Restoration Practices for Subtropical Dry Forests in Puerto Rico: Ecological and Economic Aspects for Establishment of Native Trees Species

By

José Gilberto Martínez Rodríguez

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Approved by:

______________________________ ____________________

Stefanie L. Whitmire, Ph.D. Date

Member, Graduate Committee

______________________________ ____________________

Jarrod M. Thaxton, Ph.D. Date

Member, Graduate Committee

______________________________ ____________________

Skip J. Van Bloem, Ph.D. Date

President, Graduate Committee

______________________________ ____________________

Norma I. Sojo-Ramos, MSLS Date

Representative of Graduate Studies

______________________________ ____________________

Skip J. Van Bloem, Ph.D. Date

Department Chairperson

Abstract

Subtropical dry forests that are degraded by human activities may take centuries to recover. Reforestation projects can be an important instrument for the regeneration of dry forests. However, the costs and labor requirements are a challenge. This project explored five management practices (control, irrigation, mulch, mulch-irrigation and mulch-irrigation plus bulldozing) for establishment native tree species. In the rainy season of September 2007 in the Cabo Rojo National Wildlife Refuge, six native species were planted in two different types of soil (clay and loamy sand). Soil moisture and grass cover were measured to help explain mechanisms that affected success. I evaluated the economic and labor requirements in comparison to the ecological benefits to determine the cost-effectiveness of management practices used to establish native tree species. Three years after planting, the survival rate of the saplings was 81% in both soil types. All species together had approximately more 50% of height growth in clay soil than loamy sand soil. Saplings planted with mulch showed higher growth compared to control and irrigation in loamy sand. Mulch management decreased grass cover and maintained soil moisture over time, and this helped increased growth and survival in the first stage of establishment. Ligh bulldozing after surface helps to maintain weed control for one year after treatment, but after at three years the establishment and growth was not higher than mulch. Mulch/irrigation in combination with bulldozing increased soil moisture and growth, but mulch management was the most cost effective technique for the establishment of native tree species over time. The fastest growing species were *C. fruticosum* and *T. heterophylla*, then *B. Simaruba;* those that showed medium to low growth were *B. buceras*, *B. succulenta* and *E. aerolatum*. The study established that the combination of mulch management with the species, in order of highest growth, *C. fruticosum* > *T. heterophyla* > *B. simaruba* > *B. buceras*, yielded the most cost-effective management for the restoration of subtropical dry forests.

Resumen

La intensa actividad humana a degradado los bosques secos subtropicales que pueden tardar siglos en recuperarse sin la restauración activa. La reforestación puede ser un instrumento importante para para la regeneración de los bosques secos. Sin embargo, los costos y los requerimientos de labor hacen que los proyectos de reforestación sean difíciles sin mucho mantenimiento, tales como el riego y control de pastos. En 2007 se establece un proyecto de investigación en el Refugio Nacional de Vida Silvestre de Cabo Rojo que evalúa cinco prácticas de manejo (control, riego, cubierta de heno, cubierta/riego y cubierta/riego más la remoción de yerbas) para el establecimiento de especies de árboles nativos. Para la temporada de lluvia en Septiembre 2007, seis especies nativas fueron sembradas en dos tipos de suelo (textura arcillosa y franco arenoso). Se evaluó como las prácticas de manejo influencian en el éxito del establecimiento de las especies de árboles nativos en proyectos de reforestación en los bosques secos. La humedad de suelo y la cobertura de yerbas fueron medidas para ayudar a explicar los mecanismos que afectan el éxito de establecimiento. Al mismo tiempo se comparo los requerimientos económicos y de labor con los resultados ecológicos (sobrevivencia y crecimiento) para determinar la costo-efectividad de las prácticas de manejo. Todas las especies juntas tuvieron aproximadamente más de 50% de crecimiento en el suelo arcilloso que el franco arenoso. Los arboles juveniles manejados con cubierta de heno presentaron mayor crecimiento cuando se compara con los manejos de riego o control en suelo franco arenoso. El efecto del "buldócer" en la superficie del suelo ayuda a controlar las yerbas luego de un año, pero al pasar tres años el establecimiento y crecimiento no fueron mayores que el manejo con cubierta de heno. Cubierta de heno con riego y el efecto de "buldócer" incrementaron la humedad de suelo y el crecimiento en los arboles juveniles, pero la inversión adicional hacen que el manejo con cubierta de heno sea más costo-efectivo. Las más rápidas de crecimiento lo fueron las especies *C. fruticosum* y *T. heterophylla*, luego *B. simaruba* y las que presentaron un mediano y de bajo crecimiento los fueron *B. buceras*, *B. succulenta* and *E. aerolatum*. El estudio estableció que la combinación de la cubierta de heno con las especie de mayor incremento *C. fruticosum* > *T. heterophyla* > *B. simarub* > *B. buceras* ayudaran a un manejo mas costo-efectivo para la restauración de bosques secos subtropicales.

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Chapter 1

Introduction to the Thesis

Ecological restoration is a set of multidisciplinary actions on degraded natural elements of an ecosystem that will promote the recovery of typical characteristics of the original ecosystem. Since Aldo Leopold in performed the restoration of 25 acres in Wisconsin in 1935, much has been learned about the restoration of ecosystems, but more remains unknown than known. Clewell, Rieger and Munro (2000) suggest that "the primary objective of most ecological restoration projects should be to restore an ecosystem that contains sufficient biodiversity to continue their maturation process naturally and be able to evolve over time in response to changing environmental conditions."

Globally, tropical and subtropical dry forest (STDF) ecosystems have been degraded over-exploitation and unsustainable land use by human activities, affecting the structure and composition of forest coverage; they are considered the most threatened ecosystems (Janzen 1988). The need to restore subtropical dry forests is critical (Carvajal 2001), and despite of the current information on ecological processes more research is needed to help understand and improve success of ecological restoration. STDF originally represented 42% of the tropical forest worldwide (Ewel and Whitmore 1973, Murphy & Lugo 1986), and hosts roughly 40% of the world’s human population; STDF have extreme temperatures, high levels of evapo-transpiration, low precipitation, and low soil moisture, which contribute to slow regeneration and influence trees mortality (Mclaren & McDonald, 2003). The subtropical dry forest covered approximately 17.6% of the land area in Puerto Rico (Murphy *et al.* 1995). Most of the forest cover of the STDF in Puerto Rico has been eliminated due to the conversion of this ecosystem to subsistence farming, grazing by domestic animals, selective logging for charcoal production and urban development (Molina-Colón and Lugo 2006).

The regeneration of woody plants is limited by high solar radiation and low water availability during dry seasons and weeds that are strong competitors for resources, particularly water (Aide *et al.* 1995). It is necessary to develop local experience in methodological practices to generate more useful recommendations for restoration of STDF. Restoration with native species may be the most cost-effective and realistic strategy to rehabilitate pastureland to a more diverse ecosystem (Lugo 1992). Dobson (1997) suggests that human management of initial composition of species may be necessary to get the desired regeneration of the ecosystem. It is necessary to study how to help accelerate the restoration process of dry forest ecosystems and to determine which species will have higher probabilities of survival and growth in extreme environments. Concurrently it also necessary to evaluate the labor and maintenance costs of management techniques to determine the most cost effective practice with for native tree species establishment, this can help to determine the best decisions when establishing a restoration project.

The Cabo Rojo National Wildlife Refuge (CRNWR) is located in the southwest corner of Puerto Rico. The area has been classified under the Holdridge life zones system as subtropical dry forest (USFWS,1995), and is dominated by the presence of exotic African grasses and legume trees that form a plain in a state of early or arrested succession (USFWS, 1996). The CRNWR manages and promotes the use of native species to restore degraded areas, but the mortality of trees is one of the biggest impediments that affect this type of management. Scientific information about what planting techniques provide the greatest and most cost-effective improvement for degraded areas is limited. This study intends to answer these questions: 1) How does the use of hay mulch, irrigation and grass removal by bulldozing influence the growth and survival of native sapling species? 2) What are the effects of these planting management techniques on soil moisture and how is that related to survival and growth? 3) Which planting management is most cost effective for the establishment of native saplings species in degraded areas of subtropical dry forests?

The results will help us to determine what decisions must be made when planning reforestation of degraded areas to reduce the mortality of native trees. The successful identification of native species and cost effective management techniques is important information for land managers in charge of the ecological restoration of a habitat.

Thesis layout

This thesis is divided into two main chapters, each describing data intended to be submitted for publication in Scientific journals. Chapter 2 describes the survival and growth of six native tree species in five planting managements on two different soils. Chapter 3 describes cost effectiveness of various management practices in terms of dollars and labor for reforestation projects in dry forests. A concluding chapter summarizes the major results of the entire project and includes important information for land managers regarding the best decisions for future restoration projects.

Chapter 2

Restoration of Caribbean Dry Forests: Planting management effects on survival and growth in reforestation projects in dry zones

Introduction

Forests in Puerto Rico have been subjected to intense deforestation and human activity for almost five centuries, which has resulted in dramatic losses of cover (Miles et al., 2006, Ramjohn et al., 2012). Only 4% of the original subtropical dry forests remain intact, representing about 35,407 ha (Murphy et al., 1995 and Gould *et al.,* 2008). Forested land has been extensively converted to savanna and secondary forests dominated by non-native species, or has been logged, burned or converted into agricultural or urbanized land (Murphy & Lugo 1986; Swaine 1992). This ecosystem constitutes tree communities growing in warm to hot climates. In the last 80 years the economy of Puerto Rico has changed from agrarian to manufacturing. The subsequent decline of the agriculture sector in Puerto Rico facilitated natural forest regeneration and the forest cover increased from 7% to 40% by the year 2003 (Brandeis et al., 2007). Rainfall occurs with a pronounced seasonality and 2-6 months of drought each year (Olivares & Median 1992).

Caribbean dry forest recovery can take decades. Recovery from intensive anthropogenic effects is much slower in comparison to regeneration following natural disturbances. Passive restoration in dry ecosystems is inhibited by many factors that may contribute to prolonged recovery, including a lack of seed arrival, high levels of seed predation and the vulnerability of the newly germinated seedlings to herbivory, pathogens and drought (Castilleja, 1991). Competition with grasses and herbaceous species, often introduced as forage crops, limit forest regeneration (Aide and Cavelier, 1994). Secondary forests in Puerto Rico are dominated by exotic legume trees, but with time, help from these legume trees may eventually increase the establishment of native species (Weaver and Chinea 2003, Molina Colón and Lugo 2006, Pérez Martinez 2007). A few studies in recent years have investigated patterns of succesional processes in secondary forests and factors limiting recovery on degraded areas of Caribbean tropical dry forests (Weaver and Schwagerl 2008, Santiago-García et al. 2008, Wolfe and Van Bloem 2011). Results of these studies suggest that most native saplings are killed by high solar radiation, low water availability, fire, and competition with exotic grass, reducing succesional processes. Thaxton et al., (2011) studied the reintroduction of native tree species of Hawaii in habitats ecologically similar to the ecosystems of the Caribbean dry forest, suggesting that altering soil moisture may be one of the primary mechanisms through which grasses limit native seedling establishment. They also recommend grass removal as a result as an effective management practice to increase the soil moisture, survival and growth of degraded tropical dry forests. McLaren & McDonald (2003) suggested that shading and moisture supplementation increased germination and seedling survival, and were more important limiting factors than light for seedling recruitment in dry forests (see also Castilleja 1991). Adding mulch reduces the competition between unwanted grasses and positively affects soil properties such as moisture, temperature, nutrient availability and helps decrease irrigation efforts (Athy 2006).

Reforestation has been one of the management practices used to restore the structure and composition of future landscapes. This practice helps accelerate the return to conditions similar to the ecosystem before the disturbance. To increase the establishment of tree species we must take in consideration the interaction between precipitation, soil conditions and dominant species cover that determines the facilitative or competitive role of plant cover (Aide & Cavelier 1994). Active restoration projects are becoming increasingly common, but frequently the establishment of tree species in dry zones has not been successful and the individuals that do survive have not grown well enough to create forest cover. Land managers need to understand the reasons for such failures, and the conditions required to achieve successful restoration. The success of restoration projects usually requires an appropriate management plan (Rey Benayas and Camacho, 2004), but these can be hard to develop in the absence of Scientific data.

My research helps show how some common management practices affect survival and growth of native subtropical dry forest tree species for ecological restoration in southwest Puerto Rico.

The specific questions were:

- How do management practices influence the success of native sapling species in reforestation projects in southwest Puerto Rico?
- How do management practices affect soil moisture and grass cover and how do these influence survival and growth?

Materials and Methods

Study area

The study site is located in the Cabo Rojo National Wildlife Refuge (CRNWR), part of the Caribbean Islands National Wildlife Refuge Complex, at the southwestern tip of Puerto Rico. It is classified in the system Holdridge life zone system as subtropical dry forest (Ewel and Whitmore, 1973). Its area is approximately 587 acres (not including the Salinas tract) and its center is located at 67° 10' W longitude and 17° 59' N latitude (Figure 2.1). The climate is dry with an average annual rainfall of 625 mm, means annual temperature above 26°C (Lugo-Camacho et al. 2009) and has an annual ratio of potential evapotranspiration to precipitation greater than 1. Periods of higher rainfall occur during the fall (September – November) and late spring (May). The summer and winter are dry seasons (USFWS, 1995). This land had been used for cattle ranching and agriculture for almost two centuries before being transferred to the US Fish and Wildlife Service in 1974 (Figure 2.2), but cattle ranching continued until 1978 when the first refuge manager arrived (Weaver and Schwagerl 2008). The native flora was almost totally removed by human and agricultural disturbance. This habitat is now dominated by exotic trees species such *Leucaena leucocephala* (Lam), *Albizzia lebbeck (L.)*, *Parkinsonia aculeate* (L.), *Tamarindus indica* (L.) and *Prosopis juliflora* (Sw.) DC. (Zuill 1985) and grasses such as *Megathyrsus maximus* (Jacq.) (guinea grass) and *Cenchrus ciliare* (L.) (buffel grass). These grasses are aggressive competitors for light and water and retard the regeneration of native trees species. They now cover most of the refuge converting it to an early succesional savanna (Weaver and Schwagerl 2008). If the native vegetation was intact CRNWR would probably have a diverse forest of trees of the West Indies, where the species *Bucida buceras* L. and *Bursera simaruba* (L.) Sarg., dominate the forest canopy (USFWS, 1996).

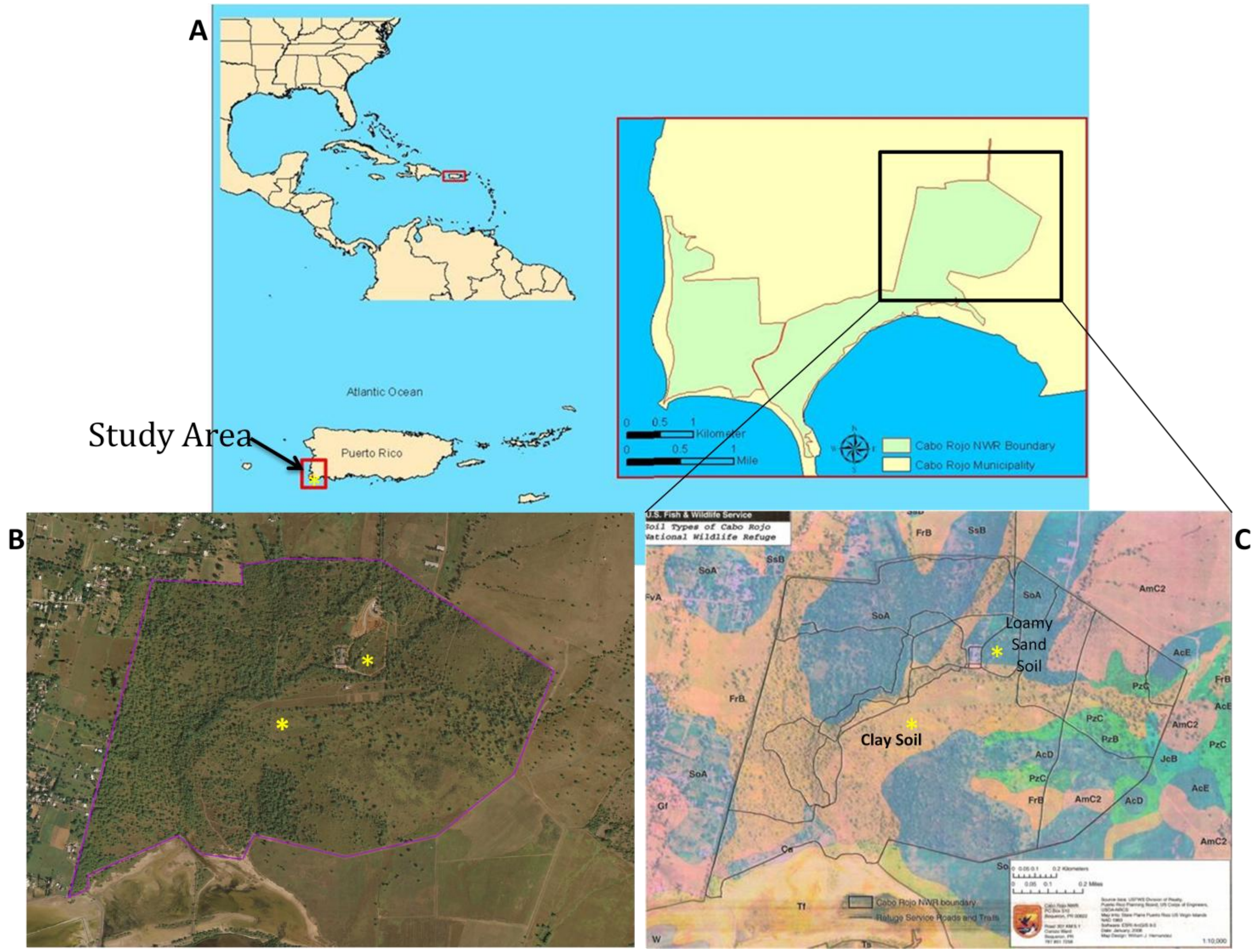


Figure 2.1. A- The study area located at the southwestern tip of Puerto Rico. B- The boundaries of Cabo Rojo National Wildlife Refuge. C- Soil series within the Refuge, blue is Sosa Series (Loamy sand) and beige is Melones Series (Clay), other colors are soil types were not considered in the study because they comprise little area in the Refuge. Images from US Fish and Wildlife Service.

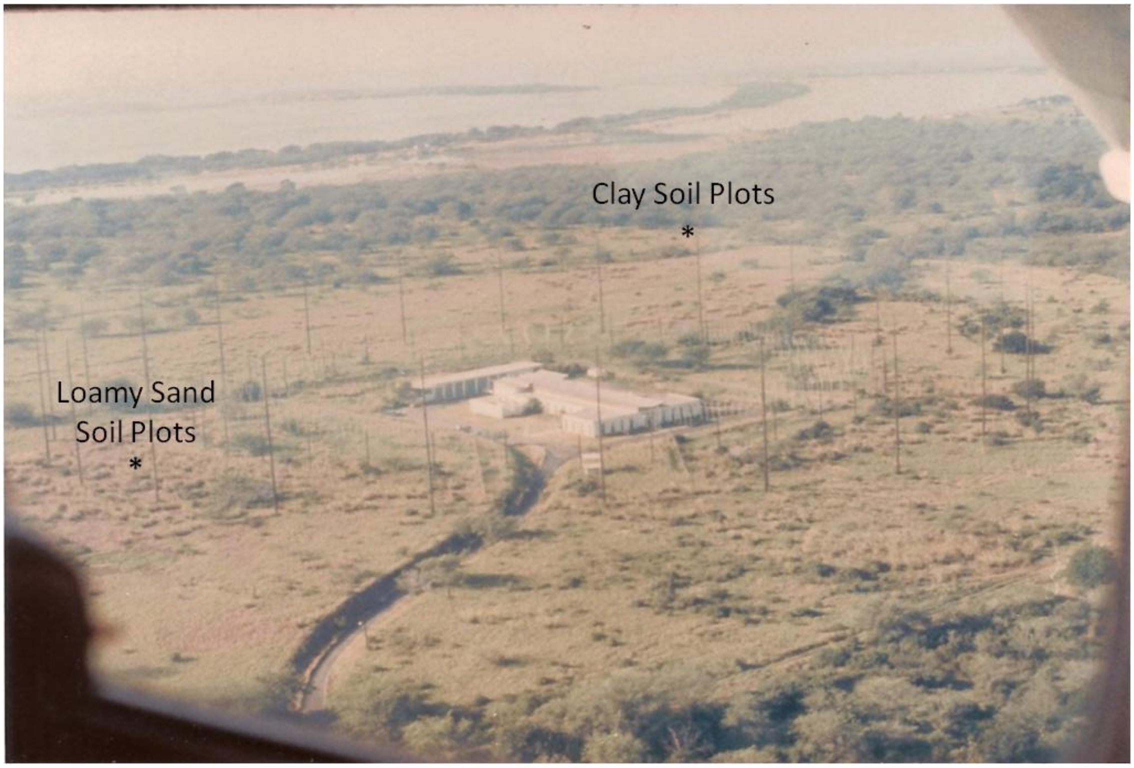


Figure 2.2. Study area when under management by the Foreign Broadcast Information Service in 1970 study area locations on each soil series. Photo by US Fish and Wildlife Service.

Soil description

The plots were established in the two soil series, loamy sand (*fine, kaolinitic, isohyperthermic Aridic Haplustalfs*) (Soil Survey Staff, 2006) and clay (*fine, smectitic, isohyperthermic Chromic Calcitorrerts*) (Soil Survey Staff, 2008); that have the most coverage area in CRNWR (Figure 2.1). Based on the description in the Updated Taxonomic Classification of the Soils of Puerto Rico (Beinroth et al. 2003), the clay soils were previously characterized as Fraternidad Series. This soil has a clay texture at the surface, medium natural fertility and is difficult to work. Water moves slowly through the soil and it has limited suitability for cultivated crops because shrinking and swelling of the clay may damage young plants. Lack of water and the high clay content limit the use of this soil. The loamy sand soils are characterized by loamy sand texture at the surface, and the acid soil has low natural fertility but is easy to work. The slowly permeable, stratified layer limits the depth to which roots can grow and the amount of water available to plants. The layers above the stratified layer are rapidly permeable and have a low capacity to hold water available to plants. The low water-holding capacity limits the suitability of this soil for cultivated crops. Most of the acreage is in low-producing pasture. Soil nutrient content was low for each soil series, although cation concentrations in the clay soil were higher than loamy sand soil (Table 2.1).

Table 2.1. Average total soil nutrient content for each soil series as determined from five subsamples for each soil.

Nutrients*	**Clayey Soil**	**Loamy Sand Soil**
Carbon (%)	3.53 (.45)	0.85(.38)
Nitrogen (%)	0.30 (.04)	0.08 (.03)
Sulfur (%)	0.04 (0.01)	0.01 (.00)
Al(mg/g)	19.17 (1.23)	3.11 (.36)
Ca(mg/g)	11.38 (3.39)	0.69 (.19)
Mg(mg/g)	7.84 (1.49)	0.40 (.10)
Na(mg/g)	0.11 (.03)	0.02 (.00)
Fe(mg/g)	30.15 (1.91)	10.97 (1.05)
K(mg/g)	2.64 (.18)	0.30 (.10)
Mn(mg/g)	1.51 (.18)	0.40 (.09)
P(mg/g)	0.48 (.10)	0.18 (.03)

* The top 8-10 cm of soil was sampled. The values of soil P were analyzed by the Olsen method and the other standard elements were analyzed following the Montana Soil-NIST 2711 soil research methods. Numbers in parentheses are standard deviations. Analyses provided by the Soil Analysis Laboratory of the U.S. Forest Service-International Institute of Tropical Forestry.

Experimental Designs

During the rainy season in late September 2007, I planted one hundred saplings for each of six native species; *Bourreria succulent* Jacq. , *Bucida buceras L., Bursera simaruba (*L.) Sarg., *Citharexylum fruticosum* L. , *Erythroxylum areolatum* L. and *Tabebuia heterophylla* DC. Britton. These species are available from local nurseries and have a suitable characteristic to growth the dry forest life zone. All saplings were acquired from local sources (Table 2.2). Individuals from each species were randomly selected for treatments and acclimated prior to transplanting. All saplings received water only once a week for the last month before planting. At the time of planting, each sapling was placed with the soil from its pot and 50 mL of granular super-phosphate fertilizer (0-50-0) into a pre-dug hole and watered with 8 L of water. All holes were dug with a Bobcat machine, using a power auger 12 inches wide to a depth of 0.5 meter. The saplings were planted in a randomized block design, with soil type as the block. I established five management treatments and two arrangements, for a total of five plots in each soil type. The individuals of each species were planted with 1.5 m x 1.5 m spacing between each tree (Figure 2.3). The total number of individuals of each species by treatment was 10 for each soil and 5 for each arrangemets. The plots were mowed before establishing of five management treatments. The treatments were selected based on practices frequently used by managers in reforestation projects (Table 2.3): (1) Control, where only the grass was cut before reforestation and watered on the day of planting. This represents the traditional reforestation project and no further care was given to the trees after planting. (2) Irrigation treatments that received approximately 11 L of water at planting and an additional 11 L of watering whenever 10 consecutive days passed without at least 10 mm of rainfall. (3) Hay mulch, with one grass hay bale (10 Kg – 14 Kg) scattered around the base of each sapling. The hay bales are from the local farmer.

(4) The combination of mulch and irrigation. (5) Mulch and irrigation plus bulldozing effect, removed 2-3 of surface with a bobcat A-300 Turbo (Figure 2.7). This represents a common way to prepare land after construction and control grass for reforestation.

Table 2.2. List of species, sources, sample size and means of initial of height and basal diameter for the six tree species planted in this study. Leaf habit and type of seed dispersal (Little, Wadsworth and Marrero 2001). Numbers in parentheses are standard deviations.

	Family	Boraginaceae	Combretaceae	Burseracea	Verbenacea	Erythroxylaceae	Bignoniaceae
	Species	*Bourreria succulenta* Jacq.	*Bucida bucera*	*Bursera simaruba (L.) Sarg.*	*Citharexylum fruticosum L.*	*Erythroxylum areolatum* L.	*Tabebuia heterophylla* (DC.) Britton
Sources	FWS Cabo Rojo Refuge				X		
	DNR Guanica Forest			X		X	
	Conservation Trust of Puerto Rico	X	X	X			
	Private Nursery (Yauco)						X
Leaf Habit	Deciduos		X	X		X	X
	Evergreen	X			X		
Seed dispersal	Animal	X		X	X	X	
	Wind		X				X
Initial Measurements	Number of Planted	100	100	100	100	100	100
	Height (m)	0.73(.36)	0.82 (.24)	0.85(.19)	0.65(.15)	1.03(.23)	0.74(.18)
	Basal Diameter (cm)	0.86(.30)	0.86(.25)	1.07(.36)	0.79(.21)	1.03(.28)	1.08(.33)

Table 2.3. Description for all planting treatments implemented after the initial moving for six native species saplings planted in September 2007, on Cabo Rojo National Wildlife Refuge.

	Hay-Grass Mulch	Watering	Description
Control	No	No	The saplings only received approximately 11 L of water in the time of planting. These represent the traditional reforestation projects.
Irrigation	No	Yes	Watering when 10 consecutive days passed without rainfall.
Mulch	Yes	No	Each sapling had one grass hay bale placed around it.
Mulch-Irrigation	Yes	Yes	Each sapling had one grass hay bale placed around and watering when 10 consecutive days passed without rainfall.
Much-Irrigation + Bulldozing	Yes	Yes	Combination of mulch and irrigation treatments plus bulldozing effect with a Bobcat (A-300). This removed 2-3 inches of soil surface (Figure 2.7).
Time of planting	Cut the grass before reforestation, each sapling was placed with the soil from its pot and 50 mL of granular super-phosphate fertilizer (0-50-0) into a pre-dug hole and watered with 8 L of water.		

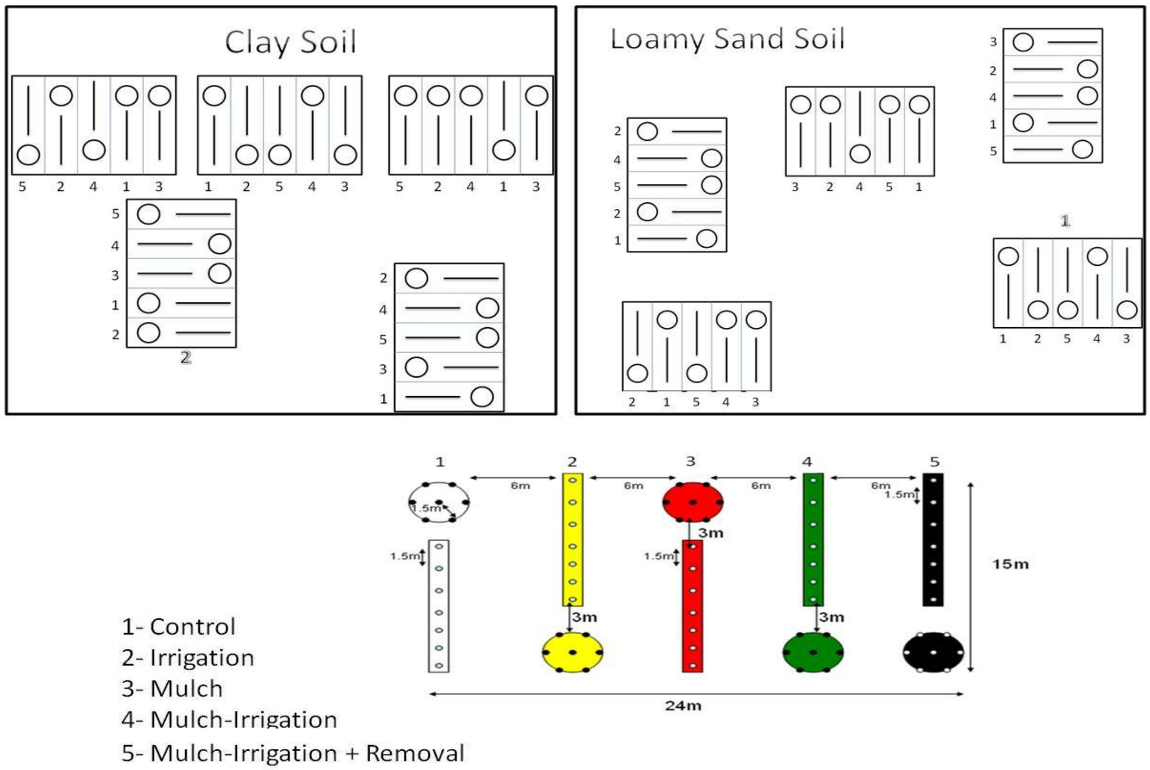


Figure 2.3. Layout of five plots for each soil series. All plots had five management treatments with two planting arrangements (line or group). The distance between trees and each planting managements is illustrated below.

Sapling growth

We examined the sapling performance by measuring growth increments and survival for 3 years (October 2007 to December 2010). All saplings were marked at 10 cm above the ground with a permanent marker to improve the precision of remeasurements in height (Figure 2.4b). All measures were taken with vertical stem as the distance above the ground to highest live meristem. Basal diameter was measured at 10 cm above ground level and calculated as the average of two perpendicular measurements taken with calipers to the nearest 0.1 mm. Growth data in height and diameter calculated as:

Height increment = H (t) – H (ti); where H = Height, t= time in years, i= initial measure

Diameter increment = D (t) – D (ti); where D = diameter, t= time in years, i= initial measure

(a)

(b)

Figure 2.4. Photos illustrate how I measured height (a) and basal diameter (b) in Cabo Rojo National Wildlife Refuge. All saplings were marked at 10 cm with a permanent marker to improve the precision of remeasurements in height as the distance above the ground of the highest live meristem. Basal diameter was measured at 10 cm above ground level and calculated as the average of two perpendicular measurements taken with calipers to the nearest 0.1 mm.

Grass cover

Grass cover was recorded each four months for one year (October 2007 to October 2008), and measured as the percentage of grass around each sapling (Figure 2.5). A 50 cm by 50 cm grid divided into 50 rectangles of 10 cm by 5 cm was used to estimate cover. Grass cover was converted into six cover categories: (0 blocks) 0%, (1-10 blocks) 20%, (11-20 blocks) 40%, (21-30 blocks) 60%, (31-40 blocks) 80% and (41-50 blocks) 100%.

Figure 2.5. Grid used for measuring grass cover. Grid (50 cm by 50 cm) which is divided into squares of 10 cm by 5 cm. I used six categories (0) 0%, (1-10) 20%, (11-20) 40%, (21-30) 60%, (31-40) 80% and (41-50) 100%.

Soil moisture

Soil volumetric water content was measured with an Em50 data logger and EC-20 sensor probes (Decagon Devices). We randomly selected one plot in each soil type and installed 10 sensor probes in the top 20 cm of soil (Figure 2.6). Two sensor probes were installed in each management treatments, one in each arrangement (line and group). The sensor was placed 6 inches next to one species (*B. succulenta*) selected randomly. The Em50 data logger recorded one reading each 5 minutes, but for my study I used the highest ratio of soil volumetric water content for each day for one year (March 2008 - February 2009). Some days the sensors had negative readings or no data was recorded at all. This occurred when the sensor lost contact with the soil. When this happened, the negative results were not included. Precipitation was monitored throughout the study, using daily rainfall measurements from the Western Regional Climate Center (WRCC, www.wrcc.dri.edu). The weather station was located in CRNWR, within 1 km of the planting sites.

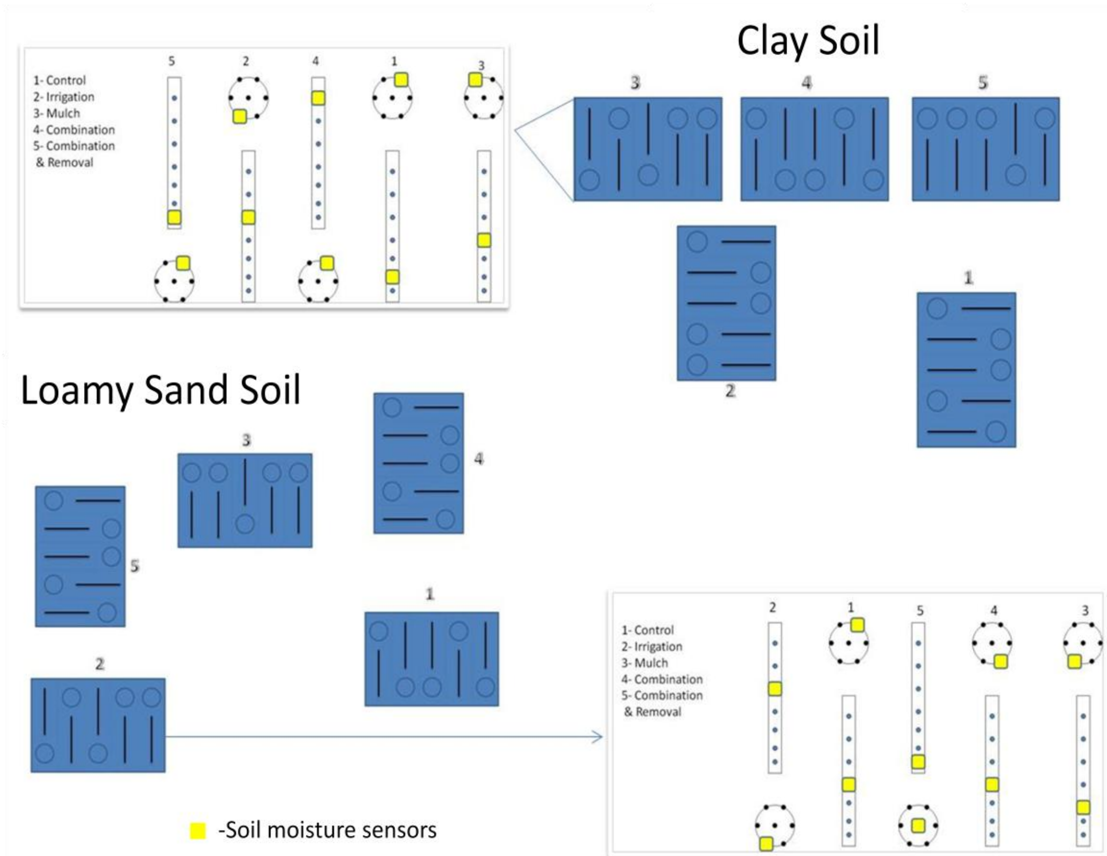


Figure 2.6. Randomly selected one plot on each soil series and put one sensor probe for measure soil moisture in line and group arrangements on five planting managements.

Figure 2.7. Photo of bulldozing effect with a Bobcat (A-300 Turbo). Removed 2-3 inches of soil surface.

Statistical Analysis

Infostat Professional Software, (Version 2011. FCA, National University of Córdoba, Argentina) was used for the statistical analyses. To verify the normality of the variables I used a Shapiro-Wilks test. I assumed a priori that there were differences among species and soils type. I analyzed growth and survival on each species separately to avoid interaction among soil, species, and treatments. The arrangements (line and group) had a effect (Appendix C), but did not show significant interaction with species or with treatments, which was excluded from all models to improve the power of the test.

Survival rates 3-years after planting were evaluated using a Chi-square test. For effects of soil, species, management treatments and arrangements on growth increments I first used Analysis of Covariance (ANCOVA), in which, change in height or basal diameter were the dependent variables and initial sapling size was the covariate. Saplings that did not survive after planting were not included in the growth analyses. I used a contrast test to compare mulch/irrigation and bulldozing treatments had similar effect. The contrast was not significant ($p > 0.05$) therefore I excluded bulldozing treatment and I used two-way ANOVA, to evaluate the effects of irrigation and mulch on species growth in each soil after 1 year and after 3 years.

Treatment effects on grass cover and soil moisture were analyzed for each soil separately and arrangements was excluded from models. For grass cover I tested three different times after planting (4 months, 8 months and 12 months). For soil moisture I selected six events of rainfall and watering followed by 10 days without rain. Day five and nine were used for testing which treatments retained more soil moisture over time. All tests were evaluated with Tukey-Kramer differences test for significance at $p < 0.05$.

Results

Precipitation

Annual rainfall was 676 mm in 2007, 1180 mm in 2008, 641 mm in 2009, and 1123 mm in 2010, but monthly rainfall totals varied substantially (Figure 2.8). A single rainfall event in September 2008, produced 16.92 inches of rain in just 24 hours as a result of tropical storm Hanna. The refuge experienced major flooding and severe damage. The study area was affected for this event, but trees were killed.

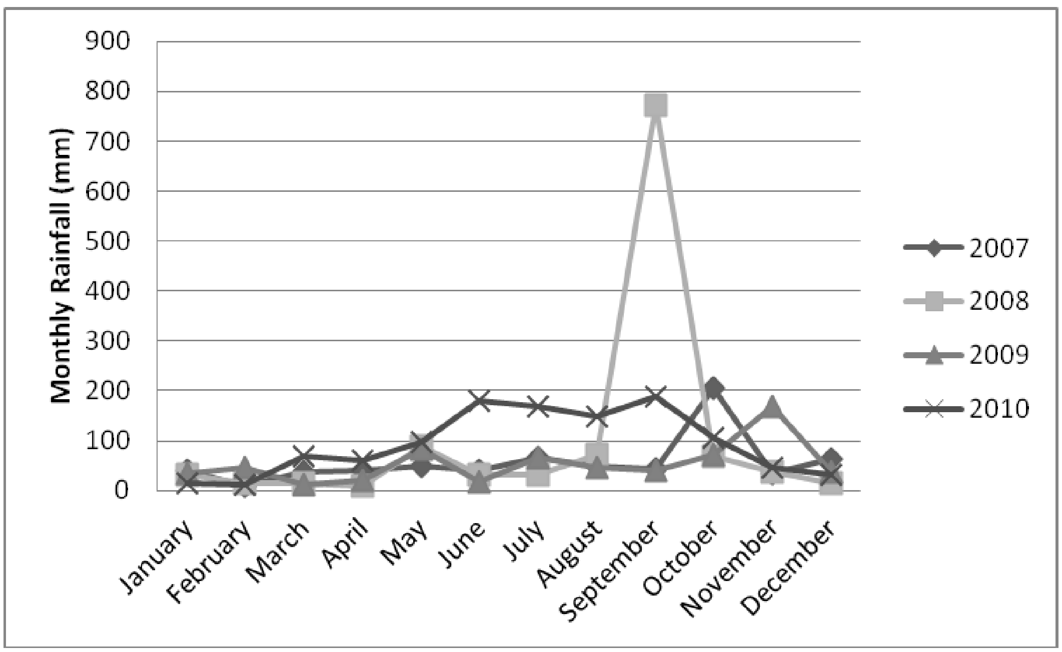


Figure 2.8 Mean monthly rainfall data from the Cabo Rojo Weather Station for 2007 to 2010, about 1 km south of study site. Annual mean rainfall was 676 mm in 2007, 1180 mm in 2008, 641 mm in 2009, and 1123 mm in 2010.

Sapling survival

Three years after planting the sapling survival rate of the six species was 81% in both soil types (Table 2.4). Overall, the survivorship of native tree species had no significant difference in management treatments with clay soil (χ_2=3.98, 4 df, P < 0.4093), however, in loamy sand soil the irrigation treatments had only 60% survivorship across species (χ_2=22.49, 4 df, P < 0.0002), compared to 83-91% for other treatments (Appendix A). Species by management treatments did not show significant differences on clay soil, even though *C. fruticosum* had a 40 % survival rate in control and 60% in mulch while *Bucida buceras* had 60% in irrigation and mulch treatments. In loamy sand, *E. areolatum* had only 40% survival (χ_2=18.75, 4 df, P < 0.0009) and *T. heterophylla* had only 50% (χ_2=11.25, 4 df, P < 0.0239) in the irrigation treatment (Appendix A). Across all management treatments only a few species experienced less than 80% survival (Figure 2.9): *C. fruticosum* (68%) in clay, *B. succulenta* (64%) in loamy sand and *B. buceras* in both clay (72%) and in loamy sand (76%). Management treatments did not show significant differences in *B. succulenta*, but we observe low survival (30 %) in irrigation on loamy sand soil (Table 2.4).

Table 2.4. Survival rates after of three years for six native tree species in all treatment on clay soil and loamy sand soil.

Species	Control		Irrigation		Mulch		Mulch/Irrigation		Mulch/Irrigation +Removal		Total in Species	
	Clay	Loamy Sand	Clay	Loamy Sand	Clay	Loamy Sand	Clay	Loamy Sand	Clay	Loamy Sand	Clay	Loamy Sand
Bosu	70	80	100	30	70	60	90	70	80	80	82	64
Bubu	70	60	60	70	60	80	90	80	80	89	72	76
Busi	100	100	90	100	100	100	80	100	80	90	90	98
Cifr	40	80	90	70	60	90	70	100	80	90	68	86
Erae	90	90	80	40	90	100	90	90	100	100	90	84
Tahe	90	100	100	50	80	70	60	80	90	100	84	80
Total in Treatments	77	85	87	60	77	83	80	87	85	91	81	81

* *Bourreria succulenta (*Bosu), *Bucida buceras (*Bubu*), Bursera simaruba (*Busi), *Citharexylum fruticosum (*Cifr), *Erythroxylum areolatum (*Erae), and *Tabebuia heterophylla (*Tahe)

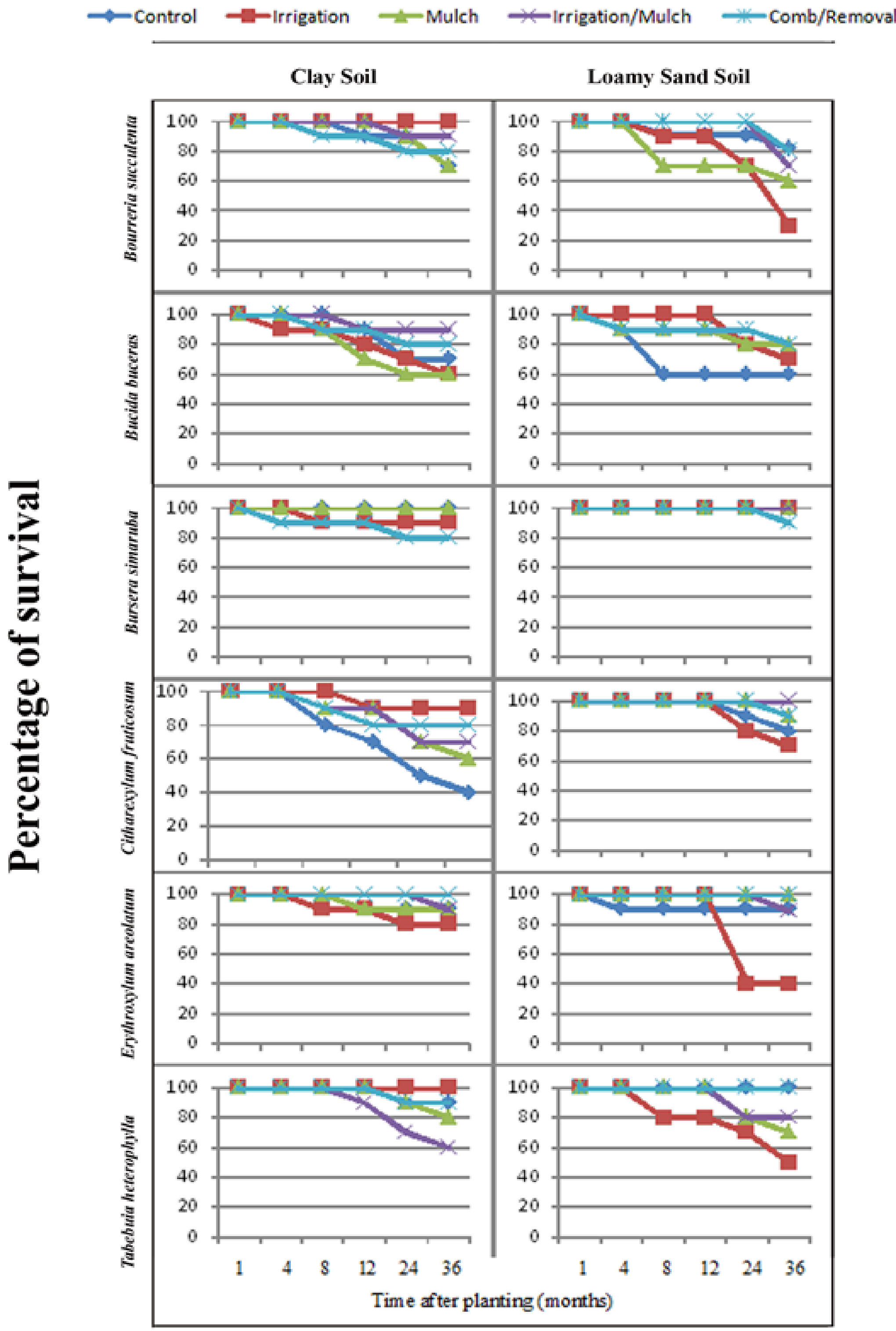


Figure 2.9. Survival rates for six native tree species by planting management on clay and loamy sand soil.

Sapling Growth

Height and diameter had similar responses, for this reason I only discuss the height growth results after three years, but in the Appendix C and Appendix F show all diameter result in each species for one and three years after planting. Overall, the ANCOVA model for 3-years of height growth showed all main effects were significant (soil, species, management treatments and arrangements) as expected, but only found interaction in species x management treatments p = 0.0068 (Appendix C). In both soil types the contrast test showed mulch/irrigation and bulldozing treatments were similar in height growth for three years (Appendix E). Overall, the mean height of all saplings on clay soil (-0.38 to 2.70m) was greater than on loamy sand (-0.81 to 2.15m). Diameter growth of species on clay (-1.19 to 5.15cm) and loamy sand soil was (-0.71 to 3.84cm) (Figure 2.10). Arrangement in soil types no show significant effect on overall species growth (Figure 2.11). After three years treatments made almost no difference in clay soil (Figure 2.12). Across species in loamy sand, mulch had a positive effect on growth (Figure 2.12). In both soil types, across all treatments the species *T. heterophylla and C. fruticosum* had the greatest growth and *E. aerolatum* had the lowest (Figure 2.13). The ANCOVA showed negative co-efficient in the covariate of initial height (Appendix C and Appendix F). This indicates that taller saplings had less growth. Perhaps this is because they were root bound in the pot and so did not grow well to begin with growth.

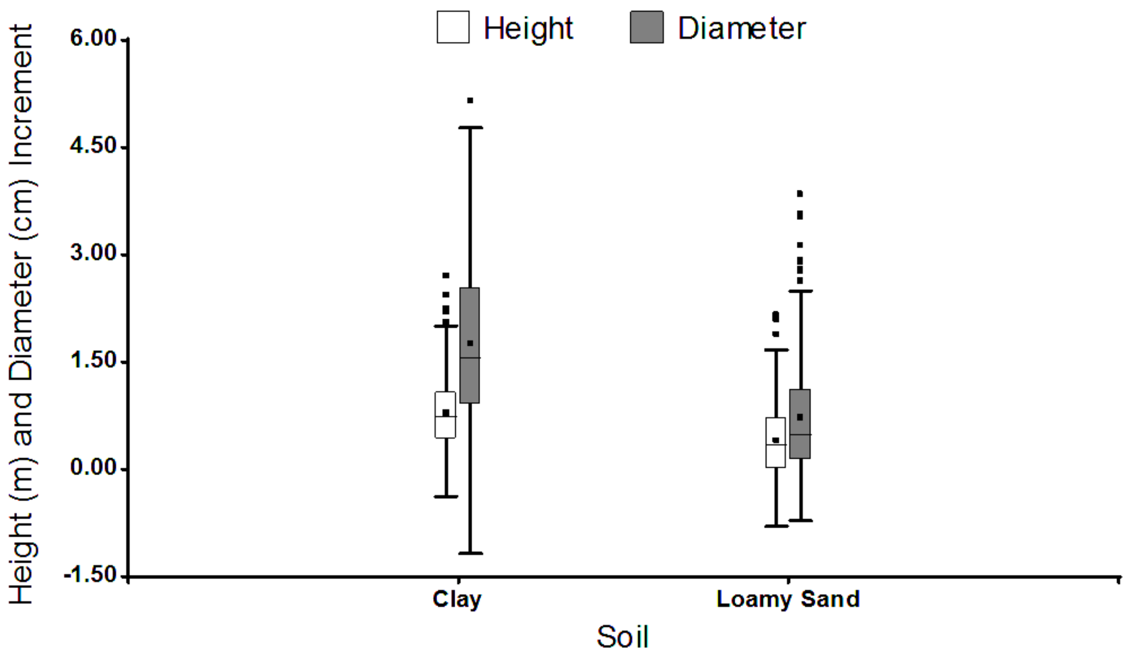


Figure 2.10. Box plots of sapling growth increments (m) pooled across species.

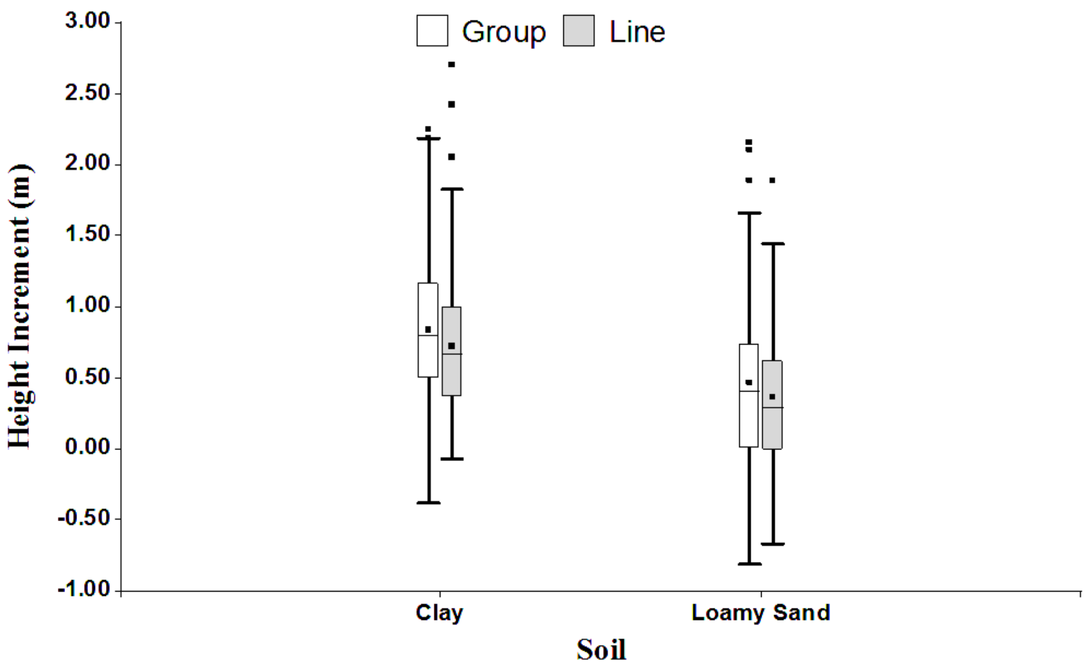
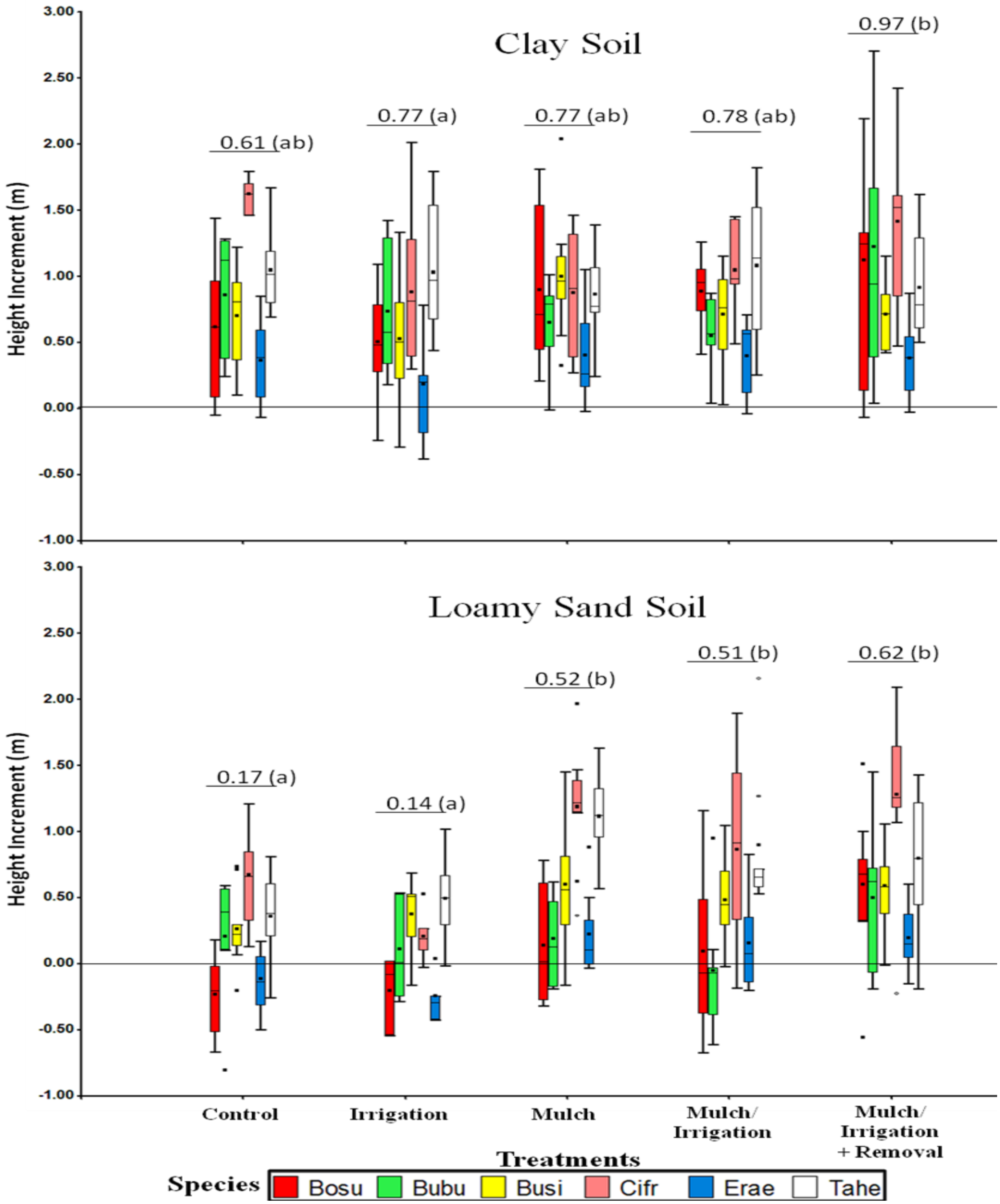


Figure 2.11. Mean height after 3 years by planting arrangement for clay and loamy sand soils.



Figuere 2.12. Height increments for three years (October 2007 to October 2010) of six native tree species in all management treatments on clay and loamy sand. Numbers above the bars are means of treatment and letters represent significant differences across treatments, that share the same letters were significantly different in the management treatments. See Table 2.4 for species code.

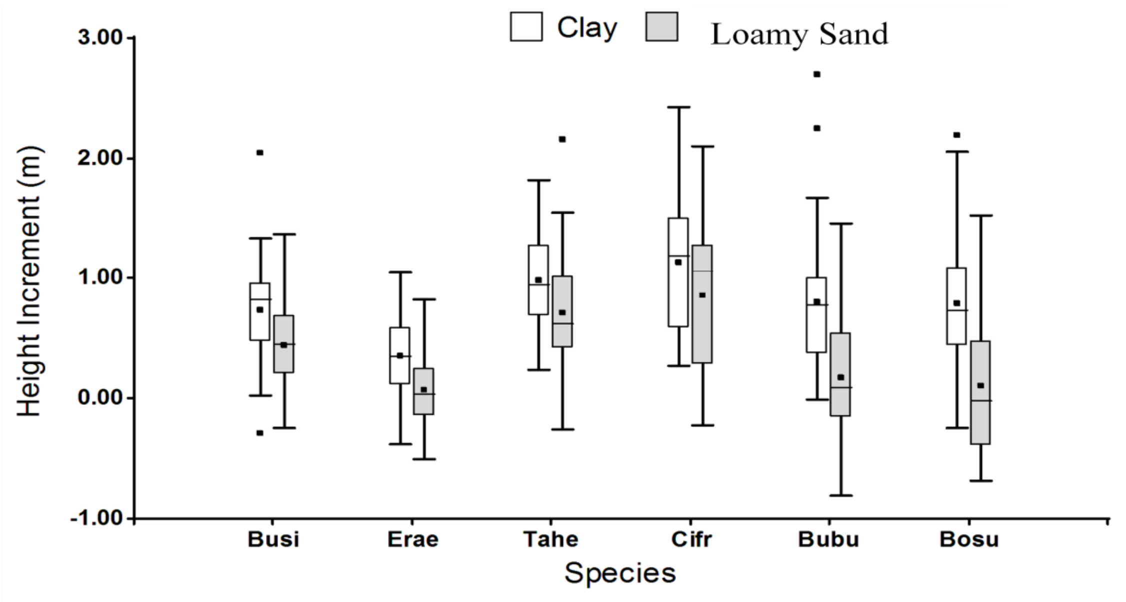


Figure 2.13. Mean height increments of six native tree species across all treatments on clay soil and loamy sand soil. See Table 2.4 for species code.

Table 2.5. Significant treatment effects on growth based on two-way ANCOVA. See Table 2.4 for species code.

	One Year Height Increments (m)		Three Years Height Increments (m)	
Species	Clay Soil	Loamy Sand Soil	Clay Soil	Loamy Sand Soil
Bosu	Mulch			Mulch
Bubu				
Busi				Mulch
Cifr		Mulch	Interaction	Irrigation Mulch
Erae	Interaction			Mulch
Tahe	Mulch	Mulch		Mulch

Grass Cover

Grass cover increased in control and irrigation treatments over time, while mulch treatments stayed lower (Figure 2.14). In clay soil the contrast tests showed that mulch/irrigation and mulch/irrigation plus bulldozing treatments only had significant difference in the 8th and the 12th months but In clay soil mulch/irrigation and mulch/irrigation plus bulldozing treatments had similar grass cover in 4 months, but after 8 months and 12 months bulldozing effect decreased by 34% and 55%, respectively (Figure 2.14), (p= < 0.0001), both treatments had a similar effect in loamy sand soil (Table 2.6). The two-way ANOVA showed mulch reduced grass cover significantly, after one year grass cover was 54% and 12% in clay and loamy sand soil, respectively. In contrast, irrigation was approximately 98% and 75% in clay and loamy sand, respectively (Appendix G).

Table 2.6. Significance P-values of treatment effect from two-way ANOVA on grass cover for one year under different combinations of irrigation and mulch. The contrast compared effects between mulch/irrigation and mulch/irrigation bulldozing effects in grass cover for one year in both soils.

	Clay soil			**Loamy sand soil**		
	4 months	8 months	12 months	4 months	8 months	12 months
Contrast	0.0735	<0.0001	<0.0001	0.2893	0.4399	0.8639
Irrigation	<0.0001	0.0042	0.0045	0.0001	0.0002	0.0450
Mulch		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Interaction		0.0189	0.0483	0.0001	0.0023	0.0036

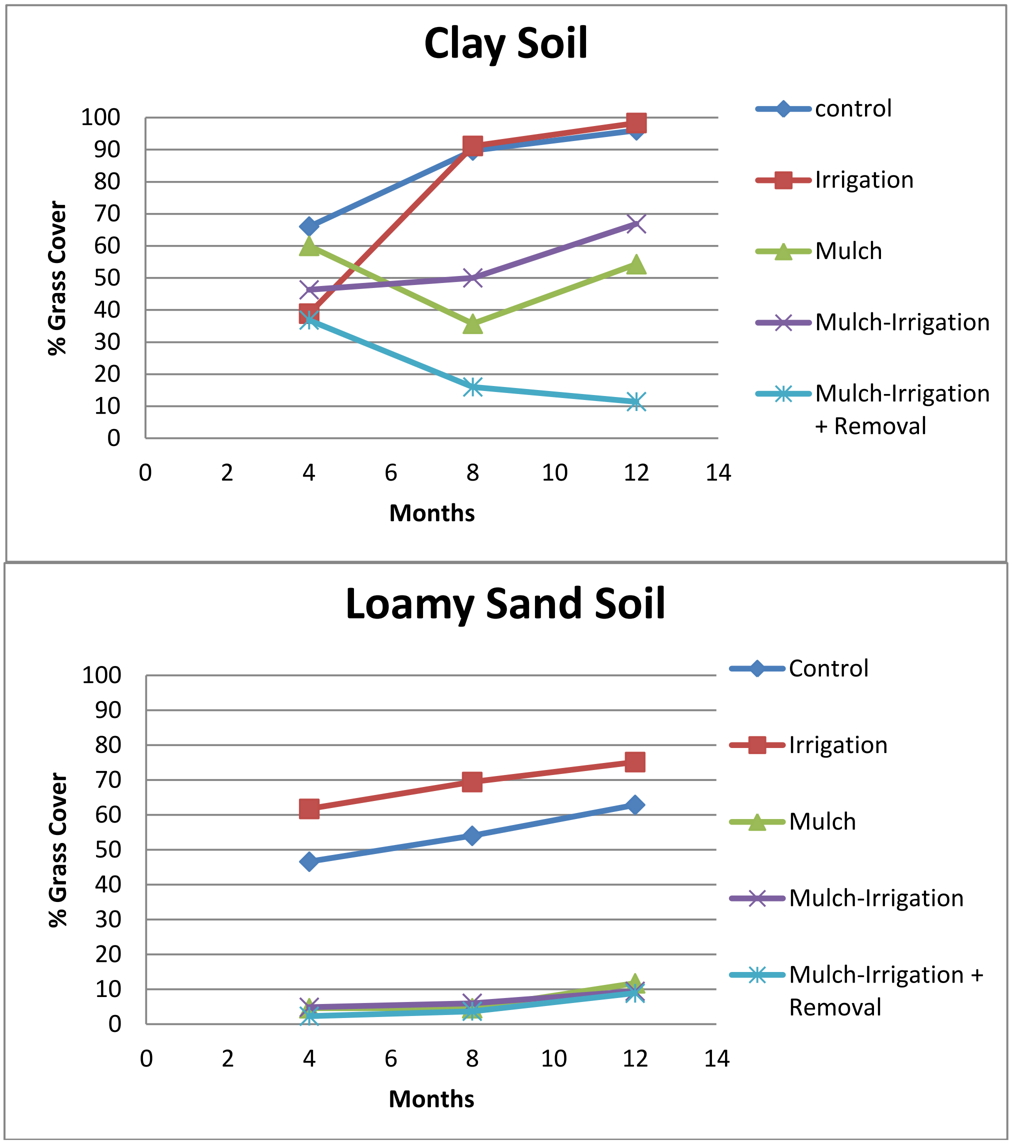


Figure 2.14. Mean percent grass cover three times after planting in all treatments.

Soil Moisture

Maximum value of SVWC for six events of rain in clay and loamy sand soil was 0.41m^3/m^3 and 0.24 m^3/m^3, respectively (Table 2.8) and watering events in clay and loamy sand soil has 0.36 m^3/m^3 and 0.21 m^3/m^3, respectively (Table 2.9). The one-way ANOVA with the contrast test demonstrate that management treatments with mulch/irrigation and mulch/irrigation plus bulldozing had similar effects in SVWC for both soils after rain and watering events (Figure

2.15). The two-way ANOVA model for SVWC showed that 9 days of rain events there was no significant difference among treatments in clay soil (irrigation, mulch and irrigation x mulch interaction with p = 0.8945, 0.4044 and 0.4461, respectively). After rain events in clay the treatments no had different compare with control (Figure 2.15), but after 9 days in watering events mulch was significant than control p = 0.0014 (Table 2.15). Mulch and irrigation treatment increased SVWC on loamy sand soil over time in rain and watering events (p = 0.0073 and 0.0166, respectively) compared to irrigation and control treatments.

Table 2.7. P-values of treatment effects from two-way ANOVA used to test the differences of soil volumetric water content under different combinations of irrigation and mulch. The contrast compared effects between mulch/irrigation and mulch/irrigation plus bulldozing for in SVWC for both soils after rain and watering events.

		Rain events		**Watering events**	
		5 Days	9 Days	5 Days	9 Days
Clay soil	Contrast	0.3557	0.5782	0.2355	0.3687
	Irrigation				
	Mulch				
	Interaction			0.0015	0.0014
Loamy sand soil	Contrast	0.6216	0.7690	0.0898	0.4198
	Irrigation		0.0391	0.0002	0.0011
	Mulch	0.0017	0.0002	<0.0001	0.0001
	Interaction		0.0073	0.0032	0.0166

Table 2.8. Mean and standard error (SE) soil volumetric water content (m^3/m^3) after six rain events on planting treatments in each soil types.

Day	Soil	Treatments	n	Mean	S.E.	Min	Max
1	Clay	Control	4	0.30	0.04	0.24	0.34
1	Clay	Irrigation	12	0.31	0.07	0.16	0.40
1	Clay	Mulch	12	0.34	0.08	0.18	0.41
1	Clay	Mulch/ Irrigation	11	0.34	0.05	0.23	0.39
1	Clay	Mulch/Irrigation +Removal	12	0.31	0.05	0.22	0.37
5	Clay	Control	4	0.25	0.07	0.15	0.29
5	Clay	Irrigation	12	0.27	0.08	0.11	0.37
5	Clay	Mulch	12	0.29	0.06	0.17	0.36
5	Clay	Mulch/ Irrigation	11	0.27	0.07	0.11	0.36
5	Clay	Mulch/Irrigation +Removal	12	0.24	0.08	0.07	0.33
9	Clay	Control	4	0.16	0.08	0.07	0.26
9	Clay	Irrigation	12	0.20	0.07	0.07	0.30
9	Clay	Mulch	12	0.23	0.06	0.14	0.31
9	Clay	Mulch/ Irrigation	11	0.17	0.08	0.07	0.31
9	Clay	Mulch/Irrigation +Removal	12	0.15	0.08	0.01	0.30

Day	Soil	Treatments	n	Mean	S.E.	Min	Max
1	Loamy Sand	Control	7	0.08	0.04	0.01	0.11
1	Loamy Sand	Irrigation	12	0.07	0.03	0.02	0.13
1	Loamy Sand	Mulch	13	0.19	0.05	0.05	0.24
1	Loamy Sand	Mulch/ Irrigation	13	0.15	0.03	0.11	0.19
1	Loamy Sand	Mulch/Irrigation +Removal	11	0.16	0.04	0.11	0.24
5	Loamy Sand	Control	7	0.05	0.03	0.01	0.10
5	Loamy Sand	Irrigation	12	0.05	0.04	0.00	0.12
5	Loamy Sand	Mulch	13	0.08	0.04	0.03	0.15
5	Loamy Sand	Mulch/ Irrigation	13	0.11	0.03	0.07	0.15
5	Loamy Sand	Mulch/Irrigation +Removal	11	0.11	0.04	0.05	0.18
9	Loamy Sand	Control	6	0.03	0.03	0.00	0.07
9	Loamy Sand	Irrigation	11	0.03	0.02	0.00	0.08
9	Loamy Sand	Mulch	12	0.04	0.03	0.01	0.11
9	Loamy Sand	Mulch/ Irrigation	12	0.09	0.03	0.05	0.13
9	Loamy Sand	Mulch/Irrigation +Removal	10	0.08	0.04	0.04	0.14

Table 2.9. Mean and standard error (SE) soil volumetric water content (m³/m³) after watering six events of planting treatments in each soil types.

Day	Soil	Treatments	n	Mean	S.E.	Min	Max
	Clay	Control	6	0.09	0.05	0.00	0.14
	Clay	Irrigation	12	0.29	0.09	0.10	0.35
1	Clay	Mulch	12	0.19	0.08	0.02	0.25
	Clay	Mulch/Irrigation	9	0.27	0.10	0.08	0.34
	Clay	Mulch/Irrigation +Removal	12	0.28	0.09	0.10	0.36
	Clay	Control	6	0.09	0.05	0.00	0.14
	Clay	Irrigation	12	0.20	0.09	0.04	0.30
5	Clay	Mulch	12	0.19	0.08	0.02	0.25
	Clay	Mulch/Irrigation	9	0.12	0.08	0.02	0.24
	Clay	Mulch/Irrigation +Removal	12	0.16	0.09	0.01	0.27
	Clay	Control	5	0.09	0.06	0.00	0.14
	Clay	Irrigation	10	0.14	0.08	0.01	0.21
9	Clay	Mulch	10	0.19	0.09	0.02	0.25
	Clay	Mulch/Irrigation	9	0.06	0.04	0.00	0.11
	Clay	Mulch/Irrigation +Removal	10	0.09	0.07	0.01	0.20

Day	Soil	Treatments	n	Mean	S.E.	Min	Max
	Loamy Sand	Control	12	0.01	0.01	0.00	0.02
	Loamy Sand	Irrigation	12	0.05	0.05	0.00	0.13
1	Loamy Sand	Mulch	11	0.02	0.02	0.00	0.05
	Loamy Sand	Mulch/Irrigation	12	0.13	0.07	0.02	0.21
	Loamy Sand	Mulch/Irrigation +Removal	12	0.14	0.08	0.02	0.24
	Loamy Sand	Control	12	0.01	0.01	0.00	0.02
	Loamy Sand	Irrigation	12	0.01	0.01	0.00	0.04
5	Loamy Sand	Mulch	12	0.02	0.01	0.00	0.04
	Loamy Sand	Mulch/Irrigation	12	0.05	0.03	0.00	0.08
	Loamy Sand	Mulch/Irrigation +Removal	12	0.07	0.05	0.00	0.15
	Loamy Sand	Control	10	3.0E-03	0.01	0.00	0.02
	Loamy Sand	Irrigation	10	0.01	0.01	0.00	0.03
9	Loamy Sand	Mulch	9	0.01	0.01	0.00	0.03
	Loamy Sand	Mulch/Irrigation	10	0.05	0.03	0.00	0.09
	Loamy Sand	Mulch/Irrigation +Removal	9	0.06	0.04	0.00	0.11

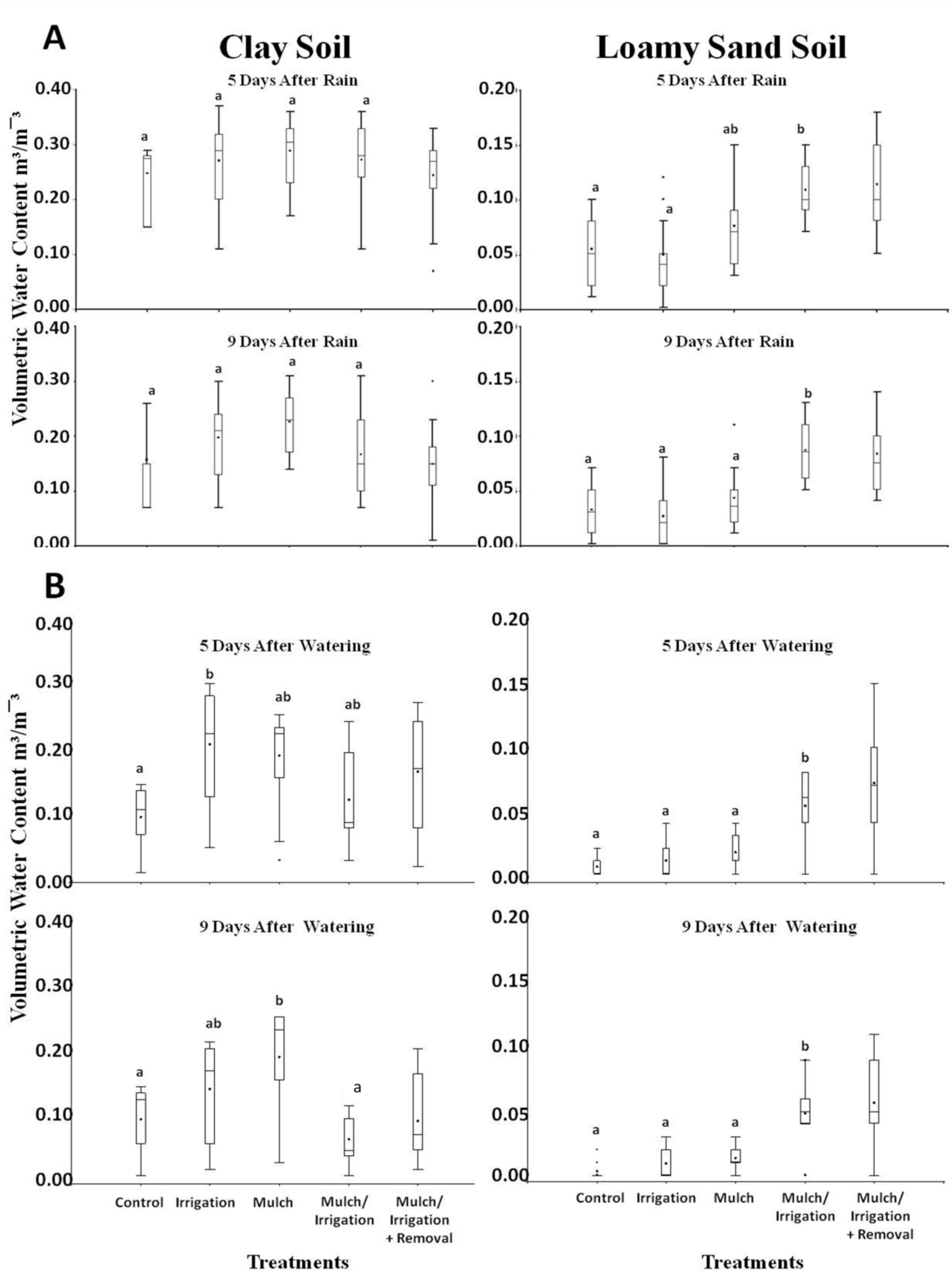


Figure 2.15. Box plots of (SVWC) five and nine days after rain (A) and watering (B) in clay and loamy sand soil. SVWC between mulch-irrigation and mulch-irrigation plus bulldozing was not significantly different for any treatment, time or soil combination as determined by contrast analysis. Boxes of different letters show significant differences in SVWC.

Discussion

Dry tropical ecosystems are a consequence of the low rainfall, long periods of drought, and high evaporation; the main limiting factor for plant survival is water (Murphy and Lugo 1986). Local research of native plant establishment in subtropical dry forests of Puerto Rico has shown that water stress decreased the survival of native species in early life stages (Carvajal 2001, Santiago-Garcia 2010, Wolfe and Van Bloem 2011). My study showed that after three years of planting, the overall survival rate for saplings planted in clay and loamy sand soil was 81%. In clay soil the survival rate and growth did not show large differences between management treatments. The higher than normal annual precipitation in 2008 (1180mm) and 2010 (1123mm) (Figure 2.8), as well as soil characteristics, such as high water retention in clay soil, contributed to the survival and growth of the saplings. In contrast, loamy sand had only 60% sapling survival in irrigation treatments, the low water retention and high percent of grass to compete for water affect the establishment. Also, irrigation without protection of much has high water loss in open areas and direct sun conditions.

Use of mulch in the first stage of establishment for native sapling species had a positive effect on their growth that was not seen in the management treatments without mulch use (control and irrigation). Mulch decreases evaporation and helps reduce the need for irrigation; the result is improved soil properties which cause marked responses in plant development, including increased growth (Haywood 1999). Grass cover was also significantly decreased by any mulch treatment and this help to increased the success of native species establishment. This result agreed with other studies reported when grass were eliminated increased survival and growth (Sun and Dickinson 1996, Thaxton et al., 2011). Bulldozing effect has additional decreases grass removal; however, bulldozing treatments did not present more growth or survival in the trees. In the dry periods after rain or watering events the soil moisture in irrigation managements with loamy sand soil appeared lower than in mulch/irrigation management. Supplementary irrigation alone did not suffice for establishing native species, but the combination with mulch helped preserve more soil moisture over time. Sapling species planted in loamy sand soil showed the control and irrigation management treatments had lower survival and growth rate. I conclude this to be the result of higher presence of grass cover around the saplings. I observed many cases in which the height of the grass surpassed the height of some of the saplings, which may have contributed to the decrease in soil moisture. According to Rey Benayas et al., (2003) the dense root systems of many invasive grasses are strong competitors for resources, particularly water.

The different requirements in each growth stage of the native species complicate the management for their establishment. Shade increases survival and establishment in native seedling species under stressful conditions in the early stages (Ray and Brown 1995, Carvajal 2001, McLaren and McDonald 2003, Santiago-Garcia 2010), but after their establishment, open areas favor successful growth in the later stages (Pauleus 2012). Mulch management techniques intended to facilitate the establishment of native saplings species in open areas dominated by exotic grasses. However, the diverse species used in my project showed differing levels of tolerance to the variable factors such as irrigation and mulch. Overall, the six native species planted in clay soil during the rainy season were not dependent on management treatment for survival and growth; however, in the loamy sand soil the species showed increased survival and sapling performance when planted with mulch and irrigated. The fastest growing species were *C. fruticosum* and *T. heterophylla*, then *B. Simaruba;* those that showed medium to low growth were *B. buceras, B. succulenta* and *E. aerolatum*. Santiago-Garcia (2010) reported that survival differences could be attributed to different planting times (wet or dry season), and mentioned that watering after planting was important for the establishment of native trees. He also reported that trees planted at the CRNWR during the rainy season had survival a rate of more than 90% while those planted during the dry season in Sierra Bermeja had only 35% survival rate. Wolfe and Van Bloem (2011) reported that the low survival rate and slow growth of seedlings and saplings were associated to long drought periods and that these conditions limited native forest regeneration in grass-invaded areas. Barajas-Guzman et al. (2006) have tested different mulch types in soil restoration areas and have found that the combination of mulch with fast-growing species is the best option for dry forest restoration. Mulch management techniques suppressed grasses and reduced soil moisture loss over time. In the first stages for establishment saplings, mulch is the most effective for increasing native species performance and can help accelerate the succesional trajectory in subtropical dry forest.

Chapter 3
Economic factors and labor requirements of Caribbean dry forest restoration with native tree species

Introduction

Passive restoration may take more than 50 years for the recovery of dry forests into pasturelands, because of limitation of resources such as water, nutrients, and seed and dispersal vectors (Vieira and Scariot 2006). High mortality rates during early stages are generally associated with the competition for water (Castilleja, 1991, McLaren and McDonald 2003, and Benayas et al. 2005). By comparison, active restoration process using particular management techniques such as planting, watering, weeding, and grass control can produce forests with a particular composition or structure (Rey Benayas et al. 2008). Reforestation can be an important instrument for the reintroduction of similar vegetation to the original plant community and to help with the restoration of the ecosystem (Lugo, 1988). These techniques accelerate the natural succession processes by increasing vegetation structure and diversity (Parrotta 1992), as well as establishment ecological corridors for wildlife.

The uncertainty of the weather and extreme conditions make restoration challenging even when adequate resources and equipment are available for restoration. Costs and labor requirements make reforestation projects difficult, particularly it long term maintenance is required. The decision to establish restoration projects for conservation and increased diversity involves many issues for public agencies and private landowners, such as availability of resources, time labor and funding.

It is important to consider the economic prospects of the practice before investing, but local information about cost investments and labor requirements is necessary for successful for establishment of native species (Engel and Parrotta, 2001). Forest regeneration at the Cabo Rojo National Wildlife Refuge (CRNWR) has been slow due to degraded soil and low diversity, as well as the presence of several herbs, vines and aggressive exotic grass species which now cover much of the refuge (USFWS, 1996). The CRNWR management plan includes many activities for restoration and conservation of native habitat for wildlife. From 1980 to 2006, CRNWR personnel and volunteers planted more than 8,000 trees in CRNWR (Weaver and Schwagerl 2008), but to obtain success in the establishment and growth of the species these efforts depend on high operation costs and frequent maintenance.

To design suitable restoration projects and implement the most cost-effective planting management for Caribbean dry forests, the survival and growth of native sapling trees was analyzed and compared with the costs and labor requirements associated with each of the management treatments.

The objective of this chapter is to evaluate the economic and labor requirements in comparison to the ecological benefits to determine the cost-effectiveness of management practices used to establish native tree species.

Methods and Material

Study area

The study site is located in Cabo Rojo National Wildlife Refuge (CRNWR) at the southwestern tip of Puerto Rico. It is classified in the of Holdridge life zone system as subtropical dry forest (Ewel and Whitmore, 1973). The climate is dry with frequent drought periods and average annual rainfall of 625 mm, mean annual temperature above 26°C (Lugo-Camacho et alt. 2009), making water a limiting resource for tree establishment. Past land uses included almost two hundred years of sugar cane production and cattle ranching. The native flora was almost totally removed by human and agricultural disturbance. The habitat is now dominated by exotic trees species and grasses, the grasses are aggressive competitors for light and water and retard the regeneration of native trees species. Most of the refuge has therefore been converted it to an early succesional savanna (Weaver and Schwagerl 2008).

Experimental design and data collection

A total of 700 sapling trees from 7 species we used for this study. I planted one hundred saplings of seven native species. All saplings were acquired from PR Department of Natural Resources and Environment, Conservation Trust of Puerto Rico, and US Fish and Wildlife Service. At the time of planting, each sapling was taken from its pot and planted with 50 mL of granular super-phosphate fertilizer (0-50-0) into a pre-dug hole and watered with 8 L of water. All holes were dug with a Bobcat machine (A-300 Turbo), using a power auger 12 inches wide to a depth of 0.5 meter.

Saplings were planted to evaluate the effectiveness of five management practices in promoting growth and survival. In the two arrangements for this project (line and group) we used the following treatments: (1) Control (2) Irrigation (3) Hay mulch (4) The combination of mulch and irrigation. (5) Mulch and irrigation plus bulldozing (Table 2.3). For each management treatment there were 140 individual saplings planted, and the associated cost investments and labor requirements were recorded for 11 months (September 2007 to July 2008) and compared to sapling survival and height growth of 3 years (October 2007 to December 2010). It is thus to realize observer results in three years with only one year the maintenance. We analyzed which management treatments were more cost effective for to increase survival and growth with or without maintenance for one year. The data used to calculate costs and labor requirements for each management treatments were: material costs such as the price of the trees ($3/tree), water ($32/1000 L, supply 11.32 L/tree = $0.36/tree), hay mulch ($2/bale), average diesel consumption per hour of each heavy equipment ($3.79/gl) and average work hour ($10/hr for one person). For all activities related to plantation establishment (sapling planting) and maintenance (watering and weeding), the aforementioned costs, were included in the total costs, but cost to purchase or rent all tools and heavy equipment were not include, because Cabo Rojo National Wildlife Refuge supplied this equipment. For a small reforestation project it is necessary to have heavy machinery (Water truck, Bobcat, Weeding tractor), for only one to two days. The reforestation costs were calculated based on actual market prices for the study area (Southwest of Puerto Rico). We decided to compare other management treatments with our control, because the control had the minimum cost input and that represents the traditional reforestation practice without maintenance where the survival of the planted sapling depends solely on the weather conditions.

We combined the data from economic and ecological aspects of the study to evaluate cost-effectiveness for each planting managements. The total cost of each management treatments was computed by adding all operation cost that is mentioned above. The ratio and cost-effectiveness compared with control treatment were calculated as follows:

A $$\text{Ratio of Survival} = \frac{\text{\% Survival in each treatment}}{\text{\% Survival in control treatment}}$$

B $$\text{Ratio of height Increment} = \frac{\text{Mean of growth in each treatments}}{\text{Mean of height increment in control treatment}}$$

C $$\text{\% Cost} = \frac{\text{Cost of each treatment}}{\text{cost of control treatment}} \times 100$$

D $$\text{\% of Cost-effectiveness Survival} = \frac{\text{Ratio of survival}}{\text{Ratio of cost}} \times 100$$

E $$\text{\% Cost-effectiveness Increment} \quad \frac{\text{Ratio of growth}}{\text{Ratio of cost}} \times 100$$

Results

The total costs for the establishment of 140 saplings in each management treatments were: control ($580), irrigation ($1,651), mulch ($880), irrigation/mulch ($1,947) and irrigation/mulch plus bulldozing ($1,979) (Table 3.1). The average of total work hours for planting 70 trees in the line and group arrangements was 5.67 hr and 5.75 hr, respectively (Table 3.1). The costs of watering only on planting days for control and mulch treatments cost $51 ($0.36/tree). The treatments with irrigation were watered fifteen times in 11 months at a cost of $765 ($5.46/tree) (Table 3.1). Establishment costs for all watering managements were approximately 75% higher than for the control and mulch, due to the need of more maintenance hours and supplemental water. Control and mulch had lower work hours to establish 140 trees, 9hr and 11hr respectively. Irrigation, mulch/irrigation and mulch/irrigation plus bulldozing required more work hours 37hr, 38hr and 40hr, respectively.

Total diesel consumption and work hours used in opening heavy equipment for planting 700 saplings native trees were 345 L and 64hr, respectively, both constituted 14% ($987) of the total costs. The diesel cost in control and mulch managements was $0.15/tree, for irrigation and mulch/irrigation it was $0.70 and for combination plus bulldozing it was $0.80. The average total cost of work hours and diesel consumption for each management was $40 w/hr and $60/diesel for control and hay mulch, $180 w/hr and $278/diesel for irrigation and mulch-irrigation and $200 w/hr and $313/diesel for combination plus bulldozing.

Survival rates and height growth at the end of three years after reforestation were 81% - 48cm, 73% - 44cm, 80% - 64cm, 83% - 66cm, and 88% - 81cm in control, irrigation, mulch, mulch/irrigation and mulch/irrigation plus bulldozing, respectively (Table 3.2). The cost of one tree in the planting managements of control, irrigation, mulch, mulch/irrigation and combination plus bulldozing were approximately $4.15, $11.80, $6.25, $13.90 and $14.10, respectively (Table 3.3). The inversion costs in mulch treatment were 1.5 and watering treatments were between 2.8 to 3.4 more times expensive compared with control (Table 3.3). The most cost-effective treatment for establishment sapling trees in this area was mulch, with more than twice the cost-effectiveness of survival rate and growth compared with the watering treatments. Analysis of materials and labor inputs showed that all management practices increased cost relative to control, but that mulching was most cost-effective when compared on a unit increment basis (Figure 3.1).

Discussion

Reforestation projects in dry ecosystems are challenging, little money and resources available makes it even more complicated. In this study I showed that mulch management is the most practical and cost-effective choice for the establishment of native trees in subtropical dry forests. Mulch management improved survivorship, increased growth increments of saplings, and lowered maintenance costs over time. Scientists suggested that the dominance of aggressive exotic grasses and shrubs decreased growth and establishment of native species (Castilleja 2001, Brown and Ray 1993, Santiago-Rivera 2010, Wolfe and Van Bloem 2011). Removal of grasses is a management strategy that could be applicable with different tools and machinery, but each one depends on the cost and labor. One situation to be considered before grass removal if the area has exotic legume trees, the species can help to establish native species. Some studies suggest certain exotic legume trees facilitate native sapling establishment and reduce water stress (Carvajal 2001, Santiago-Garcia et al., 2008, Wolfe and Van Bloem 20012). Thaxton et al., (2011) suggested that shade increases seedling survival in areas where grass removal with bulldozing is not possible, such as where some native species are already established. However, most of the open areas in southwest Puerto Rico are dominated by aggressive exotic grasses, and these compete with native species for the space, water and nutrients (McLaren & McDonald, 2003). In this case the mulch managements are considered the first practice to apply before using bulldozing to establish native species in dry forest zones.

Pimentel et al. (2005) reported that alien invasive weeds are more serious pests than native weeds. In fact, approximately $4 billion/year in herbicides are applied to U.S. crops, and $3 billion of that annual cost are associated with the control of alien invasive weeds. Parrotta and Knowles (1999) suggested that weeding around seedling establishments is not an expensive management tool when compared to the total costs of common practices used to restore tropical forests. Engel and Parrotta (2001) concluded that together manual weeding and herbicide application accounted for only 20% of all implantation costs.

In my study irrigation managements provided no benefit over control. Compared with control the additional investment in irrigation per tree was $7.65 and the increased growth was less than control. The application of bulldozing accounted for 28% of all implementation costs, while mulch management only accounted for 13% of these costs. Lightly plowing the surface of the soil with the bobcat machine helped to maintain weed control and reduce the competition for at least one year after of establishment, but the final result after three years suggests that the establishment and growth was not higher than the mulch management. When we consider the additional costs and labor requirements added by supplementary watering and the use of heavy machinery for controlling grass species in my reforestation project, obviously mulch is the most cost effective management strategy. My results agreed with another study, conducted on Czech Republic (Dostálek et al., 2007), which showed the five year period after planting the tree and shrub had 2.26 m of growth with straw mulch and was the method that did not require follow-up maintenance and appeared to be the most advantageous technique with regard to cost-effectiveness and seedling prosperity.

This study shows different management practices for the establishment of native tree species in dry forest. Based on the success of the species and the practice most cost-effectiveness of my results in areas that do not have access a heavy equipment, is important to consider human labor to make the holes and incorporate mulch around the tree for reduce competition and loss soil moisture and planting in rain season the native species with fastest growing already identified, to obtain reforestation projects with low maintenance and little economic investment.

Table 3.1. Times and costs operations for each managements through the first year of establishment of the reforestation project (2007-2008).

		Times (Hours) (70 trees)		Cost of material and operations/hrs in each managements (140 trees)									
		Line	Group	Control		Irrigation		Mulch		Mulch/Irrigation		Mulch/Irrigation+ Bulldozing	
				Time/hr	Costs	Time/hr	Costs	Time/hr	Costs	Time/hr	Costs	Time/hr	Costs
	140 Trees cost [a]	---	---		420		420		420		420		420
	Watering [b]	0.5	0.5	1	51	15	765	1	51	15	765	15	765
	Hay mulch [c]	0.83	0.83	---	---	---	---	2	280	2	280	2	280
	Planting tree	1.5	1.5	4	---	4	---	4	---	4	---	4	---
Diesel consumption	Bobcat (Dug hole)	0.83	0.92	2	8	2	8	2	8	2	8	2	8
	Water Truck	0.67	0.67	1	6	15	85	1	6	15	85	15	85
	Weeding Tractor	0.5	0.5	1	5	1	5	1	5	1	5	1	5
	Bulldozing	0.83	0.83	---	---	---	---	---	---	---	---	2	15
	Work hour [d]	5.67	5.75	9hr	$90	37hr	$368	11hr	$110	38hr	$384	40hr	$401
	Total costs				$580		$1,651		$880		$1,947		$1,979

[a] Average cost of one tree in 1gl pot =$ 3. [b] Average of water ($32/1000 L, supply 11.32 L/tree = $0.36/tree),
[c] 1 bale of hay grass cost $2 (1bale/tree). [d] Average cost of 1 worker hour = $10. Diesel consumption for hour ($3.79/gl)

Table 3.2. Cost-effectiveness of planting treatments compared with control.

	Total cost	Ratio of cost	% Survival	Ratio of Survival	%Cost-effectiveness Survival	Growth (cm)	Ratio of Growth (cm)	%Cost-effectiveness Growth
Control	580		81			48		
Irrigation	1651	2.8	73	0.91	33	44	92	32
Mulch	880	1.5	80	0.99	65	64	133	88
Mulch/Irrigation	1947	3.4	83	1.03	31	66	138	41
Mulch/Irrigation + Bulldozing	1979	3.4	88	1.08	32	81	169	49

Table 3.3. The cost per tree in all management treatments and the additional growth and investment compare with control treatments.

	Cost per tree (1 Year)	% Survival by managements	Height Growth (3 Years)	Additional growth compare with control	Additional cost compare with control	Additional Cost of cm/growth by tree	Cost of cm/growth by tree
Control	$4.15	81	48 cm	Baseline	Baseline	Baseline	$0.09
Irrigation	$11.80	73	44 cm	-4 cm/tree	$ 7.65/ tree	No consider	$0.26
Mulch	$6.25	80	64 cm	16 cm/ tree	$2.10/ tree	$0.13 cm/ tree	$0.10
Mulch/Irrigation	$13.90	83	66 cm	18 cm/tree	$9.75/ tree	$0.54 cm/ tree	$0.21
Mulch/Irrigation + Bulldozing	$14.10	88	81 cm	33 cm/tree	$9.95/ tree	$0.30 cm/ tree	$0.17

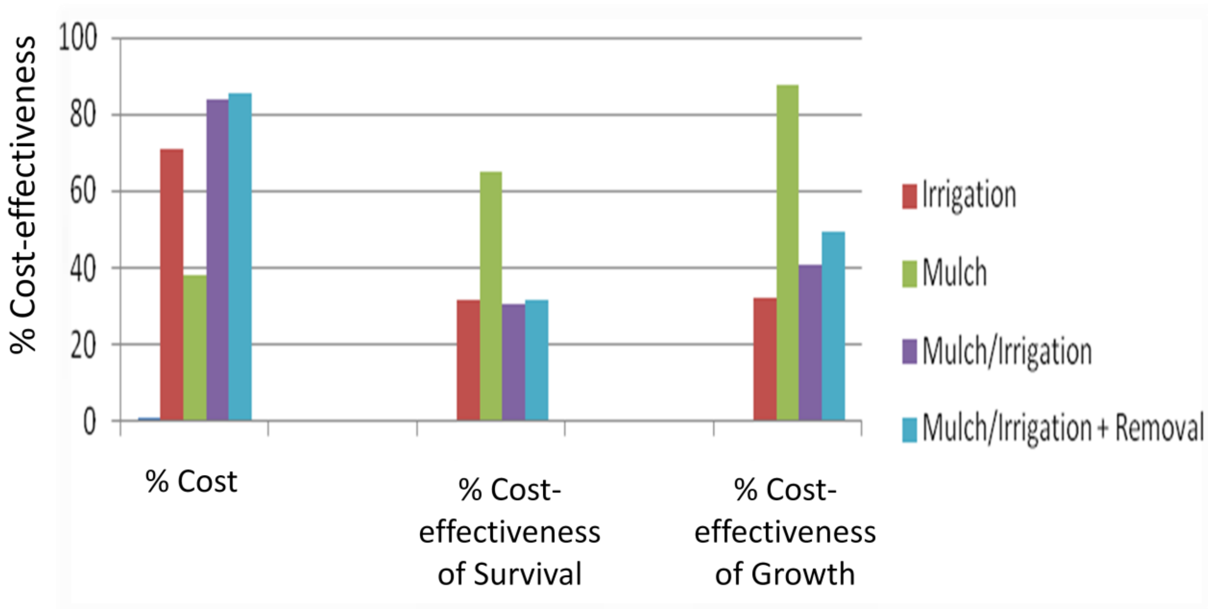


Figure 3.1. Mean percent cost and cost-effectiveness for each treatment relative to the control treatment.

Chapter 4
Conclusions

The results from my research would help to determine what management techniques we should use during reforestation projects to increase survival and growth and to accelerate the restoration of the habitat. The following can be concluded from 3-years of monitoring of different results of the managements techniques on the survival and growth of native saplings species in the Cabo Rojo National Wildlife Refuge:

- Clay soil displayed great survival of the native sapling species without management after planting and showed more success in growth than loamy sand soil. Additional management intervention like mulch, irrigation and bulldozing is not necessary for establishment sapling native tree.
- Loamy sand soil needed mulch management for sapling establishment and to have a positive growth impact on native saplings.
- Among all of the management treatments in clay soil not had difference in soil moisture.
- Mulch alone in loamy sand retained more soil moisture compared to the control and irrigation managements.
- Treatment of irrigation alone not provides benefit on growth and survival over control.
- Lightly bulldozing effect the soils surface helps to maintain weed control for as one year after treatment, but the final at three years the establishment and growth not had higher than mulch.
- Mulch/irrigation or combination with bulldozer effect does increase growth, but only mulch management was the most cost effective technique for the establishment of native tree species over time.

- Saplings planted with mulch showed higher growth when compared to control and irrigation. Mulch management decreased grass cover by 50-80% and maintaining soil moisture over time and this help to increased growth and survival in the first stage of establishment.
- The fastest growing species for both soil types were *C. fruticosum* and *T. heterophylla* and the medium to low growth was *B. busera* > *B. buceras,* > *B. succulenta* > *E. aerolatum*.

Recommendations

Management implication

- Clay soil is better for establish native tree species without managements after planting.
- Mulch management increases the successes in native dry forest species and is the most cost-effectiveness practices for establishment sapling native species.
- Good species for reforestation projects in dry forests are *Citharexylum fruticosum, Tabebuia heterophylla* and *Bursera simaruba*, they showed higher growth than other species.
- Increment the volunteer participation reduces the high cost of labor greatly requirement in restoration projects.

Future Research

- Continue monitoring to obtain long term data of the successful of the native species, to improve the reforestation projects and reduces the mortality.
- Compare the canopy that develops from the native species group and line arrangements and evaluate if they reduce or suppress exotic grasses.
- Use other native, endemic, rare and endangered species of the dry zone to increase the diversity and evaluate the establishment and growth.

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Appendix A. Contingency tables for percent survival analysis at the end of three years of six native tree species in all planting treatments on clay and loamy sand soil.

Contingency table
Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Clay	Bosu	Control	30	70	100
Clay	Bosu	Irrigation	0	100	100
Clay	Bosu	Mulch	30	70	100
Clay	Bosu	Mulch/Irrigation	10	90	100
Clay	Bosu	Mulch/Irrigation+Removal	20	80	100
Clay	Bosu	Total	18	82	100

Statistic	Value	df	p
Chi -square (Pearson)	4.61	4	0.3300
Chi -square (ML-G2)	6.2	4	0.1850
Contingency Coef. (Cramer)	0.21		
Contingency Coef. (Pearson	0.29		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Clay	Bubu	Control	30	70	100
Clay	Bubu	Irrigation	40	60	100
Clay	Bubu	Mulch	40	60	100
Clay	Bubu	Mulch/Irrigation	10	90	100
Clay	Bubu	Mulch/Irrigation+Removal	20	80	100
Clay	Bubu	Total	28	72	100

Estadístico	Valor	gl	p
Chi -square (Pearson)	3.37	4	0.4974
Chi -square (ML-G2)	3.65	4	0.4558
Contingency Coef. (Cramer)	0.18		
Contingency Coef. (Pearson	0.25		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Clay	Busi	Control	0	100	100
Clay	Busi	Irrigation	10	90	100
Clay	Busi	Mulch	0	100	100
Clay	Busi	Mulch/Irrigation	20	80	100
Clay	Busi	Mulch/Irrigation+Removal	20	80	100
Clay	Busi	Total	10	90	100

Statistic	Value	df	p
Chi -square (Pearson)	4.44	4	0.3492
Chi -square (ML-G2)	5.99	4	0.1999
Contingency Coef. (Cramer)	0.21		
Contingency Coef. Pearson.	0.29		

Absolute frequencies					
In columns:Survival					
Soil	Specie	Treatments	Dead	Alive	Total
Clay	Cifr	Control	60	40	100
Clay	Cifr	Irrigation	10	90	100
Clay	Cifr	Mulch	40	60	100
Clay	Cifr	Mulch/Irrigation	30	70	100
Clay	Cifr	Mulch/Irrigation+Removal	20	80	100
Clay	Cifr	Total	32	68	100

Statistic	Value	df	p
Chi -square (Pearson)	6.8	4	0.1468
Chi -square (ML-G2)	7.04	4	0.1338
Contingency Coef. Cramer	0.26		
Contingency Coef. Pearson	0.35		

Absolute frequencies					
In columns:Survival					
Soil	Specie	Treatments	Dead	Alive	Total
Clay	Erae	Control	10	90	100
Clay	Erae	Irrigation	20	80	100
Clay	Erae	Mulch	10	90	100
Clay	Erae	Mulch/Irrigation	10	90	100
Clay	Erae	Mulch/Irrigation+Removal	0	100	100
Clay	Erae	Total	10	90	100

Statistic	Value	df	p
Chi -square (Pearson)	2.22	4	0.695
Chi -square (ML-G2)	3	4	0.5586
Contingency Coef. (Cramer)	0.15		
Contingency Coef. Pearson	0.21		

Absolute frequencies					
In columns:Survival					
Soil	Specie	Treatments	Dead	Alive	Total
Clay	Tahe	Control	10	90	100
Clay	Tahe	Irrigation	0	100	100
Clay	Tahe	Mulch	20	80	100
Clay	Tahe	Mulch/Irrigation	40	60	100
Clay	Tahe	Mulch/Irrigation+Removal	10	90	100
Clay	Tahe	Total	16	84	100

Statistic	Value	df	p
Chi -square (Pearson)	6.85	4	0.1443
Chi -square (ML-G2)	7.5	4	0.1119
Contingency Coef. (Cramer)	0.26		
Contingency Coef. (Pearson	0.35		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Bosu	Control	20	80	100
Loamy Sand	Bosu	Irrigation	70	30	100
Loamy Sand	Bosu	Mulch	40	60	100
Loamy Sand	Bosu	Mulch/Irrigation	30	70	100
Loamy Sand	Bosu	Mulch/Irrigation+Removal	20	80	100
Loamy Sand	Bosu	Total	36	64	100

Statistic	Value	df	p
Chi -square (Pearson)	7.47	4	0.1133
Chi -square (ML-G2)	7.43	4	0.1148
Contingency Coef. (Cramer)	0.27		
Contingency Coef. (Pearson	0.36		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Bubu	Control	40	60	100
Loamy Sand	Bubu	Irrigation	30	70	100
Loamy Sand	Bubu	Mulch	20	80	100
Loamy Sand	Bubu	Mulch/Irrigation	20	80	100
Loamy Sand	Bubu	Mulch/Irrigation+Removal	10	90	100
Loamy Sand	Bubu	Total	24	76	100

Statistic	Value	df	p
Chi -square (Pearson)	2.85	4	0.5831
Chi -square (ML-G2)	2.91	4	0.5725
Contingency Coef. (Cramer)	0.17		
Contingency Coef. (Pearson	0.23		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Busi	Control	0	100	100
Loamy Sand	Busi	Irrigation	0	100	100
Loamy Sand	Busi	Mulch	0	100	100
Loamy Sand	Busi	Mulch/Irrigation	0	100	100
Loamy Sand	Busi	Mulch/Irrigation+Removal	10	90	100
Loamy Sand	Busi	Total	2	98	100

Statistic	Value	df	p
Chi -square (Pearson)	4.08	4	0.3951
Chi -square (ML-G2)	3.3	4	0.5086
Contingency Coef. (Cramer)	0.2		
Contingency Coef. (Pearson	0.27		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Cifr	Control	20	80	100
Loamy Sand	Cifr	Irrigation	30	70	100
Loamy Sand	Cifr	Mulch	10	90	100
Loamy Sand	Cifr	Mulch/Irrigation	0	100	100
Loamy Sand	Cifr	Mulch/Irrigation+Removal	10	90	100
Loamy Sand	Cifr	Total	14	86	100

Statistic	Value	df	p
Chi -square (Pearson)	4.32	4	0.3646
Chi -square (ML-G2)	5.27	4	0.2609
Contingency Coef. (Cramer)	0.21		
Contingency Coef. (Pearson	0.28		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Erae	Control	10	90	100
Loamy Sand	Erae	Irrigation	60	40	100
Loamy Sand	Erae	Mulch	0	100	100
Loamy Sand	Erae	Mulch/Irrigation	10	90	100
Loamy Sand	Erae	Mulch/Irrigation+Removal	0	100	100
Loamy Sand	Erae	Total	16	84	100

Statistic	Value	df	p
Chi -square (Pearson)	18.75	4	0.0009
Chi -square (ML-G2)	17.5	4	0.0015
Contingency Coef. (Cramer)	0.43		
Contingency Coef. (Pearson	0.52		

Absolute frequencies
In columns:Survival

Soil	Specie	Treatments	Dead	Alive	Total
Loamy Sand	Tahe	Control	0	100	100
Loamy Sand	Tahe	Irrigation	50	50	100
Loamy Sand	Tahe	Mulch	30	70	100
Loamy Sand	Tahe	Mulch/Irrigation	20	80	100
Loamy Sand	Tahe	Mulch/Irrigation+Removal	0	100	100
Loamy Sand	Tahe	Total	20	80	100

Statistic	Value	df	p
Chi -square (Pearson)	11.25	4	0.0239
Chi -square (ML-G2)	13.95	4	0.0074
Contingency Coef. (Cramer)	0.34		
Contingency Coef. (Pearson	0.43		

Appendix B. Contingency tables for survival percentage analysis at the end of three years of treatments by soil with species pooled in each soil types.

Clay Soil

Absolute frequencies
In columns:Survival

Soil	Treatments	Alive	Dead	Total
Clay	Control	77	23	100
Clay	Irrigation	87	13	100
Clay	Mulch	77	23	100
Clay	Mulch/Irrigation	80	20	100
Clay	Mulch/Irrigation+Removal	85	15	100
Clay	Total	81	19	100

Statistic	Valor	gl	p
Chi Cuadrado Pearson	3.38	4	0.4965
Chi Cuadrado MV-G2	3.45	4	0.4849
Coef.Conting.Cramer	0.08		
Coef.Conting.Pearson	0.11		

Loamy Sand Soil

Absolute frequencies
In columns:Survival

Soil	Treatments	Alive	Dead	Total
Loamy Sand	Control	85	15	100
Loamy Sand	Irrigation	60	40	100
Loamy Sand	Mulch	83	17	100
Loamy Sand	Mulch/Irrigation	86	14	100
Loamy Sand	Mulch/Irrigation+Removal	90	10	100
Loamy Sand	Total	81	19	100

Statistic	Valor	gl	p
Chi Cuadrado Pearson	22.49	4	0.0002
Chi Cuadrado MV-G2	20.13	4	0.0005
Coef.Conting.Cramer	0.19		
Coef.Conting.Pearson	0.26		

Appendix C. ANCOVA table for final height and diameter increments in one year and three years.

Variable	N	R²	R² Aj	CV		
1 Year of Height (m) Increment	486	0.64	0.52	82.96		
S.V.	**SS**	**df**	**MS**	**F**	**p-value**	**Coef**
Model	23.05	120	0.19	5.35	<0.0001	
Soil	2.50E-03	1	2.50E-03	0.07	0.7933	
Species	2.92	5	0.58	16.26	<0.0001	
Treatments	3.6	4	0.9	25.07	<0.0001	
Arrangement	0.17	1	0.17	4.71	0.0306	
Initial Height	2.27	1	2.27	63.07	<0.0001	-0.35
Soil*Species	0.97	5	0.19	5.41	0.0001	
Soil*Treatments	0.38	4	0.09	2.63	0.0341	
Soil*Arrangement	1.20E-05	1	1.20E-05	3.30E-04	0.9855	
Species*Treatments	2.84	20	0.14	3.95	<0.0001	
Species*Arrangement	0.27	5	0.05	1.53	0.1802	
Treatments*Arrangement	0.15	4	0.04	1.04	0.388	
Soil*Species*Treatments	0.97	20	0.05	1.35	0.1426	
Soil*Species*Arrangement	0.12	5	0.02	0.69	0.628	
Soil*Treatmentst*Arrangement	0.14	4	0.04	1	0.4057	
Species*Treatments*Arrangement	1.49	20	0.07	2.07	0.0048	
Soil*Species*Treatments*Arrangeme	0.91	20	0.05	1.26	0.203	
Error	13.11	365	0.04			
Total	36.17	485				

Variable	N	R²	R² Aj	CV		
3 Years of Height (m) Increment	486	0.59	0.46	71		
S.V.	**SS**	**df**	**MS**	**F**	**p-value**	**Coef**
Model	94.22	120	0.79	4.41	<0.0001	
Soil	17.54	1	17.54	98.51	<0.0001	
Species	15.51	5	3.1	17.42	<0.0001	
Treatments	10.88	4	2.72	15.27	<0.0001	
Arrangement	1.39	1	1.39	7.81	0.0055	
Initial Height	6.9	1	6.9	38.74	<0.0001	-0.62
Soil*Species	3.13	5	0.63	3.52	0.004	
Soil*Treatments	2.15	4	0.54	3.03	0.0178	
Soil*Arrangement	2.10E-04	1	2.10E-04	1.20E-03	0.9729	
Species*Treatments	7.13	20	0.36	2	0.0068	
Species*Arrangement	0.33	5	0.07	0.37	0.866	
Treatments*Arrangement	0.99	4	0.25	1.39	0.2362	
Soil*Species*Treatments	2.41	20	0.12	0.68	0.8491	
Soil*Species*Arrangement	0.16	5	0.03	0.18	0.9696	
Soil*Treatmentst*Arrangement	0.56	4	0.14	0.79	0.5336	
Species*Treatments*Arrangement	2.9	20	0.15	0.82	0.6945	
Soil*Species*Treatments*Arrangeme	2.64	20	0.13	0.74	0.783	
Error	64.98	365	0.18			
Total	159.2	485				

Variable	N	R²	R² Aj	CV		
1 Year of Diameter (cm) Increment	486	0.6	0.47	73.44		
S.V	**SS**	**df**	**MS**	**F**	**p-value**	**Coef**
Model	67.81	120	0.57	4.55	<0.0001	
Soil	0.44	1	0.44	3.5	0.062	
Species	19.21	5	3.84	30.94	<0.0001	
Treatments	19.34	4	4.83	38.92	<0.0001	
Arrangement	0.15	1	0.15	1.21	0.2717	
Initial Height	5.12	1	5.12	41.26	<0.0001	-0.45
Soil*Species	4.73	5	0.95	7.62	<0.0001	
Soil*Treatments	0.06	4	0.02	0.12	0.9746	
Soil*Arrangement	1.70E-05	1	1.70E-05	1.40E-04	0.9907	
Species*Treatments	4.34	20	0.22	1.75	0.025	
Species*Arrangement	0.38	5	0.08	0.61	0.6922	
Treatments*Arrangement	0.21	4	0.05	0.42	0.7957	
Soil*Species*Treatments	2.55	20	0.13	1.03	0.4285	
Soil*Species*Arrangement	0.71	5	0.14	1.14	0.3366	
Soil*Treatments*Arrangement	0.17	4	0.04	0.35	0.8464	
Species*Treatments*Arrangement	4.4	20	0.22	1.77	0.0223	
Soil*Species*Treatments*Arrangeme	1.97	20	0.1	0.79	0.7219	
Error	45.33	365	0.12			
Total	113.14	485				

Variable	N	R²	R² Aj	CV		
3 Years of Diameter (cm) Increment	486	0.6	0.47	66		
S.V	**SS**	**df**	**MS**	**F**	**p-value**	**Coef**
Model	366.88	120	3.06	4.57	<0.0001	
Soil	102.94	1	102.94	153.83	<0.0001	
Species	88.46	5	17.69	26.44	<0.0001	
Treatments	48.68	4	12.17	18.19	<0.0001	
Arrangement	1.82	1	1.82	2.72	0.0998	
Initial Height	1.32	1	1.32	1.97	0.1614	-0.23
Soil*Species	17.27	5	3.45	5.16	0.0001	
Soil*Treatments	4.66	4	1.16	1.74	0.1404	
Soil*Arrangement	0.47	1	0.47	0.71	0.401	
Species*Treatments	12.63	20	0.63	0.94	0.5318	
Species*Arrangement	1.15	5	0.23	0.34	0.8861	
Treatments*Arrangement	2.56	4	0.64	0.96	0.432	
Soil*Species*Treatments	13.48	20	0.67	1.01	0.4528	
Soil*Species*Arrangement	2.69	5	0.54	0.8	0.5477	
Soil*Treatments*Arrangement	1.77	4	0.44	0.66	0.6181	
Species*Treatments*Arrangement	16	20	0.8	1.2	0.2543	
Soil*Species*Treatments*Arrangeme	12.06	20	0.6	0.9	0.5862	
Error	244.26	365	0.67			
Total	611.13	485				

Appendix D. ANCOVA table for final height in three years of treatments by soil with species pooled in each soil types.

. Clay Soil

Soil	Variable	N	R^2	R^2 Aj	CV
Clay	3 Years Height	243	0.22	0.21	60.24

S.V.	SS	df	MS	F	P-value	Coef
Model	15.15	5	3.03	13.74	<0.0001	
Management	3.39	4	0.85	3.84	0.0048	
Initial Height	12.96	1	12.96	58.74	<0.0001	-0.89
Error	52.27	237	0.22			
Total	67.42	242				

Test:Tukey Alpha=0.05 LSD=0.26052
Error: 0.2205 df: 237

Management	Means	n	E.E.		
Mulch/Irrigation+Bulldozing	0.97	51	0.07	A	
Mulch	0.78	46	0.07	A	B
Mulch/Irrigation	0.77	48	0.07	A	B
Control	0.77	46	0.07	A	B
Irrigation	0.61	52	0.07		B

Loamy Sand Soil

Soil	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	3 Years Height	243	0.33	0.32	112.7

S.V.	SS	df	MS	F	P-value	Coef
Model	24.75	5	4.95	23.31	<0.0001	
Management	9.01	4	2.25	10.61	<0.0001	
Initial Height	16.82	1	16.82	79.21	<0.0001	-1.04
Error	50.33	237	0.21			
Total	75.08	242				

Test:Tukey Alpha=0.05 LSD=0.25679
Error: 0.2124 df: 237

Management	Means	n	E.E.		
Comb/Removal	0.62	55	0.06	A	
Mulch	0.52	50	0.07	A	
Mulch/Irrigation	0.51	51	0.07	A	
Control	0.17	51	0.06		B
Irrigation	0.14	36	0.08		B

Appendix E. Contrast test comparing mulch/irrigation and bulldozing treatments for height growth in each soil type by species separately.

Clay Soil

Bourreria succulenta (Palo de Vaca)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bosu	Height Increment	41	0.19	0.07	67.99

S.V.	SS	df	MS	F	p-value	Coef
Model	2.39	5	0.48	1.65	0.1739	
Management	2.06	4	0.52	1.78	0.1557	
Initial Height	0.27	1	0.27	0.93	0.3408	-0.24
Error	10.17	35	0.29			
Total	12.56	40				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.28	0.32	1	0.32	1.11	0.2991
Total		0.32	1	0.32	1.11	0.2991

*Bucida buceras (*Ucar)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bubu	Height Increment	36	0.28	0.16	67.23

S.V.	SS	df	MS	F	p-value	Coef
Model	3.41	5	0.68	2.35	0.0654	
Management	1.93	4	0.48	1.65	0.1865	
Initial Height	1.2	1	1.2	4.11	0.0517	-0.83
Error	8.73	30	0.29			
Total	12.15	35				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.56	1.26	1	1.26	4.34	0.0457
Total		1.26	1	1.26	4.34	0.0457

Bursera simaruba **(Almacigo)**

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Busi	Height Increment	45	0.21	0.11	52.1

S.V.	SS	df	MS	F	p-value	Coef
Model	1.55	5	0.31	2.13	0.0822	
Management	1	4	0.25	1.71	0.1668	
Initial Height	0.43	1	0.43	2.98	0.0922	-0.6
Error	5.68	39	0.15			
Total	7.23	44				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.04	0.01	1	0.01	0.05	0.8203
Total		0.01	1	0.01	0.05	0.8203

Citharexylum fruticosum **(Pendula)**

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Cifr	Height Increment	34	0.34	0.22	42.93

S.V.	SS	df	MS	F	p-value	Coef
Model	3.33	5	0.67	2.85	0.0334	
Management	2.23	4	0.56	2.39	0.075	
Initial Height	0.67	1	0.67	2.87	0.1011	-0.99
Error	6.54	28	0.23			
Total	9.87	33				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.28	0.29	1	0.29	1.23	0.2768
Total		0.29	1	0.29	1.23	0.2768

Erythroxylum areolatum (Coca Falsa)

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Erae	Height Increment	45	0.37	0.29	76.44

S.V.	SS	df	MS	F	p-value	Coef
Model	1.61	5	0.32	4.58	0.0022	
Management	0.59	4	0.15	2.11	0.0978	
Initial Height	1.33	1	1.33	18.96	0.0001	-0.81
Error	2.75	39	0.07			
Total	4.36	44				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	-0.02	2.20E-03	1	2.20E-03	0.03	0.86
Total		2.20E-03	1	2.20E-03	0.03	0.86

Tabebuia heterophylla (Roble Nativo)

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Tahe	Height Increment	42	0.09	0	42.7

S.V.	SS	df	MS	F	p-value	Coef
Model	0.62	5	0.12	0.7	0.6243	
Management	0.15	4	0.04	0.22	0.9283	
Initial Height	0.33	1	0.33	1.9	0.1766	-0.62
Error	6.32	36	0.18			
Total	6.93	41				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	-0.07	0.02	1	0.02	0.1	0.7487
Total		0.02	1	0.02	0.1	0.7487

Loamy Sand Soil

Bourreria succulenta (Palo de Vaca)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bosu	Height Increment	32	0.54	0.45	407.69

S.V.	SS	df	MS	F	p-value	Coef
Model	5.27	5	1.05	6.08	0.0007	
Management	4.15	4	1.04	5.98	0.0015	
Initial Height	2.02	1	2.02	11.65	0.0021	-0.75
Error	4.51	26	0.17			
Total	9.79	31				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.32	0.37	1	0.37	2.12	0.1572
Total		0.37	1	0.37	2.12	0.1572

*Bucida buceras (*Ucar)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bubu	Height Increment	37	0.5	0.42	205.67

S.V.	SS	df	MS	F	p-value	Coef
Model	3.98	5	0.8	6.27	0.0004	
Management	1.12	4	0.28	2.2	0.0924	
Initial Height	2.58	1	2.58	20.35	0.0001	-1.24
Error	3.94	31	0.13			
Total	7.92	36				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.44	0.75	1	0.75	5.91	0.021
Total		0.75	1	0.75	5.91	0.021

Bursera simaruba (Almacigo)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Busi	Height Increment	49	0.25	0.17	71.33

S.V.	SS	df	MS	F	p-value	Coef
Model	1.44	5	0.29	2.91	0.024	
Management	0.74	4	0.19	1.87	0.1326	
Initial Height	0.79	1	0.79	7.96	0.0072	-0.72
Error	4.26	43	0.1			
Total	5.7	48				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	-0.01	8.20E-04	1	8.20E-04	0.01	0.9277
Total		8.20E-04	1	8.20E-04	0.01	0.9277

Citharexylum fruticosum (Pendula)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Cifr	Height Increment	43	0.35	0.26	62.18

S.V.	SS	df	MS	F	p-value	Coef
Model	5.67	5	1.13	3.97	0.0055	
Management	5.15	4	1.29	4.52	0.0045	
Initial Height	0.15	1	0.15	0.51	0.4796	0.47
Error	10.55	37	0.29			
Total	16.22	42				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.56	1	1	1	3.5	0.0691
Total		1	1	1	3.5	0.0691

Erythroxylum areolatum (Coca Falsa)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Erae	Height Increment	42	0.27	0.17	414.91

S.V.	SS	df	MS	F	p-value	Coef
Model	0.99	5	0.2	2.7	0.0361	
Management	0.98	4	0.24	3.33	0.0202	
Initial Height	8.20E-05	1	8.20E-05	1.10E-03	0.9735	0.01
Error	2.64	36	0.07			
Total	3.63	41				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	0.05	0.01	1	0.01	0.18	0.6748
Total		0.01	1	0.01	0.18	0.6748

Tabebuia heterophylla (Roble Nativo)

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Tahe	Height Increment	40	0.5	0.43	52.38

S.V.	SS	df	MS	F	p-value	Coef
Model	4.74	5	0.95	6.86	0.0002	
Management	2.53	4	0.63	4.58	0.0046	
Initial Height	2.17	1	2.17	15.67	0.0004	-1.49
Error	4.7	34	0.14			
Total	9.44	39				

Contrast test

Management	Contrast	SS	df	MS	F	p-value
Mulch+Irrigation vs Bulldozing	-0.2	0.18	1	0.18	1.3	0.2616
Total		0.18	1	0.18	1.3	0.2616

Appendix F. Two-way ANCOVA table to test the factor of irrigation and mulch in differences in height and diameter for one and three years after planting in six native tree species; *Bourreria succulenta (*Bosu), *Bucida buceras (*Bubu*)*, *Bursera simaruba (*Busi), *Citharexylum fruticosum (*Cifr), *Erythroxylum areolatum (*Erae), and *Tabebuia heterophylla (*Tahe) in all planting treatments on clay and loamy sand soil.

Height increments

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bosu	1 Year Height	33	0.38	0.29	78.81

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.64	4	0.16	4.29	0.0079	
Irrigation	0.02	1	0.02	0.45	0.5075	
Mulch	0.22	1	0.22	5.90	0.0218	
Initial Height	0.30	1	0.30	8.05	0.0084	-0.28
Irrigation*Mulch	0.01	1	0.01	0.14	0.7155	
Error	1.05	28	0.04			
Total	1.69	32				

Test:Tukey Alfa=0.05 DMS=0.13885

Error: 0.0375 df: 28

Irrigation	Means	n	E.E.	
YES	0.24	19	0.04	A
NO	0.19	14	0.05	A

Test:Tukey Alfa=0.05 DMS=0.13808

Error: 0.0375 df: 28

Mulch	Means	n	E.E.		
YES	0.30	16	0.05	A	
NO	0.13	17	0.05		B

Test:Tukey Alfa=0.05 DMS=0.26182

Error: 0.0375 df: 28

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.31	9	0.06	A
NO	YES	0.29	7	0.07	A
YES	NO	0.17	10	0.06	A
NO	NO	0.10	7	0.07	A

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bosu	3 Year Height	33	0.15	0.03	57.86

S.V.	SS	df	MS	F	p-value	Coef
Model.	1.02	4	0.26	1.21	0.3268	
Irrigation	0.03	1	0.03	0.14	0.7118	
Mulch	0.86	1	0.86	4.07	0.0533	
Initial Height	1.1E-03	1	1.1E-03	0.01	0.9435	-0.02
Irrigation*Mulch	0.02	1	0.02	0.09	0.7640	
Error	5.89	28	0.21			
Total	6.91	32				

Test:Tukey Alfa=0.05 DMS=0.32897

Error: 0.2103 df: 28

Irrigation	Means	n	E.E.	
NO	0.75	14	0.12	A
YES	0.69	19	0.11	A

Test:Tukey Alfa=0.05 DMS=0.32714

Error: 0.2103 df: 28

Mulch	Means	n	E.E.		
YES	0.89	16	0.12	A	
NO	0.56	17	0.11		B

Test:Tukey Alfa=0.05 DMS=0.62032

Error: 0.2103 df: 28

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.89	7	0.18	A
YES	YES	0.88	9	0.15	A
NO	NO	0.61	7	0.17	A
YES	NO	0.50	10	0.15	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bubu	1 Year Height	28	0.46	0.36	69.68

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.56	4	0.14	4.84	0.0056	
Irrigation	0.02	1	0.02	0.81	0.3762	
Mulch	0.04	1	0.04	1.24	0.2776	
Initial Height	0.39	1	0.39	13.31	0.0013	-0.52
Irrigation*Mulch	0.03	1	0.03	1.17	0.2904	
Error	0.67	23	0.03			
Total	1.23	27				

Test:Tukey Alfa=0.05 DMS=0.13335

Error: 0.0290 df: 23

Irrigation	Means	n	E.E.	
NO	0.21	13	0.05	A
YES	0.15	15	0.05	A

Test:Tukey Alfa=0.05 DMS=0.13335

Error: 0.0290 df: 23

Mulch	Means	n	E.E.	
YES	0.22	15	0.05	A
NO	0.14	13	0.05	A

Test:Tukey Alfa=0.05 DMS=0.25376

Error: 0.0290 df: 23

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.28	6	0.07	A
YES	YES	0.15	9	0.06	A
YES	NO	0.14	6	0.07	A
NO	NO	0.13	7	0.07	A

Bucida buceras

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Bubu	3 Year Height	28	0.20	0.06	49.18

S.V.	SS	df	MS	F	p-value	Coef
Model.	0.91	4	0.23	1.46	0.2459	
Irrigation	0.01	1	0.01	0.09	0.7653	
Mulch	0.03	1	0.03	0.19	0.6651	
Initial Height	0.51	1	0.51	3.26	0.0842	-0.60
Irrigation*Mulch	0.01	1	0.01	0.04	0.8509	
Error	3.58	23	0.16			
Total	4.49	27				

Test:Tukey Alfa=0.05 DMS=0.30899

Error: 0.1558 df: 23

Irrigation	Means	n	E.E.	
NO	0.71	13	0.11	A
YES	0.66	15	0.10	A

Test:Tukey Alfa=0.05 DMS=0.30899

Error: 0.1558 df: 23

Mulch	Means	n	E.E.	
NO	0.72	13	0.12	A
YES	0.65	15	0.11	A

Test:Tukey Alfa=0.05 DMS=0.58798

Error: 0.1558 df: 23

Irrigation	Mulch	Means	n	E.E.	
NO	NO	0.76	7	0.16	A
YES	NO	0.68	6	0.16	A
NO	YES	0.66	6	0.16	A
YES	YES	0.64	9	0.14	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Busi	1 Year Height	37	0.09	0.00	167.96

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.13	4	0.03	0.75	0.5624	
Irrigation	0.01	1	0.01	0.16	0.6895	
Mulch	0.03	1	0.03	0.76	0.3890	
Initial Height	0.06	1	0.06	1.53	0.2254	-0.24
Irrigation*Mulch	0.01	1	0.01	0.32	0.5751	
Error	1.36	32	0.04			
Total	1.49	36				

Test:Tukey Alfa=0.05 DMS=0.13822
Error: 0.0424 df: 32

Irrigation	Means	n	E.E.	
NO	0.10	20	0.05	A
YES	0.08	17	0.05	A

Test:Tukey Alfa=0.05 DMS=0.13801
Error: 0.0424 df: 32

Mulch	Means	n	E.E.	
YES	0.12	18	0.05	A
NO	0.06	19	0.05	A

Test:Tukey Alfa=0.05 DMS=0.26011
Error: 0.0424 df: 32

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.15	10	0.07	A
YES	YES	0.09	8	0.07	A
YES	NO	0.07	9	0.07	A
NO	NO	0.06	10	0.07	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Busi	3 Year Height	37	0.23	0.14	54.91

S.V.	SS	df	MS	F	p-value	Coef
Model.	1.57	4	0.39	2.42	0.0686	
Irrigation	0.38	1	0.38	2.33	0.1370	
Mulch	0.52	1	0.52	3.22	0.0820	
Initial Height	0.46	1	0.46	2.82	0.1030	-0.64
Irrigation*Mulch	0.04	1	0.04	0.25	0.6226	
Error	5.18	32	0.16			
Total	6.74	36				

Test:Tukey Alfa=0.05 DMS=0.26983

Error: 0.1618 df: 32

Irrigation	Means	n	E.E.	
NO	0.82	20	0.09	A
YES	0.62	17	0.10	A

Test:Tukey Alfa=0.05 DMS=0.26943

Error: 0.1618 df: 32

Mulch	Means	n	E.E.	
YES	0.84	18	0.10	A
NO	0.60	19	0.09	A

Test:Tukey Alfa=0.05 DMS=0.50778

Error: 0.1618 df: 32

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.98	10	0.13	A
YES	YES	0.71	8	0.14	A
NO	NO	0.67	10	0.13	A
YES	NO	0.53	9	0.13	A

Citharexylum fruticosum

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Cifr	1 Year Height	26	0.27	0.13	54.36

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.31	4	0.08	1.97	0.1370	
Irrigation	0.03	1	0.03	0.75	0.3963	
Mulch	0.10	1	0.10	2.66	0.1180	
Initial Height	0.19	1	0.19	4.81	0.0396	-0.57
Irrigation*Mulch	0.05	1	0.05	1.15	0.2958	
Error	0.83	21	0.04			
Total	1.14	25				

Test:Tukey Alfa=0.05 DMS=0.16422

Error: 0.0394 df: 21

Irrigation	Means	n	E.E.	
YES	0.38	16	0.05	A
NO	0.31	10	0.06	A

Test:Tukey Alfa=0.05 DMS=0.16199

Error: 0.0394 df: 21

Mulch	Means	n	E.E.	
YES	0.41	13	0.06	A
NO	0.27	13	0.06	A

Test:Tukey Alfa=0.05 DMS=0.31348

Error: 0.0394 df: 21

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.49	7	0.08	A
NO	YES	0.33	6	0.08	A
NO	NO	0.28	4	0.10	A
YES	NO	0.27	9	0.07	A

Citharexylum fruticosum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Cifr	3 Year Height	26	0.33	0.21	40.30

S.V.	SS	df	MS	F	p-value	Coef
Model.	2.17	4	0.54	2.64	0.0629	
Irrigation	0.32	1	0.32	1.56	0.2256	
Mulch	0.22	1	0.22	1.07	0.3132	
Initial Height	0.39	1	0.39	1.92	0.1806	-0.82
Irrigation*Mulch		1.22	1	1.22	5.95	0.0237
Error	4.32	21	0.21			
Total	6.49	25				

Test:Tukey Alfa=0.05 DMS=0.37517

Error: 0.2058 df: 21

Irrigation	Means	n	E.E.	
NO	1.22	10	0.15	A
YES	0.98	16	0.12	A

Test:Tukey Alfa=0.05 DMS=0.37007

Error: 0.2058 df: 21

Mulch	Means	n	E.E.	
NO	1.20	13	0.14	A
YES	1.00	13	0.13	A

Test:Tukey Alfa=0.05 DMS=0.71617

Error: 0.2058 df: 21

Irrigation	Mulch	Means	n	E.E.	
NO	NO	1.55	4	0.23	A
YES	YES	1.11	7	0.18	A
NO	YES	0.89	6	0.19	A
YES	NO	0.86	9	0.15	A

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Erae	1 Year Height	35	0.49	0.42	89.25

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.31	4	0.08	7.18	0.0004	
Irrigation	0.01	1	0.01	0.53	0.4716	
Mulch	0.02	1	0.02	1.70	0.2023	
Initial Height	0.26	1	0.26	24.48	<0.0001	-0.39
Irrigation*Mulch	1.2E-04	1	1.2E-04	0.01	0.9161	
Error	0.32	30	0.01			
Total	0.63	34				

Test:Tukey Alfa=0.05 DMS=0.07177

Error: 0.0108 df: 30

Irrigation	Means	n	E.E.	
YES	0.14	17	0.03	A
NO	0.11	18	0.02	A

Test:Tukey Alfa=0.05 DMS=0.07177

Error: 0.0108 df: 30

Mulch	Means	n	E.E.	
YES	0.15	18	0.02	A
NO	0.10	17	0.03	A

Test:Tukey Alfa=0.05 DMS=0.13520

Error: 0.0108 df: 30

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.16	9	0.03	A
NO	YES	0.13	9	0.03	A
YES	NO	0.12	8	0.04	A
NO	NO	0.09	9	0.03	A

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Erae	3 Year Height	35	0.38	0.29	78.92

S.V.	SS	df	MS	F	p-value	Coef
Model.	1.36	4	0.34	4.55	0.0055	
Irrigation	0.25	1	0.25	3.28	0.0800	
Mulch	0.24	1	0.24	3.26	0.0810	
Initial Height	1.10	1	1.10	14.63	0.0006	-0.80
Irrigation*Mulch	0.14	1	0.14	1.82	0.1871	
Error	2.25	30	0.08			
Total	3.62	34				

Test:Tukey Alfa=0.05 DMS=0.18916

Error: 0.0750 df: 30

Irrigation	Means	n	E.E.	
NO	0.42	18	0.07	A
YES	0.25	17	0.07	A

Test:Tukey Alfa=0.05 DMS=0.18916

Error: 0.0750 df: 30

Mulch	Means	n	E.E.	
YES	0.42	18	0.06	A
NO	0.25	17	0.07	A

Test:Tukey Alfa=0.05 DMS=0.35632

Error: 0.0750 df: 30

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.44	9	0.09	A
NO	NO	0.40	9	0.09	A
YES	YES	0.39	9	0.09	A
YES	NO	0.10	8	0.10	A

Tabebuia heterophylla

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Tahe	1 Year Height	33	0.43	0.35	46.23

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.46	4	0.11	5.28	0.0027	
Irrigation	3.7E-03	1	3.7E-03	0.17	0.6841	
Mulch	0.21	1	0.21	9.56	0.0045	
Initial Height	0.30	1	0.30	13.99	0.0008	-0.67
Irrigation*Mulch	0.01	1	0.01	0.46	0.5030	
Error	0.61	28	0.02			
Total	1.06	32				

Test:Tukey Alfa=0.05 DMS=0.10490
Error: 0.0216 df: 28

Irrigation	Means	n	E.E.	
NO	0.33	17	0.04	A
YES	0.31	16	0.04	A

Test:Tukey Alfa=0.05 DMS=0.10548
Error: 0.0216 df: 28

Mulch	Means	n	E.E.		
YES	0.40	14	0.04	A	
NO	0.24	19	0.04		B

Test:Tukey Alfa=0.05 DMS=0.19942
Error: 0.0216 df: 28

Irrigation	Mulch	Means	n	E.E.		
NO	YES	0.43	8	0.05	A	
YES	YES	0.37	6	0.06	A	B
YES	NO	0.24	10	0.05	A	B
NO	NO	0.23	9	0.05		B

Tabebuia heterophylla

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Tahe	3 Year Height	33	0.10	0.00	43.30

S.V.	SS	df	MS	F	p-value	Coef
Model.	0.54	4	0.13	0.75	0.5687	
Irrigation	0.02	1	0.02	0.10	0.7523	
Mulch	0.01	1	0.01	0.04	0.8372	
Initial Height	0.31	1	0.31	1.74	0.1977	-0.68
Irrigation*Mulch	0.13	1	0.13	0.70	0.4099	
Error	5.05	28	0.18			
Total	5.59	32				

Test:Tukey Alfa=0.05 DMS=0.30296

Error: 0.1804 df: 28

Irrigation	Means	n	E.E.	
YES	1.01	16	0.12	A
NO	0.96	17	0.10	A

Test:Tukey Alfa=0.05 DMS=0.30465

Error: 0.1804 df: 28

Mulch	Means	n	E.E.	
NO	1.00	19	0.10	A
YES	0.97	14	0.11	A

Test:Tukey Alfa=0.05 DMS=0.57595

Error: 0.1804 df: 28

Irrigation	Mulch	Means	n	E.E.	
YES	YES	1.05	6	0.17	A
NO	NO	1.04	9	0.14	A
YES	NO	0.96	10	0.14	A
NO	YES	0.88	8	0.15	A

Loamy Sand Soil

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bosu	1 Year Height	24	0.24	0.07	116.23

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.13	4	0.03	1.46	0.2521	
Irrigation	0.01	1	0.01	0.67	0.4230	
Mulch	0.07	1	0.07	3.38	0.0815	
Initial Height	2.5E-03	1	2.5E-03	0.11	0.7393	-0.03
Irrigation*Mulch	0.01	1	0.01	0.57	0.4593	
Error	0.42	19	0.02			
Total	0.54	23				

Test:Tukey Alfa=0.05 DMS=0.12721

Error: 0.0219 df: 19

Irrigation	Means	n	E.E.	
YES	0.06	10	0.05	A
NO	0.01	14	0.04	A

Test:Tukey Alfa=0.05 DMS=0.12654

Error: 0.0219 df: 19

Mulch	Means	n	E.E.		
YES	0.10	13	0.04	A	
NO	-0.03	11	0.05		B

Test:Tukey Alfa=0.05 DMS=0.24766

Error: 0.0219 df: 19

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.15	7	0.06	A
NO	YES	0.05	6	0.06	A
YES	NO	-0.03	3	0.09	A
NO	NO	-0.03	8	0.05	A

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bosu	3 Year Height	24	0.29	0.14	403.45

S.V.	SS	df	MS	F	p-value	Coef
Model.	1.33	4	0.33	1.96	0.1423	
Irrigation	0.02	1	0.02	0.14	0.7171	
Mulch	0.95	1	0.95	5.61	0.0286	
Initial Height	0.79	1	0.79	4.64	0.0443	-0.58
Irrigation*Mulch	0.05	1	0.05	0.29	0.5940	
Error	3.23	19	0.17			
Total	4.56	23				

Test:Tukey Alfa=0.05 DMS=0.35476

Error: 0.1700 df: 19

Irrigation	Means	n	E.E.	
YES	-0.06	10	0.14	A
NO	-0.12	14	0.11	A

Test:Tukey Alfa=0.05 DMS=0.35289

Error: 0.1700 df: 19

Mulch	Means	n	E.E.		
YES	0.15	13	0.12	A	
NO	-0.33	11	0.15		B

Test:Tukey Alfa=0.05 DMS=0.69065

Error: 0.1700 df: 19

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.23	7	0.17	A
NO	YES	0.06	6	0.17	A
NO	NO	-0.31	8	0.15	A
YES	NO	-0.34	3	0.25	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bubu	1 Year Height	29	0.09	0.00	233.01

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.09	4	0.02	0.62	0.6559	
Irrigation	1.6E-03	1	1.6E-03	0.04	0.8358	
Mulch	0.02	1	0.02	0.49	0.4915	
Initial Height	0.03	1	0.03	0.77	0.3894	-0.14
Irrigation*Mulch	0.02	1	0.02	0.45	0.5069	
Error	0.87	24	0.04			
Total	0.96	28				

Test:Tukey Alfa=0.05 DMS=0.14582

Error: 0.0362 df: 24

Irrigation	Means	n	E.E.	
NO	0.03	14	0.05	A
YES	0.02	15	0.05	A

Test:Tukey Alfa=0.05 DMS=0.14617

Error: 0.0362 df: 24

Mulch	Means	n	E.E.	
NO	0.05	13	0.05	A
YES	4.5E-04	16	0.05	A

Test:Tukey Alfa=0.05 DMS=0.27651

Error: 0.0362 df: 24

Irrigation	Mulch	Means	n	E.E.	
YES	NO	0.07	7	0.07	A
NO	NO	0.04	6	0.08	A
NO	YES	0.03	8	0.07	A
YES	YES	-0.03	8	0.07	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bubu	3 Year Height	29	0.46	0.37	187.26

S.V.	SS	df	MS	F	p-value	Coef
Model.	2.14	4	0.54	5.09	0.0041	
Irrigation	0.03	1	0.03	0.24	0.6275	
Mulch	0.02	1	0.02	0.17	0.6860	
Initial Height	1.88	1	1.88	17.91	0.0003	-1.17
Irrigation*Mulch	0.03	1	0.03	0.33	0.5726	
Error	2.53	24	0.11			
Total	4.67	28				

Test:Tukey Alfa=0.05 DMS=0.24874

Error: 0.1052 df: 24

Irrigation	Means	n	E.E.	
NO	0.11	14	0.09	A
YES	0.05	15	0.08	A

Test:Tukey Alfa=0.05 DMS=0.24934

Error: 0.1052 df: 24

Mulch	Means	n	E.E.	
YES	0.11	16	0.08	A
NO	0.06	13	0.09	A

Test:Tukey Alfa=0.05 DMS=0.47166

Error: 0.1052 df: 24

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.17	8	0.12	A
YES	NO	0.06	7	0.12	A
NO	NO	0.05	6	0.14	A
YES	YES	0.04	8	0.12	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Busi	1 Year Height	40	0.09	0.00	129.84

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.16	4	0.04	0.84	0.5114	
Irrigation	0.01	1	0.01	0.17	0.6807	
Mulch	0.11	1	0.11	2.37	0.1326	
Initial Height	0.05	1	0.05	1.08	0.3068	-0.21
Irrigation*Mulch	0.02	1	0.02	0.37	0.5480	
Error	1.64	35	0.05			
Total	1.79	39				

Test:Tukey Alfa=0.05 DMS=0.13881

Error: 0.0468 df: 35

Irrigation	Means	n	E.E.	
YES	0.16	20	0.05	A
NO	0.13	20	0.05	A

Test:Tukey Alfa=0.05 DMS=0.13881

Error: 0.0468 df: 35

Mulch	Means	n	E.E.	
YES	0.20	20	0.05	A
NO	0.09	20	0.05	A

Test:Tukey Alfa=0.05 DMS=0.26078

Error: 0.0468 df: 35

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.24	10	0.07	A
NO	YES	0.17	10	0.07	A
NO	NO	0.10	10	0.07	A
YES	NO	0.09	10	0.07	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Busi	3 Year Height	40	0.16	0.06	74.58

S.V.	SS	df	MS	F	p-value	Coef
Model.	0.70	4	0.17	1.62	0.1922	
Irrigation	1.7E-03	1	1.7E-03	0.02	0.9021	
Mulch	0.50	1	0.50	4.58	0.0394	
Initial Height	0.32	1	0.32	2.91	0.0967	-0.53
Irrigation*Mulch	0.06	1	0.06	0.56	0.4600	
Error	3.79	35	0.11			
Total	4.49	39				

Test:Tukey Alfa=0.05 DMS=0.21126

Error: 0.1083 df: 35

Irrigation	Means	n	E.E.	
YES	0.43	20	0.07	A
NO	0.41	20	0.08	A

Test:Tukey Alfa=0.05 DMS=0.21126

Error: 0.1083 df: 35

Mulch	Means	n	E.E.		
YES	0.54	20	0.08	A	
NO	0.30	20	0.07		B

Test:Tukey Alfa=0.05 DMS=0.39690

Error: 0.1083 df: 35

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.57	10	0.11	A
YES	YES	0.51	10	0.11	A
YES	NO	0.35	10	0.11	A
NO	NO	0.26	10	0.10	A

Citharexylum fruticosum

Soil	Species	Variable	N	R²	R² Aj	CV
Loamy Sand	Cifr	1 Year Height	34	0.36	0.27	43.21

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.96	4	0.24	4.09	0.0095	
Irrigation	0.01	1	0.01	0.09	0.7672	
Mulch	0.72	1	0.72	12.30	0.0015	
Initial Height	0.09	1	0.09	1.45	0.2381	-0.42
Irrigation*Mulch	0.18	1	0.18	3.06	0.0908	
Error	1.71	29	0.06			
Total	2.67	33				

Test:Tukey Alfa=0.05 DMS=0.17026

Error: 0.0589 df: 29

Irrigation	Means	n	E.E.	
YES	0.45	17	0.07	A
NO	0.42	17	0.06	A

Test:Tukey Alfa=0.05 DMS=0.17085

Error: 0.0589 df: 29

Mulch	Means	n	E.E.		
YES	0.59	19	0.06	A	
NO	0.29	15	0.06		B

Test:Tukey Alfa=0.05 DMS=0.32216

Error: 0.0589 df: 29

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.68	10	0.09	A	
NO	YES	0.50	9	0.09	A	B
NO	NO	0.35	8	0.09		B
YES	NO	0.23	7	0.10		B

Citharexylum fruticosum

Soil	Species	Variable	N	R²	R² Aj	CV
Loamy Sand	Cifr	3 Year Height	34	0.34	0.25	57.11

S.V.	SS	df	MS	F	p-value	Coef
Model.	3.58	4	0.89	3.72	0.0146	
Irrigation	1.23	1	1.23	5.13	0.0312	
Mulch	2.55	1	2.55	10.61	0.0029	
Initial Height	0.21	1	0.21	0.85	0.3628	0.65
Irrigation*Mulch	0.03	1	0.03	0.11	0.7404	
Error	6.98	29	0.24			
Total	10.56	33				

Test:Tukey Alfa=0.05 DMS=0.34409

Error: 0.2406 df: 29

Irrigation	Means	n	E.E.		
NO	0.91	17	0.12	A	
YES	0.46	17	0.14		B

Test:Tukey Alfa=0.05 DMS=0.34529

Error: 0.2406 df: 29

Mulch	Means	n	E.E.		
YES	0.96	19	0.11	A	
NO	0.41	15	0.13		B

Test:Tukey Alfa=0.05 DMS=0.65108

Error: 0.2406 df: 29

Irrigation	Mulch	Means	n	E.E.		
NO	YES	1.16	9	0.17	A	
YES	YES	0.77	10	0.18	A	B
NO	NO	0.67	8	0.17	A	B
YES	NO	0.15	7	0.19		B

Erythroxylum areolatum

Soil	Species	Variable	N	R²	R² Aj	CV
Loamy Sand	Erae	1 Year Height	31	0.19	0.06	118.40

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.05	4	0.01	1.51	0.2277	
Irrigation	2.8E-03	1	2.8E-03	0.34	0.5676	
Mulch	2.4E-04	1	2.4E-04	0.03	0.8675	
Initial Height	1.7E-03	1	1.7E-03	0.21	0.6526	-0.04
Irrigation*Mulch	0.04	1	0.04	5.33	0.0291	
Error	0.22	26	0.01			
Total	0.27	30				

Test:Tukey Alfa=0.05 DMS=0.06833

Error: 0.0083 df: 26

Irrigation	Means	n	E.E.	
NO	0.07	19	0.02	A
YES	0.05	12	0.03	A

Test:Tukey Alfa=0.05 DMS=0.06788

Error: 0.0083 df: 26

Mulch	Means	n	E.E.	
YES	0.06	18	0.02	A
NO	0.06	13	0.03	A

Test:Tukey Alfa=0.05 DMS=0.13092

Error: 0.0083 df: 26

Irrigation	Mulch	Means	n	E.E.	
NO	NO	0.11	9	0.03	A
YES	YES	0.09	8	0.03	A
NO	YES	0.03	10	0.03	A
YES	NO	0.01	4	0.05	A

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Erae	3 Year Height	31	0.26	0.15	434.84

S.V.	SS	df	MS	F	p-value	Coef
Model.	0.74	4	0.18	2.30	0.0858	
Irrigation	0.02	1	0.02	0.30	0.5892	
Mulch	0.73	1	0.73	9.12	0.0056	
Initial Height	0.03	1	0.03	0.33	0.5688	0.16
Irrigation*Mulch	0.04	1	0.04	0.44	0.5146	
Error	2.09	26	0.08			
Total	2.83	30				

Test:Tukey Alfa=0.05 DMS=0.21222

Error: 0.0805 df: 26

Irrigation	Means	n	E.E.	
NO	0.01	19	0.07	A
YES	-0.05	12	0.09	A

Test:Tukey Alfa=0.05 DMS=0.21085

Error: 0.0805 df: 26

Mulch	Means	n	E.E.		
YES	0.15	18	0.07	A	
NO	-0.19	13	0.09		B

Test:Tukey Alfa=0.05 DMS=0.40663

Error: 0.0805 df: 26

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.15	8	0.10	A
NO	YES	0.14	10	0.09	A
NO	NO	-0.12	9	0.09	A
YES	NO	-0.25	4	0.14	A

Tabebuia heterophylla

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Tahe	1 Year Height	30	0.68	0.63	49.59

S.V.	SS	df	MS	F	p-valor	Coef
Model.	1.41	4	0.35	13.59	<0.0001	
Irrigation	0.01	1	0.01	0.41	0.5300	
Mulch	0.91	1	0.91	35.22	<0.0001	
Initial Height	0.32	1	0.32	12.31	0.0017	-0.68
Irrigation*Mulch	0.01	1	0.01	0.30	0.5889	
Error	0.65	25	0.03			
Total	2.06	29				

Test:Tukey Alfa=0.05 DMS=0.12165

Error: 0.0259 df: 25

Irrigation	Means	n	E.E.	
YES	0.34	13	0.05	A
NO	0.30	17	0.04	A

Test:Tukey Alfa=0.05 DMS=0.12111

Error: 0.0259 df: 25

Mulch	Means	n	E.E.		
YES	0.50	15	0.04	A	
NO	0.14	15	0.04		B

Test:Tukey Alfa=0.05 DMS=0.23226

Error: 0.0259 df: 25

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.51	8	0.06	A	
NO	YES	0.50	7	0.06	A	
YES	NO	0.18	5	0.07		B
NO	NO	0.11	10	0.05		B

Tabebuia heterophylla

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Tahe	3 Year Height	30	0.48	0.39	53.21

S.V.	SS	df	MS	F	p-value	Coef
Model.	3.26	4	0.82	5.72	0.0021	
Irrigation	5.6E-04	1	5.6E-04	3.9E-03	0.9504	
Mulch	2.25	1	2.25	15.79	0.0005	
Initial Height	0.80	1	0.80	5.62	0.0257	-1.08
Irrigation*Mulch	0.01	1	0.01	0.04	0.8507	
Error	3.57	25	0.14			
Total	6.83	29				

Test:Tukey Alfa=0.05 DMS=0.28530

Error: 0.1426 df: 25

Irrigation	Means	n	E.E.	
NO	0.69	17	0.09	A
YES	0.68	13	0.11	A

Test:Tukey Alfa=0.05 DMS=0.28402

Error: 0.1426 df: 25

Mulch	Means	n	E.E.		
YES	0.97	15	0.10	A	
NO	0.40	15	0.10		B

Test:Tukey Alfa=0.05 DMS=0.54472

Error: 0.1426 df: 25

Irrigation	Mulch	Means	n	E.E.			
NO	YES	0.99	7	0.14	A		
YES	YES	0.95	8	0.14	A	B	
YES	NO	0.41	5	0.17		B	C
NO	NO	0.39	10	0.12			C

Diameter increments

Clay Soil

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bosu	1 Year Diameter	33	0.36	0.27	164.07

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.78	4	0.70	3.91	0.0121	
Irrigation	0.15	1	0.15	0.85	0.3633	
Mulch	0.24	1	0.24	1.32	0.2597	
Initial Diameter	2.19	1	2.19	12.30	0.0015	-0.96
Irrigation*Mulch	0.05	1	0.05	0.29	0.5935	
Error	4.98	28	0.18			
Total	7.76	32				

Test:Tukey Alfa=0.05 DMS=0.30255

Error: 0.1779 df: 28

Irrigation	Means	n	E.E.	
YES	0.26	19	0.10	A
NO	0.12	14	0.12	A

Test:Tukey Alfa=0.05 DMS=0.30087

Error: 0.1779 df: 28

Mulch	Means	n	E.E.	
YES	0.28	16	0.11	A
NO	0.11	17	0.10	A

Test:Tukey Alfa=0.05 DMS=0.57051

Error: 0.1779 df: 28

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.39	9	0.14	A
NO	YES	0.17	7	0.16	A
YES	NO	0.14	10	0.14	A
NO	NO	0.07	7	0.16	A

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bosu	3 Year Diameter	33	0.20	0.08	80.84

S.V.	SS	df	MS	F	p-valor	Coef
Model.	6.83	4	1.71	1.72	0.1745	
Irrigation	0.64	1	0.64	0.65	0.4278	
Mulch	1.70	1	1.70	1.71	0.2014	
Initial Diameter	4.19	1	4.19	4.21	0.0497	-1.33
Irrigation*Mulch	0.01	1	0.01	0.01	0.9237	
Error	27.86	28	0.99			

Total	34.68	32				

Test:Tukey Alfa=0.05 DMS=0.71548

Error: 0.9949 df: 28

Irrigation	Means	n	E.E.	
YES	1.15	19	0.23	A
NO	0.85	14	0.27	A

Test:Tukey Alfa=0.05 DMS=0.71150

Error: 0.9949 df: 28

Mulch	Means	n	E.E.	
YES	1.23	16	0.25	A
NO	0.77	17	0.25	A

Test:Tukey Alfa=0.05 DMS=1.34914

Error: 0.9949 df: 28

Irrigation	Mulch	Means	n	E.E.	
YES	YES	1.40	9	0.33	A
NO	YES	1.07	7	0.38	A
YES	NO	0.90	10	0.32	A
NO	NO	0.64	7	0.38	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bubu	1 Year Diameter	28	0.78	0.74	36.38

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.88	4	0.72	20.63	<0.0001	
Irrigation	0.02	1	0.02	0.66	0.4247	
Mulch	0.63	1	0.63	18.03	0.0003	
Initial Diameter	1.75	1	1.75	50.21	<0.0001	-1.03
Irrigation*Mulch	0.01	1	0.01	0.32	0.5785	
Error	0.80	23	0.03			
Total	3.68	27				

Test:Tukey Alfa=0.05 DMS=0.14629

Error: 0.0349 df: 23

Irrigation	Means	n	E.E.	
NO	0.41	13	0.05	A
YES	0.35	15	0.05	A

Test:Tukey Alfa=0.05 DMS=0.14629

Error: 0.0349 df: 23

Mulch	Means	n	E.E.		
YES	0.54	15	0.05	A	
NO	0.23	13	0.05		B

Test:Tukey Alfa=0.05 DMS=0.27838

Error: 0.0349 df: 23

Irrigation	Mulch	Means	n	E.E.		
NO	YES	0.59	6	0.08	A	
YES	YES	0.48	9	0.06	A	B
NO	NO	0.24	7	0.07		B
YES	NO	0.22	6	0.08		B

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Bubu	3 Year Diameter	28	0.19	0.05	45.88

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.05	4	0.51	1.39	0.2689	
Irrigation	6.1E-05	1	6.1E-05	1.6E-04	0.9899	
Mulch	0.54	1	0.54	1.45	0.2400	
Initial Diameter	0.59	1	0.59	1.59	0.2196	-0.60
Irrigation*Mulch	0.36	1	0.36	0.99	0.3309	
Error	8.49	23	0.37			
Total	10.54	27				

Test:Tukey Alfa=0.05 DMS=0.47568
Error: 0.3692 df: 23

Irrigation	Means	n	E.E.	
YES	1.15	15	0.16	A
NO	1.14	13	0.18	A

Test:Tukey Alfa=0.05 DMS=0.47568
Error: 0.3692 df: 23

Mulch	Means	n	E.E.	
YES	1.29	15	0.16	A
NO	1.01	13	0.17	A

Test:Tukey Alfa=0.05 DMS=0.90518
Error: 0.3692 df: 23

Irrigation	Mulch	Means	n	E.E.	
NO	YES	1.41	6	0.27	A
YES	YES	1.16	9	0.21	A
YES	NO	1.13	6	0.26	A
NO	NO	0.88	7	0.23	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Busi	1 Year Diameter	37	0.28	0.19	45.29

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.30	4	0.58	3.05	0.0310	
Irrigation	0.06	1	0.06	0.34	0.5660	
Mulch	2.11	1	2.11	11.14	0.0022	
Initial Diameter	0.15	1	0.15	0.81	0.3734	-0.25
Irrigation*Mulch	0.02	1	0.02	0.10	0.7560	
Error	6.05	32	0.19			
Total	8.35	36				

Test:Tukey Alfa=0.05 DMS=0.29165
Error: 0.1890 df: 32

Irrigation	Means	n	E.E.	
YES	0.91	17	0.11	A
NO	0.83	20	0.10	A

Test:Tukey Alfa=0.05 DMS=0.29122

Error: 0.1890 df: 32

Mulch	Means	n	E.E.		
YES	1.11	18	0.10	A	
NO	0.63	19	0.10		B

Test:Tukey Alfa=0.05 DMS=0.54884

Error: 0.1890 df: 32

Irrigation	Mulch	Means	n	E.E.		
YES	YES	1.13	8	0.15	A	
NO	YES	1.09	10	0.14	A	B
YES	NO	0.70	9	0.14	A	B
NO	NO	0.57	10	0.14		B

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Busi	3 Year Diameter	37	0.21	0.12	32.26

S.V.	SS	df	MS	F	p-valor	Coef
Model.	6.22	4	1.56	2.18	0.0939	
Irrigation	1.05	1	1.05	1.47	0.2350	
Mulch	2.28	1	2.28	3.19	0.0835	
Initial Diameter	2.23	1	2.23	3.12	0.0869	0.96
Irrigation*Mulch	0.04	1	0.04	0.05	0.8176	
Error	22.87	32	0.71			
Total	29.09	36				

Test:Tukey Alfa=0.05 DMS=0.56708

Error: 0.7146 df: 32

Irrigation	Means	n	E.E.	
NO	2.75	20	0.19	A
YES	2.41	17	0.21	A

Test:Tukey Alfa=0.05 DMS=0.56625

Error: 0.7146 df: 32

Mulch	Means	n	E.E.	
YES	2.83	18	0.20	A
NO	2.33	19	0.19	A

Test:Tukey Alfa=0.05 DMS=1.06718

Error: 0.7146 df: 32

Irrigation	Mulch	Means	n	E.E.	
NO	YES	2.96	10	0.27	A
YES	YES	2.69	8	0.30	A
NO	NO	2.53	10	0.27	A
YES	NO	2.12	9	0.28	A

Citharexylum fruticosum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Cifr	1 Year Diameter	26	0.39	0.27	83.60

S.V.	SS	df	MS	F	p-valor	Coef
Model.	1.47	4	0.37	3.36	0.0284	
Irrigation	0.24	1	0.24	2.22	0.1513	
Mulch	0.95	1	0.95	8.74	0.0075	
Initial Diameter	0.05	1	0.05	0.49	0.4938	-0.20
Irrigation*Mulch	0.10	1	0.10	0.93	0.3449	
Error	2.29	21	0.11			
Total	3.76	25				

Test:Tukey Alfa=0.05 DMS=0.27327
Error: 0.1092 df: 21

Irrigation	Means	n	E.E.	
YES	0.42	16	0.08	A
NO	0.22	10	0.11	A

Test:Tukey Alfa=0.05 DMS=0.26956
Error: 0.1092 df: 21

Mulch	Means	n	E.E.		
YES	0.52	13	0.09	A	
NO	0.12	13	0.10		B

Test:Tukey Alfa=0.05 DMS=0.52165
Error: 0.1092 df: 21

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.69	7	0.12	A	
NO	YES	0.35	6	0.14	A	B
YES	NO	0.15	9	0.11		B
NO	NO	0.08	4	0.17		B

Citharexylum fruticosum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Cifr	3 Year Diameter	26	0.16	0.00	55.13

S.V.	SS	df	MS	F	p-valor	Coef
Model.	3.42	4	0.85	0.97	0.4472	
Irrigation	0.84	1	0.84	0.95	0.3414	
Mulch	0.11	1	0.11	0.13	0.7253	
Initial Diameter	0.31	1	0.31	0.35	0.5614	0.48
Irrigation*Mulch	2.05	1	2.05	2.31	0.1435	
Error	18.60	21	0.89			
Total	22.02	25				

Test:Tukey Alfa=0.05 DMS=0.77827
Error: 0.8858 df: 21

Irrigation	Means	n	E.E.	
YES	1.69	16	0.24	A
NO	1.32	10	0.30	A

Test:Tukey Alfa=0.05 DMS=0.76769

Error: 0.8858 df: 21

Mulch	Means	n	E.E.	
NO	1.57	13	0.28	A
YES	1.44	13	0.26	A

Test:Tukey Alfa=0.05 DMS=1.48566

Error: 0.8858 df: 21

Irrigation	Mulch	Means	n	E.E.	
YES	YES	1.92	7	0.36	A
NO	NO	1.68	4	0.47	A
YES	NO	1.47	9	0.32	A
NO	YES	0.95	6	0.38	A

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Clay	Erae	1 Year Diameter	35	0.73	0.70	54.78

S.V.	SS	df	MS	F	p-valor	Coef
Model.	4.13	4	1.03	20.53	<0.0001	
Irrigation	0.04	1	0.04	0.80	0.3770	
Mulch	0.23	1	0.23	4.55	0.0412	
Initial Diameter	3.38	1	3.38	67.13	<0.0001	-1.07
Irrigation*Mulch	0.05	1	0.05	0.95	0.3376	
Error	1.51	30	0.05			
Total	5.64	34				

Test:Tukey Alfa=0.05 DMS=0.15494

Error: 0.0503 df: 30

Irrigation	Means	n	E.E.	
YES	0.42	17	0.05	A
NO	0.35	18	0.05	A

Test:Tukey Alfa=0.05 DMS=0.15494

Error: 0.0503 df: 30

Mulch	Means	n	E.E.		
YES	0.46	18	0.05	A	
NO	0.30	17	0.05		B

Test:Tukey Alfa=0.05 DMS=0.29187

Error: 0.0503 df: 30

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.54	9	0.07	A
NO	YES	0.39	9	0.07	A
NO	NO	0.30	9	0.07	A
YES	NO	0.30	8	0.08	A

Erythroxylum areolatum

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Erae	3 Year Diameter	35	0.52	0.46	36.55

S.V.	SS	df	MS	F	p-valor	Coef
Model.	6.32	4	1.58	8.25	0.0001	
Irrigation	0.01	1	0.01	0.08	0.7858	
Mulch	0.33	1	0.33	1.74	0.1974	
Initial Diameter	5.33	1	5.33	27.83	<0.0001	-1.34
Irrigation*Mulch	1.3E-05	1	1.3E-05	6.7E-05	0.9935	
Error	5.74	30	0.19			
Total	12.07	34				

Test:Tukey Alfa=0.05 DMS=0.30218

Error: 0.1915 df: 30

Irrigation	Means	n	E.E.	
NO	1.08	18	0.10	A
YES	1.04	17	0.11	A

Test:Tukey Alfa=0.05 DMS=0.30218

Error: 0.1915 df: 30

Mulch	Means	n	E.E.	
YES	1.15	18	0.10	A
NO	0.96	17	0.11	A

Test:Tukey Alfa=0.05 DMS=0.56922

Error: 0.1915 df: 30

Irrigation	Mulch	Means	n	E.E.	
NO	YES	1.18	9	0.15	A
YES	YES	1.13	9	0.15	A
NO	NO	0.98	9	0.15	A
YES	NO	0.94	8	0.16	A

Tabebuia heterophylla

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Tahe	1 Year Diameter	33	0.58	0.52	38.68

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.65	4	0.66	9.50	0.0001	
Irrigation	4.3E-03	1	4.3E-03	0.06	0.8064	
Mulch	0.45	1	0.45	6.42	0.0172	
Initial Diameter	2.32	1	2.32	33.18	<0.0001	-0.77
Irrigation*Mulch	0.04	1	0.04	0.64	0.4305	
Error	1.95	28	0.07			
Total	4.61	32				

Test:Tukey Alfa=0.05 DMS=0.18845

Error: 0.0698 df: 28

Irrigation	Means	n	E.E.	
YES	0.61	16	0.07	A
NO	0.59	17	0.06	A

Test:Tukey Alfa=0.05 DMS=0.18951
Error: 0.0698 df: 28

Mulch	Means	n	E.E.		
YES	0.72	14	0.07	A	
NO	0.48	19	0.06		B

Test:Tukey Alfa=0.05 DMS=0.35827
Error: 0.0698 df: 28

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.74	8	0.09	A
YES	YES	0.69	6	0.11	A
YES	NO	0.53	10	0.08	A
NO	NO	0.43	9	0.09	A

Tabebuia heterophylla

Soil	Species	Variable	N	R²	R² Aj	CV
Clay	Tahe	3 Year Diameter	33	0.07	0.00	48.98

S.V.	SS	df	MS	F	p-valor	Coef
Model.	2.73	4	0.68	0.52	0.7211	
Irrigation	0.08	1	0.08	0.06	0.8078	
Mulch	0.07	1	0.07	0.05	0.8202	
Initial Diameter	0.45	1	0.45	0.34	0.5645	-0.34
Irrigation*Mulch	2.04	1	2.04	1.56	0.2221	
Error	36.67	28	1.31			
Total	39.40	32				

Test:Tukey Alfa=0.05 DMS=0.81632
Error: 1.3096 df: 28

Irrigation	Means	n	E.E.	
NO	2.31	17	0.28	A
YES	2.21	16	0.30	A

Test:Tukey Alfa=0.05 DMS=0.82089
Error: 1.3096 df: 28

Mulch	Means	n	E.E.	
YES	2.30	14	0.31	A
NO	2.21	19	0.26	A

Test:Tukey Alfa=0.05 DMS=1.55190
Error: 1.3096 df: 28

Irrigation	Mulch	Means	n	E.E.	
NO	NO	2.51	9	0.38	A
YES	YES	2.51	6	0.47	A
NO	YES	2.10	8	0.41	A
YES	NO	1.91	10	0.36	A

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bosu	1 Year Diameter	24	0.13	0.00	142.70

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.27	4	0.07	0.71	0.5933	
Irrigation	0.07	1	0.07	0.72	0.4061	
Mulch	0.07	1	0.07	0.77	0.3912	
Initial Diameter	0.01	1	0.01	0.07	0.8014	0.05
Irrigation*Mulch	1.6E-04	1	1.6E-04	1.7E-03	0.9676	
Error	1.78	19	0.09			
Total	2.05	23				

Test:Tukey Alfa=0.05 DMS=0.26363
Error: 0.0939 df: 19

Irrigation	Means	n	E.E.	
YES	0.16	10	0.11	A
NO	0.05	14	0.08	A

Test:Tukey Alfa=0.05 DMS=0.26224
Error: 0.0939 df: 19

Mulch	Means	n	E.E.	
YES	0.17	13	0.09	A
NO	0.04	11	0.11	A

Test:Tukey Alfa=0.05 DMS=0.51323
Error: 0.0939 df: 19

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.23	7	0.13	A
NO	YES	0.11	6	0.13	A
YES	NO	0.10	3	0.18	A
NO	NO	-0.01	8	0.11	A

Bourreria succulenta

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bosu	3 Year Diameter	24	0.17	0.00	198.93

S.V.	SS	df	MS	F	p-valor	Coef
Model.	1.53	4	0.38	0.98	0.4433	
Irrigation	0.02	1	0.02	0.06	0.8090	
Mulch	0.74	1	0.74	1.87	0.1872	
Initial Diameter	0.09	1	0.09	0.22	0.6421	0.20
Irrigation*Mulch	0.03	1	0.03	0.09	0.7694	
Error	7.46	19	0.39			
Total	9.00	23				

Test:Tukey Alfa=0.05 DMS=0.53923
Error: 0.3927 df: 19

Irrigation	Means	n	E.E.	
YES	0.18	10	0.22	A
NO	0.11	14	0.17	A

Test:Tukey Alfa=0.05 DMS=0.53638
Error: 0.3927 df: 19

Mulch	Means	n	E.E.	
YES	0.35	13	0.18	A
NO	-0.06	11	0.23	A

Test:Tukey Alfa=0.05 DMS=1.04977
Error: 0.3927 df: 19

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.43	7	0.26	A
NO	YES	0.27	6	0.26	A
NO	NO	-0.05	8	0.23	A
YES	NO	-0.07	3	0.37	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bubu	1 Year Diameter	29	0.14	0.00	102.43

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.14	4	0.04	1.00	0.4276	
Irrigation	0.03	1	0.03	0.82	0.3752	
Mulch	3.5E-05	1	3.5E-05	9.7E-04	0.9754	
Initial Diameter	0.02	1	0.02	0.53	0.4734	-0.19
Irrigation*Mulch	0.10	1	0.10	2.69	0.1143	
Error	0.87	24	0.04			
Total	1.01	28				

Test:Tukey Alfa=0.05 DMS=0.14583
Error: 0.0362 df: 24

Irrigation	Means	n	E.E.	
YES	0.11	15	0.05	A
NO	0.05	14	0.05	A

Test:Tukey Alfa=0.05 DMS=0.14618
Error: 0.0362 df: 24

Mulch	Means	n	E.E.	
YES	0.08	16	0.05	A
NO	0.08	13	0.06	A

Test:Tukey Alfa=0.05 DMS=0.27652
Error: 0.0362 df: 24

Irrigation	Mulch	Means	n	E.E.	
YES	NO	0.17	7	0.07	A
NO	YES	0.11	8	0.07	A
YES	YES	0.06	8	0.07	A
NO	NO	-0.01	6	0.08	A

Bucida buceras

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Bubu	3 Year Diameter	29	0.15	3.4E-03	85.87

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.27	4	0.07	1.02	0.4150	
Irrigation	0.03	1	0.03	0.47	0.5004	
Mulch	4.8E-03	1	4.8E-03	0.07	0.7916	
Initial Diameter	4.7E-04	1	4.7E-04	0.01	0.9342	0.03
Irrigation*Mulch	0.22	1	0.22	3.23	0.0850	
Error	1.61	24	0.07			
Total	1.88	28				

Test:Tukey Alfa=0.05 DMS=0.19858

Error: 0.0671 df: 24

Irrigation	Means	n	E.E.	
NO	0.18	14	0.07	A
YES	0.11	15	0.07	A

Test:Tukey Alfa=0.05 DMS=0.19905

Error: 0.0671 df: 24

Mulch	Means	n	E.E.	
NO	0.16	13	0.08	A
YES	0.13	16	0.07	A

Test:Tukey Alfa=0.05 DMS=0.37654

Error: 0.0671 df: 24

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.25	8	0.09	A
YES	NO	0.21	7	0.10	A
NO	NO	0.10	6	0.11	A
YES	YES	0.01	8	0.09	A

Bursera simaruba

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Busi	1 Year Diameter	40	0.25	0.16	92.11

S.V.	SS	df	MS	F	p-valor	Coef
Model.	1.48	4	0.37	2.89	0.0363	
Irrigation	2.5E-04	1	2.5E-04	2.0E-03	0.9650	
Mulch	1.36	1	1.36	10.56	0.0026	
Initial Diameter	0.06	1	0.06	0.48	0.4939	0.15
Irrigation*Mulch	0.09	1	0.09	0.70	0.4097	
Error	4.50	35	0.13			
Total	5.98	39				

Test:Tukey Alfa=0.05 DMS=0.23012

Error: 0.1285 df: 35

Irrigation	Means	n	E.E.	
NO	0.36	20	0.08	A
YES	0.35	20	0.08	A

Test:Tukey Alfa=0.05 DMS=0.23012

Error: 0.1285 df: 35

Mulch	Means	n	E.E.		
YES	0.54	20	0.08	A	
NO	0.17	20	0.08		B

Test:Tukey Alfa=0.05 DMS=0.43234

Error: 0.1285 df: 35

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.58	10	0.11	A	
NO	YES	0.49	10	0.11	A	B
NO	NO	0.22	10	0.11	A	B
YES	NO	0.12	10	0.11		B

Bursera simaruba

Soil	Species	Variable	N	R²	R² Aj	CV
Loamy Sand	Busi	3 Year Diameter	40	0.28	0.20	89.98

S.V.	SS	df	MS	F	p-valor	Coef
Model.	5.13	4	1.28	3.38	0.0195	
Irrigation	0.05	1	0.05	0.12	0.7260	
Mulch	4.31	1	4.31	11.33	0.0019	
Initial Diameter	1.2E-03	1	1.2E-03	3.2E-03	0.9550	-0.02
Irrigation*Mulch	0.75	1	0.75	1.99	0.1676	
Error	13.30	35	0.38			
Total	18.43	39				

Test:Tukey Alfa=0.05 DMS=0.39577

Error: 0.3801 df: 35

Irrigation	Means	n	E.E.	
YES	0.68	20	0.14	A
NO	0.61	20	0.14	A

Test:Tukey Alfa=0.05 DMS=0.39577

Error: 0.3801 df: 35

Mulch	Means	n	E.E.		
YES	0.97	20	0.14	A	
NO	0.32	20	0.14		B

Test:Tukey Alfa=0.05 DMS=0.74353

Error: 0.3801 df: 35

Irrigation	Mulch	Means	n	E.E.		
NO	YES	1.08	10	0.20	A	
YES	YES	0.87	10	0.20	A	B
YES	NO	0.49	10	0.20	A	B
NO	NO	0.14	10	0.20		B

Citharexylum fruticosum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Cifr	1 Year Diameter	34	0.50	0.43	50.09

S.V.	SS	df	MS	F	p-valor	Coef
Model.	3.07	4	0.77	7.11	0.0004	
Irrigation	3.3E-03	1	3.3E-03	0.03	0.8624	
Mulch	2.54	1	2.54	23.57	<0.0001	
Initial Diameter	0.25	1	0.25	2.35	0.1360	0.75
Irrigation*Mulch	0.16	1	0.16	1.51	0.2293	
Error	3.12	29	0.11			
Total	6.19	33				

Test:Tukey Alfa=0.05 DMS=0.23026

Error: 0.1077 df: 29

Irrigation	Means	n	E.E.	
YES	0.49	17	0.08	A
NO	0.47	17	0.08	A

Test:Tukey Alfa=0.05 DMS=0.23106

Error: 0.1077 df: 29

Mulch	Means	n	E.E.		
YES	0.77	19	0.08	A	
NO	0.20	15	0.09		B

Test:Tukey Alfa=0.05 DMS=0.43570

Error: 0.1077 df: 29

Irrigation	Mulch	Means	n	E.E.			
YES	YES	0.85	10	0.11	A		
NO	YES	0.68	9	0.11	A	B	
NO	NO	0.27	8	0.12		B	C
YES	NO	0.14	7	0.13			C

Citharexylum fruticosum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Cifr	3 Year Diameter	34	0.36	0.28	64.48

S.V.	SS	df	MS	F	p-valor	Coef
Model.	7.19	4	1.80	4.14	0.0090	
Irrigation	0.68	1	0.68	1.57	0.2208	
Mulch	6.83	1	6.83	15.71	0.0004	
Initial Diameter	0.69	1	0.69	1.59	0.2172	1.23
Irrigation*Mulch	0.05	1	0.05	0.12	0.7318	
Error	12.60	29	0.43			
Total	19.78	33				

Test:Tukey Alfa=0.05 DMS=0.46234

Error: 0.4344 df: 29

Irrigation	Means	n	E.E.	
NO	0.92	17	0.16	A
YES	0.63	17	0.17	A

Test:Tukey Alfa=0.05 DMS=0.46395

Error: 0.4344 df: 29

Mulch	Means	n	E.E.		
YES	1.23	19	0.15	A	
NO	0.31	15	0.18		B

Test:Tukey Alfa=0.05 DMS=0.87484

Error: 0.4344 df: 29

Irrigation	Mulch	Means	n	E.E.		
NO	YES	1.42	9	0.23	A	
YES	YES	1.04	10	0.22	A	B
NO	NO	0.42	8	0.24		B
YES	NO	0.21	7	0.25		B

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Erae	1 Year Diameter	31	0.36	0.26	70.48

S.V.	SS	df	MS	F	p-valor	Coef
Model.	0.37	4	0.09	3.61	0.0180	
Irrigation	0.02	1	0.02	0.90	0.3515	
Mulch	0.26	1	0.26	9.97	0.0040	
Initial Diameter	0.01	1	0.01	0.43	0.5187	-0.11
Irrigation*Mulch	0.04	1	0.04	1.55	0.2242	
Error	0.67	26	0.03			
Total	1.05	30				

Test:Tukey Alfa=0.05 DMS=0.12027

Error: 0.0258 df: 26

Irrigation	Means	n	E.E.	
YES	0.19	12	0.05	A
NO	0.13	19	0.04	A

Test:Tukey Alfa=0.05 DMS=0.11949

Error: 0.0258 df: 26

Mulch	Means	n	E.E.		
YES	0.26	18	0.04	A	
NO	0.06	13	0.05		B

Test:Tukey Alfa=0.05 DMS=0.23044

Error: 0.0258 df: 26

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.33	8	0.06	A	
NO	YES	0.19	10	0.05	A	B
NO	NO	0.07	9	0.05		B
YES	NO	0.05	4	0.08		B

Erythroxylum areolatum

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Erae	3 Year Diameter	31	0.25	0.14	91.92

S.V.	SS	df	MS	F	p-valor	Coef
Model.	1.94	4	0.48	2.20	0.0968	
Irrigation	9.1E-04	1	9.1E-04	4.1E-03	0.9493	
Mulch	1.65	1	1.65	7.50	0.0110	
Initial Diameter	0.02	1	0.02	0.11	0.7400	-0.16
Irrigation*Mulch	4.8E-03	1	4.8E-03	0.02	0.8843	
Error	5.72	26	0.22			
Total	7.66	30				

Test:Tukey Alfa=0.05 DMS=0.35102
Error: 0.2202 df: 26

Irrigation	Means	n	E.E.	
YES	0.39	12	0.15	A
NO	0.38	19	0.11	A

Test:Tukey Alfa=0.05 DMS=0.34875
Error: 0.2202 df: 26

Mulch	Means	n	E.E.		
YES	0.63	18	0.11	A	
NO	0.13	13	0.14		B

Test:Tukey Alfa=0.05 DMS=0.67259
Error: 0.2202 df: 26

Irrigation	Mulch	Means	n	E.E.	
YES	YES	0.65	8	0.17	A
NO	YES	0.61	10	0.15	A
NO	NO	0.14	9	0.16	A
YES	NO	0.13	4	0.24	A

Tabebuia heterophylla

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Tahe	1 Year Diameter	30	0.64	0.59	36.98

S.V.	SS	df	MS	F	p-valor	Coef
Model.	3.44	4	0.86	11.29	<0.0001	
Irrigation	0.02	1	0.02	0.27	0.6046	
Mulch	2.80	1	2.80	36.73	<0.0001	
Initial Diameter	0.01	1	0.01	0.08	0.7837	0.08
Irrigation*Mulch	0.16	1	0.16	2.14	0.1562	
Error	1.91	25	0.08			
Total	5.35	29				

Test:Tukey Alfa=0.05 DMS=0.20854
Error: 0.0762 df: 25

Irrigation	Means	n	E.E.	
NO	0.69	17	0.07	A
YES	0.63	13	0.08	A

Test:Tukey Alfa=0.05 DMS=0.20761

Error: 0.0762 df: 25

Mulch	Means	n	E.E.		
YES	0.98	15	0.07	A	
NO	0.34	15	0.08		B

Test:Tukey Alfa=0.05 DMS=0.39816

Error: 0.0762 df: 25

Irrigation	Mulch	Means	n	E.E.		
NO	YES	1.09	7	0.10	A	
YES	YES	0.88	8	0.10	A	
YES	NO	0.39	5	0.12		B
NO	NO	0.29	10	0.09		B

Tabebuia heterophylla

Soil	Species	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	Tahe	3 Year Diameter	30	0.56	0.49	49.14

S.V.	SS	df	MS	F	p-valor	Coef
Model.	15.07	4	3.77	7.98	0.0003	
Irrigation	0.91	1	0.91	1.94	0.1764	
Mulch	10.49	1	10.49	22.21	0.0001	
Initial Diameter	0.30	1	0.30	0.63	0.4358	0.59
Irrigation*Mulch	1.66	1	1.66	3.52	0.0724	
Error	11.81	25	0.47			
Total	26.89	29				

Test:Tukey Alfa=0.05 DMS=0.51923

Error: 0.4724 df: 25

Irrigation	Means	n	E.E.	
NO	1.42	17	0.17	A
YES	1.05	13	0.20	A

Test:Tukey Alfa=0.05 DMS=0.51690

Error: 0.4724 df: 25

Mulch	Means	n	E.E.		
YES	1.86	15	0.18	A	
NO	0.61	15	0.19		B

Test:Tukey Alfa=0.05 DMS=0.99134

Error: 0.4724 df: 25

Irrigation	Mulch	Means	n	E.E.		
NO	YES	2.29	7	0.26	A	
YES	YES	1.43	8	0.25	A	B
YES	NO	0.68	5	0.31		B
NO	NO	0.55	10	0.22		B

Appendix G. Two-way ANOVA table to test the differences in grass cover for one under different combinations of irrigation and mulch.

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Clay	4 months	%	280	0.10	0.09	61.01

S.V.	SS	df	MS	F	p-value
Model.	32404.29	3	10801.43	10.42	<0.0001
Irrigation	29212.86	1	29212.86	28.17	<0.0001
Mulch	35.71	1	35.71	0.03	0.8529
Irrigation*Mulch	3155.71	1	3155.71	3.04	0.0822
Error	286222.86	276	1037.04		
Total	318627.14	279			

Test:Tukey Alfa=0.05 DMS=7.55306

Error: 1037.0393 df: 276

Irrigation	Means	n	E.E.		
NO	63.00	140	2.72	A	
Yes	42.57	140	2.72		B

Test:Tukey Alfa=0.05 DMS=7.55306

Error: 1037.0393 df: 276

Mulch	Means	n	E.E.	
Yes	53.14	140	2.72	A
No	52.43	140	2.72	A

Test:Tukey Alfa=0.05 DMS=14.00759

Error: 1037.0393 df: 276

Irrigation	Mulch	Means	n	E.E.			
NO	No	66.00	70	3.85	A		
NO	Yes	60.00	70	3.85	A	B	
Yes	Yes	46.29	70	3.85		B	C
Yes	No	38.86	70	3.85			C

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Clay	8 months	%	280	0.54	0.53	34.18

S.V.	SS	df	MS	F	p-value
Model.	165627.14	3	55209.05	106.40	<0.0001
Irrigation	4321.43	1	4321.43	8.33	0.0042
Mulch	158412.86	1	158412.86	305.28	<0.0001
Irrigation*Mulch	2892.86	1	2892.86	5.57	0.0189
Error	143217.14	276	518.90		
Total	308844.29	279			

Test:Tukey Alfa=0.05 DMS=5.34279

Error: 518.9027 df: 276

Irrigation	Means	n	E.E.		
Yes	70.57	140	1.93	A	
NO	62.71	140	1.93		B

Test:Tukey Alfa=0.05 DMS=5.34279

Error: 518.9027 df: 276

Mulch	Means	n	E.E.		
No	90.43	140	1.93	A	
Yes	42.86	140	1.93		B

Test:Tukey Alfa=0.05 DMS=9.90852

Error: 518.9027 df: 276

Irrigation	Mulch	Means	n	E.E.			
Yes	No	91.14	70	2.72	A		
NO	No	89.71	70	2.72	A		
Yes	Yes	50.00	70	2.72		B	
NO	Yes	35.71	70	2.72			C

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Clay	12 months	%	280	0.43	0.43	27.51

S.V.	SS	df	MS	F	p-value
Model.	99337.14	3	33112.38	70.36	<0.0001
Irrigation	3862.86	1	3862.86	8.21	0.0045
Mulch	93622.86	1	93622.86	198.93	<0.0001
Irrigation*Mulch	1851.43	1	1851.43	3.93	0.0483
Error	129897.14	276	470.64		
Total	229234.29	279			

Test:Tukey Alfa=0.05 DMS=5.08827

Error: 470.6418 df: 276

Irrigation	Means	n	E.E.		
Yes	82.57	140	1.83	A	
NO	75.14	140	1.83		B

Test:Tukey Alfa=0.05 DMS=5.08827

Error: 470.6418 df: 276

Mulch	Means	n	E.E.		
No	97.14	140	1.83	A	
Yes	60.57	140	1.83		B

Test:Tukey Alfa=0.05 DMS=9.43650

Error: 470.6418 df: 276

Irrigation	Mulch	Means	n	E.E.			
Yes	No	98.29	70	2.59	A		
NO	No	96.00	70	2.59	A		
Yes	Yes	66.86	70	2.59		B	
NO	Yes	54.29	70	2.59			C

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Loamy sand	4 months	%	280	0.72	0.72	53.36

S.V.	SS	df	MS	F	p-value
Model.	179051.43	3	59683.81	242.04	<0.0001
Irrigation	4165.71	1	4165.71	16.89	0.0001
Mulch	171022.86	1	171022.86	693.57	<0.0001
Irrigation*Mulch	3862.86	1	3862.86	15.67	0.0001
Error	68057.14	276	246.58		
Total	247108.57	279			

Test:Tukey Alfa=0.05 DMS=3.68305

Error: 246.5839 df: 276

Irrigation	Means	n	E.E.		
Yes	33.29	140	1.33	A	
NO	25.57	140	1.33		B

Test:Tukey Alfa=0.05 DMS=3.68305

Error: 246.5839 df: 276

Mulch	Means	n	E.E.		
No	54.14	140	1.33	A	
Yes	4.71	140	1.33		B

Test:Tukey Alfa=0.05 DMS=6.83043

Error: 246.5839 df: 276

Irrigation	Mulch	Means	n	E.E.			
Yes	No	61.71	70	1.88	A		
NO	No	46.57	70	1.88		B	
Yes	Yes	4.86	70	1.88			C
NO	Yes	4.57	70	1.88			C

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Loamy sand	8 months	%	280	0.70	0.70	56.73

S.V.	SS	df	MS	F	p-value
Model.	231295.71	3	77098.57	213.49	<0.0001
Irrigation	4972.86	1	4972.86	13.77	0.0002
Mulch	222892.86	1	222892.86	617.19	<0.0001
Irrigation*Mulch	3430.00	1	3430.00	9.50	0.0023
Error	99674.29	276	361.14		
Total	330970.00	279			

Test:Tukey Alfa=0.05 DMS=4.45720

Error: 361.1387 df: 276

Irrigation	Means	n	E.E.		
Yes	37.71	140	1.61	A	
NO	29.29	140	1.61		B

Test:Tukey Alfa=0.05 DMS=4.45720

Error: 361.1387 df: 276

Mulch	Means	n	E.E.		
No	61.71	140	1.61	A	
Yes	5.29	140	1.61		B

Test:Tukey Alfa=0.05 DMS=8.26614

Error: 361.1387 df: 276

Irrigation	Mulch	Means	n	E.E.			
Yes	No	69.43	70	2.27	A		
NO	No	54.00	70	2.27		B	
Yes	Yes	6.00	70	2.27			C
NO	Yes	4.57	70	2.27			C

Soil	Date	Variable	N	R^2	R^2 Aj	CV
Loamy sand	12 months	%	280	0.67	0.67	52.22

S.V.	SS	df	MS	F	p-value
Model.	244438.57	3	81479.52	188.74	<0.0001
Irrigation	1750.00	1	1750.00	4.05	0.0450
Mulch	238972.86	1	238972.86	553.57	<0.0001
Irrigation*Mulch	3715.71	1	3715.71	8.61	0.0036
Error	119148.57	276	431.70		
Total	363587.14	279			

Test:Tukey Alfa=0.05 DMS=4.87321

Error: 431.6977 df: 276

Irrigation	Means	n	E.E.		
Yes	42.29	140	1.76	A	
NO	37.29	140	1.76		B

Test:Tukey Alfa=0.05 DMS=4.87321

Error: 431.6977 df: 276

Mulch	Means	n	E.E.		
No	69.00	140	1.76	A	
Yes	10.57	140	1.76		B

Test:Tukey Alfa=0.05 DMS=9.03766

Error: 431.6977 df: 276

Irrigation	Mulch	Means	n	E.E.			
Yes	No	75.14	70	2.48	A		
NO	No	62.86	70	2.48		B	
NO	Yes	11.71	70	2.48			C
Yes	Yes	9.43	70	2.48			C

Appendix H. ANOVA table for statistical tests for soil volumetric water content on five and nine days of rain and watering events in each treatments of each soil and contrast test comparing mulch/irrigation and bulldozing treatments.

Analysis of variance

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	5	% SVWC	51	0.05	0	27.42

Table of Analysis of Variance (Type III SS)

S.V	SS	df	MS	F	p-value
Model	0.01	4	3.60E-03	0.66	0.6228
Treatments	0.01	4	3.60E-03	0.66	0.6228
Error	0.25	46	0.01		
Total	0.26	50			

Contrast

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	0.03	4.70E-03	1	4.70E-03	0.87	0.3557
Total		0.01	4	3.60E-03	0.66	0.6228

Test:Tukey Alfa=0.05 DMS=0.09569

Error: 0.0054 df: 46

Treatments	Means	n	E.E.	
Mulch	0.29	12	0.02	A
Mulch/ Irrigation	0.27	11	0.02	A
Irrigation	0.27	12	0.02	A
Control	0.25	4	0.04	A
Mulch/Irrigation+ Bulldozing	0.24	12	0.02	A

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	9	% SVWC	51	0.15	0.08	40.17

Table of Analysis of Variance (Type III SS)

S.V	SS	df	MS	F	p-value
Model	0.04	4	0.01	2.07	0.1003
Treatments	0.04	4	0.01	2.07	0.1003
Error	0.25	46	0.01		
Total	0.29	50			

Contrast

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	0.02	1.70E-03	1	1.70E-03	0.31	0.5782
Total		0.04	4	0.01	2.07	0.1003

Test:Tukey Alfa=0.05 DMS=0.09599

Error: 0.0054 df: 46

Treatments	Means	n	E.E.	
Mulch	0.23	12	0.02	A
Irrigation	0.20	12	0.02	A
Mulch/ Irrigation	0.17	11	0.02	A
Control	0.16	4	0.04	A
Mulch/Irrigation+ Bulldozing	0.15	12	0.02	A

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	5	% SVWC	51	0.37	0.32	44.18

Table of Analysis of Variance (Type III SS)

S.V	SS	df	MS	F	p-value
Model	0.04	4	0.01	6.9	0.0002
Treatments	0.04	4	0.01	6.9	0.0002
Error	0.06	46	1.40E-03		
Total	0.1	50			

Contrast

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	-0.01	3.30E-04	1	3.30E-04	0.25	0.6216
Total		0.04	4	0.01	6.9	0.0002

Test:Tukey Alfa=0.05 DMS=0.04698

Error: 0.0014 df: 46

Treatments	Means	n	E.E.		
Mulch/Irrigation+ Bulldozing	0.12	10	0.01	A	
Mulch/ Irrigation	0.11	12	0.01	A	
Mulch	0.07	12	0.01	A	B
Control	0.06	6	0.02		B
Irrigation	0.05	11	0.01		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	9	% SVWC	51	0.47	0.43	51.88

Table of Analysis of Variance (Type III SS)

S.V	SS	df	MS	F	p-value
Model	0.03	4	0.01	10.29	<0.0001
Treatments	0.03	4	0.01	10.29	<0.0001
Error	0.04	46	8.40E-04		
Total	0.07	50			

Contrast

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	3.70E-03	7.30E-05	1	7.30E-05	0.09	0.769
Total		0.03	4	0.01	10.29	<0.0001

Test:Tukey Alfa=0.05 DMS=0.03699

Error: 0.0008 df: 46

Treatments	Means	n	E.E.		
Mulch/ Irrigation	0.09	12	0.01	A	
Mulch/Irrigation+ Bulldozing	0.08	10	0.01	A	
Mulch	0.04	12	0.01		B
Control	0.03	6	0.01		B
Irrigation	0.03	11	0.01		B

Appendix I. ANOVA table for statistical tests of soil volumetric water content on five and nine days of watering events in each treatments of each soil and contrast test comparing mulch/irrigation and bulldozing treatments.

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	5	% SVWC	51	0.2	0.13	52.41

S.V.	SS	df	MS	F	p-value
Model.	0.08	4	0.02	2.81	0.036
Treatments	0.08	4	0.02	2.81	0.036
Error	0.32	46	0.01		
Total	0.4	50			

Contrasts

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	-0.04	0.01	1	0.01	1.44	0.2355
Total		0.08	1	0.01	1.44	0.2355

Test:Tukey Alfa=0.05 DMS=0.10720

Error: 0.0070 df: 46

Treatments	Means	n	E.E.		
Irrigation	0.2	12	0.02	A	
Mulch	0.19	12	0.02	A	B
Mulch/Irrigation+ Bulldozing	0.16	12	0.02	A	B
Mulch/Irrigation	0.12	9	0.03	A	B
Control	0.09	6	0.03		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	9	% SVWC	44	0.34	0.27	61.28

S.V.	SS	df	MS	F	p-value
Model.	0.1	4	0.02	5.02	0.0023
Treatments	0.1	4	0.02	5.02	0.0023
Error	0.19	39	4.90E-03		
Total	0.29	43			

Contrasts

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	-0.03	4.10E-03	1	4.10E-03	0.83	0.3687
Total		0.1	4	0.02	5.02	0.0023

Test:Tukey Alfa=0.05 DMS=0.09723

Error: 0.0049 df: 39

Treatments	Means	n	E.E.		
Mulch	0.19	10	0.02	A	
Irrigation	0.14	10	0.02	A	B
Control	0.09	5	0.03		B
Mulch/Irrigation+ Bulldozing	0.09	10	0.02		B
Mulch/Irrigation	0.06	9	0.02		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	5	% SVWC	60	0.53	0.49	83

S.V.	SS	df	MS	F	p-value
Model.	0.04	4	0.01	15.41	<0.0001
Treatments	0.04	4	0.01	15.41	<0.0001
Error	0.04	55	6.80E-04		
Total	0.08	59			

Contrasts

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	-0.02	2.00E-03	1	2.00E-03	2.98	0.0898
Total		0.04	4	0.01	15.41	<0.0001

Test:Tukey Alfa=0.05 DMS=0.02994

Error: 0.0007 df: 55

Treatments	Means	n	E.E.		
Mulch/Irrigation+ Bulldozing	0.07	12	0.01	A	
Mulch/Irrigation	0.05	12	0.01	A	
Mulch	0.02	12	0.01		B
Irrigation	0.01	12	0.01		B
Control	0.01	12	0.01		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	9	% SVWC	48	0.5	0.45	90.37

S.V.	SS	df	MS	F	p-value
Model.	0.02	4	0.01	10.69	<0.0001
Treatments	0.02	4	0.01	10.69	<0.0001
Error	0.02	43	5.40E-04		
Total	0.05	47			

Contrasts

Treatments	Contrast	SS	df	MS	F	p-value
Mulch-Irrigation vs Mulch-Irrigation + Bulldozing	-0.01	3.60E-04	1	3.60E-04	0.66	0.4198
Total		0.02	4	0.01	10.69	<0.0001

Test:Tukey Alfa=0.05 DMS=0.03011

Error: 0.0005 df: 43

Treatments	Means	n	E.E.		
Mulch/Irrigation+Bulldozing	0.06	9	0.01	A	
Mulch/Irrigation	0.05	10	0.01	A	
Mulch	0.01	9	0.01		B
Irrigation	0.01	10	0.01		B
Control	3.00E-03	10	0.01		B

Appendix J. Table for statistical tests of ANOVA model with factorial 2 x 2 for soil volumetric water content on rain events in each planting treatments of each soil.

Soil	Days	Variable	N	R²	R² Aj	CV
Clay	5.00	% SVWC	39	0.03	0.00	26.38

S.V.	SS	df	MS	F	p-value
Modelo.	0.01	3	1.9E-03	0.36	0.7811
Irrigation	9.4E-05	1	9.4E-05	0.02	0.8945
Mulch	3.7E-03	1	3.7E-03	0.71	0.4044
Irrigation*Mulch	3.1E-03	1	3.1E-03	0.59	0.4461
Error	0.18	35	0.01		
Total	0.19	38			

Test:Tukey Alpha=0.05 LSD=0.04749

Error: 0.0052 df: 35

Irrigation	Means	n	E.E.	
YES	0.27	23	0.02	A
NO	0.27	16	0.02	A

Test:Tukey Alpha=0.05 LSD=0.04749

Error: 0.0052 df: 35

Mulch	Means	n	E.E.	
YES	0.28	23	0.02	A
NO	0.26	16	0.02	A

Test:Tukey Alpha=0.05 LSD=0.09250

Error: 0.0052 df: 35

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.29	12	0.02	A
YES	YES	0.27	11	0.02	A
YES	NO	0.27	12	0.02	A
NO	NO	0.25	4	0.04	A

Soil	Days	Variable	N	R²	R² Aj	CV
Clay	9.00	% SVWC	39	0.14	0.06	36.05

S.V.	SS	df	MS	F	p-value
Modelo.	0.03	3	0.01	1.83	0.1604
Irrigation	8.1E-04	1	8.1E-04	0.17	0.6855
Mulch	2.8E-03	1	2.8E-03	0.59	0.4494
Irrigation*Mulch	0.02	1	0.02	4.07	0.0514
Error	0.17	35	4.9E-03		
Total	0.20	38			

Test:Tukey Alpha=0.05 LSD=0.04574

Error: 0.0049 df: 35

Irrigation	Means	n	E.E.	
NO	0.19	16	0.02	A
YES	0.18	23	0.01	A

Test:Tukey Alpha=0.05 LSD=0.04574

Error: 0.0049 df: 35

Mulch	Means	n	E.E.	
YES	0.20	23	0.01	A
NO	0.18	16	0.02	A

Test:Tukey Alpha=0.05 LSD=0.08910

Error: 0.0049 df: 35

Irrigation	Mulch	Means	n	E.E.	
NO	YES	0.23	12	0.02	A
YES	NO	0.20	12	0.02	A
YES	YES	0.17	11	0.02	A
NO	NO	0.16	4	0.03	A

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	5.00	% SVWC	41	0.33	0.28	47.41

S.V.	SS	df	MS	F	p-value
Modelo.	0.02	3	0.01	6.12	0.0017
Irrigation	2.1E-03	1	2.1E-03	1.67	0.2039
Mulch	0.01	1	0.01	11.40	0.0017
Irrigation*Mulch	3.8E-03	1	3.8E-03	2.97	0.0930
Error	0.05	37	1.3E-03		
Total	0.07	40			

Test:Tukey Alpha=0.05 LSD=0.02262

Error: 0.0013 df: 37

Irrigation	Means	n	E.E.	
YES	0.08	23	0.01	A
NO	0.06	18	0.01	A

Test:Tukey Alpha=0.05 LSD=0.02271

Error: 0.0013 df: 37

Mulch	Means	n	E.E.		
YES	0.09	24	0.01	A	
NO	0.05	17	0.01		B

Test:Tukey Alpha=0.05 LSD=0.04312

Error: 0.0013 df: 37

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.11	12	0.01	A	
NO	YES	0.07	12	0.01	A	B
NO	NO	0.06	6	0.01		B
YES	NO	0.05	11	0.01		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	9.00	% SVWC	41	0.48	0.44	55.28

S.V.	SS	df	MS	F	p-value
Modelo.	0.03	3	0.01	11.43	<0.0001
Irrigation	3.4E-03	1	3.4E-03	4.58	0.0391
Mulch	0.01	1	0.01	16.49	0.0002
Irrigation*Mulch	0.01	1	0.01	8.06	0.0073
Error	0.03	37	7.4E-04		
Total	0.05	40			

Test:Tukey Alpha=0.05 LSD=0.01730

Error: 0.0007 df: 37

Irrigation	Means	n	E.E.		
YES	0.06	23	0.01	A	
NO	0.04	18	0.01		B

Test:Tukey Alpha=0.05 LSD=0.01737

Error: 0.0007 df: 37

Mulch	Means	n	E.E.		
YES	0.06	24	0.01	A	
NO	0.03	17	0.01		B

Test:Tukey Alpha=0.05 LSD=0.03297

Error: 0.0007 df: 37

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.09	12	0.01	A	
NO	YES	0.04	12	0.01		B
NO	NO	0.03	6	0.01		B
YES	NO	0.03	11	0.01		B

Appendix K. Table for statistical tests of ANOVA model with factorial 2 x 2 for soil volumetric water content on watering events in each planting treatments of each soil.

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	5.00	% SVWC	39	0.26	0.19	50.58

S.V.	SS	df	MS	F	p-value
Modelo.	0.08	3	0.03	4.03	0.0146
Irrigation	4.5E-03	1	4.5E-03	0.69	0.4128
Mulch	2.1E-04	1	2.1E-04	0.03	0.8580
Irrigation*Mulch	0.08	1	0.08	11.79	0.0015
Error	0.23	35	0.01		
Total	0.31	38			

Test:Tukey Alpha=0.05 LSD=0.05270
Error: 0.0066 df: 35

Irrigation	Means	n	E.E.	
YES	0.16	21	0.02	A
NO	0.14	18	0.02	A

Test:Tukey Alpha=0.05 LSD=0.05270
Error: 0.0066 df: 35

Mulch	Means	n	E.E.	
YES	0.15	21	0.02	A
NO	0.15	18	0.02	A

Test:Tukey Alpha=0.05 LSD=0.10073
Error: 0.0066 df: 35

Irrigation	Mulch	Means	n	E.E.		
YES	NO	0.20	12	0.02	A	
NO	YES	0.19	12	0.02	A	B
YES	YES	0.12	9	0.03	A	B
NO	NO	0.09	6	0.03		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Clay	9.00	% SVWC	34	0.37	0.31	57.77

S.V.	SS	df	MS	F	p-value
Modelo.	0.09	3	0.03	5.84	0.0029
Irrigation	0.01	1	0.01	2.63	0.1154
Mulch	7.6E-04	1	7.6E-04	0.15	0.7013
Irrigation*Mulch	0.06	1	0.06	12.34	0.0014
Error	0.15	30	0.01		
Total	0.24	33			

Test:Tukey Alpha=0.05 LSD=0.04993

Error: 0.0050 df: 30

Irrigation	Means	n	E.E.	
NO	0.14	15	0.02	A
YES	0.10	19	0.02	A

Test:Tukey Alpha=0.05 LSD=0.04993

Error: 0.0050 df: 30

Mulch	Means	n	E.E.	
YES	0.12	19	0.02	A
NO	0.11	15	0.02	A

Test:Tukey Alpha=0.05 LSD=0.09543

Error: 0.0050 df: 30

Irrigation	Mulch	Means	n	E.E.		
NO	YES	0.19	10	0.02	A	
YES	NO	0.14	10	0.02	A	B
NO	NO	0.09	5	0.03		B
YES	YES	0.06	9	0.02		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	5.00	% SVWC	48	0.56	0.53	82.84

S.V.	SS	df	MS	F	p-value
Modelo.	0.02	3	0.01	18.60	<0.0001
Irrigation	0.01	1	0.01	16.81	0.0002
Mulch	0.01	1	0.01	29.29	<0.0001
Irrigation*Mulch	3.0E-03	1	3.0E-03	9.71	0.0032
Error	0.01	44	3.1E-04		
Total	0.03	47			

Test:Tukey Alpha=0.05 LSD=0.01024

Error: 0.0003 df: 44

Irrigation	Means	n	E.E.		
YES	0.03	24	3.6E-03	A	
NO	0.01	24	3.6E-03		B

Test:Tukey Alpha=0.05 LSD=0.01024

Error: 0.0003 df: 44

Mulch	Means	n	E.E.		
YES	0.04	24	3.6E-03	A	
NO	0.01	24	3.6E-03		B

Test:Tukey Alpha=0.05 LSD=0.01919

Error: 0.0003 df: 44

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.05	12	0.01	A	
NO	YES	0.02	12	0.01		B
YES	NO	0.01	12	0.01		B
NO	NO	0.01	12	0.01		B

Soil	Days	Variable	N	R^2	R^2 Aj	CV
Loamy Sand	9.00	% SVWC	39	0.53	0.48	96.29

S.V.	SS	df	MS	F	p-value
Modelo.	0.01	3	4.1E-03	12.92	<0.0001
Irrigation	4.0E-03	1	4.0E-03	12.73	0.0011
Mulch	0.01	1	0.01	18.73	0.0001
Irrigation*Mulch	2.0E-03	1	2.0E-03	6.33	0.0166
Error	0.01	35	3.2E-04		
Total	0.02	38			

Test:Tukey Alpha=0.05 LSD=0.01156

Error: 0.0003 df: 35

Irrigation	Means	n	E.E.		
YES	0.03	20	4.0E-03	A	
NO	0.01	19	4.1E-03		B

Test:Tukey Alpha=0.05 LSD=0.01156

Error: 0.0003 df: 35

Mulch	Means	n	E.E.		
YES	0.03	19	4.1E-03	A	
NO	0.01	20	4.0E-03		B

Test:Tukey Alpha=0.05 LSD=0.02172

Error: 0.0003 df: 35

Irrigation	Mulch	Means	n	E.E.		
YES	YES	0.05	10	0.01	A	
NO	YES	0.01	9	0.01		B
YES	NO	0.01	10	0.01		B
NO	NO	3.0E-03	10	0.01		B