MAIZE YIELD AND SOIL PROPERTY RESPONSE TO *Entada abyssinica* CUTTINGS IN THE ADAMAWA LOWLANDS, CAMEROON

By

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The thesis: “Maize Yield and Soil Property Response to *Entada abyssinica* cuttings in the Adamawa Lowlands, Cameroon” is hereby approved in partial fulfillment of the requirement for the Degree MASTER OF SCIENCE IN FORESTRY

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ABSTRACT

Decreasing crop yields and soil fertility are a major concern of most farmers in the Adamawa Province, Cameroon, West Central Africa. Chemical fertilizers are generally beyond their means. Thus a need exists for an inexpensive, natural, and sustainable chemical fertilizer alternative.

The purpose of this study was to determine the effects of *Entada abyssinica* prunings through the cut-and-carry method on maize yield and soil properties. Cuttings were applied to a 30 x 15m plot in two quantities (1.25 kg/plot and 2.50 kg/plot) and two different application methods (mixed or mulched). Optimal maize yield occurred when 2.50 kg prunings per plot were mixed with the soil. Soil samples data from the plot showed significant changes in some soil properties including increases in potassium, organic matter, organic carbon, and soil pH.

For the smallholder farmer without the means to acquire chemical fertilizer, *Entada abyssinica* cuttings are an effective alternative. *Entada abyssinica* is indigenous to Africa and is valued for its multiple uses. This study indicates that positive results can be experienced in the same cropping season, which can lead to increased adoption rates and less dependence on inorganic fertilizers.

LIST OF ACRONYMS

CAR	Central African Republic
CDU	Cameroon Democratic Union
CRTV	Cameroon Radio Television
GIC	Groupe d'Initiative Communitaire
HIPC	Heavily Indebted Poor Countries Initiative
IITA	International Institute for Tropical Agriculture
IRAD	Institute of Agricultural Research for Development
MINAGRI	Ministry of Agriculture
MINEF	Ministry of Environment and Forests
MINREST	Ministry of Technical Research
NGO	Non Governmental Organization
NUDP	National Union for Democracy and Progress
PCV	Peace Corps Volunteer
SDF	Social Democratic Front
UN	United Nations
UPC	Union of the People of Cameroon
USAID	United States Agency for International Development
ZEW	Zonal Extension Worker

CHAPTER 1 GENERAL INTRODUCTION

As an Agroforestry Extension Agent with Peace Corps Cameroon I was posted in the village of Mbang-Mboum, a small canton in the Adamawa lowlands. My primary responsibilities were to teach motivated farmers the techniques of agroforestry and to identify farmer leaders who would adopt a technique or two in their farms and pass on this knowledge to others.

Armed with a year of stateside coursework and three months of in-country training, I began visiting farms in my work area and asking farmers how they could improve their land. “Buy us fertilizer so we’ll have more maize” was the common demand.

The agroforestry technique green manuring could naturally and sustainably improve soil fertility and would be a perfect substitute for man-made inputs. How could a city boy from Detroit convince subsistence farmers in sub- Saharan Africa to adopt this technique?

Patience. Building trust. Hard work. Tangible results. Luck.

Combining my primary assignment and my research seemed like a smart approach. After campaigning for some land, I created a demonstration plot in the center of my village that exhibited green manure’s effects on maize yield and was also given a larger plot in another village to conduct field trials for my research on green manure. Thus, I was able to assist farmers and accomplish my research needs simultaneously.

My objective for this study was to examine green manure's effect on maize yield and soil properties utilizing the cut and carry method and to provide farmers in Mbang-Mboum and the surrounding villages with a chemical fertilizer alternative. I hypothesized that both maize yield and soil properties would show significant changes.

Chapter 2 provides background information about the country of Cameroon and concludes with a summary of environmental issues facing the country and policies to combat them. The Adamawa Province where the study took place is discussed in Chapter 3 including the different ethnic groups that reside in the province and their occupations. Additionally, the village of Mbang-Mboum is described in more detail.

In Chapter 4 the motivation for my research is explained, particularly its importance to subsistence farmers in the Adamawa. I outline the methodology for my field trials in Chapter 5: location, tree species used, experimental design, and field work, concluding with a description of the statistical analysis utilized in the trials and data collected.

Chapter 6 presents the data collected during this experiment including maize yield, macronutrient, and micronutrient soil sample test results. I continue in chapter 7 with the results and discussion section. I begin with maize yield and continue with specific soil properties. Throughout this chapter, comparisons of my results to other studies are made. Chapter 8 covers conclusions drawn from this field trial. I examine the results of this study as they relate to present day conditions in the Adamawa lowlands and conclude with suggestions to increase agroforestry adoption rates in the province.

SECTION 1

GENERAL BACKGROUND

CHAPTER 2 BACKGROUND

The Republic of Cameroon has been in the global spotlight on numerous occasions over the past several decades. In 1987, Lake Nyos in the Southwest Province released poisonous gases killing approximately 2000 villagers as they slept. The National Soccer team's 1990 performance in the World Cup competition brought praise to the Indomitable Lions throughout the international soccer community. 1999 brought recognition as the world's most corrupt nation (Transparency International, 1999) and also in 2003 with the completion of a controversial underground oil pipeline from Chad to the city of Kribi on the Atlantic Ocean. In 2006, scientists traced the origin of the HIV virus to chimpanzees also in the Southwest Province and the country reached the World Bank's Heavily Indebted Poor Countries (HIPC) initiative completion point (World Bank, 2006). Because of its political stability, however, Cameroon receives little attention when compared to other Central African countries. Much is yet to be explored.

Description of Cameroon

Cameroon is a triangle-shaped country stretching from the Gulf of Guinea in the south to Lake Chad (Figures 1 and 2) in the north. With a land area of 475,400 km^2 (World Bank, 2006), it ranks as the world's 53rd largest country, approximately the size of the U.S. state of California (State Department, 2006). Frontier countries include Nigeria to the west, Equatorial Guinea and Gabon to the south, the Democratic Republic of Congo and the Central African Republic to the east, and Chad to the north. The capital city Yaoundé lies in the Center Province (Figure 3).

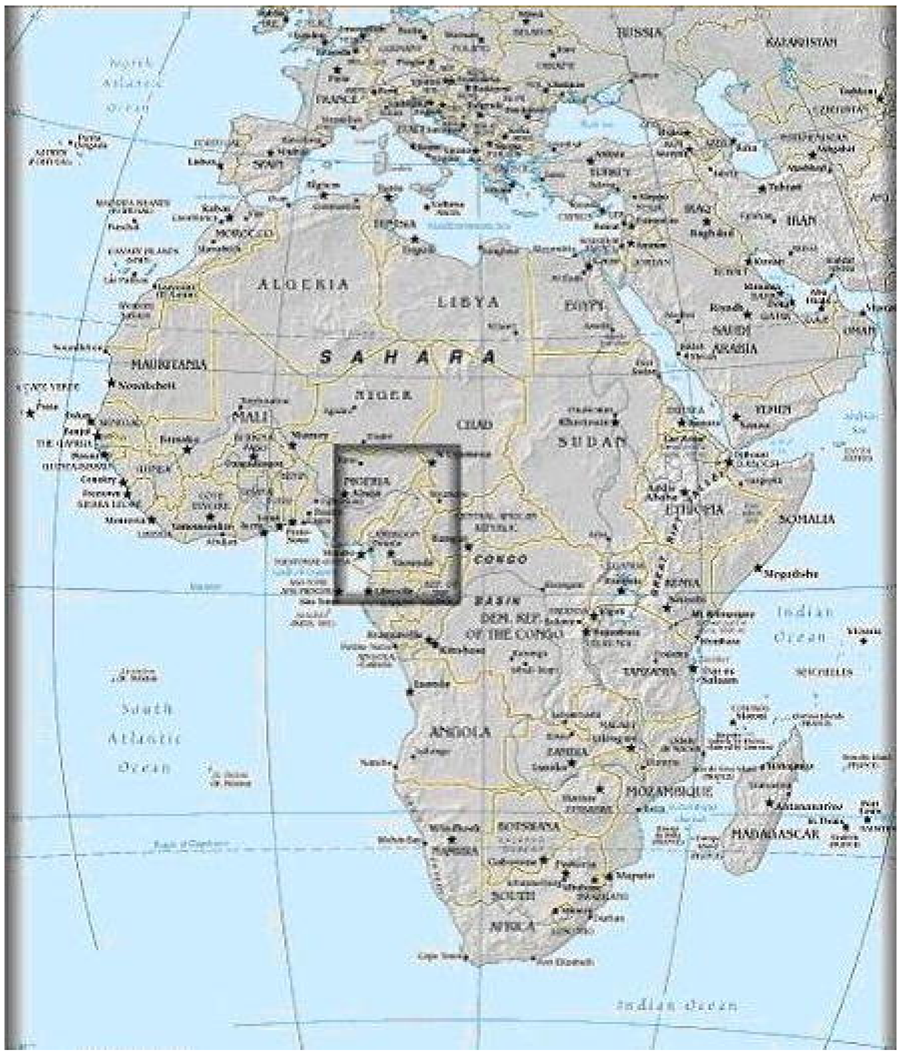


Figure 1 Cameroon is located in West Central Africa. Source: http://www.lexnet.be/africa.jpg

Figure 2 Yaoundé, the capital of Cameroon. Source: https://www.cia.gov/cia/publications/factbook/geos/cm/html.

Figure 3 The Omnisport area of Yaoundé. Photo by Brian Satterlee.

Administrative Divisions

The country is composed of ten provinces: the Adamawa Province, Center Province, East Province, Extreme North Province, Littoral Province, North Province, Northwest Province, West Province, South Province, and Southwest Province (Figure 4). The East Province is the largest, followed by the Center, the North, and the Adamawa while the West is the most densely populated, the East the least (Table 1). Cameroon is divided into 58 divisions and further subdivided into subdivisions and districts.

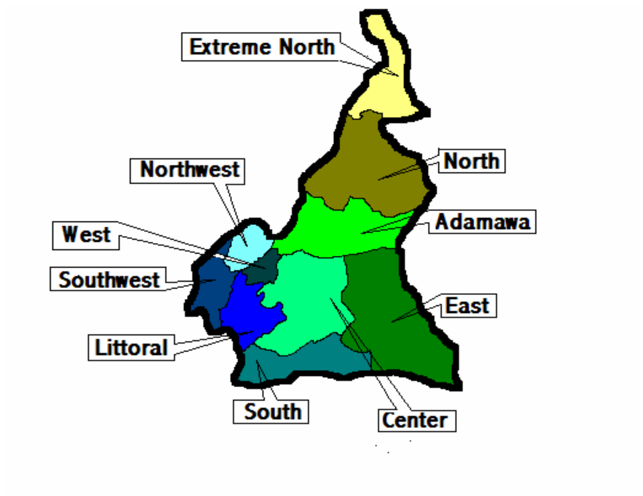


Figure 4 Cameroon's 10 Provinces

Table 1 Population density of Cameroon's ten provinces. Source: Yebit, 2004

PROVINCE	POPULATION (Millions)	AREA (km^2)	DENSITY (Population/ km^2)
Adamawa	0.7	62,000	11.3
Center	2.3	69,000	33.3
East	0.7	109,000	6.4
Extreme North	2.5	34,360	72.8
Littoral	1.9	21,500	88.4
North	1.1	68,000	16.2
Northwest	1.7	17,400	97.7
South	0.5	47,190	10.6
Southwest	1.2	34,720	34.6
West	1.8	13,890	129.6

History

Portuguese sailors landed on the coast near present day Douala in 1472 and were amazed at the number of prawns and crayfish in the Wouri River and named it Rio dos Camarões, the phrase which gives Cameroon its name (Peace Corps, 2002). Centuries of trade with Europeans and contact with Christian missionaries along the coast followed and moved inland in the late 1800s when malaria was suppressed through the use of quinine (State Department, 2006).

Cameroon became the German colony of *Kamerun* in 1884 (State Department, 2006). Infrastructure improvement projects including roads and railways were undertaken as well as the construction of hospitals and schools (Figure 5). After World War I the country was divided between Britain and France (World Bank, 2006); France received a larger share of the country. Its influence is still prevalent today as evidenced by the use of the French education system, language, and continued military advising (Wolf, 2001).

Figure 5 A German-built primary school. Photo by Brian Satterlee.

In December 1958 the region was given self-government and in 1960 complete independence and United Nations (UN) membership (World Bank, 2006). The British southern and French portions were combined in 1961. The northern British section joined Nigeria. Thus the Federal Republic of Cameroon was born with Ahmadou Ahidjo as the country's first president (World Bank, 2006).

Ahidjo was a French-educated Fulani from the North. In 1966 he banned all political parties but the one with which he was affiliated and suppressed the Union of the Peoples of Cameroon (UPC) party rebellion in the late 1960s. He resigned in 1982 (State Department, 2006). His Prime Minister, Paul Biya, a Bulu-Beti from the South, succeeded Ahidjo, survived a 1984 *coup d'etat*, and continues to serve as president today (State Department, 2006).

Government

Based on the French civil law system, Cameroon has a powerful central government that is controlled by the President (State Department, 2006). He has the authority to appoint and dismiss cabinet members as well as most government officials. He has complete veto power and control over the state owned firms' finances without consulting the country's National Assembly, a 180-member branch that adopts laws by majority vote. He heads the Supreme Court, consisting of the president, the minister of justice, and the judicial advisers. A law's constitutionality can only be reviewed when he requests it (State Department, 2006). Local government functions such as property and domestic disputes are handled by traditional rulers and councils (Figure 6).

Figure 6 His Majesty the Belaka (Traditional Ruler). Photo by Brian Satterlee.

Amendments to the country's 1972 constitution were made in 1995 resulting in a revised constitution in 1996 (State Department, 2006). Changes included the creation of a 100-member Senate, regional tribunals, and limiting the president's term to seven years with one additional term. The Social Democratic Front (SDF), the National Union for Democracy and Progress (NUDP), and the Cameroon Democratic Union (CDU) parties oppose the People's Democratic movement which has been in power since independence in 1960 (State Department, 2006).

With such a powerful central government it follows that the media is heavily censored. The state owned company Cameroon Radio Television (CRTV) monopolizes the airwaves although legislation against such a practice passed in 2000 (State Department, 2006). The government has shut down newspapers, failed to issue broadcast licenses to private networks, and arrested journalists. Human rights activists remain concerned over reports of the Government's beatings, illegal searches, and unwarranted arrests (State Department, 2006).

The People

English and French are the two official languages, although there are over 200 others spoken within the country including Fulfuldé, pidgin, and Ewondo. Fulfuldé is said to be spoken by approximately 10,000,000 people throughout West and Central Africa (Peace Corps, 2002). There are over 250 ethnic groups of Bantu, Sudanese, and Arabic origins: the western highlanders, the coastal tropical forest peoples, the southern tropical forest peoples, the Islamic peoples of the Sahel and central highlands, and the Kirdi (non-Islamic) of the northern desert and central highlands (State Department, 2006). The Bamileke, Bamoun, and Tikar groups in the Western Highlands make up the majority of Cameroon's population (Figure 7).

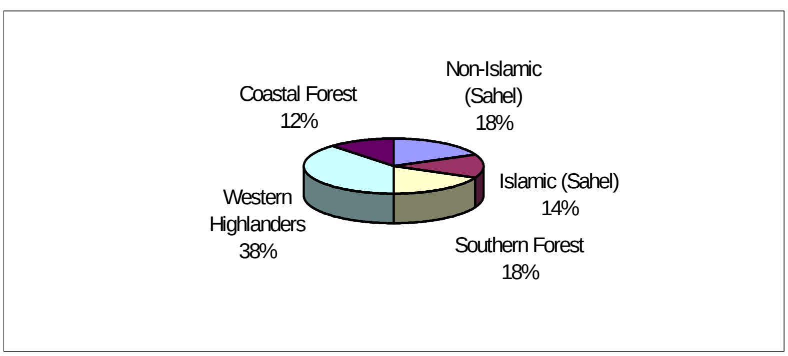


Figure 7 Cameroon's Demographic Profile. Source: CIA 2006.

Religious Practices

Christianity and indigenous beliefs account for 75% of the population's faith (State Department, 2006). Christians generally live in the southern provinces while animism is practiced in smaller, remote villages throughout the country. Muslims dominate the Grand North (Adamawa, North, and Extreme North provinces) and regularly participate in the activities the religion dictates like the Fete de Ramadan (Figure 8). Regardless of the belief system, sorcery and witchcraft are often used to explain events such as poor harvests, drought, and even death (Peace Corps, 2002). Allah's or God's will is also used to explain floods that wipe out roads and bridges rather than poor engineering (Beets, 1990).

Figure 8 The Fete de Ramadan celebration. Photo by Brian Satterlee.

Health

There is a high risk of major infectious diseases throughout the country. Food or waterborne diseases include bacterial diarrhea, hepatitis A, and typhoid fever. Malaria and yellow fever are high risks as is a water contact disease known as schistosomiasis. Meningococcal meningitis can invade respiratory systems and lead to early mortality (CIA, 2006). For example, male life expectancy is only 50.98 years, 51.34 years for females, and 51.16 years for the total population (CIA, 2006). Children up to fourteen years (Figure 9) represent 41.2% of the population and are most at risk because of their low social status. People living with HIV/AIDS were estimated at 560,000 with an annual mortality rate of approximately 10%. Traditional remedies composed of roots, leaves, and flowers are often substituted for more modern treatments (CIA, 2006).

Figure 9 Children comprise 41.2% of population. Photo by Brian Satterlee.

Economy

Cameroon is often referred to as Africa's bread basket because it is one of the few net food exporters in Africa and agriculture is the driving force behind the economy (Peace Corps, 2002). Approximately 70% of the population is involved in agriculture and these activities account for more than 44% of Gross Domestic Product (GDP) (CIA, 2006). Main cash crops are coffee, cocoa, cotton, oilseed, and rubber (Figure 10). Other agricultural products include bananas, sugar cane, corn, and other grains such as wheat and millet.

Figure 10 Cotton harvested in the Grand North. Photo by Brian Satterlee.

In addition to farming and agriculture, Cameroon's labor force is also involved in petroleum production, food processing, aluminum production, and light consumer goods (CIA, 2006). These activities account for 55% of GDP and employ more than 2 million workers (CIA, 2006). Tourists attracted to the country's seven national parks and West Africa's tallest peak, Mt. Cameroon, provide a source of additional income for guides, porters, drivers, and hotel workers.

Over 30% of Cameroon's 6.86 million labor force is unemployed and 48% of the population is living below the poverty line (CIA, 2006). Many set up craft shops in large cities and target tourist dollars. Others manage large herds of cattle and sell one or two weekly to raise money for farm input costs such as labor and fertilizer (Figure 11).

Figure 11 A Butcher in the North Province village of Pitoa. Photo by Brian Satterlee.

Cameroon's exports are valued at $US 3.236 billion (CIA, 2006) and include crude oil, petroleum products, and lumber (Figure 12). Major trading partners include Belgium, France, Italy, the Netherlands, and Spain (State Department, 2006). The country imports electrical equipment, fuel, food, machinery, and transport equipment totaling $US 2.514 billion (CIA, 2006), approximately a third of which comes from France and Nigeria (Figure 13).

Figure 12 Timber transported to Douala via train for export. Photo by Brian Satterlee.

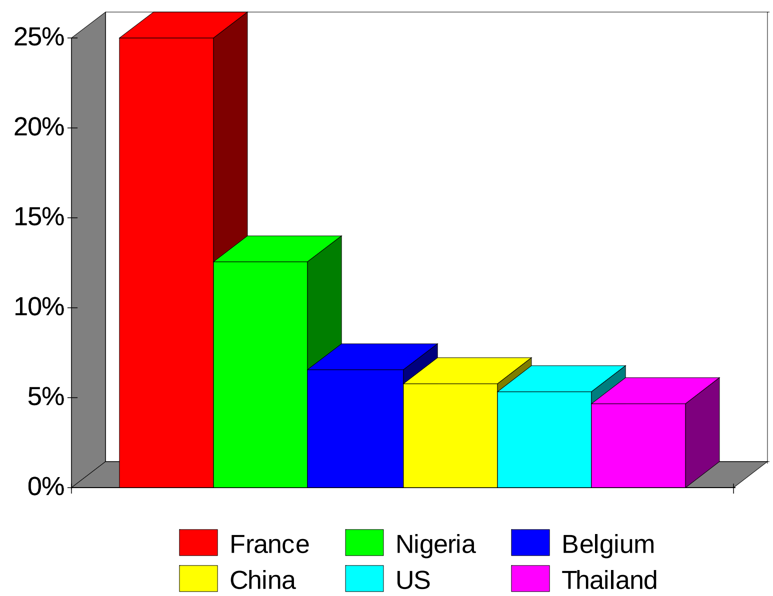


Figure 13 Cameroon trading as a percentage of Total Exports. Source: CIA 2006

Geography

Its distinct climatic regions and five geographic zones (Figure 14) have led people to refer to Cameroon as “Africa in Miniature” or the “Microcosm of Africa” (Nyamnjoh, 1999). The densely forested, hot and humid coastal plain is home to Douala, Cameroon’s largest city and financial capital. It receives the most rainfall in the country. Lower in humidity and cooler, the low southern plateau has an average elevation of 450 to 600m and is primarily tropical rainforest (Onguene, 2001). Both regions are home to 22 primate species and notable tree types including oil palms, mahogany, teak, and ebony. The Western Highlands, with fertile volcanic soils, contains hills, plateaus, and mountains that extend over 1000km north. The Adamawa Highlands are a combination of grasslands, forests, and mountains that separate the north and south. Elevations are approximately 1000m. Unlike the regions to the south, the Adamawa Highlands have only two seasons; the dry season and the wet, both lasting approximately six months. Finally the savanna plain (Figure 15) extends northward to the border between Nigeria and Chad. Rainfall varies between 400 and 750mm annually with temperatures up to 45ºC (Figure 16). Desertification is a major environmental concern in this region.

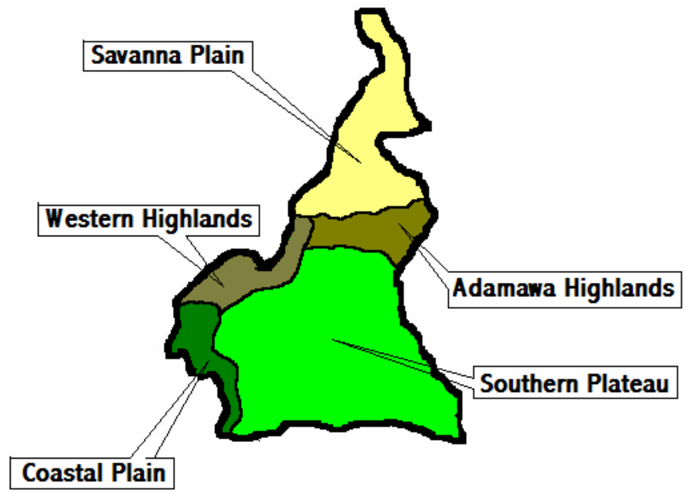


Figure 14 Geographic Regions.

Figure 15 The savannah plains near Garoua. Photo by Brian Satterlee.

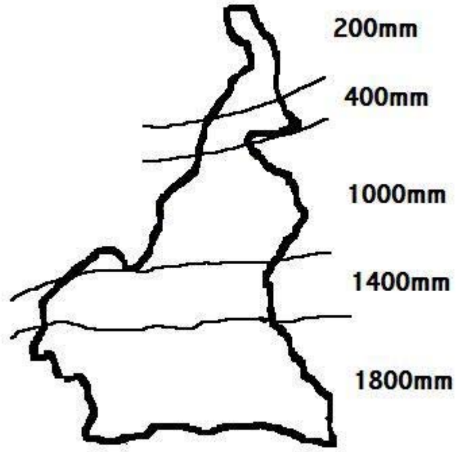


Figure 16 Annual rainfall by region. (Adapted from Yebit, 2004)

Four major rivers in the south flow directly into the Gulf of Guinea. Two others, the Dja and the Kadeï, drain into the Congo River. In the Grand North (Adamawa, North, and Extreme North Provinces), the Benoué flows into the Niger and the Logone (Figure 17) into Lake Chad.

Figure 17 Children fishing in the Bini River, a Logone river tributary. Photo by Brian Satterlee.

The Environmental Issues

During the mid-1980s the world market for Cameroon's major exports (coffee and cocoa) crashed, forcing more people into the agricultural sector (Yebit, 2004). This resulted in a per capita decrease in the amount of arable land available for cultivation and an increase in deforestation in order to satisfy the demand for such land. Forested area decreased rapidly as new plots were cleared. For example, between 1990 and 1995 total forested area declined 3.3% (Yebit, 2004). Over 2200 km^2 was lost annually between 2000 and 2005 (World Bank, 2006).

Naturally the exploitation of the forested areas leads to other concerns. Wildlife habitat for Cameroon's diverse animal species was lost. Surface runoff caused soil erosion and the loss of valuable nutrients critical to sustain acceptable crop yields. Springs dried up. The fallow periods in swidden-fallow cultivation systems (Figure 18) were eliminated (Yebit, 2004). Tree species used for fuel wood, medicinal, and ceremonial purposes disappeared. As population increased people left the areas in search of new lands and resources which became less abundant. Farmer-grazer conflicts became commonplace. The cycle continues today.

Figure 18 Swidden-fallow in the Adamawa. Photo by Brian Satterlee

Environmental Policy

The government of Cameroon created the Ministry of Environment and Forests (MINEF), the Ministry of Agriculture (MINAGRI), and the Ministry of Technical Research (MINREST) to combat the country's environmental concerns (Yebit, 2004). MINREF oversees forest management, timber harvesting, propagation, and agroforestry (Figure 19). MINAGRI utilizes Zonal Extension Workers (ZEWs) to work with farmers in promoting sustainable farming techniques. MINREST collaborates with international organizations such as IRAD (Institute of Agricultural Research for Development), IITA (International Institute for Tropical Agriculture), and ICRAF (International Center for Research in Agroforestry). These research institutes conduct field trials and make suggestions based on their findings.

Figure 19 Nurseries are a common tree propagation method. Photo by Brian Satterlee.

CHAPTER 3 STUDY AREA BACKGROUND

The Adamawa Province

The Adamawa Province comprises approximately 64,000 km² and is the gateway to the Grand North. It is the third largest province yet ranks 8th in population density at 11.3 persons /km². It is often dubbed the Forgotten Province because of its lack of development. It borders the Center and East Provinces to the south, Nigeria to the east, the Central African Republic to the west, the Northwest and West Provinces to the southwest, and the North Province to the north. There are five administrative divisions or departments; Djérem, Faro-et-Déo, Mayo-Banyo, Mbéré, and Vina (Figure 20). The capital city is Ngaoundéré. (Yebit, 2004).

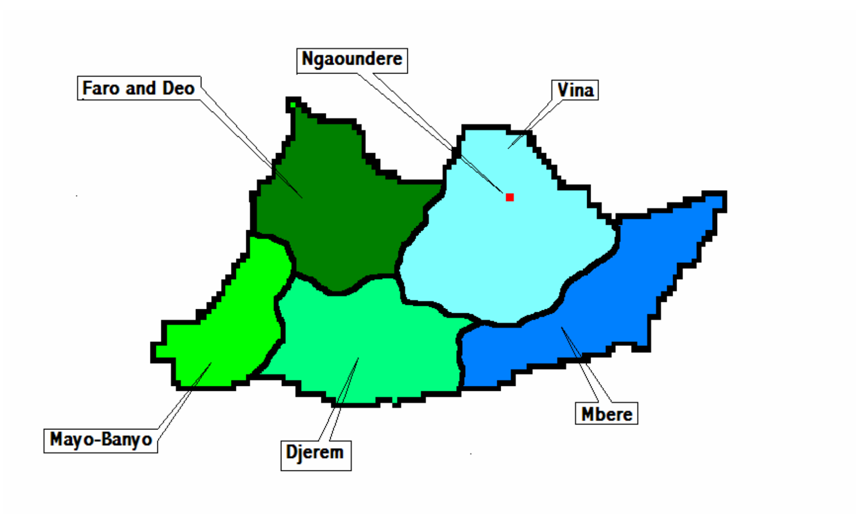


Figure 20 The Administrative Divisions in the Adamawa Province.

People

There are over ten ethnic groups that reside in the Adamawa (Figure 21). The majority are the Fulbé, Mboum, Duru, Gbaya, and Haussa (Peace Corps, 2002). The Fulbé are proud and religious Muslims, often wealthier than other groups because of their large cattle herds. The Mboum are reported to be the first settlers in the area (Hino, 1984) and farming was their principal occupation. The Duru migrated into the Adamawa between the late 1600 and 1700s in search of farmland and intermarried with the Mboum. Originating from Central Africa, the Gbaya came to the Adamawa in the early 1700s and were generally subordinate to the Mboum. Haussa arrived at the same time as the Gbaya from West Africa and engaged in trading cattle and kola nuts.

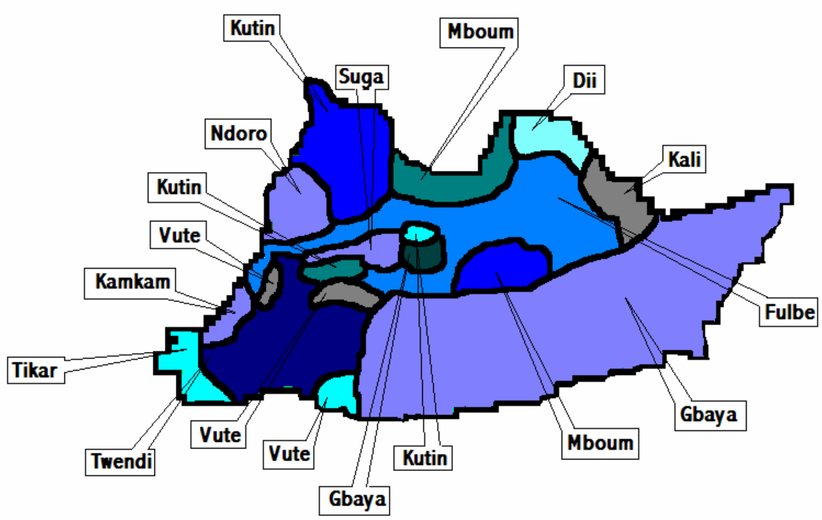


Figure 21 Ethnic groups of the Adamawa Province. Adapted from Peace Corps, 2002.

The Fulbé Islamized most of the Adamawa shortly after their arrival in the mid-19th century. The Mboum, Duru, and Gbaya were given the choice of converting or being enslaved (Hino, 1984). Few resisted. Today the groups peacefully co-exist and have mutually benefited from knowledge exchange. For example, the Mboum educated the Fulbé about maize cultivation. The Fulbé in turn shared their animal husbandry knowledge.

Economy

Cattle production is the Adamawa's major economic activity due to the province's low population density and consistent and thick grass cover. Most of the animals are humpbacked zebu (*Bos indicus*) owned by the Fulbé (Figure 22). The herds are often transported along the western third of the province and along the Chadian border to the big markets in Yaoundé, Douala, Gabon, and the Congo (Yebit, 2004).

Figure 22 Zebu cattle. Photo by Brian Satterlee.

Like the majority of Cameroon people, farming is the principal activity in the Adamawa as well, generally an upland cereal based system which is the prevalent system in semi-arid climates (Beets, 1990). Approximately 25 years ago, millet and manioc dominated small fields (Yebit, 2004). Today maize (*Zea mays*) cultivation is the principal farm crop on bigger plots, sometimes more than five hectares in size. Smaller gardens of sugar cane (*Saccharum officinarum*), tomatoes (*Lycopersicon lycopersicum*), snap beans (*Phaseolus vulgaris*), pepper (*Capsicum annum*), pineapple (*Ananas comosus*), and groundnuts [peanuts] (*Arachis hypogaea*) supplement income and add nutrients to people's diets (Figure 23).

Figure 23 A small garden in the Adamawa Province. Photo by Brian Satterlee.

Additional sources of income include using the area's natural resources to construct and sell rope, fencing, and bricks as well as self-employment as tailors and operating plows (Figures 24-28).

Figure 24 A Mboum man making rope. Photo by Brian Satterlee.

Figure 25 Locally made fencing. Photo by Brian Satterlee

Figure 26 Bricks sell for 25 French CFA each. Photo by Brian Satterlee.

Figure 27 A Fulbé man supplementing his income as a tailor. Photo by Brian Satterlee.

Figure 28 A Duru family plowing a client's field. Photo by Brian Satterlee.

Geography

The Adamawa is perhaps Cameroon's most diverse area (Yebit, 2004). Mountainous areas like the Gotel and Mambila Mountains border Nigeria and to the east the Tchabal Mbabo peak at 2460 m. The Adamawa Plateau then begins to the north at about 6 degrees latitude and continues to about 8 degrees. It stretches east to the Central African Republic (CAR). Altitudes average 1000 to 2000 m, but dip to a low of 500 m in the Djérem and Mbéré valleys.

Soils are generally brown or brownish-red ferralitic developed from ancient basalts (Figure 29), the result of the annual shift between dry and wet conditions and soil wash from the mountains (Mapongmetsem, 2005). Iron and aluminum content is high causing oxidized hardpans. Many of the province's mountains contain a mixture of several soil types.

Figure 29 Brownish-red basalt soils in the Adamawa. Photo by Brian Satterlee.

The Adamawa is often referred to as Cameroon's water tower because many of the country's rivers begin in the province (Yebit, 2004). They all fall into a tropical regime, a period of high water from May to September (rainy season) and a period of low water or possibly complete dryness from October to April. They drain into three basins: the Niger River, Lake Chad, and the Atlantic Ocean (Yebit, 2004).

Climate

The climate of the Adamawa Plateau is classified as tropical of the Sudano-Guinean type (Mapongmetsem, 2005). There are two seasons. The dry season or *la saison seche* (Figure 30) begins in November and lasts until April. Nightly temperatures from November to January are around 15°C. In March and April afternoon temperatures climb to over 38°C . The wet season (*la saison de pluie*) starts in April. Rainfall averages approximately 1300 mm annually. Heaviest precipitation occurs in the months of May, June, and August. The vista changes from light brown to a sea of green as vegetation springs back to life (Figure 31).

Figure 30 Dry season in the Adamawa. Photo by Brian Satterlee.

Figure 31 Wet season in the Adamawa. Photo by Brian Satterlee.

Trees

Most of the Adamawa is sparsely wooded savanna with heavily wooded areas bordering the many rivers and streams (Yebit, 2004). Notable tree species include *Eucalyptus cameldulensis* and *Ficus spp* as well as fruit trees such as mango (*Mangifera indica*), papaya (*Carica papaya*), avocado (*Persea americana*), banana (*Banana spp*), grapefruit (*Citrus paradisi*), and oDifference (*Citrus sinensis*) (Figure 32). Agroforestry species (Figure 33) include *Caesalpinia decapitala, Senna siamea,* and *Entada abyssinica* (Mapongmetsem, 2005).

Figure 32 Eucalyptus, mango, papaya trees. Photo by Brian Satterlee.

Figure 33 *Senna siamea* tree. Photo by Brian Satterlee.

Mbang-Mboum

Mbang-Mboum is a Muslim dominated canton located at latitude 7°30’ N and longitude 13°50’ E (Figure 34). The name is derived from the neighboring mountains (Mbang) and the area’s first settlers (Mboum) (Ahmadou, 2004). Population is approximately 900 (Ahmadou, 2004). There is no electricity or running water and limited health care at the village health center. The principal activity is maize cultivation, using a mid-elevation cultivar, SHABA (Christensen, 1994). Market day is every Wednesday when villagers sell their grains and other produce from homegardens (Figure 35). Methods to increase yields and income are a top priority.

Figure 34 The village of Mbang-Mboum. Photo by Brian Satterlee.

Figure 35 Market day is every Wednesday in Mbang-Mboum. Photo by Brian Satterlee.

Mbang-Mboum and other villages throughout the Adamawa suffer from a lack of infrastructure, economic development, and social programs in comparison to the northern and southern provinces. Farming is generally the only available occupation. Access to markets is difficult due to poor roads. Life skill programs including financial management, time management, and family planning are uncommon. The government eliminated its 65% subsidy of fertilizer costs; crop yields are dwindling. People here feel lost, forgotten, and desperate.

SECTION 2

RESEARCH

CHAPTER 4 INTRODUCTION TO RESEARCH

Adamawa residents have sufficient water resources, a favorable climate, and low population density. The various ethnic groups boast of peaceful co-existence for centuries. Vegetation used for firewood, to construct houses, fencing, and rope is adequate. Desertification is not yet a major concern. However, inhabitants of the Forgotten Province have not experienced development programs enjoyed in other areas of Cameroon.

The government once subsidized the cost of fertilizers, so farmers enjoyed higher yields, increased income, and ample food supply. Today those subsidies have been eliminated. Farmer morale suffers. Thus a need exists for an inexpensive, natural, and sustainable chemical fertilizer alternative in the Adamawa. Using green manure is an excellent choice (Beets, 1990).

Adoption of a new technology such as green manure is a difficult and slow process, particularly when new methods originate from a development worker. Farmers have been practicing the same techniques for generations and are hesitant to change them. A whole seasons' crop could be lost by a poorly executed technical introduction. Often it is simply not worth the risk.

The challenge was to convince farmers that green manure was a viable chemical fertilizer alternative. Telling people is rarely as effective as teaching them. The combination of hands on education and tangible results was the key. Thus, the purpose of this field trial was to determine how the leaves of *Entada abyssinica* used as green manure would improve maize yield and soil properties. Perhaps favorable results could convince farmers of its value.

CHAPTER 5 METHODS

Entada abyssinica cuttings were applied as a mulch (spread evenly on the surface) or mixed with the soil using a hoe in two different quantities. Maize was sown and harvested at physiological maturity. Soils samples were taken prior to applying the cuttings and again five weeks before harvest. Yield data was obtained after harvest. Characteristics of the trial plot will be described first in this section followed by information about *Entada abyssinica.* Next, the experimental design will be explained preceding a description of the field work used for the trial. Finally, this section will conclude with a description of the statistical analysis methodology.

Location

The research plot was located in a two-hectare farm in the village of Luomo-nangue. Located approximately 8 km northwest of Mbang-Mboum, Luomo-nangue bordered the recently completed Ngaoundéré-Touboro highway (Figure 36). The farm was protected by barbed wire and wood posts on three sides. The fourth side bordered a stream and was left unprotected. Crop damage from free roaming cattle and monkeys from the surrounding mountains had been experienced in the past. The plot was planted in maize in July 2005 and laid fallow after harvest. Trials began in July 2006.

Figure 36 The village of Luomo-nangue. Photo by Brian Satterlee.

Species used

Entada abyssinica (Steud.ex A.) is a savannah tree that grows to 12m (FAO, 2006). Its branches are low to the ground. The crown is narrow and open (Figure 37). The bark has crevices and is gray in color (Figure 38). Leaves are alternate, compound, and bipinnate measuring up to 45cm in length with up to 20 pairs of leaflets. Flowers are white to creme colored, 7 to 15cm long (Figure 39). Pods can grow 15 to 30cm in length and contain 12 to 15 seeds (Figure 40 and Figure 41). The seeds are encased in a two-winged capsule (Figure 42). There are 3900 to 4000 seeds per kilogram (Figure 43), (FAO, 2006).

Figure 37 *Entada abyssinica* tree during the dry season. Photo by Brian Satterlee.

Figure 38 *Entada abyssinica* bark is creviced and fire resistant. Photo by Brian Satterlee.

Figure 39 *Entada abyssinica* leaves and flowers. Photo by Brian Satterlee.

Figure 40 *Entada abyssinica* seed pods can measure up to 30cm. Photo by Brian Satterlee.

Figure 41 *Entada abyssinica* seed pods. Photo by Brian Satterlee.

Figure 42 *Entada abyssinica* seed envelope. Photo by Brian Satterlee.

Figure 43 There are 3900 to 4000 seeds per kilogram. Photo by Brian Satterlee.

Entada abyssinica is native to Africa and can be found throughout the Sudanian and Guinean Savannas from Ivory Coast in West Africa to Somalia in East Africa and as far south as Mozambique (World Agroforestry Center, 2006). It is a member of the Fabaceae family and the Mimosaceae subfamily. Members of the family are important sources of animal feed or green manure (FAO, 2006). It fixes atmospheric nitrogen. Growing at elevations between 60 and 2300m and requiring rainfall from 500 to 1300mm, it tolerates soils ranging from loam to clay loams and at times friable clay over laterite (FAO, 2006). It is shade intolerant (FAO, 2006).

Entada abyssinica can be propagated through seedlings, direct sowing, and reproduce naturally by root suckers, seed, and coppicing. Seed treatment involves placing the seeds in hot water overnight then placing them in polypots. Germination rates vary between 70 and 90%. Seedlings are outplanted after 3 to 4 months (Figure 44), (FAO, 2006).

Figure 44 Outplanting a seedling from a polypot. Photo by Brian Satterlee.

Indigenous tree species like *Entada abyssinica* have often been used throughout the tropics to satisfy peoples' basic needs. Rural households depend on trees for firewood, fruit, and traditional medicines as well as to provide shade and fodder for livestock (Nair, 1998). Indigenous tree species are found to be more resistant to pests and diseases than non-native species. Exotic species, on the other hand, are prone to pest and disease problems and can also become invasive.

Entada abyssinica is used throughout Africa as medicine, mulch, and in rainmaking ceremonies (FAO, 2006). The root bark is boiled and then removed and the remaining liquid is consumed as a traditional remedy for chronic cough, headache, and stomach pains (Rukangira, 2004). In the Nkol-Nguele village in the Center Province of Cameroon, the fruit is used as a scraping stick to smooth calabash walls during pottery making (Swartz, 1989). Found in the Adamawa Province of Cameroon (Mapongmetsem et al, 2005), it is commonly known as *pade waandu* or monkey sandals because of the shape of its leaflets (Figure 45).

Figure 45 *Entada abyssinica* leaflets. Photo by Brian Satterlee

Because *Entada abyssinica* is abundant and well recognized in the Adamawa it can be rapidly incorporated in the farm system. Green manuring involves adding leafy biomass to soils in order to improve soil fertility (Thurston, 1997). Valuable nutrients such as nitrogen, phosphorous, and potassium are released into the soil as the biomass decomposes. The biomass also holds water that assists in transporting nutrients to the roots of associated crops, like maize. Green manure also suppresses weed growth, improves soil structure, and helps in the prevention of soil erosion.

Experimental Design

A complete-block design of five blocks with five treatments was laid out sequentially on a plot measuring 30 x 15 m (Figure 46). Each subplot measured 6 x 3 m. The following specifications were arranged in each block:

1. Treatment A was the **control**. No cuttings were applied.
2. Treatment B used 1.25 kg cuttings and was mixed with the soil using a hoe **(1.25/Mix)**.
3. Treatment C used 1.25 kg cuttings and was mulched on the surface **(1.25/Mulch)**.
4. Treatment D used 2.50 kg cuttings and was mixed with the soil using a hoe **(2.50/Mix)**.
5. Treatment E used 2.50 kg cuttings and was mulched on the surface **(2.50/Mulch)**.

The rationale for the selected quantity of cuttings follows similar experiments in Africa. Kang *et al* (1981a) used nitrogen rate (N-rate) equivalences of 30 and 60 kilograms per hectare (30 and 60 kg N/ha) with *Leucaena leucocephala* prunings as green manure for maize. Similarly, Mugendi *et al* (1999a) used 60kg N/ha equivalencies of *Calliandra calothyrsus* and *Leucaena leucocephala* and monitored soil-fertility changes and maize yield. *Entada abyssinica* nitrogen equivalencies at 1.25 kg and 2.50 kg are 20 and 40 kg N/ha respectively.

Block					
1	A	B	D	E	C
2	D	C	A	B	E
3	B	D	E	C	A
4	A	B	E	C	D
5	D	C	B	A	E

Figure 46 Complete block design of experimental layout.

Field Preparation

Subplots were delineated with nylon cord and wooden stakes. Five soil sample locations were randomly selected in each subplot and taken with a soil auger at 20cm depths (Figure 47). Soil samples were bagged, labeled (Figure 48), and taken to IRAD Nkolbisson office in Yaoundé. Analysis (method in parentheses) included particle size distribution (Pipette method), organic carbon (Black and Walkey method), total nitrogen (mineralization with a Tecator), organic matter (Walkey and Black), C:N ratio, available phosphorus (Bray II), exchangeable cations (Ammonium Acetate N at pH 7), and cation exchange capacity (determination by KCl according to BASCOM at pH 8.1), (Yemefack, 2006). Next the plot was cleared and weeded (Figure 49).

Figure 47 Taking soil samples with soils auger. Photo by Brian Satterlee.

Figure 48 Soils auger and bagged soils samples. Photo by Brian Satterlee.

Figure 49 Cleared and weeded trial plot. Photo by Brian Satterlee.

Cuttings applications

Small branches of *Entada abyssinica* trees bordering the farm were cut with a machete (Figure 50). Generally this species is not intercropped with field crops because of its shallow root system and competition for water, light, and nutrients. Stems larger than 10mm were removed (Figure 51) and the remaining smaller stems and leaves were allowed to air dry for three days. Cutting and removing stems required 8.5 labor hours. The cuttings were then weighed (Figure 52) and either mixed with the soil using a hoe or applied evenly on the top of the soil as a mulch to the subplots. This process took 11 labor hours.

Figure 50 Cutting *Entada abyssinica* branches. Photo by Brian Satterlee.

Figure 51 Removing large stems. Photo by Brian Satterlee.

Figure 52 Weighing *Entada abyssinica* cuttings. Photo by Brian Satterlee.

Sowing maize

Sowing the maize cultivar SHABA followed traditional practices using local tools. SHABA is a mid-elevation variety that was developed in 1988 by a USAID project in the Shaba Province, Democratic

Republic of the Congo (formerly Zaire). It was introduced and adopted in the Adamawa Province of Cameroon shortly afterwards (Christensen, 1994).

Spacing distance also followed traditional planting methods. Maize was sown at a spacing of 80 cm x 25 cm. The intra-row spacing (25 cm) allows enough distance to avoid competition between the individual maize plants. Inter-row spacing (80 cm) provides an adequate distance for farmers' access when weeding and harvesting.

Two seeds were planted per hole and later thinned to one 2 weeks after planting (2 WAP). Following a common practice, the seeds were treated with an insecticide prior to planting (Figure 53). The plot was weeded 2 WAP, 6 WAP, and 12 WAP (Figure 54). Leaves and small stems of *Entada abyssinica* were cut, dried for three days, and applied again 6 WAP in the same levels as the first application (1.25kg and 2.50kg). Maize was harvested at physiological maturity, the husks removed, and weighed (wet weight) including the cob by subplot to obtain yield (Figure 55). The preceding activities are summarized in Table 2.

Figure 53 Sowing maize two seeds per hole. Photo by Brian Satterlee.

Figure 54 Weeding. Photo by Brian Satterlee.

Figure 55 Weighing maize. Photo by Brian Satterlee.

Activity	Date (2006)	WAP	Labor hours
Soil samples	April 18	N/A	N/A
Clear plot	May 22 week	N/A	18.00
Cut *Entada abyssinica*	May 30	N/A	8.50
Apply cuttings	June 2	N/A	11.00
Sow maize	June 9	N/A	7.00
Weed, thin maize	June 26	2	10.00
Weed, cut *Entada abyssinica*	July 19	6	16.00
Apply cuttings	July 22	6	11.00
Soil samples	August 14	10	N/A
Weed	August 30	12	8.00
Harvest, weigh maize	September 21	15	6.00
Soils Test Results	November 24	N/A	N/A

Table 2 Schedule and labor hours used for 0.11 hectare research plot.

Statistical Analysis

Analysis of variance (ANOVA) following Steele and Torrie (1960) was conducted on the data set according to the experimental design using the SAS (SAS Institute, 2003) procedures PROC UNIVARIATE, PROC MEANS, PROC GLM, and PROC CORR. Means of soil properties before and after treatment were tested with paired t-test and declared significantly different at $P < 0.10$. Correlations using Pearson's Correlation were declared significant at $P < 0.10$. P values are reported throughout the Results and Discussion chapter. Appendix B shows the SAS code used in the statistical analysis of the data set.

CHAPTER 6 DATA

Data for this study consists of soil samples analyzed at IRAD Nkolbisson and maize yield information, both from the trial plot in Luomo-nangue. Results from soil sample analysis for clay content, fine silt content, coarse silt content, total silt content, fine sand content, coarse sand content, total sand content, organic carbon, nitrogen, organic matter, carbon to nitrogen ratio, pH (water method), pH (KCl method), calcium, magnesium, potassium, sodium, sum of bases, base saturation, available phosphorus, acidity, and Cation Exchange Capacity (CEC) are represented in Table 3 through Table 26 respectively. The complete data set is shown in Appendix B.

The first soil samples (Test 1) were taken before any field preparation for the trial began. The second samples (Test 2) were taken approximately ten weeks after the trial began. Thus both applications of *Entada abyssinica* cuttings had been applied and allowed to decompose prior to the second soil samples being taken.

Table 3 Maize yield in kilograms by treatment

Treatment	**Yield**	**Average**	**Difference**[1]
A	26.74	5.35	7.92
B	30.37	6.07	4.62
C	20.80	4.16	5.28
D	37.96	7.59	5.28
E	20.14	4.03	4.29
Total	136.01		

[1] Difference = High value – low value throughout tables

Table 4 Clay Content Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	25.08	10.70	36.00	12.90
B	18.50	23.60	35.20	5.80
C	19.20	8.40	34.62	4.00
D	22.50	12.70	35.52	10.10
E	20.76	6.40	33.48	3.60

Table 5 Fine Silt Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	26.88	10.70	26.96	6.90
B	27.34	5.10	24.88	6.50
C	28.54	4.70	25.82	4.30
D	25.86	7.70	26.26	4.80
E	30.46	14.80	25.58	6.50

Table 6 Coarse Silt Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	24.54	5.80	12.60	5.00
B	23.94	2.60	12.94	4.20
C	25.58	3.50	12.54	3.30
D	30.44	12.30	15.44	3.00
E	22.76	14.30	15.64	2.40

Table 7 Total Silt Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	51.42	14.70	39.58	4.30
B	51.28	4.20	37.82	5.80
C	54.10	5.00	38.38	7.70
D	56.26	15.40	41.72	6.00
E	53.20	4.10	41.24	7.90

Table 8 Fine Sand Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	7.62	2.10	12.96	8.50
B	8.88	4.20	13.70	3.00
C	7.24	4.00	14.00	8.50
D	5.58	4.00	10.92	6.60
E	6.24	2.50	11.20	3.20

Table 9 Coarse Sand Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	14.26	5.80	11.44	7.00
B	18.16	2.90	12.88	5.50
C	18.82	6.70	13.04	2.70
D	15.72	8.10	11.86	5.50
E	19.84	5.30	14.06	7.60

Table 10 Total Sand Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	21.88	6.20	24.40	15.50
B	27.02	5.40	26.60	4.40
C	26.06	8.60	27.02	10.70
D	21.30	11.00	22.78	10.60
E	26.04	5.20	25.30	9.90

Table 11 Organic Carbon Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	1.500	0.33	1.500	0.11
B	1.416	0.22	1.448	0.07
C	1.498	0.13	1.513	0.25
D	1.462	0.32	1.542	0.08
E	1.544	0.17	1.580	0.09

Table 12 Nitrogen Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	0.350	0.16	0.384	0.21
B	0.394	0.14	0.384	0.07
C	0.408	0.30	0.380	0.15
D	0.332	0.08	0.348	0.13
E	0.408	0.26	0.332	0.13

Table 13 Organic Matter Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	2.5858	0.569	2.5862	0.189
B	2.4412	0.380	2.4962	0.121
C	2.5822	0.224	2.6102	0.413
D	2.5206	0.552	2.6582	0.138
E	2.6616	0.293	2.7240	0.155

Table 14 C:N Ratio

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	4.38	2.40	4.04	2.40
B	3.66	1.30	3.80	0.80
C	3.88	2050	4.10	1.60
D	4.40	0.30	4.54	2.10
E	3.92	2.10	4.92	2.10

Table 15 pH Water

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	6.14	0.20	6.00	0.20
B	6.26	0.30	6.02	0.30
C	6.14	0.30	6.06	0.10
D	6.20	0.20	6.34	0.80
E	6.16	0.20	6.12	0.10

Table 16 pH KCl

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	4.18	0.40	4.76	0.20
B	4.08	0.30	4.68	0.20
C	4.18	0.40	4.60	0.60
D	4.06	0.10	4.62	0.20
E	4.38	1.10	4.78	0.30

Table 17 Calcium (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	3.686	1.32	4.288	1.32
B	3.628	1.11	3.990	1.10
C	3.852	1.23	4.084	0.15
D	3.828	0.52	3.976	0.53
E	3.538	1.01	4.248	0.55

Table 18 Magnesium (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	0.866	0.37	0.434	0.14
B	0.936	0.40	0.442	0.20
C	0.968	0.24	0.350	0.11
D	0.852	0.30	0.334	0.15
E	0.836	0.33	0.398	0.03

Table 19 Potassium (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	0.178	0.04	0.630	0.42
B	0.196	0.03	0.664	0.51
C	0.140	0.08	0.698	0.23
D	0.180	0.01	0.674	0.51
E	0.140	0.04	0.856	0.35

Table 20 Sodium (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	0.056	0.03	0.124	0.07
B	0.078	0.05	0.126	0.11
C	0.040	0.06	0.134	0.04
D	0.070	0.05	0.126	0.09
E	0.052	0.02	0.146	0.06

Table 21 Sum of Bases (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	5.038	1.39	5.264	1.00
B	5.310	0.32	5.584	1.27
C	4.276	1.54	5.116	0.37
D	4.930	0.97	5.108	0.82
E	4.566	1.34	5.648	0.48

Table 22 Cation Exchange Capacity (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	24.08	7.50	26.76	12.40
B	27.00	6.50	24.10	7.10
C	28.92	7.40	16.96	13.40
D	25.20	13.00	22.54	12.80
E	27.44	9.30	24.66	3.00

Table 23 Base Saturation Percent

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	21.20	4.00	20.40	8.00
B	19.80	6.00	23.40	12.00
C	15.00	8.00	33.20	25.00
D	20.40	9.00	24.00	15.00
E	16.80	4.00	23.00	4.00

Table 24 Available Phosphorus (ppm)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	6.86	2.60	8.38	4.00
B	5.60	6.20	9.00	18.10
C	7.40	5.30	7.54	4.50
D	6.30	5.70	7.66	5.00
E	7.06	3.20	11.22	13.00

Table 25 Acidity (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	1.454	1.15	0.604	1.21
B	1.152	1.74	0.940	0.62
C	1.610	2.33	0.830	0.61
D	1.618	1.16	0.862	0.74
E	0.924	1.16	1.196	1.18

Table 26 ECEC (cmol/kg)

Treatment	Test 1 Average	Test 1 Difference	Test 2 Average	Test 2 Difference
A	6.492	0.55	5.868	0.41
B	6.462	1.69	6.524	1.73
C	5.886	3.43	5.946	0.87
D	6.548	0.78	5.970	0.67
E	5.490	2.22	6.844	1.28

SECTION 3

IMPLICATIONS OF STUDY

CHAPTER 7 RESULTS AND DISCUSSION

Leguminous plants produce sufficient amounts of biomass which can be used as green manure to release nutrients into the soil and improve soil physical properties. As a result, soil fertility is increased, inorganic fertilizer use can be reduced, and crop yields can be improved naturally (Ogunnika, 2005). For example, *Entada abyssinica* leaves, raches, and petioles contain 2.99% N, 0.30% P, 0.75% K, 2.58% Ca, and 0.46% Mg (Anthofer *et al*., 1998). In this experiment maize yield and some soil properties experienced significant differences depending on the application method, the amount, and the interaction between these two variables as a direct result of *Entada abyssinica's* use as green manure.

Maize Yield

Yield depended upon how the cuttings were incorporated. Mixed incorporation generated 3.76 metric tons/hectare (Figure 56), which was significantly greater than mulching and the control ($P = 0.0613$). Mulching and the control were not significantly different from each other. Additionally, mixing a higher quantity of *Entada abyssinica* cuttings showed a significant correlation to yield and generated 4.22 metric tons/hectare, the highest of the four treatments and higher than the control (Figure 57), ($r = 0.45$, $p = 0.02$).

Figure 56 Maize yield (metric tons/hectare) by treatment

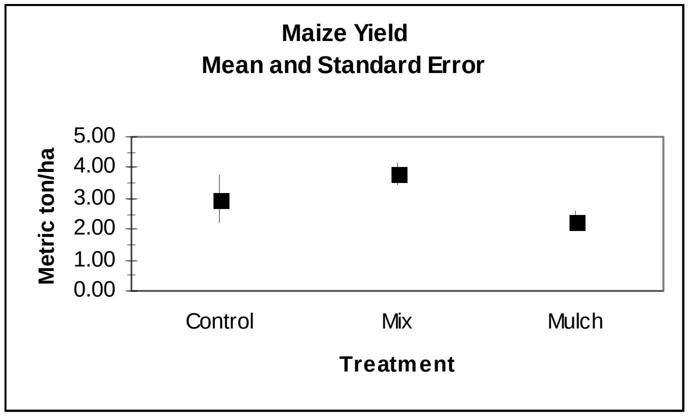
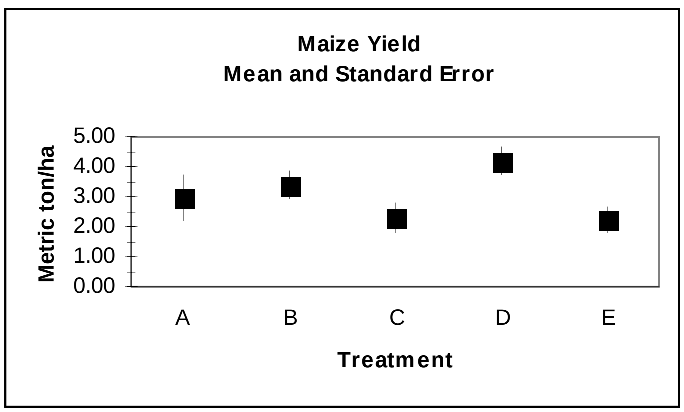


Figure 57 Maize Yield by treatment



In a related study by Mugendi *et al*. (1999b) in the Eastern Province of Kenya, similar quantities of *Leucaena leucocephala* cuttings mixed into the soil without supplemental inorganic fertilizer generated over four metric tons/hectare maize grain yield. Mixing rather than mulching resulted in higher maize yields as well in a field trial by Kang *et al*. (1981b) in southern Nigeria. In this experiment using *Entada abyssinica* cuttings, mixing resulted in highest yields.

However, these findings are not consistent with other trials involving different application methods of leguminous cuttings. Read *et al*.

(1985) used eight treatments with five replications in a randomized complete block design in southwest Nigeria. No difference in maize yield was shown between the two methods. Similarly, an alley cropping experiment in Haiti by Isaac *et al*. (2004) found no maize yield increase when cuttings applied were mixed or mulched.

Economically, this trial indicates that adopting the practice of green manure with *Entada abyssinica* can have enormous, rapid results for smallholder farmers in the Adamawa. For example, assume that a 100 kg sack of maize costs 9,000 FCFA ($US 18.33)[2] and a farmer uses a quarter hectare for maize cultivation. Compared to the control plot yield, mixing *Entada abyssinica* cuttings at a rate of 347 kg per quarter hectare would result in an additional three sacks of maize valued at 27,000 FCFA ($US 54.99). Even after subtracting the additional labor cost of mixing the cuttings with a hoe (6000 FCFA, $US 12.22), the farmer is left with an extra 21,000 FCFA ($US 42.77). This additional revenue could pay for fees and supplies for a secondary school student for an entire year.

Soil Properties

Plants require seventeen essential elements in order to grow and reproduce. Generally, these elements are crucial to plant survival and cannot be replaced by other elements. They are classified as either macronutrients or micronutrients based on the plant requirement (Jones and Jacobsen, 2005).

Despite a lack of formal agricultural education, farmers in the

[2] 1$US = 491 FCFA on 3/22/2007 (Source: http://www.xe.com/ucc/convert.cgi)

Adamawa are knowledgeable about the benefits of nitrogen, potassium, and phosphorous to their crop yields. They know that these three elements comprise the majority of maize's macronutrient demands (Leonard, 1981). Unfortunately, NPK chemical fertilizers are generally beyond their means and even when purchased are used at levels well below those recommended.

In most of the tropics and particularly in Africa, nitrogen deficiency is the single most limiting factor to crop yields (Mugendi et al, 1999b). In this experiment, no statistically significant differences among the treatments and the control were found for nitrogen ($P = 0.5287$). Nitrogen percent Differenced from 0.332% to 0.408% before *Entada abyssinica* cuttings were applied and 0.332% to 0.384% five weeks before maize harvest (Table 27). According to a soil scientist from IRAD Nkolbisson who analyzed the soil samples, initial nitrogen levels can be considered very high in all treatments and the control in this experiment (Yemefack, 2006).

Table 27 Nitrogen percent by treatment

Treatment	Test 1	Test 2
A	0.350	0.384
B	0.394	0.384
C	0.408	0.380
D	0.332	0.348
E	0.408	0.332

Notes Test 1 = Results from soil samples taken prior to cutting application
Test 2 = Results from soils samples taken five weeks before maize harvest

Potassium promotes starch and sugar formation, stalk and root growth, and ear development (Leonard, 1981). Potasssium levels increased significantly across all treatments and the control in this experiment (Table 28). The control treatment increased over 250%, due perhaps to a crop residue collected in the second soil samples. Treatment B through Treatment E increased 239%, 399%, 274%, and 511% respectively. Several studies support similar findings when using agroforestry species to improve soil properties. Raddad *et al.* (2005) reported K increases when *Acacia senegal* was used for improved fallow while Kang *et al.* (1999) found higher soil potassium concentration in a long term alley cropping trial with four different hedgerow species in Nigeria. When the cuttings were mulched potassium showed a significant increase and higher final levels (P = 0.0635).

Table 28 Potassium percent by treatment

Treatment	Test 1	Test 2
A	0.178	0.630
B	0.196	0.664
C	0.140	0.698
D	0.180	0.674
E	0.140	0.856

Notes Test 1 = Results from soil samples taken prior to cuttings application
Test 2 = Results from soils samples taken five weeks before maize harvest

Phosphorous is important for root growth, flowering, and seed formation (Leonard, 1981). Maize grown on phosphorous deficient soils suffer from stunting, delayed maturity, and poor ear development (Crozier, 2000). In this experiment, mulching 2.50 kg of *Entada abyssinica* showed a significant increase for P (Table 29). Treatment B through Treatment E increased 60.71%, 1.89%, 21.59%, and 58.92 % respectively while the control increased 22.16%. Kaho *et al.* (2004) also found available P to increase in soil samples taken at 0 to 15cm depths over four years under a *Desmodium distortum* fallow trial in Cameroon's Center province. Leaching of phosphorous from agricultural soils is generally low due to its insolubility and could be a factor in the increase (Stevenson, 1986).

Table 29 Phosphorous (ppm) by treatment

Treatment	Test 1	Test 2
A	6.86	8.38
B	5.60	9.00
C	7.40	7.54
D	6.30	7.66
E	7.06	11.22

Notes Test 1 = Results from soil samples taken prior to cuttings application
Test 2 = Results from soils samples taken five weeks maize harvest

An additional problem concerning NPK chemical fertilizers occurred in both the 2005 and 2006 cropping season in Mbang-Mboum and surrounding villages. Four GICs (Groupe d'Initiative Communitaire) pooled their resources and purchased chemical fertilizer through an NGO located in Ngaoundéré, the district capital. The shipment did not arrive in time for timely field application and farmers sowed maize without it. Two whole seasons' maize crop yield was drastically reduced. According to the results of this experiment, the use of *Entada abyssinica* could have at least partly reduced this loss.

Exposure to the use of tree litter as an organic soil fertility improvement method has been minimal in the Adamawa. Farmers are unaware of its ability to enhance the microclimate and its effectiveness in suppressing weed growth. Their use of crop residues and cattle manure during the dry season, however, indicates an understanding of organic matter use to improve soil fertility. It is natural, inexpensive, and sustainable and has been utilized throughout the province for decades.

The soils tests results showed organic matter buildup as a result of *Entada abyssinica* use and could be a valuable complement to farmers' traditional practices (Table 30). Additionally, significant differences were found between how the cuttings were incorporated ($P = 0.0559$) and amount of cuttings applied ($P = 0.0060$). Ogunnika *et al.* (2005) found organic matter soil content to increase as well when soil including four nitrogen-fixing trees' leaf fall was compared with untreated farmland soil in southwest Nigeria.

Conversely, Aweto and Iyanda (2003) found no significant increase in organic matter in soils under thirty *Newbouldia laevis* trees in ten plots in southwestern Nigeria.

Table 30 Organic matter percent by treatment

Treatment	Test 1	Test 2
A	2.586	2.586
B	2.441	2.496
C	2.582	2.610
D	2.521	2.658
E	2.662	2.724

Notes Test 1 = Results from soil samples taken prior to cuttings application
Test 2 = Results from soils samples taken five weeks before maize harvest

Besides increasing soil fertility, organic matter contributes to soil aggregation, aids in reducing erosion, and helps prevent micronutrient leaching (Sanchez, 1976). Every farmer should strive to increase the organic matter in his or her farm (Kohnke, 1966). However, adoption depends on expected returns and particularly the speed at which these returns are realized (Scoones and Toulmin, 1999). This trial, over a single cropping season, indicates immediate soil characteristics improvement by including organic matter in farmers' cropping systems and could potentially help increase adoption rates in the Adamawa. Kang *et al.* (1999) showed that the use of organic matter in Nigeria could maintain soil productivity over the long-term as well.

Organic carbon is a component of organic matter and provides an energy source for soil microorganisms. These microorganisms in turn assist in the decomposition of organic matter (Howell, 2004). In this trial the organic carbon was found to vary significantly with amount of cuttings applied (P = 0.0076). A greater quantity of cuttings will result in greater organic carbon availability. In a field trial in Ibadan, Nigeria, Kang *et al.* (1985) applied *Leucaena leucocephala* cuttings over a six year period and found organic carbon soil content to increase each year and by 65% overall.

Changes in other soil property and related fertility indicators in this trial were shown to be significant. Decreases were shown for pH (water method), magnesium, and CEC. The carbon to nitrogen ratio (C:N Ratio), pH (KCl method), calcium, sodium, sum of bases, and base saturation showed significant increases. No significant block impact was found. It was included in the experimental design as the study size was originally larger but later reduced. Soil property changes in the control plots are a result of macronutrient and micronutrient demands and additions of the associated maize crop.

Table 31 summarizes the results found from the statistical analysis of this data set. Correlation results reinforce those found by the analysis of variance.

Table 31 ANOVA declared significantly different at P < 0.10. Values in red are significant. Decreases denoted with * symbol.

	ANOVA		
VARIABLE	HOWINC	AMOUNT	HOWINC*AMOUNT
Yield	0.0613	0.5226	0.4478
N	0.7372	0.1670	0.8388
K	0.0635	0.1334	0.1827
P	0.5152	0.4691	0.1312
OM	0.0559	0.0060	0.5882
OC	0.1255	0.0076	0.5705
Ca	0.2312	0.6181	0.5548
Mg	0.2363	0.2965	0.0127*
C:N Ratio	0.3565	0.0531	0.8938
pH (water method)	0.1415	0.0173*	0.0880*
pH (KCl method)	0.4247	0.3828	0.0916
Na	0.1653	0.5420	0.5420
Sum of Bases	0.8290	0.8602	0.0053
CEC	0.0696*	0.1341	0.0301
Base Saturation	0.0674	0.0841	0.0548

Notes HOWINC = How the cuttings were incorporated
AMOUNT = Amount (kg) of cuttings applied
HOWINC*AMOUNT = Interaction between how the cuttings were incorporated and amount of cuttings applied

Data from Table 31 indicates that this one year study improved maize yield and soil properties with the use of *Entada abyssinica* cuttings as green manure. Mixing the cuttings resulted in significantly higher maize yields. In addition, greater amounts of cuttings significantly increased organic matter. As a result, the soil in this trial became less acidic as indicated by an increase in pH (KCl method). The reduced acidity made soil nutrients more readily available. Potassium and sodium increased significantly. As components in determining a soil's base saturation and sum of bases, it follows that these two soil fertility indicators increased as well. Magnesium levels were originally low, supported by low calcium to magnesium ratios. The associated maize crop's demand for this nutrient may have caused it to decrease significantly.

How the cuttings were applied impacted yield, potassium, organic matter, pH (water method), CEC, and base saturation. Amount showed significant increases for organic matter and organic carbon. The interaction between how the cuttings were applied and amount of cuttings affected magnesium as well as sum of bases, CEC, and base saturation.

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS

Farmers in the Adamawa province lead a simple but extremely hard life. Days begin before dawn with a hike to their farms, perhaps after a cup of tea. Once there, they engage in exhausting work including tilling and weeding with tools often considered to be primitive. Returning to their mud huts at dusk, they eat, socialize, and bed down for the night. The cycle continues day after day.

Subsistence farmers' small scale farms and home gardens provide not only their food source but their income as well. Generally, any excess is sold at the weekly market and the revenue used to pay school fees and taxes, buy clothing, help an ill family member, and maybe a rare trip to the district capital. This is not a life of excess.

Population pressure is jeopardizing traditional farming practices in the Adamawa. Without methods to maintain fertility, soils are depleted of valuable nutrients necessary to sustain adequate crop yields. To compound the problem, chemical fertilizers are beyond the means of most farmers.

This study shows that the incorporation of cuttings from a local, indigenous, abundant tree species is a viable alternative to chemical fertilizer use. Not only did *Entada abyssinica* cuttings increase maize yield when mixed with the soil, but also increased organic matter and potassium, and raised soil pH levels. More importantly, these results occurred in the same cropping season.

A common shortcoming of development work is that it fails to take into consideration the needs, wants, and desires of the local community that the project aims to serve. As a member of the village of Mbang-Mboum for over two years, I personally spoke to over 700 farmers and was told that improving maize yield, immediately, was their primary objective. Fertile soil would help, but higher maize productivity was paramount (Bunch, 1999).

This study was designed in response to the most important needs of these rural farmers. It utilized a native tree species familiar to most villagers. Commonly known as *pade waandu,* or monkey sandals due to the shape of its leaflets, it is used in pottery making, provides traditional medicines, and boundary demarcation. Another use for an existing input was simply shared. Furthermore, results were immediate. The additional labor required to mix the *Entada abyssinica* cuttings would pay off in the same cropping season as well. Three additional sacks of maize valued at 21,000 FCFA ($US 42.77) could be realized at harvest from a quarter hectare of land.

Short term results emphasizing indigenous tree species is crucial to adoption rates. These adoption rates in turn provide for the sustainability of agricultural development (Bunch, 1999). This study satisfies both these requirements and could be a successful method to increase farmer's income in the Adamawa.

Farmers in the Forgotten Province will continue to live with or without outside assistance. They will persist through droughts, pest infestations, births, and deaths as they have for centuries. However, if they can be convinced to adopt the appropriate agroforestry technique, they might be recognized as the people that built their own capacity by taking a chance. And that won’t be easily forgotten.

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Appendix B

SAS code used for statistical analysis of the data set

ANOVA

```
proc glm; class  HOWINC AMOUNT BLOCK ;
model YIELD =  HOWINC AMOUNT BLOCK HOWINC*AMOUNT ;
means  HOWINC AMOUNT /tukey alpha=.1 ;

proc end;
```

Paired T Test

```
PROC MEANS  N MEAN STDERR T PRT ;

VAR DOMA;

RUN;
```

Descriptive statistics

```
PROC UNIVARIATE ;

VAR
TREATA  TREATB    TREATC    TREATD    TREATE

BLOCK    AMOUNT  HOWINC   YIELD

OC1    OC2    N1    N2    OM1    OM2    CN1    CN2
PHW1    PHW2    PHKCL1    PHKCL2    CA1    CA2
MG1    MG2    K1    K2    NA1    NA2
SUMBASE1    SUMBASE2    CEC1    CEC2
BASESAT1    BASESAT2    AVAILP1    AVAILP2
ACIDITY1    ACIDITY2    ECEC1    ECEC2

;

RUN;
```

Correlation

```
PROC CORR ;

VAR
TREATA  TREATB    TREATC    TREATD    TREATE

BLOCK    AMOUNT

HOWINC

YIELD

OC1    OC2    N1    N2    OM1    OM2    CN1    CN2
PHW1    PHW2    PHKCL1    PHKCL2    CA1    CA2
MG1    MG2    K1    K2    NA1    NA2
SUMBASE1    SUMBASE2    CEC1    CEC2
BASESAT1    BASESAT2    AVAILP1    AVAILP2
ACIDITY1    ACIDITY2    ECEC1    ECEC2

;

RUN;
```

Appendix C Soil sample results from analysis at IRAD Nkolbisson, Yaoundé, Cameroon. Test 1 from 5/2006. Test 2 from 9/2006.

Sample	Corn Yield	Clay Test1	Clay Test2	Fine Silt Test1	Fine Silt Test2	Coarse Silt Test1	Coarse Silt Test2
	YIELD	CLAY1	CLAY2	FSILT1	FSILT2	CSILT1	CSILT2
A1	3.5	30.4	39	24.4	28.2	27.1	10.6
A2	6.8	26.3	41.4	28.3	27.2	21.3	14.4
A3	2.18	19.7	38.3	30.4	25.7	25.7	11.6
A4	4.16	28	32.8	20.3	30.3	22.3	10.8
A5	10.1	21	28.5	31	23.4	26.3	15.6
B1	7.13	21.5	38.3	29.5	25.1	23.7	10.8
B2	6.8	23.6	37.3	26.8	23.1	22.5	14.6
B3	8.12	21.8	35.8	24.4	25.1	24.8	11.4
B4	3.5	24.6	32.5	27.7	28.8	23.6	12.9
B5	4.82	1	33.7	28.3	22.3	25.1	15
C1	4.16	18.1	37	30.7	28.6	26.1	13.7
C2	0.86	25	33	28.2	24.3	23.5	13
C3	6.14	18.6	33	26	24.6	27	13.3
C4	4.16	20.8	34	29.8	24.3	26.9	10.4
C5	5.48	16.6	36.1	28	27.3	24.4	12.3
D1	7.46	24.2	40.5	24.7	26.1	23.5	15.2
D2	10.1	29.4	34.7	23.5	28.8	28.8	16.2
D3	7.46	24.5	39.7	30.3	25.2	28.6	16.9
D4	4.82	16.7	32.3	28.2	24	35.5	15
D5	8.12	17.7	30.4	22.6	27.2	35.8	13.9
E1	3.5	20.5	35.1	26.9	26.7	24	17.4
E2	2.84	18.5	31.5	28.1	25.8	26.9	15.3
E3	3.5	24.6	33	28.4	20.8	23.6	15.5
E4	7.13	18.2	33.9	27.2	27.3	26.7	15
E5	3.17	22	33.9	41.7	27.3	12.6	15

Sample	Total Silt Test1	Total Silt Test2	Fine Sand Test1	Fine Sand Test2	Coarse Sand Test1	Coarse Sand Test2
	TSILT1	TSILT2	FSAND1	FSAND2	CSAND1	CSAND2
A1	51.5	38.8	8.1	12.7	10.1	9.5
A2	49.7	41.6	8.2	8.8	15.8	8.2
A3	56	37.3	8.4	12.3	15.9	12.1
A4	42.6	41.2	6.3	13.7	15.1	12.2
A5	57.3	39	7.1	17.3	14.4	15.2
B1	53.2	35.9	7.9	14.5	17.4	11.3
B2	49.2	37.7	8.1	13.3	19.2	11.3
B3	49.2	36.5	11.4	15.2	17.7	12.4
B4	51.4	41.7	7.2	13.3	16.8	12.6
B5	53.4	37.3	9.8	12.2	19.7	16.8
C1	56.7	42.4	6.9	9.3	18.2	11.3
C2	51.7	37.4	8.2	16.6	15.1	13.2
C3	53	37.9	6.7	15.1	21.8	14
C4	56.7	34.7	5.2	17.8	17.2	13.5
C5	52.4	39.5	9.2	11.2	21.8	13.2
D1	48.2	41.3	7.3	8.9	20.3	9.3
D2	52.2	45	4.6	8.8	14	11.5
D3	58.9	42.2	4.4	8.2	12.2	9.9
D4	63.6	39	3.8	13.9	15.9	14.8
D5	58.4	41.1	7.8	14.8	16.2	13.8
E1	50.9	44.2	6.6	9.5	22.1	11.3
E2	55	41.1	5.8	12.7	20.7	14.7
E3	52	36.3	6.7	11.8	16.8	18.9
E4	53.9	42.3	7.3	11	20.6	12.7
E5	54.2	42.3	4.8	11	19	12.7

Sample	Total Sand Test1	Total Sand Test2	OC Test1	OC Test2	N Test1	N Test2	Organic Matter Test1	Organic Matter Test2
	TSAND1	TSAND2	OC1	OC2	N1	N2	OM1	OM2
A1	18.2	22.2	1.39	1.53	0.33	0.41	2.396	2.638
A2	23.9	17	1.4	1.48	0.31	0.49	2.414	2.552
A3	24.4	24.4	1.47	1.55	0.35	0.4	2.534	2.672
A4	21.4	25.9	1.72	1.44	0.3	0.34	2.965	2.483
A5	21.5	32.5	1.52	1.5	0.46	0.28	2.62	2.586
B1	25.3	25.9	1.43	1.43	0.41	0.36	2.465	2.465
B2	27.2	24.6	1.26	1.47	0.37	0.35	2.172	2.534
B3	29	27.7	1.48	1.49	0.34	0.42	2.552	2.569
B4	24.1	25.8	1.47	1.43	0.48	0.42	2.534	2.465
B5	29.5	29	1.44	1.42	0.37	0.37	2.483	2.448
C1	25.2	20.6	1.55	1.53	0.6	0.44	2.672	2.638
C2	23.3	29.7	1.43	1.4	0.4	0.3	2.465	2.414
C3	28.4	29.1	1.43	1.6	0.36	0.35	2.465	2.758
C4	22.4	31.3	1.56	1.4	0.38	0.45	2.689	2.414
C5	31	24.4	1.52	1.65	0.3	0.36	2.62	2.827
D1	27.6	18.2	1.57	1.52	0.35	0.39	2.707	2.62
D2	18.6	20.3	1.26	1.52	0.29	0.4	2.172	2.62
D3	16.6	18.1	1.58	1.54	0.37	0.34	2.724	2.655
D4	19.7	28.7	1.46	1.6	0.34	0.27	2.517	2.758
D5	24	28.6	1.44	1.53	0.31	0.34	2.483	2.638
E1	28.6	20.8	1.56	1.53	0.44	0.28	2.689	2.638
E2	26.5	27.4	1.49	1.59	0.37	0.34	2.569	2.741
E3	23.4	30.7	1.56	1.62	0.31	0.26	2.689	2.793
E4	27.9	23.8	1.47	1.58	0.35	0.39	2.534	2.724
E5	23.8	23.8	1.64	1.58	0.57	0.39	2.827	2.724

Sample	C:N Ratio Test1 CN1	C:N Ratio Test2 CN2	pH Water Test1 PHW1	pH Water Test2 PHW2	pH KCL Test1 PHKCL1	pH KCL Test2 PHKCL2	Ca Test1 CA1	Ca Test2 CA2
A1	4.2	3.7	6.2	6	4.4	4.8	4	3.96
A2	4.5	3	6.2	6	4	4.7	4.08	5.1
A3	4.2	3.9	6.1	6.1	4	4.9	3.99	4.6
A4	5.7	4.2	6	6	4.3	4.7	3.6	4
A5	3.3	5.4	6.2	5.9	4.2	4.7	2.76	3.78
B1	3.5	4	6.2	5.9	4	4.8	3.1	3.6
B2	3.4	4.2	6.4	6.2	4	4.6	3.01	4.7
B3	4.4	3.6	6.2	6	4.1	4.6	4.12	4.15
B4	3.1	3.4	6.4	6	4.3	4.7	4.11	3.9
B5	3.9	3.8	6.1	6	4	4.7	3.8	3.6
C1	2.6	3.5	6	6	4	4.8	4	4
C2	3.6	4.7	6.2	6.1	4.1	4.7	4.21	4.08
C3	4	4.6	6.3	6	4.2	4.2	3.97	4.09
C4	4.1	3.1	6	6.1	4.4	4.7	2.98	4.1
C5	5.1	4.6	6.2	6.1	4.2	4.6	4.1	4.15
D1	4.5	3.9	6.3	6.1	4.1	4.6	3.58	4.2
D2	4.3	3.8	6.2	6.2	4	4.7	3.88	3.67
D3	4.3	4.5	6.2	6.3	4.1	4.7	4.1	4
D4	4.3	5.9	6.2	6.2	4	4.5	3.9	3.9
D5	4.6	4.5	6.1	6.9	4.1	4.6	3.68	4.11
E1	3.5	5.5	6.3	6.1	4.2	4.6	2.99	4.21
E2	4	4.7	6.2	6.2	5.2	4.7	3.27	4.51
E3	5	6.2	6.1	6.1	4.1	4.8	3.52	3.96
E4	4.2	4.1	6.1	6.1	4.2	4.9	4	4.28
E5	2.9	4.1	6.1	6.1	4.2	4.9	3.91	4.28

Sample	Mg Test1	Mg Test2	K Test1	K Test2	Na Test1	Na Test2	Sum Base Test1	Sum Base Test2
	MG1	MG2	K1	K2	NA1	NA2	SUMBASE1	SUMBASE2
A1	0.93	0.41	0.2	0.56	0.05	0.11	4.06	5.94
A2	1.01	0.44	0.18	0.42	0.07	0.09	5.45	5.15
A3	0.91	0.53	0.17	0.71	0.05	0.16	5.43	5.15
A4	0.84	0.4	0.18	0.84	0.07	0.13	5.05	4.94
A5	0.64	0.39	0.16	0.62	0.04	0.13	5.2	5.14
B1	0.7	0.4	0.18	0.46	0.05	0.09	5.52	5.03
B2	0.8	0.57	0.19	0.5	0.08	0.1	5.24	5.05
B3	1.08	0.49	0.2	0.88	0.07	0.13	5.2	5.38
B4	1.1	0.38	0.21	0.51	0.09	0.11	5.39	6.16
B5	1	0.37	0.2	0.97	0.1	0.2	5.2	6.3
C1	1	0.39	0.18	0.58	0.01	0.11	4.63	5.09
C2	1.08	0.4	0.17	0.66	0.05	0.13	3.62	4.96
C3	1	0.36	0.15	0.81	0.07	0.15	4.02	4.96
C4	0.84	0.29	0.1	0.7	0.03	0.15	3.95	5.24
C5	0.92	0.31	0.1	0.74	0.04	0.13	5.16	5.33
D1	0.7	0.37	0.13	0.4	0.05	0.08	4.46	5.05
D2	0.84	0.28	0.15	0.57	0.06	0.11	4.93	4.63
D3	1	0.25	0.23	0.91	0.1	0.17	5.43	5.32
D4	1	0.4	0.21	0.66	0.07	0.13	5.18	5.09
D5	0.72	0.37	0.18	0.83	0.07	0.14	4.65	5.45
E1	0.68	0.38	0.14	0.76	0.06	0.13	3.87	5.48
E2	0.7	0.39	0.13	0.65	0.05	0.11	4.15	5.66
E3	0.8	0.4	0.12	0.87	0.06	0.15	4.5	5.38
E4	1.01	0.41	0.15	1	0.05	0.17	5.21	5.86
E5	0.99	0.41	0.16	1	0.04	0.17	5.1	5.86

Sample	CEC Test1	CEC Test2	Base Sat Test1	Base Sat Test2	Available P Test1	Available P Test2
	CEC1	CEC2	BASESAT1	BASESAT2	PHOSPH1	PHOSPH2
A1	20.6	33	20	18	5.9	6.5
A2	23.8	20.6	23	25	8.5	7.6
A3	25.6	21.7	21	24	5.9	10.5
A4	22.3	29.7	23	17	7.9	8.3
A5	28.1	28.8	19	18	6.1	9
B1	24.1	22.9	23	22	3.3	4.5
B2	27.3	28.9	19	17	3.3	3.9
B3	28.9	23.4	18	23	5.6	8.4
B4	24.1	23.5	22	26	9.5	6.2
B5	30.6	21.8	17	29	6.3	22
C1	26.9	25	17	20	6.9	4.8
C2	29.3	13.7	12	36	4.7	9.2
C3	29.4	12.2	14	41	10	9.3
C4	33.2	11.6	12	45	7.9	5.6
C5	25.8	22.3	20	24	7.5	8.8
D1	28.4	25.8	16	20	7	5.9
D2	19.6	29.7	25	16	3.2	5.9
D3	24	16.9	23	31	7.3	9
D4	32.6	16.9	16	30	8.9	6.6
D5	21.4	23.4	22	23	5.1	10.9
E1	22.5	26.3	17	21	8.3	9.3
E2	24.4	24.3	17	23	5.5	5.6
E3	31.8	26.1	14	21	8.7	18.6
E4	29.5	23.3	18	25	7	11.3
E5	29	23.3	18	25	5.8	11.3

Sample	Acidity Test1	Acidity Test2	ECEC Test1	ECEC Test2
	ACIDITY1	ACIDITY2	ECEC1	ECEC2
A1	2.29	0	6.35	5.94
A2	1.14	0.6	6.59	5.75
A3	1.16	0.61	6.59	5.76
A4	1.14	1.21	6.19	6.15
A5	1.54	0.6	6.74	5.74
B1	0.57	1.17	6.09	6.2
B2	0.58	0.58	5.82	5.63
B3	1.15	1.15	6.35	6.53
B4	1.15	1.2	6.54	7.36
B5	2.31	0.6	7.51	6.9
C1	2.33	0.6	6.96	5.69
C2	2.28	1.19	5.9	6.15
C3	0	0.58	4.02	5.54
C4	1.15	1.17	5.1	6.41
C5	2.29	0.61	7.45	5.94
D1	1.72	1.32	6.18	6.37
D2	1.74	1.17	6.67	5.8
D3	1.17	0.58	6.6	5.9
D4	1.15	0.61	6.33	5.7
D5	2.31	0.63	6.96	6.08
E1	1.16	1.78	5.03	7.26
E2	0	1.2	4.15	6.86
E3	1.16	0.6	5.66	5.98
E4	1.16	1.2	6.37	7.06
E5	1.14	1.2	6.24	7.06