	2	0.16	A
Erithalis fructicosa	1.29	2	0.16	A
Jacquinia berteroi	1.34	2	0.16	A
Tabebuia heterophylla	1.36	6	0.09	A
Krugiodendrum ferreum	1.37	4	0.12	A
Exostema caribaeum	1.37	6	0.09	A
Guaiacum officinale	1.39	4	0.12	A
Leucaena leucocephala	1.39	2	0.16	A
Capparis cynophallophora	1.40	2	0.16	A
Uniola virgata	1.41	3	0.13	A
Pithecellobium unguis cati..	1.41	2	0.16	A
Eugenia foetida	1.42	4	0.12	A
Bucida buceras	1.45	2	0.16	A
Bursera simaruba	1.48	2	0.16	A
Coccoloba microstachia	1.49	2	0.16	A
Coccoloba diversifolia	1.56	3	0.13	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=0.11853

Error: 0.0533 DF: 40

year	Medians	n	S.E.	
2013	1.33	32	0.04	A
2010	1.35	30	0.04	A

($p > 0.05$)

Appendix W

ANOVA table for Chl meter, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Chl meter	82	0.44	0.14	10.57

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1.04	28	0.04	1.47	0.1137
Species	1.04	28	0.04	1.47	0.1137
Error	1.35	53	0.03		
Total	2.39	81			

Test:Tukey Alpha=0.05 MSD=0.56829

Error: 0.0254 DF: 53

Species	Medians	n	S.E.	
Krugiodendrum ferreum	1.25	3	0.09	A
Jacquinia berteroi	1.27	1	0.16	A
Haematoxylum campechianum	1.30	2	0.11	A
Urochloa maxima	1.36	2	0.11	A
Erithalis fructicosa	1.37	1	0.16	A
Thouinia portoricensis	1.41	2	0.11	A
Exostema caribaeum	1.41	4	0.08	A
Prosopis juliflora	1.42	2	0.11	A
Eugenia foetida	1.42	2	0.11	A
Guaiacum officinale	1.43	4	0.08	A
Coccoloba microstachia	1.44	3	0.09	A
Coccoloba diversifolia	1.46	2	0.11	A
Cenchrus ciliaris	1.46	3	0.09	A
Plumeria alba	1.49	3	0.09	A
Conocarpus erectus	1.49	2	0.11	A
Pisonia albida	1.49	3	0.09	A
Bucida buceras	1.49	5	0.07	A
Bourreria succulenta	1.54	4	0.08	A
Leucaena leucocephala	1.54	3	0.09	A
Capparis cynophallophora	1.57	3	0.09	A
Gymnanthes lucifera	1.58	2	0.11	A
Uniola virgata	1.58	3	0.09	A
Amyris elemifera	1.59	2	0.11	A
Bursera simaruba	1.59	3	0.09	A
Avicennia germinans	1.60	4	0.08	A
Tabebuia heterophylla	1.60	4	0.08	A
Pithecellobium unguis cati..	1.68	3	0.09	A
Swietenia mahogany	1.70	4	0.08	A
Pictetia aculeata	1.70	3	0.09	A

($p > 0.05$)

<u>Nested ANOVA table for exotic vs native legumes, Wet season</u>

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
LOG10 Chl meter	13	0.70	0.56	7.77

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.28	4	0.07	4.78	0.0290
species/species>status	0.21	1	0.21	14.30	0.0054
species>status	0.07	3	0.02	1.60	0.2634
Error	0.12	8	0.01		
Total	0.40	12			

Test:Tukey Alfa=0.05 DMS=0.15487

Error: 0.0146 df: 8

status	Mean	n	S.E		
exotic legume	1.42	7	0.05	A	
native legume	1.69	6	0.05		B

ANOVA table for Chl meter, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Chl meter	63	0.53	0.23	18.40

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.69	24	0.11	1.79	0.0532
Species	2.69	24	0.11	1.79	0.0532
Error	2.38	38	0.06		
Total	5.07	62			

Test:Tukey Alpha=0.05 MSD=0.97875

Error: 0.0626 DF: 38

Species	Medians	n	S.E.	
Bursera simaruba	0.96	2	0.18	A
Pisonia albida	1.04	3	0.14	A
Pithecellobium unguis cati..	1.06	2	0.18	A
Zanthoxylum flavum	1.16	1	0.25	A
Jacquinia berteroi	1.18	1	0.25	A
Coccoloba microstachia	1.19	4	0.13	A
Coccoloba diversifolia	1.24	2	0.18	A
Haematoxylum campechianum	1.25	3	0.14	A
Exostema caribaeum	1.26	4	0.13	A
Bucida buceras	1.26	3	0.14	A
Plumeria alba	1.27	1	0.25	A
Krugiodendrum ferreum	1.28	3	0.14	A
Tabebuia heterophylla	1.31	3	0.14	A
Amyris elemifera	1.32	3	0.14	A
Bourreria succulenta	1.35	4	0.13	A
Guaiacum officinale	1.42	3	0.14	A
Capparis cynophallophora	1.48	3	0.14	A
Gymnanthes lucifera	1.48	3	0.14	A
Avicennia germinans	1.54	2	0.18	A
Leucaena leucocephala	1.58	1	0.25	A
Conocarpus erectus	1.62	2	0.18	A
Erithalis fructicosa	1.65	2	0.18	A
Swietenia mahogany	1.70	4	0.13	A
Pictetia aculeata	1.70	3	0.14	A
Eugenia foetida	1.76	1	0.25	A

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
LOG10 Chl meter	9	0.84	0.75	10.88

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.61	3	0.20	8.82	0.0193
species/species>status	0.03	1	0.03	1.17	0.3291
species>status	0.58	2	0.29	12.65	0.0111
Error	0.12	5	0.02		
Total	0.73	8			

Test:Tukey Alfa=0.05 DMS=0.26211

Error: 0.0231 df: 5

status	Mean	n	S.E	
native legume	1.38	5	0.07	A
exotic legume	1.47	4	0.11	A

ANOVA table for Chl meter, Seasonality

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Chl meter	100	0.40	0.21	14.98

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	2.38	24	0.10	2.10	0.0079
Species	1.91	23	0.08	1.76	0.0355
year	0.47	1	0.47	10.00	0.0023
Error	3.54	75	0.05		
Total	5.93	99			

Test:Tukey Alpha=0.05 MSD=0.64512

Error: 0.0472 DF: 75

Species	Medians	n	S.E.	
Jacquinia berteroi	1.22	2	0.15	A
Krugiodendrum ferreum	1.26	6	0.09	A
Pisonia albida	1.27	6	0.09	A
Bursera simaruba	1.27	2	0.15	A
Haematoxylum campechianum	1.30	4	0.11	A
Amyris elemifera	1.33	2	0.15	A
Coccoloba diversifolia	1.35	4	0.11	A
Pithecellobium unguis cati..	1.36	4	0.11	A
Exostema caribaeum	1.38	6	0.09	A
Bucida buceras	1.41	6	0.09	A
Conocarpus erectus	1.44	2	0.15	A
Coccoloba microstachia	1.44	4	0.11	A
Bourreria succulenta	1.44	8	0.08	A
Plumeria alba	1.45	2	0.15	A
Tabebuia heterophylla	1.46	6	0.09	A
Guaiacum officinale	1.47	6	0.09	A
Capparis cynophallophora	1.52	4	0.11	A
Avicennia germinans	1.56	4	0.11	A
Erithalis fructicosa	1.57	2	0.15	A
Leucaena leucocephala	1.58	2	0.15	A
Eugenia foetida	1.58	2	0.15	A
Gymnanthes lucifera	1.60	2	0.15	A
Swietenia mahogany	1.70	8	0.08	A
Pictetia aculeata	1.70	6	0.09	A

($p > 0.05$)

Test:Tukey Alpha=0.05 MSD=0.08659

Error: 0.0472 DF: 75

year	Medians	n	S.E.		
2013	1.38	50	0.03	A	
2010	1.51	50	0.03		B

($p > 0.05$)

Appendix X

Anova table for Water Concentration, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Leaf water concentration	88	0.69	0.53	19.36

ANOVA Table (Type III)

F.V.	S	DF	MS	F	p-value
Modelo.	11500.85	29	396.58	4.43	<0.0001
species	11500.85	29	396.58	4.43	<0.0001
Error	5192.92	58	89.53		
Total	16693.77	87			

Test:Tukey Alfa=0.05 DMS=33.41242

Error: 89.5331 DF: 58

species	Medians	n	S.E.					
Uniola virgata	25.07	3	5.46	A				
Amyris elemifera	30.90	3	5.46	A	B			
Coccoloba microstachia	37.12	3	5.46	A	B	C		
Exostema caribaeum	38.55	4	4.73	A	B	C	D	
Gymnanthes lucifera	39.15	3	5.46	A	B	C	D	
Eugenia foetida	39.90	2	6.69	A	B	C	D	
Thouinia portoricensis	40.18	2	6.69	A	B	C	D	
Guaiacum officinale	40.61	4	4.73	A	B	C	D	
Krugiodendrum ferreum	40.69	3	5.46	A	B	C	D	
Coccoloba diversifolia	41.59	3	5.46	A	B	C	D	
Capparis cynophallophora	42.84	3	5.46	A	B	C	D	
Pithecellobium unguis cati..	43.62	3	5.46	A	B	C	D	
Haematoxylum campechianum	43.93	2	6.69	A	B	C	D	
Bourreria succulenta	45.25	4	4.73	A	B	C	D	
Bucida buceras	46.71	5	4.23	A	B	C	D	
Tabebuia heterophylla	48.61	4	4.73	A	B	C	D	
Erithalis fructicosa	49.32	1	9.46	A	B	C	D	
Swietenia mahogany	51.18	4	4.73	A	B	C	D	E
Jacquinia berteroi	52.94	1	9.46	A	B	C	D	E
Pictetia aculeata	54.25	3	5.46	A	B	C	D	E
Leucaena leucocephala	56.36	3	5.46	A	B	C	D	E
Prosopis juliflora	57.00	3	5.46	A	B	C	D	E

Conocarpus erectus	57.10	3	5.46	A	B	C	D	E
Cenchrus ciliaris	60.41	3	5.46		B	C	D	E
Bursera simaruba	61.79	3	5.46		B	C	D	E
Agave sisalana	63.25	2	6.69		B	C	D	E
Avicennia germinans	64.61	4	4.73			C	D	E
Pisonia albida	65.06	3	5.46			C	D	E
Plumeria alba	70.87	3	5.46				D	E
Urochloa maxima	83.65	1	9.46					E

($p > 0.05$)

Appendix Y

Anova table for N Concentration, Species variation, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Nitrogen	91	0.68	0.53	264.95

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	3.03	28	0.11	4.60	<0.0001
Species	3.03	28	0.11	4.60	<0.0001
Error	1.46	62	0.02		
Total	4.49	90			

Test:Tukey Alpha=0.05 MSD=0.50368

Error: 0.0235 DF: 62

Species	Medians	n	S.E.				
Uniola virgata	-0.46	3	0.09	A			
Jacquinia berteroi	-0.17	1	0.15	A	B		
Conocarpus erectus	-0.16	3	0.09	A	B	C	
Urochloa maxima	-0.13	3	0.09	A	B	C	
Cenchrus ciliaris	-0.13	3	0.09	A	B	C	
Erithalis fructicosa	-0.10	2	0.11	A	B	C	
Swietenia mahogany	-0.10	4	0.08	A	B	C	
Tabebuia heterophylla	-0.09	4	0.08	A	B	C	D
Coccoloba diversifolia	-0.07	3	0.09	A	B	C	D
Bourreria succulenta	-0.02	4	0.08	A	B	C	D
Bucida buceras	-0.01	5	0.07	A	B	C	D
Plumeria alba	-0.01	3	0.09	A	B	C	D
Coccoloba microstachia	-0.01	3	0.09	A	B	C	D
Eugenia foetida	0.03	2	0.11	A	B	C	D
Avicennia germinans	0.05	4	0.08		B	C	D
Thouinia portoricensis	0.07	2	0.11		B	C	D
Amyris elemifera	0.10	3	0.09		B	C	D
Guaiacum officinale	0.10	5	0.07		B	C	D
Exostema caribaeum	0.12	4	0.08		B	C	D
Gymnanthes lucifera	0.15	3	0.09		B	C	D
Haematoxylum campechianum	0.17	2	0.11		B	C	D
Bursera simaruba	0.18	3	0.09		B	C	D
Krugiodendrum ferreum	0.22	3	0.09		B	C	D
Pisonia albida	0.22	3	0.09		B	C	D
Pithecellobium unguis cati..	0.26	3	0.09		B	C	D
Pictetia aculeata	0.28	3	0.09		B	C	D
Capparis cynophallophora	0.33	3	0.09		B	C	D
Leucaena leucocephala	0.34	4	0.08			C	D
Prosopis juliflora	0.41	3	0.09				D

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Wet season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Leaf water concentration	14	0.57	0.38	12.40

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	485.06	4	121.26	2.97	0.0806
species/species>status	71.21	1	71.21	1.74	0.2192
species>status	413.85	3	137.95	3.38	0.0679
Error	367.36	9	40.82		
Total	852.42	13			

ANOVA table for Nitrogen Concentration, Species variation, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	VC
LOG10 Nitrogen	70	0.88	0.81	30.09

ANOVA table (SS type III)

F.V.	SS	DF	MS	F	p-value
Model.	1.23	25	0.05	12.90	<0.0001
Species	1.23	25	0.05	12.90	<0.0001
Error	0.17	44	3.8E-03		
Total	1.39	69			

Test:Tukey Alpha=0.05 MSD=0.22821

Error: 0.0038 DF: 44

Species	Medians	n	S.E.							
Swietenia mahogany	-3.8E-05	4	0.03	A						
Erithalis fructicosa	4.3E-03	2	0.04	A	B					
Jacquinia berteroi	4.3E-03	1	0.06	A	B					
Conocarpus erectus	0.04	2	0.04	A	B	C				
Tabebuia heterophylla	0.07	3	0.04	A	B	C	D			
Coccoloba microstachia	0.10	3	0.04	A	B	C	D			
Bucida buceras	0.10	4	0.03	A	B	C	D			
Exostema caribaeum	0.11	2	0.04	A	B	C	D			
Eugenia foetida	0.14	4	0.03	A	B	C	D			
Zanthoxylum flavum	0.15	1	0.06	A	B	C	D			
Coccoloba diversifolia	0.16	3	0.04	A	B	C	D	E		
Plumeria alba	0.17	1	0.06	A	B	C	D	E		
Bourreria succulenta	0.18	4	0.03	A	B	C	D	E		
Bursera simaruba	0.22	4	0.03	A	B	C	D	E	F	
Avicennia germinans	0.23	2	0.04	A	B	C	D	E	F	
Gymnanthes lucifera	0.23	3	0.04		B	C	D	E	F	
Guaiacum officinale	0.25	4	0.03			C	D	E	F	
Pithecellobium unguis cati..	0.26	2	0.04			C	D	E	F	
Pictetia aculeata	0.27	3	0.04			C	D	E	F	G
Haematoxylum campechianum	0.27	2	0.04				D	E	F	G

Krugiodendrum ferreum	0.29	4	0.03	D	E	F	G	
Amyris elemifera	0.30	3	0.04	D	E	F	G	H
Pisonia albida	0.38	2	0.04		E	F	G	H
Capparis cynophallophora	0.41	2	0.04			F	G	H
Leucaena leucocephala	0.49	2	0.04				G	H
Prosopis juliflora	0.52	3	0.04					H

($p > 0.05$)

Nested ANOVA table for exotic vs native legumes, Dry season

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
LOG10 Nitrogen	12	0.89	0.83	14.83

ANOVA(SS type I)

F.V.	SS	DF	MS	F	p-value
Model.	0.17	4	0.04	14.68	0.0016
species/species>status	0.09	1	0.09	31.15	0.0008
species>status	0.08	3	0.03	9.19	0.0080
Error	0.02	7	3.0E-03		
Total	0.20	11			

ANOVA table for Nitrogen Concentration, Seasonality

Analysis of variance

Variable	N	R^2	R^2 Aj	CV
Nitrogen	106	0.81	0.75	19.33

ANOVA Table (SS Type III)

F.V.	SS	DF	MS	F	p-value
Modelo.	28.57	25	1.14	13.91	<0.0001
species	25.06	24	1.04	12.71	<0.0001
year	3.45	1	3.45	41.98	<0.0001
Error	6.57	80	0.08		
Total	35.14	105			

Test:Tukey Alfa=0.05 DMS=0.82475

Error: 0.0821 df: 80

species	Medians	n	S.E.							
Erithalis fructicosa	0.77	2	0.20	A						
Jacquinia berteroi	0.85	2	0.20	A	B					
Conocarpus erectus	0.88	4	0.14	A	B	C				
Swietenia mahogany	0.91	8	0.10	A	B	C				
Tabebuia heterophylla	1.03	6	0.12	A	B	C	D			
Coccoloba microstachia	1.16	2	0.20	A	B	C	D	E		
Bucida buceras	1.16	6	0.12	A	B	C	D	E		
Coccoloba diversifolia	1.21	6	0.12	A	B	C	D	E	F	
Exostema caribaeum	1.25	4	0.14	A	B	C	D	E	F	
Eugenia foetida	1.25	4	0.14	A	B	C	D	E	F	
Bourreria succulenta	1.26	8	0.10	A	B	C	D	E	F	
Avicennia germinans	1.48	4	0.14	A	B	C	D	E	F	
Guaiacum officinale	1.53	8	0.10	A	B	C	D	E	F	G
Gymnanthes lucifera	1.56	4	0.14	A	B	C	D	E	F	G
Amyris elemifera	1.63	2	0.20		B	C	D	E	F	G
Plumeria alba	1.64	2	0.20		B	C	D	E	F	G
Haematoxylum campechianum	1.69	4	0.14			C	D	E	F	G

Pictetia aculeata	1.76	3	0.17	D E F G
Krugiodendrum ferreum	1.76	6	0.12	D E F G
Pithecellobium unguis cati..	1.80	4	0.14	D E F G H
Bursera simaruba	1.88	3	0.17	E F G H
Pisonia albida	2.02	4	0.14	F G H I
Capparis cynophallophora	2.35	4	0.14	G H I
Leucaena leucocephala	2.62	2	0.20	H I
Prosopis juliflora	2.83	4	0.14	I

(p > 0.05)

Test:Tukey Alfa=0.05 DMS=0.11079

Error: 0.0821 gl: 80

year	Medians	n	E.E.		
2010	1.35	53	0.04	A	
2013	1.71	53	0.04		B

(p > 0.05)

Appendix Z

Correlation tables

Correlación de Spearman: Coeficientes\probabilidades

	ChlA Concentration	LOG10 ChlB Concentration	Car. Concetration	LOG10 Chl meter	LOG10 Total Chlorophyll	Inter 470	LOG10 Inter 652	Inter 665
ChlA Concentration	1.00	0.00	0.00	0.32	0.00	0.63	0.42	0.52
LOG10_ChlB Concentration	0.88	1.00	0.00	0.33	0.00	0.53	0.39	0.49
Car. Concetration	0.85	0.81	1.00	0.66	0.00	0.75	0.82	0.81
LOG10_Chl meter	0.09	0.09	0.04	1.00	0.29	0.50	0.85	0.84
LOG10_Total Chlorophyll	0.99	0.93	0.86	0.09	1.00	0.58	0.38	0.48
Inter 470	-0.05	-0.06	-0.03	0.07	-0.05	1.00	0.00	0.00
LOG10_Inter 652	-0.08	-0.08	-0.02	0.02	-0.08	0.93	1.00	0.00
Inter 665	-0.06	-0.06	-0.02	0.02	-0.07	0.94	0.98	1.00

Correlación de Spearman: Coeficientes\probabilidades

	Leaf water concentration	Inter 960	Inter 980	Inter 1180	Inter 1190	Inter 1530	LOG10 Inter 1600	LOG10 Inter 1720
Leaf water concentration	1.00	0.07	0.13	0.04	0.04	0.14	0.14	0.30
Inter 960	-0.21	1.00	0.00	0.00	0.00	2.8E-08	8.5E-12	2.8E-12
Inter 980	-0.18	0.97	1.00	0.00	0.00	1.6E-09	0.00	0.00
Inter 1180	-0.24	0.89	0.93	1.00	0.00	0.00	0.00	0.00
Inter 1190	-0.24	0.88	0.92	1.00	1.00	0.00	0.00	0.00
Inter 1530	-0.18	0.67	0.73	0.88	0.89	1.00	0.00	0.00
LOG10_Inter 1600	-0.17	0.70	0.76	0.90	0.91	0.99	1.00	0.00
LOG10_Inter 1720	-0.12	0.71	0.77	0.90	0.90	0.99	0.97	1.00

Correlación de Spearman: Coeficientes\probabilidades

	Nitrogen	Inter 762	Inter 813	Inter 817	Inter 984	Inter 1192	LOG10 Inter 1497	LOG10 Inter 1730	Inter 1225
Nitrogen	1.00	0.78	0.95	0.95	0.88	0.99	0.74	0.83	0.98
Inter 762	0.03	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inter 813	0.01	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Inter 817	0.01	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
Inter 984	-0.01	0.94	0.95	0.94	1.00	0.00	0.00	0.00	0.00
Inter 1192	-8.2E-04	0.86	0.86	0.86	0.95	1.00	0.00	0.00	0.00
LOG10_Inter 1497	0.03	0.63	0.63	0.62	0.76	0.86	1.00	0.00	0.00
LOG10_Inter 1730	0.02	0.68	0.68	0.67	0.79	0.91	0.97	1.00	0.00
Inter 1225	-1.8E-03	0.86	0.86	0.86	0.95	1.00	0.86	0.91	1.00