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A MULTIDIMENSIONAL ANALYSIS OF THE GREAT GREEN WALL: THE ENVIRONMENTAL AND SOCIAL EFFECTS OF REAFFORESTATION IN SENEGAL

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To the Graduate Council:

I am submitting herewith a thesis written by Anna Eugenia Alsobrook entitled "A MULTIDIMENSIONAL ANALYSIS OF THE GREAT GREEN WALL: THE ENVIRONMENTAL AND SOCIAL EFFECTS OF REAFFORESTATION IN SENEGAL." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

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A MULTIDIMENSIONAL ANALYSIS OF THE GREAT GREEN WALL: THE ENVIRONMENTAL AND SOCIAL EFFECTS OF REAFFORESTATION IN SENEGAL

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ABSTRACT

The north-central region of Senegal is home to the Great Green Wall (GGW)—a reafforestation project aimed at restoring decades–old, degraded land conditions by establishing tree belts and community gardens. Its presence on the ground has changed the local landscape and altered the social institutions governing the daily lives of the people it aims to protect.

My study is an in-progress assessment of the GGW towards its two major goals: 1) improving the lives of the people of the Sahel and increasing their capacity to adapt to climate change and drought, and 2) improving the state of the ecosystem and increasing its resiliency to climate change and variability. Using field experiences, semi-structured interviews, and personal observations, I investigated the progress of the GGW towards its environmental and social goals in Senegal.

The young trees planted as part of the GGW have begun making environmental impacts in terms of decreasing land–surface temperatures and incident solar radiation. These changes yield improving environmental conditions capable of diversifying the economic livelihoods of the Sahelian people, as proposed by the second goal of the project.

The GGW goal of improving the lives of the people of the Sahel is characteristically hard to define, and the social impacts of the GGW at the village level are quite varied. The gardening and economic components seem to have made the most positive difference in the village. Problems with water and grazing areas, however, have prompted negative perspectives of the GGW by village-level stakeholders. Longer termed studies are encouraged to document the changes of these social impacts and how they infuence the efficacy of the initiative as a whole.

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LIST OF ABBREVIATIONS

ER .... Ecological Restoration
GEF .... Global Environment Facility
GGW .... Great Green Wall
GGWSSI .... Great Green Wall for the Sahara and Sahel Initiative
OHM .... Observatoires Hommes–Milieux
UNEP .... United Nations Environmental Programme
WFP .... World Food Program

Chapter 1: INTRODUCTION

In the last half century, the term “climate change” has become somewhat of a buzzword to promote environmental awareness. Its effects, however, are quite real, and they leave lasting impressions on the human landscape, most especially on traditional livelihoods. Desertification, or the loss of soil productivity, is one of the most detrimental facets of the changing climate, challenging these livelihoods. Societies of subsistence farming and pastoralism still exist, although heavily influenced by colonialism and economic development prospects, and they are still directly dependent upon the production of the land for survival. Should the effects of climate change destroy their natural landscape (through drought, desertification, or flood), the economic and social security of these people would be inherently jeopardized. The intense, Sahelian droughts of the 1970s and 1980s are prime examples of this devastating impact. As some of the worst droughts of the 20th Century, they ravaged the landscape, killing over 100,000 people and causing another 750,000 to become dependent upon food aid (Gaulter, 2012; UNEP, 2013). Sustainable means of mitigating the effects of the changing climate, especially as they affect land productivity, are inherently necessary in order to protect these vulnerable populations.

Desertification in the Sahel

The Sahel is a semi-arid zone of climatic and environmental transition separating the Sahara desert of northern Africa and the rainforests in the continent’s equatorial region. Figure 1.1 depicts its northern and southern boundaries, as they are defined by annual rainfall measurements—100 mm/yr in the north and 700 mm/yr in the south (Brooks, 2004). Interannual variability of rainfall can be as high as 37%, and the ecosystem

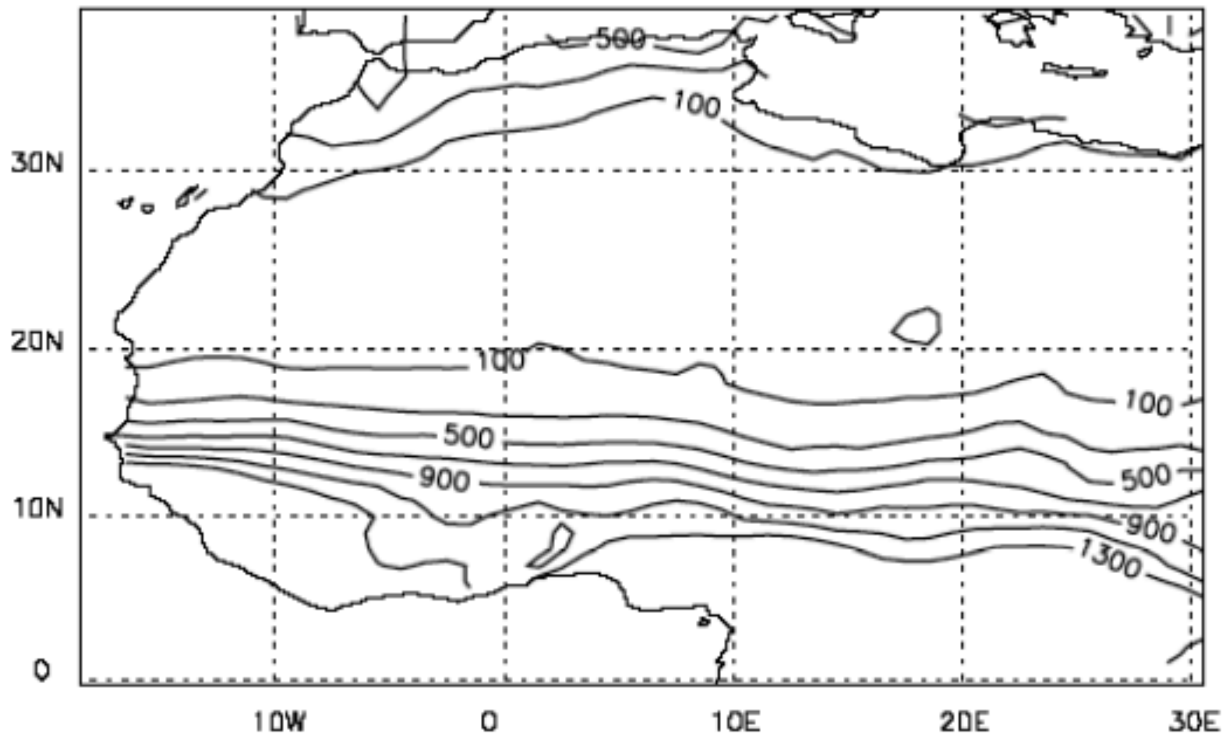

Figure 1.1: Isohyet lines representing mean annual rainfall (in mm) for northern Africa. The Sahel corresponds to the area between the 100 mm and 700 mm lines (Brooks, 2004).

responds dynamically to these fluctuations in precipitation, portraying a direct link between annual rainfall and the presence of vegetation and species composition (Le Houerou, 1989). Meager rain and extremely hot temperatures create a rain-driven ecosystem that is extremely fragile to climatic variations (Brooks, 2004).

The United Nations defines desertification as extreme "land degradation in arid, semi-arid and dry, sub-humid areas resulting from various factors, including climatic variations and human activities" (UN Convention to Combat Desertification, 2003). Desertification is an irreversible state of degradation in soil health (on a human time scale) due to a decrease in soil organic matter, a lessening of water retention, and an overall reduction in nutrients vital for plant growth.

In the Sahel, people's livelihoods are directly tied to the productivity of the land, making degradation and desertification serious problems. Many are subsistence farmers growing millet, peanuts, and sorghum for their family's food for the year. Others are agro-, nomadic, or transhumant pastoralists, raising sheep, goats, and cows. Most do not make enough money to save for the future. Instead they rely on their animals as bank accounts, selling one when a family member gets sick or married. When land does not produce sufficiently, the financial security of these people is detrimentally affected.

Great Green Wall for the Sahara and Sahel Initiative

In 2005, the Nigerian president, Olusegun Obasanjo, introduced his vision to combat desertification of the region. He proposed the development of a green wall of trees (Figure 1.2) to span the continent of Africa (15 km wide, 7,600 km long). The "tree, as a major factor governing the spatio-temporal evolution of the Sahelian environments," became the

Figure 1.2: Map of the Great Green Wall for the Sahara and Sahel Initiative. Exact location of the tree line is estimated based on news articles found in the popular media.

foundation of the *Great Green Wall for the Sahara and Sahel Initiative* [GGWSSI][1] (Initiative Africaine-Grande Murialle Verte, 2012). Obasanjo's vision developed into an integrated, ecosystem management approach of the region with a focus on improving the lives of the people of the region. Approved by the African Union in 2007, its current aims include the following:

1) improve the living condition of the people in this zone and reduce their vulnerability to climate change, climate vulnerability, and drought

2) improve the state and health of ecosystems and their resiliencies to climate change, climate variability, and drought

3) create collaborations and partnerships between international and national stakeholders (FAO-EU Partnership, 2011).

The former president of Senegal, Abdoulaye Wade, was the first major proponent of the Great Green Wall, and is credited with its name. Starting the official tree-planting phase in 2008, the country of Senegal has led the initiative into action. As of 2011, Senegal has planted 20, 234 hectares (50,000 acres) of trees, roughly equating to 2 million trees each year. In its 5th year, the project is currently taking place in the Lagbar, Mbar Toubab, Tessekere, and Widou villages, located in the Louga region of Senegal (northwest portion of the country) (Hertsgaard, 2011). Figure 1.3 shows a map of the proposed route the GGW will take in Senegal.

Several international agencies have taken interest and have promised funding (Barbier, 2011). In 2011, the Global Environment Facility (GEF) agreed to $115 million, stating the potential of the GGW to become a carbon sink (Johnkingsley, 2011). The World

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[1] GGWSSI will be used to refer to the Great Green Wall for the Sahara and Sahel Initiative, while GGW will be used to refer to the part of GGWSSI taking place in Senegal.

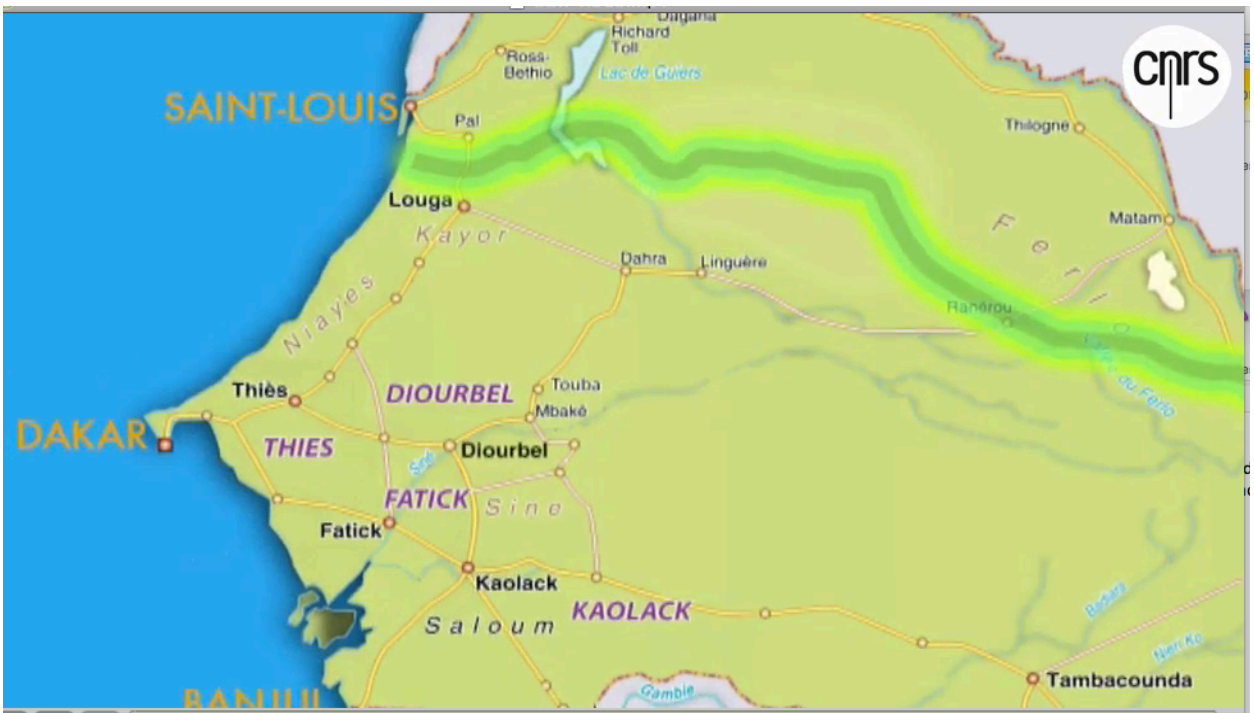

Figure 1.3: Map of the Great Green Wall in Senegal (CRNS, 2012).

Food Programme (WFP) has instituted a program that provides food for the community villagers who donate their time and labor to the planting and maintenance of the trees (Johnkingsley, 2011). The World Bank has plans to contribute $1.1 billion (Bascombe, 2012). Former colonial powers have also promised to contribute, but so far, no outside funding has yet been received by the project. According to Papa Sarr, Director of Technical Operations and second in command of GGWSSI, only the aid by the WFP has made it to the project (Papa Sarr, personal communication, June, 2013). He also mentioned that the GEF is scheduled to send its contribution to the initiative in 2014.

Despite the slow arrival of outside donations, Senegal has begun its span of the GGW using its own funds, even increasing its yearly budget from 850 million CFA (approximately $1.7 million USD) in 2008 to 1 billion CFA (approximately $2 million USD) in 2013. Since 2007, Senegal has designated and prepared lands, seeded and transplanted trees, and created and managed community gardens. Although the GGW is quite young, an in-progress assessment is merited as its presence may have started to influence the surrounding environment and local people. A study of the potential effects of establishing the GGW can be useful in other parts of the developing world currently being faced with similar natural resource issues.

Research Questions

The goals of this research project are to quantify and assess the impacts of GGW as they pertain to the first two goals of the initiative: 1) improving the living conditions of the people in the region, and 2) increasing ecosystem health and its resiliency to climate change and variability. The first part of this research project focuses on quantifying the impacts of the trees on air and land temperatures and incident solar radiation. The second part focuses on the impacts the GGW has had on the living conditions of the local population.

Environmental Impact

Previous studies in the area tend to focus on trees of mature age, aiming to describe the influence of tree canopies on the amount of understory herbaceous growth. Much of this literature shows that the presence of tree canopies significantly influences temperature and radiation measurements beneath the canopy zones. Researchers have linked the differences in these variables to increased understory herbaceous growth, which could then be defined as a characteristic of improved ecosystem health (Akpo et al., 2005; Grouzis and Akpo, 1997). The trees measured in this project are still quite young (not yet 6 years old), but the quantity of the trees and the large area in which they have been introduced are likely to lead to broad and significant impacts in the future. This particular research project aims to quantify and monitor the impacts of the young GGW trees already being seen in Senegal and determine where, how, and why they are affecting the human landscape of the area. Such a study should help determine the efficacy and physical impact of the GGW project in its early stages. Based on the previous research done by Akpo et al. (2005) and Grouzis and Akpo (1997) on fully matured trees in the study area, I posed the following four questions and hypotheses to guide my investigation of the environmental effects of the GGW:

Question 1: Is the shade provided by the young trees in the GGW starting to make a difference on the microenvironments (in terms of air temperatures, land–surface temperatures, and incident solar radiation) around them? Are these changes quantifiable?

Hypothesis 1.1: Microenvironments (in terms of air temperatures, land surface temperatures, and incident solar radiation) of sites under young trees and sites away from trees will differ and the differences will be quantifiable.

Question 1.2: Has the shade of the GGW trees influenced maximum and minimum air temperatures?

Hypothesis 1.2: Daytime air temperature (maximums) will be cooler under tree canopies, while nighttime temperatures (minimums) will be higher. The overall influence of the GGW trees will be a stabilization of these diurnal temperatures.

Question 1.3: Have the canopies of the GGW trees affected afternoon and early evening land–surface temperatures?

Hypothesis 1.3: Land-surface temperatures will be cooler under tree canopies in the afternoon and the evening as compared to land surface temperature outside the canopy zones. Again, the range of these temperatures will be decreased underneath the GGW canopies as a result of the impact of the presence of the trees.

Question 1.4: How has the GGW tree shade affected incident solar radiation beneath the tree canopies?

Hypothesis 1.3: Incident solar radiation will be lower under tree canopies as compared to incident solar radiation measured outside of the canopy zone.

Social Impact

The trees of GGW are prepared and cared for in a large tree nursery within the confines of each participating village. Hundreds of thousands of polyurethene bags are prepared with soil, seeds, and water until it is time to transplant the seedlings into the ground. This tree preparation process occurs during the hot season months (March–July) and requires massive amounts of water to keep the seedlings alive in the hot climate. The project gets its water at night and in the early morning from the community water basin in order to avoid direct competition with the local population, which obtains water from the borehole during the day. The primary aim of the social side of this research project is to assess the potentially beneficial and/or disadvantageous impacts to traditional, daily life created by the presence of the GGW in this rural area. In order to guide this assessment, the following five questions and hypotheses were posed based on my previous experiences living in a small, Senegalese community:

Question 2.1: Has the GGW affected water access and allocation to villagers in the surrounding areas?

Hypothesis 2.1: The GGW will limit water access and allocation in the area, and increase the amount of time village stakeholders spend getting water.

Question 2.2: How has the GGW impacted grazing areas for local pastoralists?

Hypothesis 2.2: Because the tree parcels are fenced spaces, the GGW will limit the overall amount of land available to local pastoralists for herding their cattle.

Questions 2.3: What is the impact of the GGW community garden initiative?

*Hypothesis 2.*3: The community garden initiative will help to improve villager nutrition as well as provide educational and leadership opportunities for women.

Question 2.4: How has the GGW affected the local economy?

*Hypothesis 2.*4: The GGW will alter local economies through job creation and increased tourism dollars.

Question 2.5: What is the perception of the GGW as a whole at different stakeholder levels?

*Hypothesis 2.*5: The perception of the GGW will differ depending on the amount of benefice that particular stakeholder is receiving from the project.

Thesis Organization

The first chapter of this thesis has provided a brief overview of the physical and cultural aspects of the Sahel, including the problem of desertification and the history and aims of the Great Green Wall for the Sahara and Sahel Initiative. It has also introduced the research questions that address the environmental and social impacts of the GGW on its participating surrounding areas.

The second chapter gives a brief background on the historical attributes of land degradation in the Sahel, tree physiology, and the interaction of tree physiology with the surrounding environment and soil conditions. It explains the methods of ecological restoration and the importance of involving the local people to ensure the success of such projects.

Research methods used to collect and analyze the data are discussed in the third chapter. The first section focuses on the measurements taken on the trees themselves, while the second section encompasses the methods used to assess the impact of the trees on the social dynamics of the area.

The fourth and fifth chapters present the results of this investigation and subsequent analytical discussion of these results. The fourth details the environmental impacts, while the fifth involves the social landscape.

Conclusions regarding both the environmental and the social effects of the GGW, to date, are seen in the sixth chapter, which summarizes the overall outcome of this research project and encourages future studies.

Chapter 2: BACKGROUND

Land Degradation

The United Nations Environmental Programme (UNEP) formally defines land degradation as a significant, temporary, or permanent loss of ecosystem function or biodiversity. Anthropogenic pressures, such as agricultural and grazing practices, deforestation, and poor resource management; climatic factors, such as droughts or floods; and combinations of both drive ecosystem degradation (UNEP, 1992).

Land degradation in the Sahel can be historically traced. Traditionally, nomadic pastoralists roamed the area to find water in the semi-arid climate. This mobility distributed the environmental impact of their lifestyles across a broad expanse of land. Colonial powers altered this way of life by drawing national borders and limiting nomadic movement, concentrating their environmental impact onto smaller spaces. Herders began settling, forming villages in the region. Their agricultural practices exhausted the soil of its nutrients, and overgrazing decreased the area's vegetal cover. As sedentary populations grew, so did demands for firewood, agricultural land, and fodder; subsequently, trees were cut down, further depleting soil health and productivity (Stewart, 2008). A study by Kirmse and Norton (1984) in the country of Chad linked the degradation of soil structure and fertility directly to repeated plowing and loss of root systems, which can dramatically increase erosion and overall loss of soil organic matter.

In semi-arid and arid ecosystems, land degradation can lead to desertification—an irreversible state of degradation in soil health (on a human time scale) due to a decrease in organic matter, a lessening of water retention, and an overall reduction in nutrients vital for plant growth (UN Convention to Combat Desertification, 2003).

Climatic factors can intensify desertification. For example, changing ocean temperatures can alter wind patterns, which affect where rains fall. Persistent desertification, however, can also alter climatic factors through decreased vegetation-atmospheric interactions that help to govern rainfall dynamics. Such feedbacks make rain-fed ecosystems extremely dependent upon climate (Brooks, 2004; Stewart, 2008)

The Sahel is one of these vulnerable ecosystems. The coefficient of variation in rainfall in the Sahel can be as high as 37%, and is thus capable of governing vegetal growth and agricultural production (Le Houerou, 1989). Figure 2.1 shows rainfall anomalies, with the mean derived only from rainy season months (June - October) from 1900–2013. The data show years of intense droughts coupled with high interannual variability.

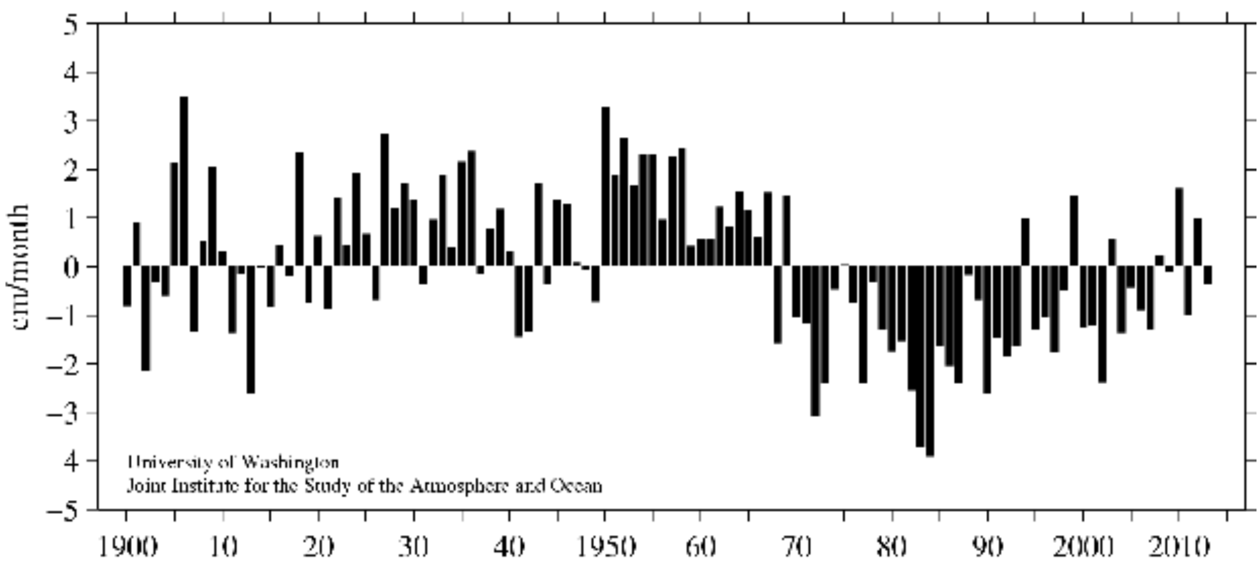

Figure 2.1: Sahel rainfall averages for rainy season months (June-October) 1950-2013. Data show overall wet period from 1950s-1960s, followed by extremely dry years during the 1970s-1990s. Data from the 2000s show high interannual variability. Data are from NOAA NCDC Global Historical Climatology Network data. Access: http://jisao.washington.edu/data/sahel/

Tree Influence on Soil Conditions

The physiology of trees and the interactions of tree physiology with the surrounding environment create unique microenvironments surrounding tree locations. Root structures stabilize the soil, helping to prevent erosion from wind and runoff. The decomposition of fallen leaves helps to recycle important nutrients, especially nitrogen and phosphorous, thus increasing soil fertility (Akpo et al., 2005; Campbell et al., 1994; Grouzis and Akpo, 1997; Mbow et al., 2008; Pallardy and Kozlowski, 2008). Removing trees destabilizes the soil structure, allowing wind to carry off the more nutrient-rich topsoil. The practice of burning vegetation for land clearance removes other natural vegetation and soil organic matter, inhibiting the infiltration of water and decreasing overall soil water capacity (Mbow et al., 2008). The presence of trees creates more positive soil environments for other herbaceous undergrowth, also known as "islands of fertility" (Grouzis and Akpo, 1997). Grouzis and Akpo (1997) found that herbaceous above-ground phytomass in the Ferlo (approximate location of the GGW) region of Senegal was 1.5–4 times greater under the canopy than in the open sunlight, and below ground phytomass was twice as great under the canopy. They also found that root-shoot ratios were much higher out in the open as opposed to under the canopy. A root-shoot ratio is the ratio of the weight of the roots to the weight of the top of the plant; it is a method of assessing plant health (Harris, 1992; Pallardy and Kozlowski, 2008). A reduction in root-shoot ratio is usually a response to more favorable growing conditions, while an increase would be indicative of the opposite (Harris, 1992).

<u>Tree Shade Influence on Microenvironments</u>

A tree's canopy has a major influence on the environment underneath it. A study done in Senegal on fully matured trees (near my study site) by Grouzis and Akpo (1997) found tree shade decreased total solar radiation by 80%, thus decreasing total evaporation. Canopies also reduce the impact of rainfall on the topsoil, thereby helping to ameliorate erosive conditions. Akpo et al. (2005) found a 16.5% reduction in rainfall beneath the canopies of certain mature *Acacia* species due to leaf interception. They also found that plant matter under these canopies retained greater amounts of water than plants in the open sunlight. This increase in water retention within the plants can be attributed to lower rates of evaporation of moisture from the ground beneath the canopies.

Canopies also affect air and soil temperatures. A 2005 study done by Akpo et al. in Senegal on fully matured *Acacia raddianna, Balanites aegyptiaca, and Ziziphus mauritania* species found that trees stabilize diurnal air temperatures. Maximum air temperatures under the trees were lower than temperatures in the open environment, while minimum temperatures were higher, indicating a reduction in total air temperature fluctuation. Soil temperatures proved similar. Under the trees, soil temperatures varied from 27–30°C, while soil temperatures out in the open ranged from 25–30°C (Akpo et al., 2005). Previous studies tend to focus on fully matured tree species, especially in an agro–forestry context. For this reason, it is important to study the effects of younger trees on their surrounding microenvironments. It not only adds to the agro–forestry and tree physiology bodies of literature, but it also helps to capture the early environmental changes influenced by the presence of the GGW.

Ecological Restoration

Depending on the severity of degraded land conditions, natural regeneration processes can be very slow or impossible (Van den Berg and Kellner, 2005). Ecological restoration (ER) is defined as the assistance to the recovery of a degraded, damaged, or destroyed ecosystem to its ecological balance (Aronson et al., 1993; Van den Berg and Kellner, 2005).

There are many tactics to restore ecosystem health. One is to create exclosures, fenced-in, protected lands built to exclude animal and human pressures. Another is afforestation, the planting of trees and shrubs in a space not previously forested. Thirdly, reafforestation is the planting of historically forested lands with native species (Le Houerou, 2010). The GGW in Senegal is an example of a reafforestation exclosure. However, success of these restoration practices is vitally linked to the discontinuation of the activities of degradation as well as the understanding and respect of an ecosystem's carrying capacity (Cao, 2008; Le Houerou, 2010).

Trees Used in GGW

Two vital factors determine which trees are planted within the GGW. The first involves choosing trees adapted to the harsh climatic conditions of the region. Located in the northern interior region of Senegal, the project area is subject to high temperatures, which drive high rates of evaporation. The second factor affecting tree choice is the consideration of the inherent value of the trees to the local population. Villagers living and working near the area need incentives to not cut down the trees. In other words, the trees themselves must be more useful or offer some kind of financial incentive for the villagers other than the prospect of firewood or fodder for their herds of cattle and goats. For these reasons, the GGW leaders in Senegal have chosen several indigenous and naturalized species as the primary species to be planted. The most common species being planted as a part of the GGW in Senegal include *Acacia senegal, Balanites aegyptiaca and Ziziphus mauritiana*. Each produces products useful to the local populations and their economies. It is the hope of GGW officials that local villagers will use these products domestically or sell them in market. Additionally, each tree chosen is relatively fast growing and drought-resistant.

Acacia senegal is a small, drought tolerant tree, native to the Sahel. It is especially known for its nitrogen-fixing capabilities and can reach heights of 3 to 6 m in environments with 300–500 mm/yr of rainfall (Kirmse and Norton, 1984). Its lifespan is 30–35 years and is found all over the African Sahel (Baumer, 1983). It produces an Arabic gum used in dying fabrics and in traditional medicines.

Also known for nitrogen-fixation and native to the region is the *Balanites aegyptiaca* which can reach 10–12 m and is found in all African drylands as well as in the middle and near East (Kirmse and Norton, 1984). It is extremely drought tolerant and thrives in areas with 200 mm/yr of rainfall. The berries it produces are used as fodder for animals, especially camels and sheep, and its oils are used in local medicines (Baumer, 1983).

Ziziphus mauritiana is typically a shrub or a small tree commonly found on sand or sandy depressions. It is naturalized to the Sahelian environment and also found in dry parts of Asia (Baumer,1983). Its fruits are eaten by humans and animals, and its leaves can be cooked in soups.

Tree influence on the Social Landscape

Because the first goal of GGW is to improve the lives of the people living within the Sahel, it is important to determine how this project, even in its first years, has affected their daily lives. Top-down approaches to natural resource management can leave village-level stakeholders feeling marginalized and neglected, which can potentially undermine project management and efficacy (Komakesh et al., 2012, Mutamba, 2004; Selfa and Endter-Wada, 2008). GGW is an *African* response to environmental problems in the area. It is being implemented, however, by an administrative level whose offices are in Dakar (250–300 km from Widou Thiengoly) and who, therefore, do not see the impacts of the project on a day-to-day basis. The region's natural resources as well as social dynamics have undoubtedly been affected by the presence of GGW on the ground. An in–progress, village-level analysis of these effects is necessary to more fully interpret the impact and progress of the GGW towards its first two goals.

Chapter 3: RESEARCH METHODS

Study Area

This research project took place in the Louga region of Senegal. An itinerary of my time there can be seen in Appendix B. Tree measurements were made approximately 7.85 km outside the village of Widou Thiengoly[2] (15.994N, 15.319W). Figure 3.1 shows the location of Widou and Figure 3.2 shows the location of the tree-study areas just outside the village. With an experimental plot planted in 2007, the GGW has been on the ground longer in Widou than in any other location, making an assessment of its impacts more practical there. Mean annual precipitation (MAP) of the area is less than 300 mm, typically distributed between June and October, with 90% occurring between July and September (Edmunds and Gaye, 1993). Landscapes of the area are characterized by small, linear dune formations known as ergs, scattered with thorny, woody shrubs and plants (Grouzis & Akpo, 1995; Grove and Warren, 1968). Soils are ferruginous latosols, meaning rock was broken down by weathering, producing a soil of clays and sesquioxides (an oxide with three atoms of oxygen and two atoms of a different element) (Young, 1980).

The village is predominantly Pulaar, although many of the GGW workers come from other areas in the country and are of other ethnicities, such as Wolof or Sereer. All community members adhere to the Islamic faith and most are practicing transhumant pastoralists.

Experimental Design: Environmental Impacts

The immense planting of trees to an area will have primary and secondary effects on the local and regional environments. The increased canopy cover will directly result in

[2] Locals refer to Widou Thiengoly as "Widou." This paper uses them interchangeably.

Figure 3.1: Location of Widou Thiengoly in Senegal (Google earth, 2013).

Figure 3.2: Great Green Wall tree stands where temperature and solar radiation measurements were taken in relation to Widou Thiengoly (Google earth, 2014).

decreased near–ground radiation, also decreasing land–surface and air temperatures. Secondary effects include increased nutrient cycling due to leaf litter, increased understory herbaceous vegetation due to more stabilized micro–environments, and increased water–retention within the soil due newly created root zones (Royer et al., 2011).

To measure the effects of young tree presence on the surrounding microclimate, I modeled my field research after a 2005 study done near the present location of a GGW site. Akpo et al. (2005) took successive measurements under tree canopies and their transition zones as well as in open-air environments, outside of canopy influence. Their focus was on quantifying the influence of shade from mature *Balanites aegyptiaca, Acacia tortilis* and *Ziziphus mauritiana* on surrounding environmental characteristics. They measured direct solar radiation, air temperatures, photosynthetic photon density, soil temperatures, soil properties (carbon, nitrogen, and phosphorous contents), and soil moisture.

Influenced by their model, I chose to take measurements inside and outside the canopy zones of the trees that had been planted as part of a GGW experimental plot in 2007, as well as inside the canopy zones of mature trees. These measurements included air temperature, land–surface temperature, and incident solar radiation. Based on the results of earlier studies (Akpo et al., 2005; Royer et al. 2011) stabilization of these variables would be expected in the mature trees, but the influence of young tree canopies on these variables was previously unknown. Stabilization was defined as a decrease in the range between the highest and lowest measured values.

Two circular study sites with a 50-m radius were created (Figure 3.3). They had both been planted within the 2007 experimental plot and were approximately 0.25 km apart. Each site and selected tree was marked with flagging tape. Each site contained

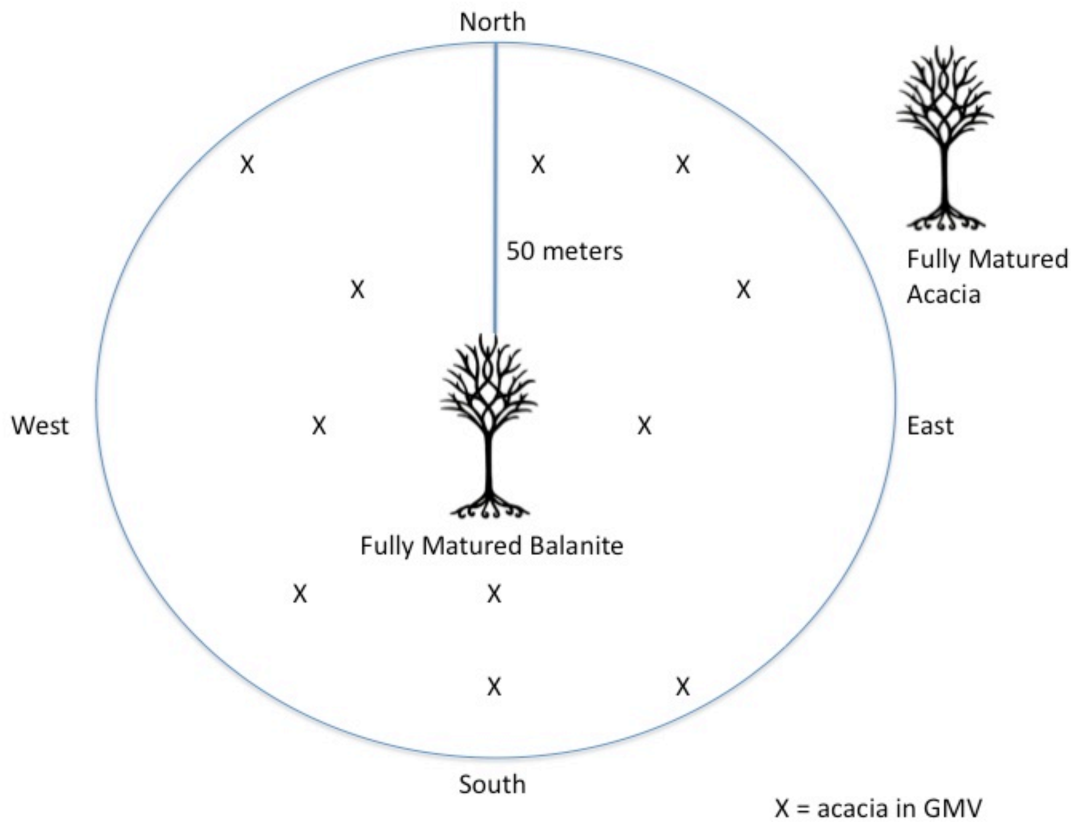

Figure 3.3: General schematic of study sites. Sites were 50 meters in diameter. Measurements were taken on 10 *Acacia senegal* trees planted as a part of the Great Green Wall. Each study site had approximately 40 trees planted for the GGW as well as one preexisting *Balanites aegyptiaca* and one preexisting *Acacia senegal*.

approximately 40 trees planted as part of the GGW, all of *Acacia senegal* species and all approximately five years in age, although only 10 per site were chosen for this research project. Each site had a preexisting, *Balanites aegyptiaca* in the center, and a preexisting *Acacia senegal* on its eastern outskirts. Age of these pre-existing trees was unknown, but all were well matured. The GGW trees were arbitrarily selected, without bias, in locations that represented the cardinal directions from each site's center *Balanites aegyptiaca* tree. The GGW trees were similar in size and shape. Sites were also similar in shrub and grass species density and composition. Air temperature, land–surface temperature, and incident solar radiation measurements were taken inside the canopies of these 24 trees as well as outside their canopy zones on a daily basis at the end of the hot season in 2013 (May/June).

<u>Environmental Field Methods</u>

Non-invasive measurements were taken on the trees at the two study sites for three weeks at the end of the 2013 hot/dry season. These measurements included land–surface temperature, air temperature, and solar radiation. Figure 3.4 shows a general schematic of these measurements.

Tree Characteristics

I determined the slope of the land and height of each chosen tree with a clinometer and used a GPS device to determine and record the spatial coordinates and base elevation of each tree within the study area. Trunk circumferences were measured at 0.3 m (1 foot) from the ground with a standard tree-diameter tape. Diameter at breast height was unattainable, due to the thorny characteristic of the trees' branches. Foliage density was

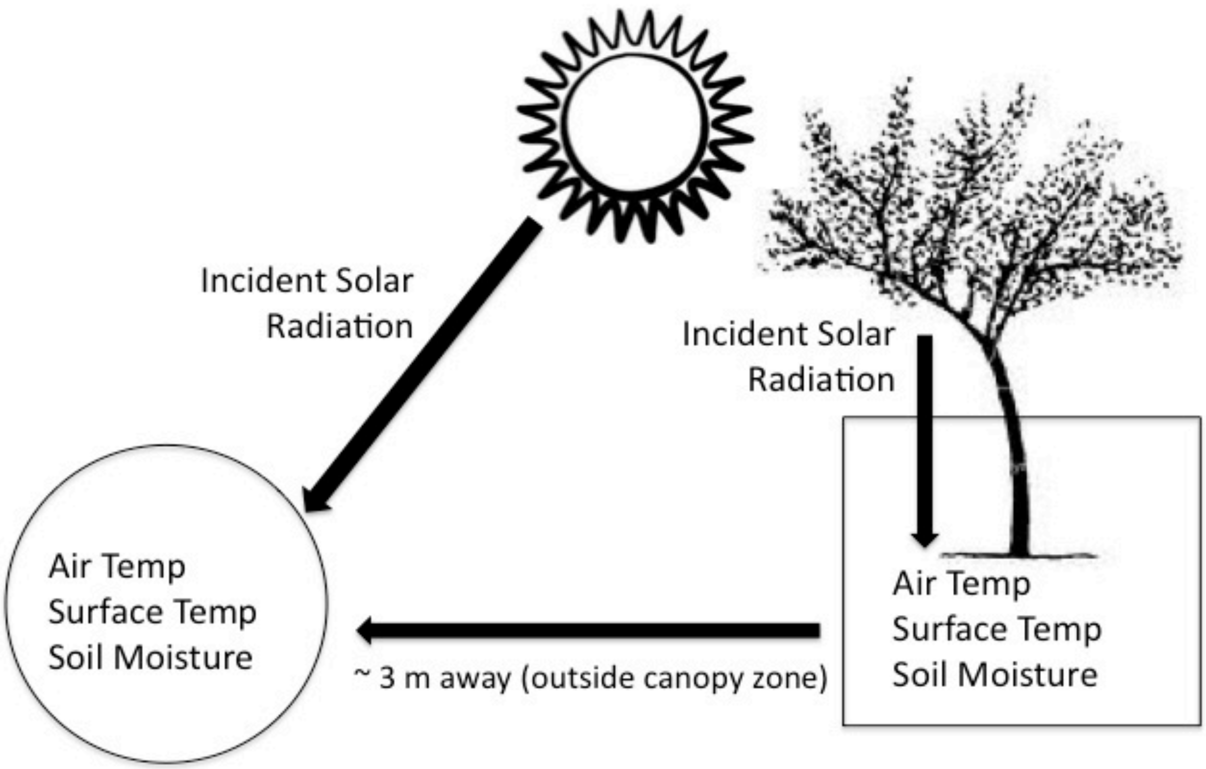

Figure 3.4: General schematic of tree measurements. Measurements were taken in late afternoon (3–5 PM) and early evening (5–7 PM) on a daily basis in May/June of the 2013 hot season.

estimated with a convex spherical densiometer. Understory vegetation and canopy breadth were photographed and noted.

Soil Characteristics

Soil color was determined visually, using a Munsell color chart. I determined soil texture using the feel, the ball squeeze, and the ribbon methods according to Colorado Master Gardner GardenNotes (Whiting et al., 2011).

Land-Surface Temperature

Land–surface temperature was measured with an infrared thermometer near the trunk of each tree in four places based on the cardinal directions. It was also measured 3–5 meters away from the trunk, so as to be outside of the canopy zone. Temperature was measured in the early afternoon (between 3:00 and 4:15 PM) and early evening (between 5:00 and 7:00 PM), on a daily basis.

Air Temperatures

Maximum and minimum air temperatures were quantified daily using a standard U-shaped thermometer that was tied to a tree branch and was reset each 24-hour period. A total of five pairs of measurements were recorded at each site: one beneath the canopy of the center *Balanites aegyptiaca*, one beneath the mature *Acacia senegal* on the eastern side of the study site, two beneath two *Acacias senegal* trees planted as part of the GGW, and one out in the open outside of any tree–canopy influence.

Solar Radiation

Solar radiation was measured using a pyranometer application, developed by Hukseflux Thermal Sensors, for the Apple iphone. Incident solar radiation was measured in two places—beneath the canopy, and outside canopy influence—three times a week. Measurements were taken in the afternoon and under a variety of cloud conditions, ranging from no cloud to complete cloud coverage.

Soil Moisture

Soil moisture was measured volumetrically using a Campbell HydroSense Time-Domain-Reflectometer. This instrument gives a measurement of volumetric moisture content integrated across the upper 12 cm of soil. This variable was only recorded once within the three–week study period because the first measurements showed soil conditions to be drier than the moisture range the instrument could detect.

<u>Statistical Analysis</u>

All field measurements were recorded by hand and entered into Microsoft Excel. Temperature and radiation measurements were then imported into R Statistical software, where a paired, one–tailed, t–test analysis was performed comparing inside canopy measurements to outside canopy measurements. I did not include the *Balanites* data in the statistical analysis as these trees are of a different species than the GGW trees, but the *Balanites* data can be found in Appendix C.

Experimental Design: Social Impacts

The first goal of GGWSSI is to improve the living conditions of the people within the Sahel. For that reason, it was essential to research the impact of the GGW on the human landscape. To determine whether and/or how the GGW affected daily lives, I had conversations with stakeholders at all levels, including project administrators, GGW workers, NGO consultants, university researchers, and villagers. At the village level, interviews were informal, semi-structured conversations that followed my IRB protocol (Appendix A). According to my IRB, all village-level interviews were conducted with confidentiality, and the names of the interviewees are respectfully withheld. Interviews with the administration in Dakar were more formal and also followed IRB protocol. No confidentiality agreement existed at this stakeholder level, as these men were GGW officials. Each conversation was tailored to its particular audience, although some questions were asked at each stakeholder level. I interviewed villagers and GGW workers in Pulaar, the local language. I recorded many of the interviews and later translated the responses from Pulaar to English.

Social Field Methods

To evaluate the social impacts from the presence of the GGW, I used interviews, conversations, and personal observations. Questions I posed to each stakeholder level are shown in the (Appendix B).

Widou Thiengoly

Because I spent the majority of my time in Widou Thiengoly, my results are most representative of the impacts of the GGW in this particular village. In Widou, I lived within the confines of the Eaux et Forets (Water and Forests, the governing branch of Senegal's protection of water and forests), with easy access to the workers directly involved with GGW. Working in the tree nursery to help them plant or prepare seeds gave me the opportunity to see the productivity of their labor as well as the functionality of the project as a whole. It also proved to be a good time to informally ask general questions about the project. Living in this center also gave me access to NGO staff and other contract workers who came in to investigate the progress.

One lesser known aspect of GGW is the project's implementation of community gardens to enhance nutrition in the area. These gardens are worked by the local women. Per Senegalese culture, women typically take the opinions of their husbands and fathers in public spaces. It is rare for them to voice their own sentiments in community meetings open to both sexes. For this reason, I had hoped that the community garden might prove to be a safe place, in which village women would feel comfortable expressing how the GGW has shaped their daily lives. I spent many hours in the community garden, working with the women, talking to them, and asking questions. To get other perspectives I walked to various villagers' homes and shops and spent time at the community water basin, making personal observations and conversing with the people obtaining water.

Outside Widou Thiengoly

With Widou as a base, I visited three other villages (Mbar Toubab, Loughere Thiolly, and Lagbar) directly involved in the project, meaning they were the central locations for the project in their surrounding areas and housed the tree nurseries (Figure 3.5). I also visited sites in Tessekere, but interviews did not take place there. In each village, I interviewed the director of the project for that village as well as ground-level workers of various jobs (tree nursery worker, women's garden manager etc.). Although not always successful, I also tried to speak to village-level politicians, such as village chiefs and local water managers. Travel between villages was difficult and time-consuming, limiting interview time in each village. Also, in many of these situations, I was received as a guest and discouraged from working, because of the "heat." After breaking this particular cultural barrier, I would walk through the village (usually with a local worker from the GGW) and try to meet whomever I could. After formalities, I would discuss my project and begin asking questions about their involvement and perceptions of GGW.

Before reaching Senegal, I had made contact with Professor Aliou Guisse from the University of Cheikh Anta Diop (Appendix D) and was able to interview him upon reaching Dakar. He is one of the co-directors of the French observatory, Observatoires Hommes-Milieux (OHM) that studies the GGW. I was also able to visit the headquarters of GGWSSI to meet with the Director General of GGWSSI, Colonel Matar Cisse, as well as the Director of Technical Operations, Papa Sarr. These two men are the highest-ranking officials in GGWSSI. My meeting with Col. Cisse was brief, so perspectives from this level of stakeholders come from Papa Sarr only.

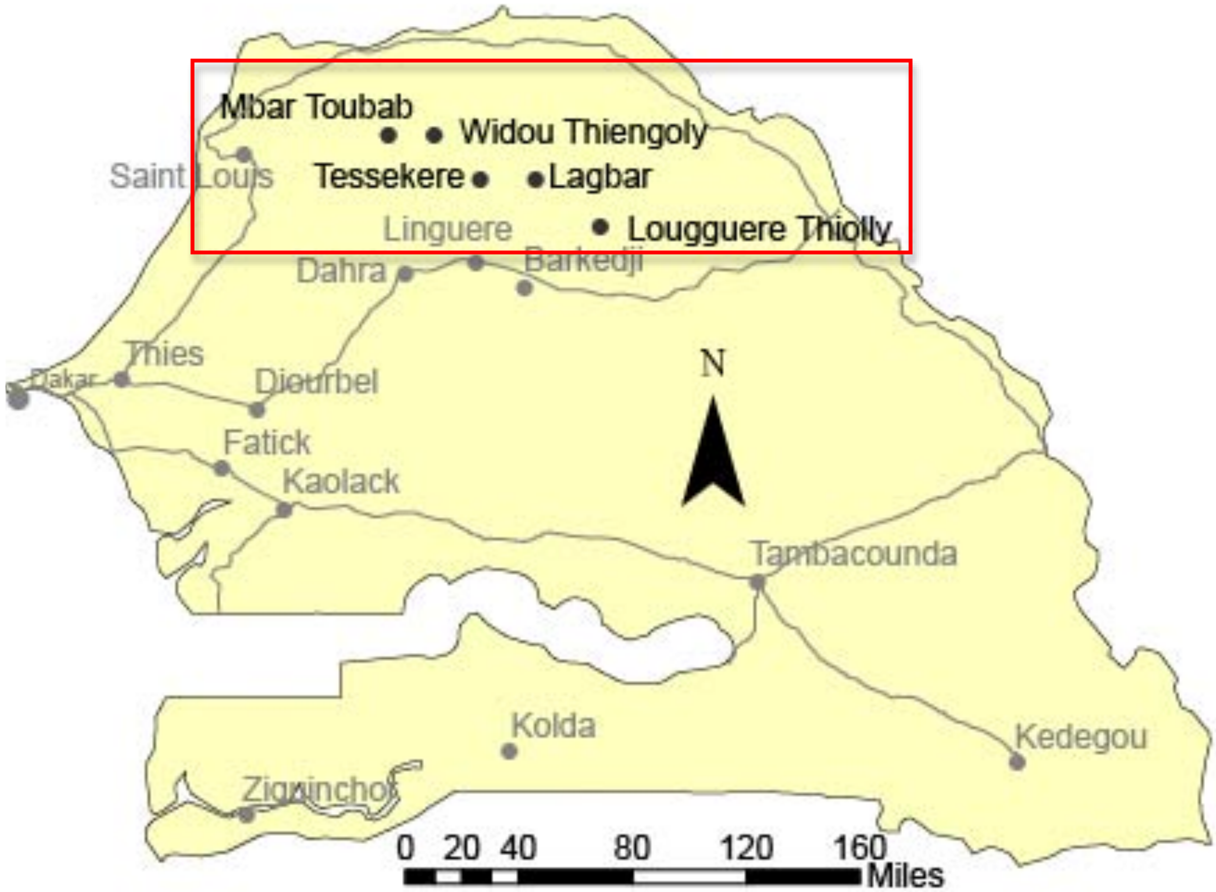

Figure 3.5: Map of the study villages for the social impacts of the GGW in Senegal.

Chapter 4: RESULTS and DISCUSSION–ENVIRONMENTAL IMPACTS

RESULTS of ENVIRONMENTAL IMPACTS

This project quantified tree impact on the microenvironment using temperature and solar radiation measurements taken during a three–week study period at the end of the 2013 hot season (May/June). The following sections focus on the tree and soil characteristics, air and land–surface temperatures, and solar radiation. The effect of the young GGW tree canopies on surrounding microenvironments (in terms of air temperatures, land–surface temperatures, and incident solar radiation) did prove to be quantifiable as hypothesized, and those results are presented below. While I measured temperature and incident radiation at both GGW *Acacia senegal* and preexisting *Balanites aegyptiaca* trees, the results presented in this chapter solely focus on the effects of the *Acacia senegal* (the *Balanites* data can be found in Appendix C). This is due to the dominance of *Acacia senegal* as a part of the GGW in my study area. Data sheets of all results can be found in Appendix C. When working to measure soil moisture, the Campbell HydroSense Time-Domain Reflectometer measured 1% volumetric water content, no matter where it was placed. It was then assumed that the soil's water content was somewhere below the instrument's detectable limit.

Tree and Soil Characteristics

Data for the slope, spatial coordinates and base elevation for each tree, with trunk circumferences and foliage cover can be found in Appendix C. Soil color proved to be 7.5YR 6/4 on the Munsell system for the first study site and 7.5YR 5/2 for the second. Soil texture was determined to be loamy sand for both sites. During the three-week study period, the trees experienced a significant increase in leaf production (Figures 4.1-4.3).

Figure 4.1: Photo of an *Acacia senegal* tree as part of the Great Green Wall, taken early in the study period, late May 2013. There is very little leaf coverage. Backpack is used as size reference.

Figure 4.2: Photo of the same *Acacia senegal* as in Figure 4.1, taken mid-June 2013. Leaf coverage is much higher.

Figure 4.3: Photo of the same *Acacia senegal* shown in Figures 4.1 and 4.2, taken later in the study period from the base of the trunk looking upwards. Photo was taken in mid-June 2013.

Air Temperatures

Both study sites showed similar distribution of data. The top graph of Figure 4.4 shows the distribution of data for the first study site and the bottom shows the data for the second study site. Because the sites were similar, I pooled the data from the two sites to perform the analysis. The distribution of all air temperatures beneath tree canopies and outside of tree canopy influence (Table 4.1) shows that air temperatures measured beneath the GGW tree canopies have the same range (21–50°C) as those measured outside of the canopies. Temperatures beneath the mature *Acacia* trees showed slightly less variance (22–45°C) and thus more stability. Air temperatures beneath the *Balanites* trees ranged from 21 to 46°C. Table 4.2 shows the number of data points for each measurement as well as the median, mean minimum, mean maximum, and subsequent range values determined for air temperature measurements taken beneath and outside of tree canopies.

Mean air temperatures (Figure 4.5) showed mean maxima to be slightly greater outside of tree canopies than inside the canopy zones of the GGW trees for seven out of eight days. For eight out of eight days, mean maximum air temperatures recorded beneath the mature *Acacia* canopies were lower than temperatures recorded both outside canopy influence and inside the GGW canopies. For five of the eight days, mean minimum air temperatures taken outside the tree-canopy zones were slightly lower than those taken inside the canopies of the mature *Acacia* and GGW trees. Overall, the shade provided by the canopies of the young GGW trees, created a more stabilized microenvironment in terms of higher mean minimum temperatures and lower mean maximum temperatures. This supports the hypothesis proposed in the introduction.

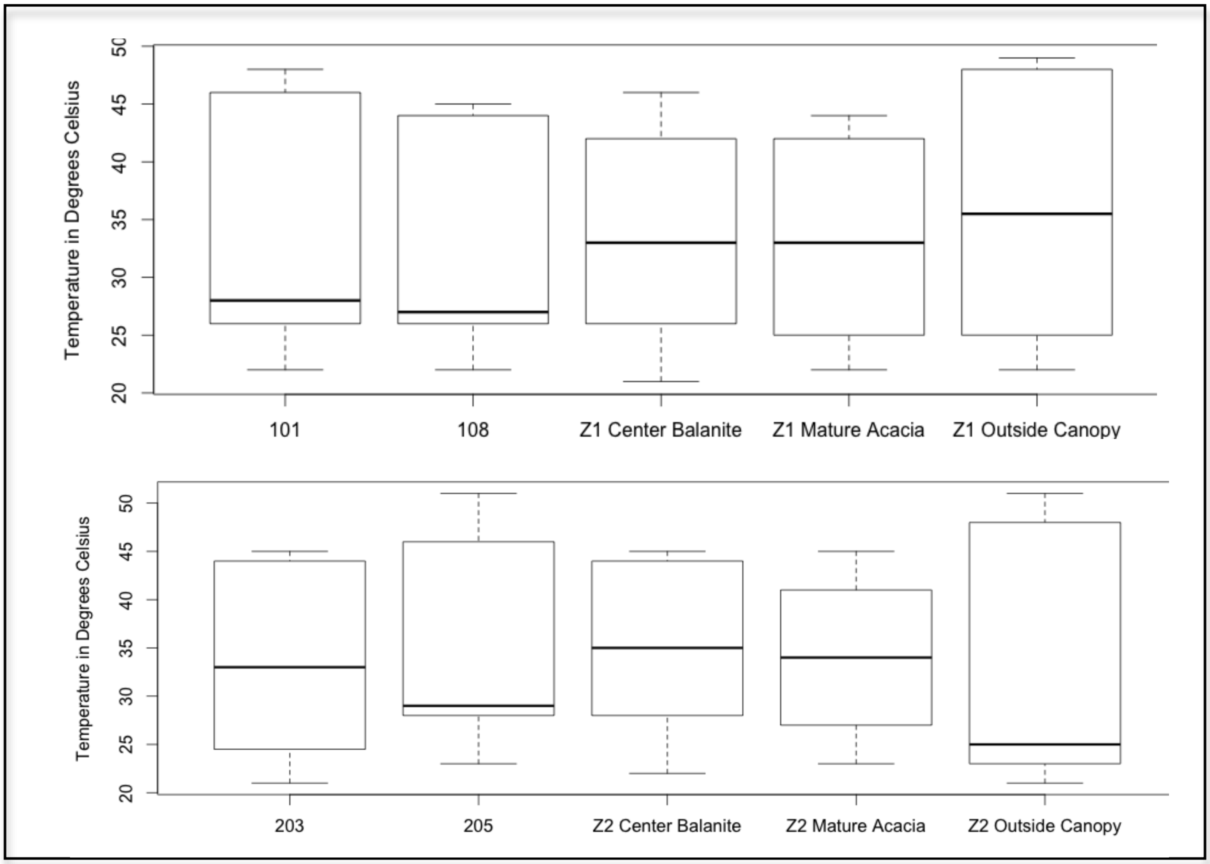

Figure 4.4: Distribution of air temperature data from study sites 1 and 2. The top graph represents data from study site 1 and the bottom represents data from study site 2. X-axis labels 101, 108, 203, and 205 are points where measurements were taken beneath the canopy of *Acacia senegal* trees planted as part of the Great Green Wall.

Table 4.1: Distribution of air temperatures recorded daily on a U–shaped thermometer[3].

GGW Min	M.Acacia Min	No Canopy Min	GGW Max	M.Acacia Max	No Canopy Max
21	22	21	40	38	45
21	22	22	41	40	48
22	23	22	42	40	46
22	23	22	43	40	45
23	23	23	44	41	49
23	25	23	44	41	48
24	25	24	44	41	49
24	26	24	44	42	48
25	26	25	44	42	47
25	27	25	44	43	49
25	27	25	44	44	49
26	28	25	44	44	45
26	28	26	45	45	50
26	28	26	45	45	
26			45		
26			45		
26			45		
26			46		
26			46		
26			46		
27			47		
27			47		
27			48		
28			48		
28			50		
29					
29					

[3] GGW = Great Green Wall; M. Acacia = mature *Acacia*; Outside = outside the influence of the tree canopy

Table 4.2: Air temperature means and medians

Measurement	Number of Samples	Mean Minimum Temperature (in °C)	Mean Maximum Temperature (in °C)	Overall Mean (in °C)	Median (in °C)	Range (Max–Min)
Inside Mature Acacia canopy	28	25	43	34	33	23
Inside GGW canopy	52	25	42	35	29	29
Outside canopy	27	24	44	35	26	29

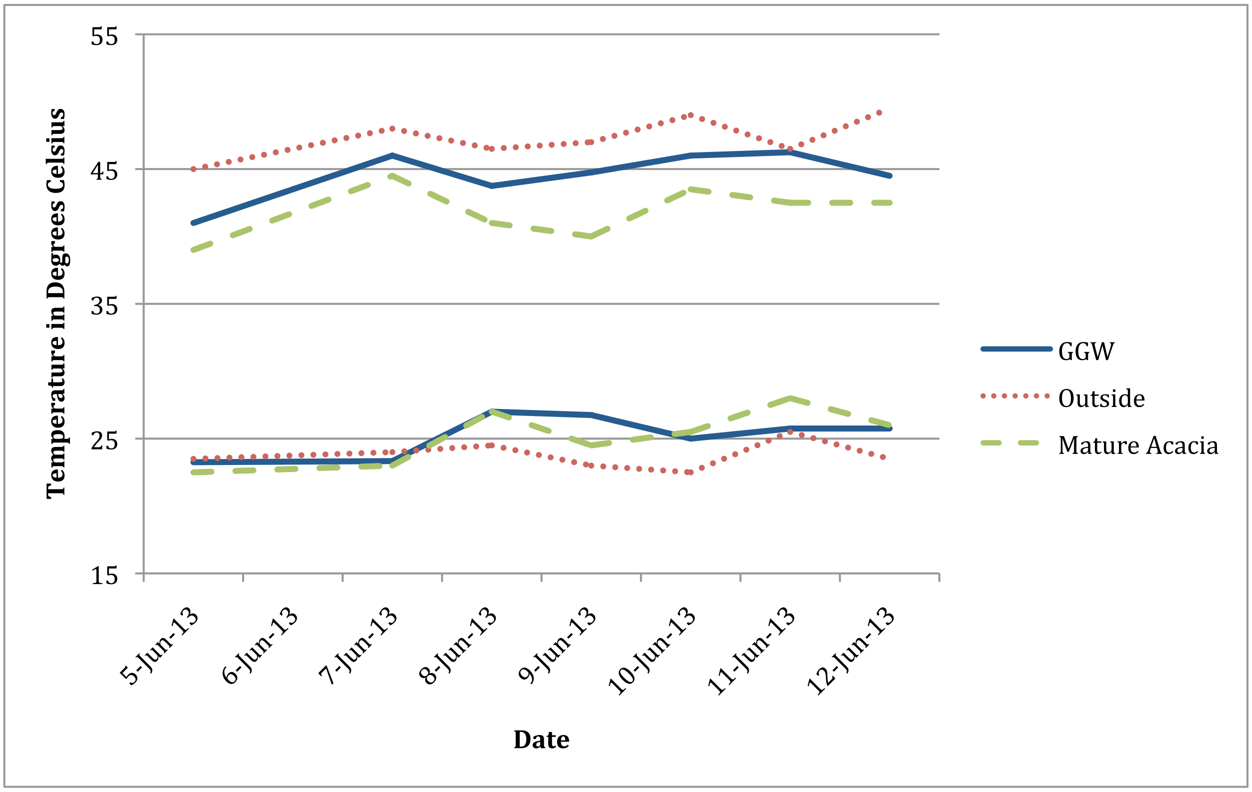

Figure 4.5: Maximum and minimum air temperatures recorded inside and outside canopy zones. Upper lines show daily maxima averaged for that particular day, while lower lines represent daily minima averaged for that day. The term "outside" refers to measurements taken outside the canopy zones.

Land–surface Temperatures

The data for land–surface temperatures from the two study sites were similar. The top graph in Figure 4.6 shows the distribution of land–surface temperatures in the first study site and the bottom graph shows the second study site. I pooled them together to perform the statistical analysis.

Afternoon

Afternoon land–surface temperatures were measured with a digital infrared thermometer between 3:00 and 4:15 PM, when the sun was still quite high. Afternoon land–surface temperatures (Figure 4.7) were lower under the canopies of GGW trees (30–56°C) as opposed to outside canopy influence (33-64°C), supporting the hypothesis of lower afternoon land–surface temperatures under the GGW tree canopies. Several factors influence the heat emitted from the land surface, most notably the aspect of the tree from which the temperature was taken. Beneath the GGW tree canopy, the west side temperatures (30–56°C) were slightly more varied than temperatures from the other three positions beneath the tree (31–52°C for north, 34–53°C for south and 35–53°C for east), as shown in Figure 4.8.

Afternoon land–surface temperatures under mature *Acacia senegal* trees showed patterns similar to those associated with the younger GGW trees. Lower and less varied temperatures were recorded beneath the canopy zones than outside the canopy locations (Figure 4.7). Temperatures recorded beneath the shade of the canopies ranged from 35 to 53°C, while temperatures outside the canopy zones ranged from 38 to 58°C. Westward temperatures (36–53°C) under the preexisting *Acacia* trees were more varied compared to

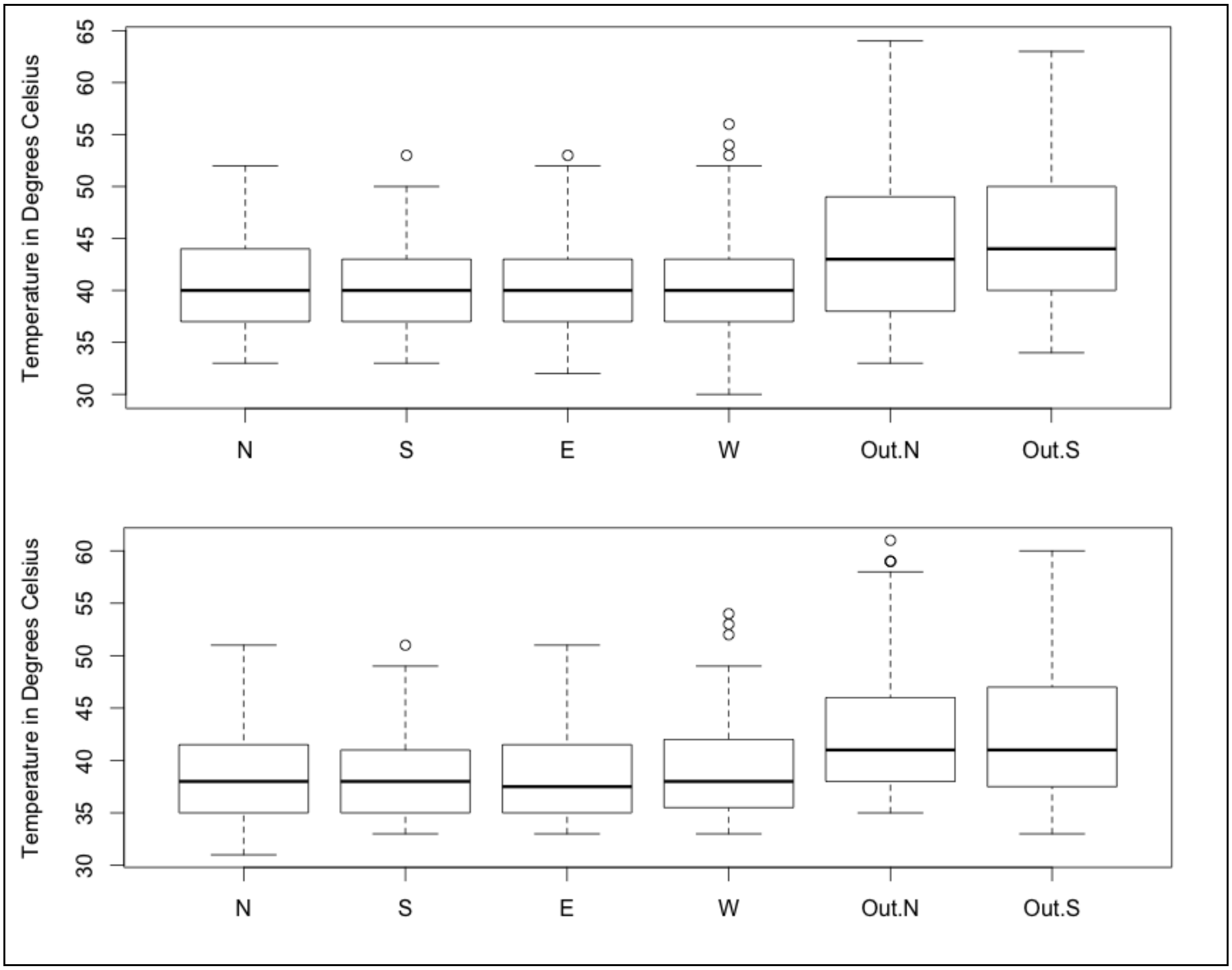

Figure 4.6: Distribution of land-surface temperature for all trees in the study sites 1 and 2. The top graph represents the data from study site 1 and the bottom graph corresponds to the data from study site 2. X-axis labels represent the aspect where the measurement was taken relative to the tree trunk. N, S, E, and W measurements were beneath the tree canopy, while Out.N and Out.S represent the measurements taken outside the canopy zone to the north and south of the tree trunk, respectively.

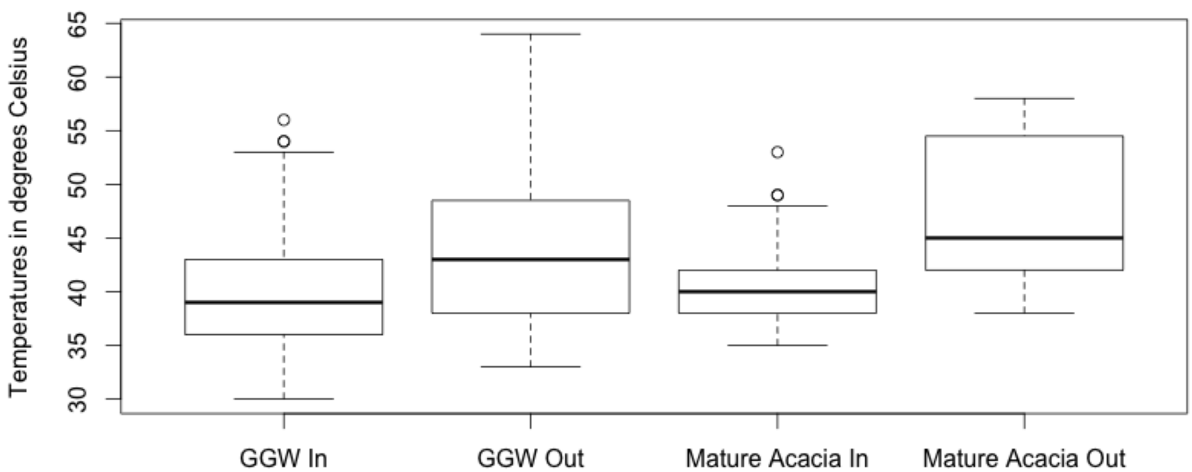

Figure 4.7: Afternoon land–surface temperatures inside the Great Green Wall and matured *Acacia senegal* tree canopy zones and outside canopy influence. Temperatures were taken with an IR thermometer between 3:00 and 4:15 PM. The horizontal bar in each box represents the median value. Circled points represent outliers.

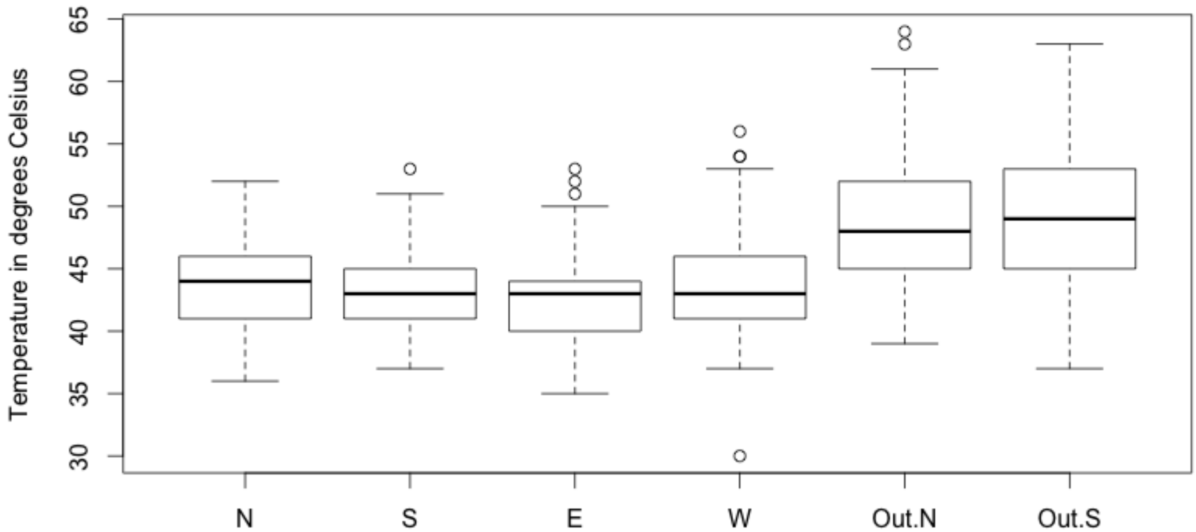

Figure 4.8: Afternoon land–surface temperatures recorded with an IR thermometer at four positions corresponding to the cardinal directions (N, S, E, and W) beneath Great Green Wall tree canopies and at two positions (Out.N and Out.S) 3-5 meters away from their trunks, outside the canopy zones. Out.N corresponds to position of measurement taken outside the canopy zone on the northern side of the tree trunk, and Out.S corresponds to the measurement taken outside the canopy zone to the south of the tree trunk.

those taken at other aspects (37–49°C for north, 37–43°C for south and 35–42°C for east) (Figure 4.9).

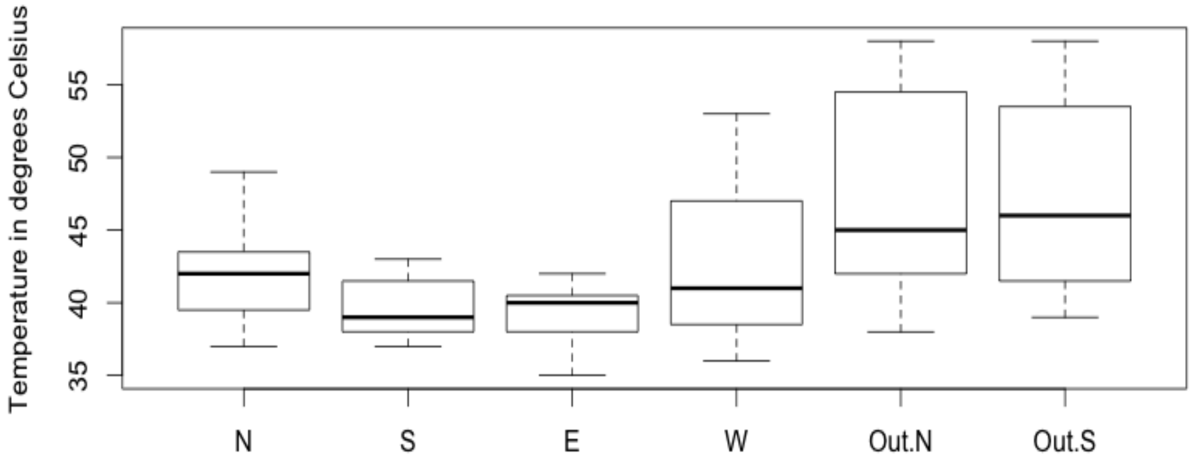

Figure 4.9: Afternoon land–surface temperatures measured beneath the canopies and 3–5 meters away from the trunks of the mature *Acacias senegal* trees. Measurements were taken based on the cardinal directions (N, S, E, and W). The x-axis shows the aspect of the position where the temperature was taken. Out.N and Out.S represent temperature measurements taken outside of the canopy zone to the north and south respectively. All measurements were recorded in degrees Celsius.

Evening

Evening land–surface temperatures were measured just prior to sundown, between 5:00 and 7:15 PM. The relationships shown by these results proved similar to those for afternoon land–surface temperatures at the same locations in the afternoon. Land–surface temperatures fluctuated more outside the GGW canopy zones (Figure 4.10). Beneath the GGW canopy, temperatures ranged from 33–43°C while temperatures outside the canopy

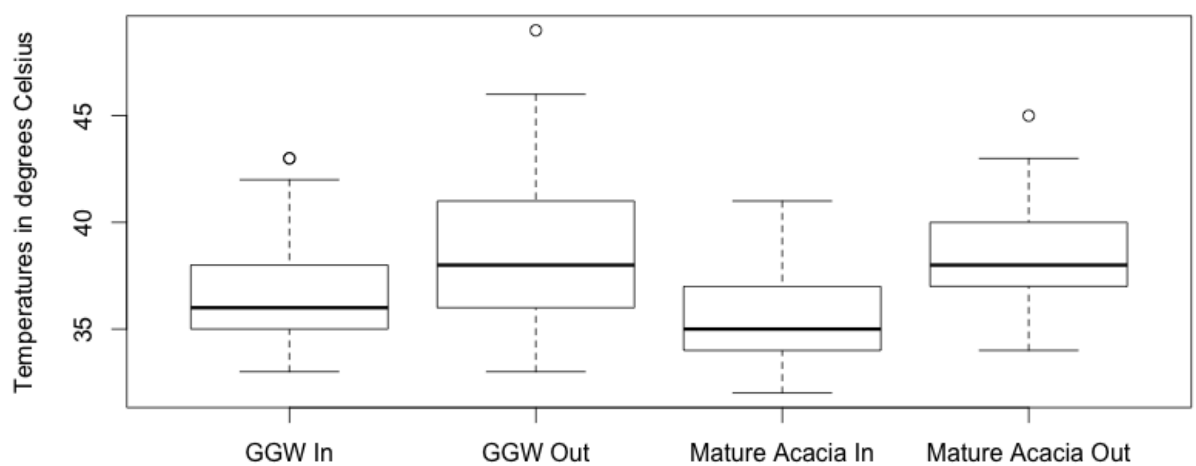

Figure 4.10: Evening land–surface temperatures inside the Great Green Wall and matured *Acacia senegal* tree canopy zones and outside canopy influence*.* Temperatures were taken with an IR thermometer between 5:00 and 7:15 PM. The horizontal bar in each box represents the median value. Circled points represent outliers.

zones ranged from 33 to 49°C. In this case, the hypothesis proposing lower land–surface temperatures in the evening was correct.

Aspect seemed less important for evening land–surface temperatures beneath GGW trees as compared to measurements taken in the afternoon. Figure 4.11 shows the distribution of temperature recorded by direction beneath the GGW tree canopies and outside of canopy influence.

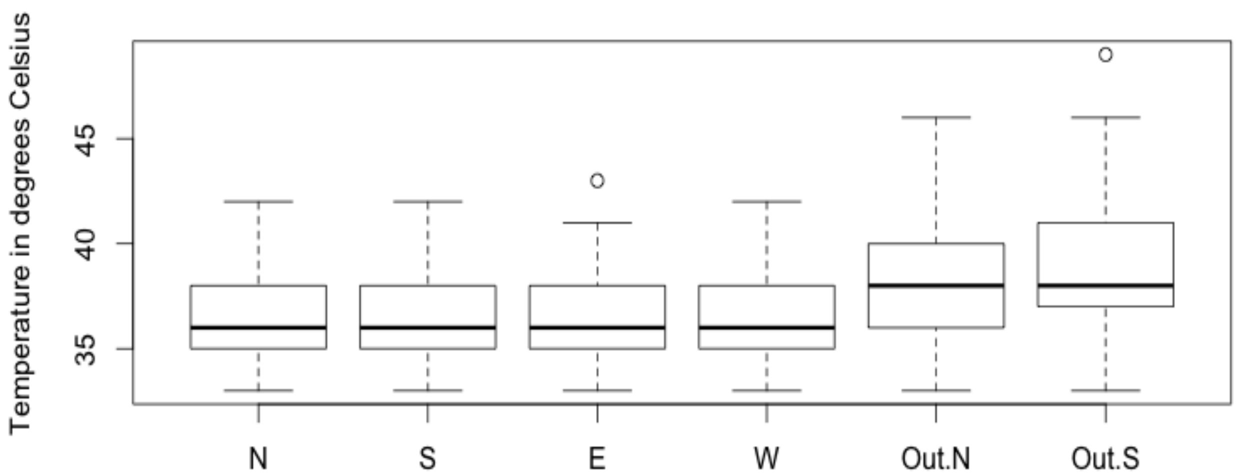

Figure 4.11: Evening land–surface temperatures measured beneath the canopies and 3–5 meters away from the trunks of the GGW trees. Measurements were taken based on the cardinal directions (N, S, E, and W). The x-axis shows the aspect of the position where the temperature was taken. Out.N and Out.S represent temperature measurements taken outside of the canopy zone to the north and south of the tree respectively. All measurements were recorded in degrees Celsius.

Trends of lower, less varied values in evening land–surface temperatures under the matured *Acacia* species were similar to those under the younger GGW trees (Figure 4.10). Evening land–surface temperature ranged from 32 to 41°C beneath the mature *Acacia* canopies and 34 to 45°C outside the canopy zone. Beneath the tree canopies of the matured *Acacia*, direction seemed to have little effect on evening surface temperatures

(Figure 4.12). Similarly, evening land–surface temperatures ranged from 33 to 40°C for the *Balanites aegyptiaca*, and 35–48°C for measurements outside *Balanites* canopy zones.

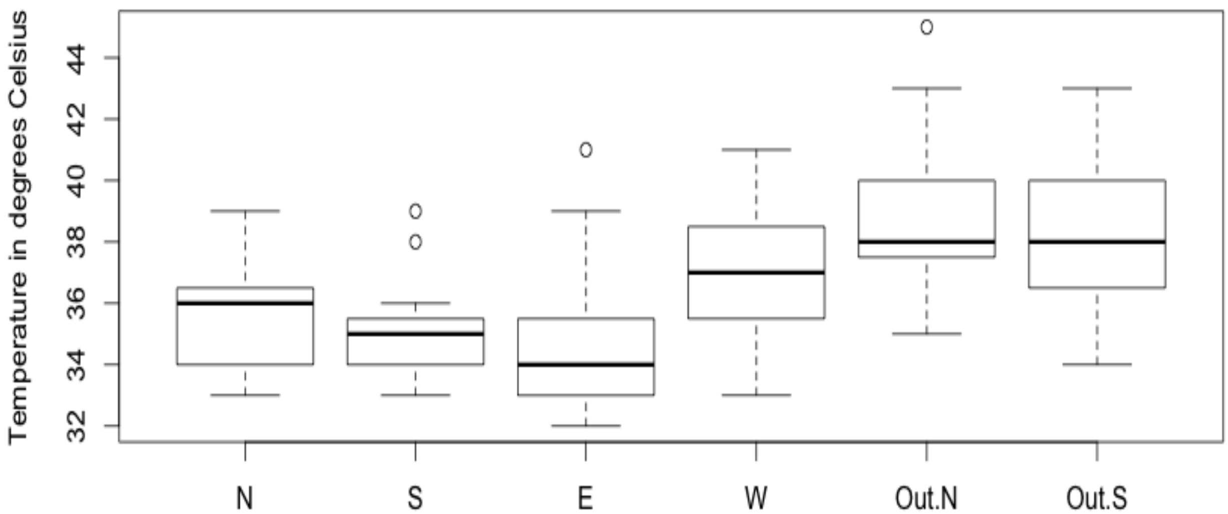

Figure 4.12: Evening land–surface temperatures taken beneath the mature *Acacia* tree canopies and 3–5 meters from their trunks with an IR thermometer. Temperatures were recorded by aspect of the measurement from the tree trunk (N, S, E, and W). The x-axis shows the aspect of the position where the temperature was taken. Out.N and Out.S represent the temperature measurements taken outside of the canopy zones to the north and south of the tree trunks respectively. All measurements were recorded in degrees Celsius.

<u>Overall Impact on Land–surface Temperature</u>

Table 4.3 shows the land surface means inside and outside the tree canopies. Using pairs of comparable data points based on the dates the measurements were taken (n = 110), a paired, one-tailed t-test was run to determine if the sample means of the land–surface temperatures outside the canopy zones were statistically different from the land surface temperatures taken inside the canopy zones. The results of the t-test for the afternoon land–surface temperatures ($p = 2.2e{-16}$, $df = 109$, $t = -10.1693$) show that the null hypothesis of no difference in the means of the temperatures taken beneath and outside canopy zones can be rejected. In contrast, the test results show that there is also

Table 4.3: Mean land-surface temperatures in degrees Celsius.

Tree	Mean Temp in degrees Celsius
Inside GGW Canopy	38
Outside GGW Canopy	42
Inside Mature *Acacia* Canopy	38
Outside Mature *Acacia* Canopy	42

strong evidence to support the alternative hypothesis that the true difference in means is less than zero (df = 109, t = –10.1693). Such results would that the mean afternoon land–surface temperatures outside the canopy zones are more likely to be greater than the mean land–surface temperatures taken beneath the canopy zone. The evening t–test results proved similar to the afternoon, showing strong evidence to support that the difference in means is very likely less than zero (p = 1.068e–14, df = 107, t = –8.8394).

The paired, one tailed t–test for mature *Acacia* trees in the afternoon revealed that the difference of the means of the land–surface temperatures beneath and outside the canopies was less than zero. (p = 0.01394, df = 10, t = –2.5703). The results of a t–test on the evening land–surface temperatures showed the same (p = 0.0005425, df = 10, t = –4.5338). Such analysis demonstrates that the presence of a tree canopy significantly influences the land–surface temperatures beneath it, and that as the GGW trees mature, they will most likely have greater impact on the land–surface temperatures beneath their canopies.

<u>Solar Radiation</u>

Mean and median values of incident solar radiation can be seen in Table 4.4. Median values very closely mirror mean measurements for all tree and non–tree sites. A boxplot (Figure 4.13) of the incident solar radiation from the study sites shows highly varied measurements, but clear differences between radiation received beneath and outside of the tree canopies. Incident solar radiation measurements beneath the tree canopies ranged from 302 to 1915 W/m^2 for trees planted as a part of the GGW and 222 to 820 W/m^2 for measurements taken beneath the matured *Acacia senegal* trees. Outside canopy

Table 4.4: Mean and median incident solar radiation values for each tree and no–tree measurement site.

	Mean	Median
Inside GGW Canopy	864	818
Outside GGW Canopy	1202	1050
Inside Mature *Acacia* Canopy	522	548
Outside mature *Acacia* Canopy	1289	1127

Figure 4.13: Incident solar radiation measured inside the canopies of the Great Green Wall and mature *Acacia* trees as well as outside of canopy influence. Y–axis is incident solar radiation measured in W/m^2.

measurements ranged from 521 to 2451 W/m^2 for the GGW trees and 601 to 2304 W/m^2 for the mature *Acacia* trees. Histograms with probability density curves for incident solar radiation for GGW trees (Figure 4.14 and 4.15) show that the majority of incident solar radiation measurements beneath the GGW tree canopies fall between 500 and 1000 W/m^2, while the majority of incident solar radiation measurements free of tree influence fall between 1000 W/m^2 and 1500 W/m^2. Approximately 78% of incident radiation measurements beneath GGW canopies was below 1000 W/m^2, while only 43% of solar radiation recorded free of GGW canopy influence was less than 1000 W/m^2. These results support the proposed hypothesis of lower rates of incident solar radiation beneath the young GGW tree canopies as compared to outside the canopy zones.

DISCUSSION of ENVIRONMENTAL IMPACTS

In this part of the chapter, I discuss the results of my fieldwork as they pertain to the GGW goal of improving ecosystem resiliency and soil productivity. I focus on air temperatures, land–surface temperatures, and incident solar radiation. Environmental conditions of the study sites are typical of the Sahelian ecosystem: low rainfall, high temperatures, and high solar radiation. Such parameters account for high rates of evaporation and low soil moisture contents. The goal of GGWSSI is to restore degraded land conditions in order to protect against drought, but also to increase the natural resiliency of the land to such conditions. A tree's physiology, coupled with its interaction with the land, is expected to help create this improved ecosystem health.

Akpo et al. (2005) are credited for studying the effects of fully matured *Balanites aegyptiaca, Acacia tortilis* and *Ziziphus mauritiana* trees on the microclimates beneath their canopies. My study focuses on younger trees of these same species being planted as a

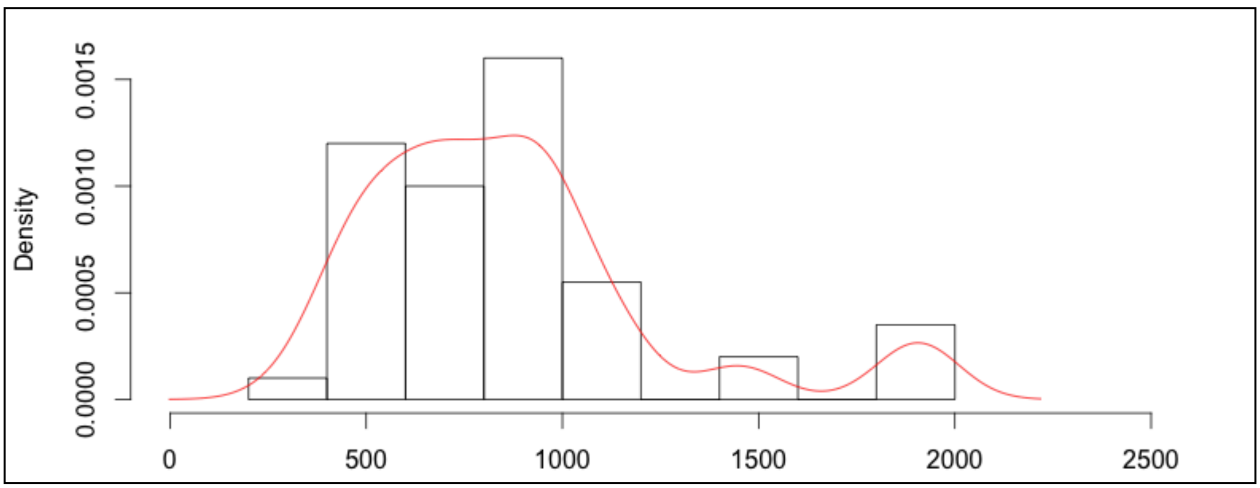

Figure 4.14: Histograms with a probability density curve of incident solar radiation taken beneath the canopies of the Great Green Wall trees. The x-axis represents the solar radiation measured in W/m².

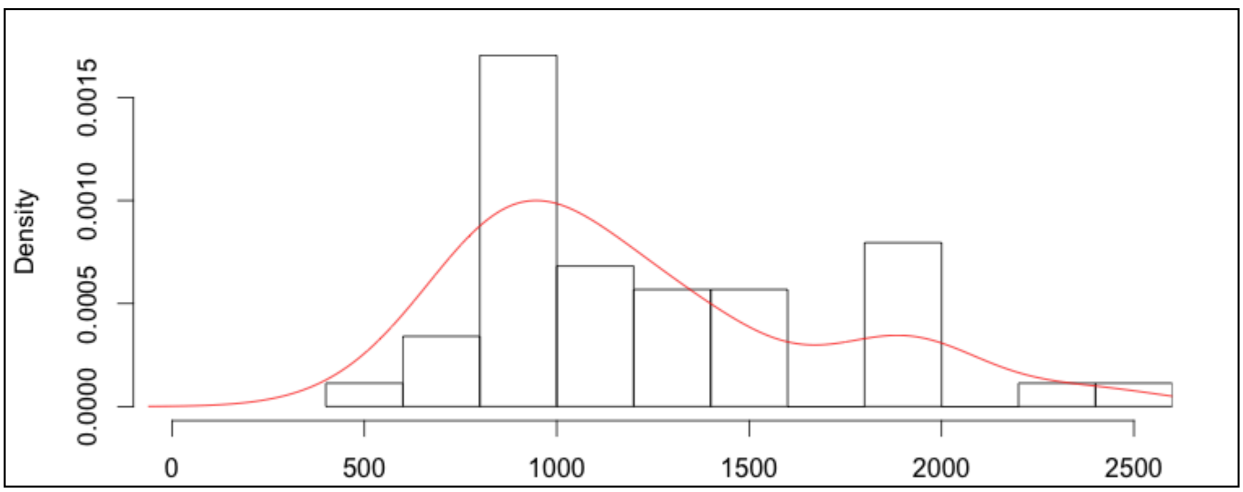

Figure 4.15: Histogram with a probability density curve of incident solar radiation taken outside the canopies of the Great Green Wall trees. The x-axis represents the solar radiation measured in W/m^2.

part of the GGW. They found that the shade under these trees increased soil moisture content and levels of carbon, nitrogen and phosphorus, while simultaneously decreasing air and soil temperatures and levels of direct solar radiation. The combination of these aspects are indicative of overall improved soil health.

This study of immature trees recorded several environmental variables during the 2013 hot season (May–June) in Senegal. Future studies would do well to document these same variables during the rainy and cold seasons as well as during changes in leaf presence (production and abscission). Continual data loggers would be especially helpful in attaining a truer estimate of these environmental variations within a diurnal period. Finally it would be interesting to note the overall effect of the GGW on soil characteristics. As an exclosured area, the GGW parcels are severely limited in the amount of natural manure from cows and goats that typically fertilize the areas in which they roam. The quantity and overall metabolic activity of the vegetation in the area may be affected without such natural fertilization.

Air Temperatures

Although the study occurred during the transition period between leaf–off and leaf–on seasons, maximum air temperatures tended to be lower under the presence of tree canopies. Tree canopies intercept some of the sun's energy, using it in photosynthetic processes and limiting the amount of radiation exposed to the area beneath it. By blocking some of the sun's radiant heat energy, the canopy lowers the average daily maximum temperatures, and thus promotes a cooler environment beneath it.

Average daily minimum air temperatures showed less difference, although they were more often lower outside the canopy zone. Akpo et al. (2005) also showed minimum air temperatures to be higher beneath tree canopies compared to measurements taken outside canopy influence. An explanation for the higher minimum temperatures under the canopy zones at night is the decrease of radiative cooling. The branches of the trees blocking some of the emitted heat from the Earth's surface from being radiated into space, creating higher air temperatures beneath canopies at night.

Lower daily maximum air temperatures and higher daily minima resulted in an overall decrease in the fluctuations of air temperatures beneath tree canopies. Such stabilization of temperatures can be conducive to other forms of understory herbaceous growth, as tree shade influences the amount of organic matter in the soil by reducing the overall temperature and decreasing rates of evaporation. Increased soil organic matter can lead to better soil fertility and water retention. As shade increases, these soil attributes also increase, to a point. The larger these trees grow and the more leaves they produce, the more impact their shade will have on the surrounding microenvironments. Better soil conditions have been linked to longer growing seasons in the canopy zone (FAO, 1999).

Land–surface Temperatures

Afternoon

The high temperatures on the land surface in the afternoon are typical of a semi-arid environment that experiences high rates of solar radiation. The presence of a tree canopy blocks some of the radiant heat hitting the ground, creating a cooler surface. The fact that westward land–surface temperatures are higher in the afternoon correlates to the position of the sun at that time of day.

Evening

Evening land-surface temperatures reflect the afternoon trends. Higher variations in temperatures were seen outside of the canopy zone, while temperatures were more stabilized beneath the branches of the trees. Directional impact seemed to be less significant on land–surface temperatures in the evening, as incident radiation is less and temperatures can fall quite quickly once the sun begins setting.

Overall Impact on Land–surface Temperatures

In land–surface temperature measurements, tree canopy presence significantly influenced the land–surface temperatures beneath it. Inside the canopy zones, mean land–surface temperatures were characteristically less than mean land–surface temperatures taken outside canopy influence. The results of the t–tests show tree–canopy presence impacted overall temperatures in a favorable way, stabilizing this microclimatic attribute beneath the tree. As the GGW trees grow and produce leaves and fruits, these impacts upon land–surface temperatures will increase. Future studies should be done on other tree species being planted as a part of the GGW, namely *Balanites aegyptiaca,* and *Ziziphus mauritania.* Additionally, longer termed studies should be considered in order to more correctly measure the interaction of tree physiology and the surrounding temperatures throughout the different seasons. During the hot/dry season in Senegal, most understory vegetation dies, and the effect of trees on land–surface temperature comes mainly from the presence of shade. Rainy seasons, however, produce a dramatic increase in overall vegetation. The physiological interactions of plants during the rainy season may have a more pronounced impact on such environmental characteristics as land–surface temperature.

Solar Radiation

Frequency of high incident solar radiation (> 1000 W/m^2) was much greater when the measurement was taken outside of the canopy than when it was taken beneath the branches of trees. The presence of the branches makes a marked difference in the amount of incident radiation reaching the ground below. Daily values varied quite extensively, but could be due to the different times the measurement was taken in the afternoon, fluctuations in cloud cover, or increases in tree foliage. A better method of documenting incident solar radiation would require a standardization of measurement at the same time each day or a data logger documenting continuous measurements throughout the days of a study period. Overall impact of the tree canopy on incident radiation is a general decrease in the measurements taken beneath the tree canopies.

As of June 2013, all trees in my study sites reached at least 1.5 meters in height (the tallest was 4 meters). They have started to make quantifiable differences on the microclimates beneath their branches in terms of air temperature, land–surface temperatures, and the amount of incident light reaching the surrounding surface. The preexisting *Acacia* trees in my study sites had heights of 30 and 32 meters respectively. As the trees of the GGW grow into maturity, so should their impacts upon the surrounding environment.

Chapter 5: RESULTS and DISCUSSION–SOCIAL IMPACTS

RESULTS of SOCIAL IMPACTS

Through interviews, conversations, and personal observations of the people I encountered while I was in the GGW field area, I was able to learn how the GGW affects the lives of people at the village level. The findings I present here represent the views of different levels of stakeholders and are subject to interpretation, as most are stakeholder opinions obtained from interviews I conducted in the Pulaar language. Most conversations started with just a few persons (2–5) and quickly attracted several others who wanted to share their sentiments (+10 persons). In conversations with increased audiences, the attitudes shared by one speaker (positive or negative) were reiterated several times by the majority of members of the group. Because I lived in Widou Thiengoly, my resulting conceptual themes are most representative of this one place. Questions and conversations posed in separate villages offered very similar results, however, making it easy to generalize the social effects from Widou to the surrounding villages.

Water

Water was the cornerstone of most conversations I had with the villagers of each GGW village. Out of the 50–65 conversations I had with village stakeholders, it was a major topic in 35–45. It was of special concern while I was there because of the time of year. The hot season yields no other opportunities or sources for villagers to get water outside of the borehole system. Additionally, water demands for domestic and animal needs (drinking, bathing etc.) increase during the hot season due to the extremely warm temperatures. The tree seedlings within the GGW tree nursery must also receive adequate amounts of water to survive the hot season (Figure 5.1).

Figure 5.1: Watering the tree nursery requires large amounts of water to be taken from the local water source. Photo taken June 2013.

According to the Sergeant in Widou (in each village, the Eaux et Forets is run by a formerly trained man of the military, typically a Sergeant), the forage (water tower) pumps water directly to the Eaux et Forets campus for 2-3 hours every two nights. The pumping occurs at night so as to avoid competition with the population. The Eaux et Forets then pays for the water by providing gas for the pump. The forage manager in Mbar Toubab said payment for water amounts to about 800 liters of gas per week. When direct access to water via a pipe from the forage was not available or was not working, GGW workers instead went to the borehole every few days to get water by truck (Figure 5.2), which they then delivered to the gardens, tree nurseries, and Eaux et Forets campuses for domestic use.

The quantities of water being sent to the Eaux et Forets were so great that the water pump oftentimes could not refill its cistern in time for the local population and their animals. This lag time in refilling the overland basin greatly affected daily life for the villagers. Because the borehole was the single water source for all the people and animals within a several kilometer radius (Widou's borehole in particular was a watering point for everyone within a 16 km radius), the presence of the GGW has greatly increased competition for this natural resource (Figure 5.3).

Many villagers (approximately 20–30) claimed that they or someone they were close to had spent up to three days waiting to get water. One villager from seven kilometers away from Widou had been in the village for two days and had yet to get water. He said as soon as he filled his basins he would return home where he would get one day of rest and then return to Widou to wait for more water. When doing so, he would leave approximately 40 liters of water at home for domestic and animal needs until he returned.

Figure 5.2: Great Green Wall workers sometimes use trucks and giant water tanks in order to get water to the tree nursery. Photo taken in Widou Thiengoly, Senegal, June 2013.

Figure 5.3; Villagers of Widou Thiengoly at the community water source getting water for their animals and family. Photo taken in June 2013.

One village respondent was especially passionate on the matter saying, *we did not create climate change or poverty*, *yet the gesse* (tree nursery), *takes lots of water and leaves little for the population* (personal interview English/Pulaar/French). He went on to mention that the people of the Eaux et Forets themselves do not have to struggle for water, as water for the compound is obtained as an official act of the GGW. Other villagers expressed similar concerns: *The biggest difference in the village since the incoming of GGW is it brought problems with water* (interview, translated from Pulaar), *GGW is only problems* (interview, translated from Pulaar), *GGW has decreased the strength of the village* (interview, translated from Pulaar), and *the only problem here is water* (interview, translated from Pulaar). These interviews indicate that the access and allocation of water in the area has been limited due to the presence of the GGW, supporting the hypothesis presented in the introduction.

This struggle for water has left most villagers feeling hydrologically marginalized. One village stakeholder explained community sentiments with a simple story (translated from Pulaar):

> *Imagine you have 2,000 CFA* (approximately $4 US) *to buy rice and vegetables for your family for dinner. Then imagine you unexpectedly have several guests arrive. You are excited to see them, but still know that you only have 2,000 CFA to use for dinner. You do what you can with the money, but you know that no one will be full. Then, those guests never leave. Your resources must be spread out over a greater number of people day in and day out. The guests continually take things out of your domestic system, without putting anything back in. This is how GGW operates in terms*

of water. We like GGW, we like the project, but we still only have 2,000 CFA to spend on dinner.

Another village stakeholder expressed similar sentiments, highlighting that the GGW is taking their local resources, but that the project is not transparent and he is unsure of the overall purpose of the GGW. A pastoralist explained that former president, Abdoulaye Wade, had promised five new wells in the area, but nothing had yet been built.

There are currently plans to convert one GGW parcel planted in 2008 (halfway between Widou and Tessekere) into a nature reserve, complete with animals (there are rumors that these animals would not be native to the area's environment and would include many tree grazers such as giraffes and zebras, etc.). According to a groundwater engineer contracted by the government, a new borehole would be built within the confines of the parcel to supply water to the animals within the reserve. Papa Sarr confirmed this plan, adding that there is potential to connect the new water source to the nearest village, Tessekere, to help alleviate some water problems there. At the time of this study, there were currently no plans to alleviate water problems in other villages.

Gardens

The development of community gardens is a smaller initiative associated with the GGW. The gardens are quite large, built with GGW money and run by a garden manager, usually a trained professional who comes from another part of the country. This manager lives within the Eaux et Forets center. Under the manager, there are democratically elected garden officials (president, vice president, secretary, and treasurer) who facilitate the selling of the garden's produce in the market. In rural, Senegalese culture, women are usually in charge of garden plots. It is rare for a man to be involved, as they are the ones in charge of growing the family's crops. An estimated 692 women are involved in the five community gardens.

In Widou, pipes, installed from the water tower to the garden, connect with a drip irrigation system (Figure 5.4) to water the crops. These lines were not working during my time there, so women came each morning to water the plants by hand. It also appeared in Widou that the pipelines from the water tower to the garden were dysfunctional. Water for the garden was obtained from the community borehole using large trucks and then transferred to uncovered cisterns (Figure 5.5).

Figure 5.4: Drip irrigation system in the community garden of Widou Thiengoly. The irrigation system did not work during the study period. Photo taken June 2013.

Figure 5.5: Uncovered water basin in the community garden of Widou Thiengoly. Women used the water in these basins to water their garden crops by hand. Photo taken June 2013.

Unlike many community gardens in Senegal, which are without access to a water source, these gardens are capable of producing throughout the year. The Sergeant for Mbar Toubab stated, *water is less of a problem (for the garden) and women can garden all year round* (interview, translated from English/Pulaar/French). Depending on the season, the gardens can grow lime and mango trees, beans, eggplant, onions, tomatoes, and hibiscus, among a variety of other crops. Before the implementation of the garden, vegetables were only available at the weekly market.

Women are in charge of garden maintenance—watering, weeding, planting, and harvesting. They are divided into groups. Each group comes on a certain day to water whatever crops are in the ground, harvest what is ready, and discuss what is needed for the garden with the garden manager (Figure 5.6). Meetings with all the women are held once a month to speak of upcoming plans and changes to the working schedule. Each garden I visited was quite large and was fenced to keep roaming animals from trampling on the crops. According to the garden manager in Widou, its garden covered 7.5 hectares. Most of the gardens in other villages were of comparable size.

The garden in Loughere Thiolly was different. It had been established before GGW entered the area. Instead of community plots, each woman owned her own plot and was active as much as she wanted to be. What she produced on her own space was hers and she could use it how she wished. Participation in the garden was struggling as it did not have direct access to water and was 0.5 kilometers away from a water source. Many women had given up gardening outside of the rainy season. When the community-managed garden is harvested, each woman takes home a share of what is produced, while a share is sold in the weekly market (Figure 5.7). Women involved in the garden can buy the

Figure 5.6: Women watering garden crops by hand in Widou Thiengoly. The black line is a non-functional drip irrigation tube. Photo taken June 2013.

Figure 5.7: Women splitting the crop of onions into shares for each woman. Photo taken in Widou Thiengoly, June 2013.

produce at a reduced price, and overall profit from what is sold at market goes into the garden's funds. These gardens are important resources for villages, as they provide for increased nutrition year-round, as well as leadership and educational opportunities for women outside of the home, supporting the proposed hypothesis.

The estimated productivity of the five community gardens from 2008 to 2011 can be seen in Table 5.1. Although equating to only 32 hectares total, the garden spaces have proved quite productive, generating an estimated revenue of almost 5,000,000 CFA (approximately $10,380 US) between 2008 and 2011.

Table 5.1: Productivity of the community gardens that are affiliated with the GGW 2008-2011.[4]

Activity	2008	2009	2010	2011	Total
Village gardens (# of gardens and # of hectares)	N/A		3 gardens 17 ha	2 gardens 115 ha	5 gardens 32 ha
Number of fruit trees in place	N/A		2,370 trees	2,080 trees	4,450 trees
Vegetable production (in tons)	N/A		12,250 tons		12,250 tons
Revenue from garden (in FCFA)	400,000 CFA		1,430,000 CFA	3,055,000 CFA	4,885,000 CFA

Grazing

Another social aspect of the GGW is its impact on the quantity of land available for grazing surrounding the villages. Each parcel of the GGW is fenced and guarded daily, usually by a villager with a machete. The fence is to exclude animals and humans from trampling on the young trees. In an area where most of the population is transhumant pastoralists, such fenced-in places severely limit the amount of area a herder can take his

[4] Data are from handouts given to the author in June 2013 by Papa Sarr, Director of Technical Operations for GGWSSI.

cattle or goats for grass. In this case, the proposed hypothesis of the GGW impact on grazing lands for the local pastoralists proved correct.

As of June 2013, seven villages were participating in GGW in Senegal. Workers of the Eaux et Forets in each village spend the year preparing the seedlings for transplant into the GGW. They also develop the lands surrounding the village to become the parcels in which these seedlings will be planted. Each parcel ranges in size from a few hundred to several thousand hectares. Table 5.2 references the number of parcels near each village. Parcel size depends upon how much money has been allocated to that particular village in that particular year. The Sergeant in charge of operations in Loughery Thiolly mentioned they had originally planned for 4,000 hectares to be planted in 2013. The administration then cut back on finances to this region of the GGW, and the parcel size decreased to only 500 hectares. According to Papa Sarr, the GGW in Senegal will eventually cover a total area of approximately 817,000 hectares.

Table 5.2: Number of GGW parcels near each village. Area per parcel is not known.

Village	Number of Parcels
Widou Thiengoly	6
Keur Alpha	4
Tessekere	4
Lagbar	7
Loughere Thiolly	4
Mbarr Toubab	6

Although the parcels for GGW are fenced off to exclude animal and human pressures, GGW has set up a system in which villagers can apply for a permit to retrieve grass for their animals from inside the parcels. They cannot bring their herds into the GGW land, but may bring in a horse and a cart to remove and collect the grass (Figure 5.8).

Figure 5.8: Parcel guard getting grass inside the confines of a Great Green Wall tree stand. Photo taken outside Mbar Toubab, June 2013.

According to the Sergeant in charge of in the village of Mbar Toubab, “if a villager needs grass, he can come into the parcel and get grass for free. He must get paper from me, but I am fair with the papers. I ask no bribes, no money, etc. I am here for the people” (interview done in English).

A prominent village stakeholder, however, noted the reduction of grass and space available for animals to graze as one of the fundamental issues the GGW brought to the village (in his opinion, second to water issues). Another man mentioned that his herd had once been able to roam for 10 km to forage for grass and now they are contained to less than five kilometers. He mentioned that, should someone’s animals roam into the parcel, without the owner having a permit, the owner would receive a ticket from the guard, which must be paid by bribe. I was in GGW parcels on most days during my stay in the study region. I saw guards two times only. One of those times, the guard was collecting grass for himself. When speaking to villagers on this issue, however, I did not come across anyone who partook in the permit system to get grass for their herds.

Economics

As hypothesized, the GGW has increased economic opportunity in the villages in which it is based. It has does this in three distinct ways: 1) job creation, 2) tourist revenue, and 3) emergence of cell phone service. In each village, the GGW has created 40–50 jobs. Many of these jobs are in the tree nursery—planting and caring for the seedlings—but other jobs include cleaners and cooks for the Eaux et Forets center, the garden manager, parcel guards, drivers, mechanics, and caretakers of Eaux et Forets animals (Figure 5.9).

Figure 5.9: The Great Green Wall has created jobs at the local level, including cooks, tree nursery workers and cleaners. Photo taken in Widou Thiengoly, June 2013.

The GGW employs both men and women, although job characteristics are highly dependent on gender. In Senegalese society, women usually serve as cooks and cleaners, but in GGW they also work in the tree nursery (pepiniere). Their roles in the pepiniere are slightly different from the men's role. Women prepare and plant the seeds, while the men prepare the soil for the seedling bags and water the existing plants. Men are also responsible for building the fences to be placed around new GGW parcels. These jobs have increased, at the villager level, the amount of disposable income in the local economy. Table 5.3 shows a list of jobs and their monthly incomes.

Table 5.3: Great Green Wall–related jobs and respective monthly incomes.

Parcel Guard	$35,000 CFA/month (approx $70 US)
Tree Nursery Workers	$54,000 CFA/month (approx $108 US)
Cleaning Lady	$50,000 CFA/month (approx $100 US)

A complaint of many of the villagers (approximately 10–20) is the demographic of people who are getting these jobs. One of the most steadfast respondents claimed: *GGW is a Cisse family project,* (Matar Cisse is the Director General of GGWSSI in Dakar), meaning that only friends and family of Matar Cisse can get the jobs that have been created by the GGW (interview, translated from English/French/Pulaar). Another village stakeholder said, *I don't have a friend in the forets* [Eaux et Forets], *so I don't have the work* (interview translated from Pulaar). These sentiments were reiterated by other villagers throughout my time in the study area. A prominent man in the village said, *they must develop the locality* in order for the project to be successful, meaning that the GGW should use more of the local labor force. He continued, saying *I am a development agent in the village, and yet there is no collaboration with the local people* (translated from English/French/Pulaar). In

Widou Thiengoly specifically, approximately half of the workers involved with GGW were from the village itself.

Most of these workers live in the Eaux et Forets compound, which gives them unique benefits. Those who live in the Eaux et Forets do not have to go to the borehole to obtain water for their domestic needs. Rather, water is either brought into the compound via through direct piping or in large trucks. Additionally, their meals are prepared by the Eaux et Forets cook. Each resident (including my research assistant and me) pays 14,000 CFA (approximately $28 US) per month for food. When visitors come to the GGW area, fancier meals are made for everyone in the Eaux et Forets compound for no additional charges.

The GGW is an internationally recognized initiative, and it brings hundreds of visitors to the area to study, record, and promote its endeavors. During my three-week stay in the study area I met with many of these visitors, including government contractors, GGW contracted mechanics, and NGO workers. The NGO, World Vision, held a conference in Widou for hundreds of Senegalese farmers to tour the GGW in the area. They came from all over Senegal and were in the area for three days, staying in massive tents and sleeping on cots (Figure 5.10).

When visitors came to Widou, meals were prepared by GGW staff, which usually employed a few more women than just the regular cook. Meals were also a little fancier when guests arrived, almost always serving meat dishes paired with bread. These subtle acts inherently increase the overall demand for these products in the market, greatly boosting the incomes of villagers who sell them.

Figure 5.10: Large numbers of visitors come to the area, helping to spur the local economy. Photo taken in Widou Thiengoly, June 2013.

Travelers would go into the local shops to buy snacks, tea, phone credit, and hygiene items for the duration of their stay in the area, pumping revenue into the local economy. Additionally, souvenirs are an important cultural aspect in Senegal. When a family member takes a trip outside of the village, it is customary for that person to bring something back to the family. Oftentimes it is something small, like tea and sugar. It is not unusual, however, for a visitor to buy something larger when they go out into the bush, like a goat or sheep, as prices in these rural areas are usually markedly less than prices for these same commodities in the cities. Although I was unable to quantify the impacts of visitors on the local economy, I did see a significant amount of monetary exchange between visitors and local business owners.

When speaking with shop owners about the economic impacts of GGW being in the area, I received mixed reviews. Most owners spoke of "no changes" before and after the arrival of GGW to the area. One said, *hundreds of people could come to be a part of GGW and she would never be aware of it* (interview translated from Pulaar). There were two shops just outside the Eaux et Forets compound, but only one of the owners mentioned having to increase his stock, although only by a small amount. Now, when he goes to the road-town of Dara to buy product to restock his shelves he will buy 10 of an item instead of five.

An economic impact felt daily by the villagers themselves revolves around the emergence of cell phones (Figure 5.11). Cell phone service entered the area in 2011. There are multiple cell phone companies within Senegal, but only one, Orange, has entered the area to date. Some people, mainly the GGW workers, explained that service was instituted in the area because of the GGW. One of these workers (not a native villager) stated that

Figure 5.11: The cause of the emergence of cell phone reception to the area is debatable, but its presence has indeed influenced the local economy. Photo taken in Widou Thiengoly, June 2013.

people like him would come into the village to work for the GGW, but would not be able to call their families or the administration in Dakar to let them know how things were progressing. Other villagers disregarded this idea. One villager said, *Cell phone service is not here because of GGW, but because there are CLIENTS willing to buy it here* (translated from Pulaar).

Time Cognizance

GGW has also affected certain cultural aspects for the people in the area. Although I was not in the Ferlo region prior to the entrance of GGW, I was in Senegal, approximately 250 km to the southeast of Widou, living in a Pulaar village for two years. During that time, I realized that villagers had very limited cognizance of the hour of the day. Most people did not wear watches (or they wore non-working watches), and the concept of time was merely marked by the day of the weekly market, the onset of rainy season, and the phase of the moon during the Islamic holiday Ramadan.

In the Widou study area, the concept of time proved to be somewhat different. Villager workers placed a much higher significance on time, down to the minute. My prior experience in Senegal taught me that "we will meet at 10 AM" meant that "we will meet anywhere between 11 AM and 3 PM." In Widou, when I told a worker we would meet at 3:30 PM, he was ready for me at 3:25 PM. A number of different drivers took me to and from the GGW parcels each day. Although our departure time for the GGW fields tended to depend on events like lunch and prayer, I was always picked back up at exactly whatever time we had specified. Tree nursery workers would also often ask me the time during their break in the middle afternoon, so as not to be late for their afternoon work hours.

Perceptions of the GGW by Stakeholder Level

Overall, as hypothesized, the perception of the GGW varies according to the benefice that particular stakeholder receives from the GGW. The majority of villagers I spoke to about the project had negative perspectives on the GGW, especially if they felt marginalized by its presence. One emphatically declared, "GGW, c'est pas sérieux!" (The GGW is not a serious project) He went on to state that the success of the project would be dependent upon *development of the locality, but that there has been no collaboration with the local people* (translated from English/French/Pulaar). Several village stakeholders cited their dismay over the lack of local people hired by the GGW, while village chiefs spoke of lack of transparency in the project. The majority of villagers cited water to be the main problem brought by the GGW, claiming that GGW had decreased the overall strength of the village by taking this resource. Some added that the only thing the GGW had brought to the village was problems.

A theme of "if it is not problems, it is not GGW" has arisen in parts of Widou, and I had several conversations with villagers who compared the GGW to a German NGO project that had taken place in the area for 27 years (1981–2007). The goal of this particular project was the protection of grasses through exclosure spaces. It did not involve tree plantings or large amounts of water. According to the director of Widou's primary school, there were no problems with water during the German project. One of the local shopkeepers expanded saying that *everyone worked for the German project, they each got paid by the month and could buy the things they needed to buy* (interview, translated from Pulaar). Their sentiments towards the GGW seem to be quite opposite of their perceptions of this former German project.

Interviews I had with women were a bit more reserved than the interviews I had with the men. It seems, however that women, for the most part, were indifferent to the project's presence on the ground outside of the community garden aspect. Culturally speaking, their viewpoints are usually shaped if not determined by what their husbands (or fathers) believe, and expressing these beliefs (whether shaped by a man or not) is considered taboo for women. Most women appreciated the garden and the ability to reap its products, and when asked the point of GGW, they all responded saying that without it they would not have vegetables.

The people with the most positive sentiments for GGW were the ones who worked for it. Starting from the administration level in Dakar down to the workers in the tree nursery, each interview with an employee held positive viewpoints on the presence of the GGW on the villages. Papa Sarr stated, "the village people are happy about the project being there" (interview in English). One villager who volunteered for the GGW on an intermittent basis stated, "the GGW caused an increase in jobs, an increase in birds, and is responsible for holding back the desert." One bitik (shop) owner spoke of the positive changes the garden had brought to the women.

DISCUSSION of SOCIAL IMPACTS

Water

There is a Pulaar saying that, "a man cannot speak his mind until his herd has drunk water." In a land dominated by meager and highly variable rainfall, and where pastoralism equates to livelihood, water is the primary concern of daily life. It is the driving force behind herd movements and it has influenced the recent sedentarization of nomadic lifestyles.

Historically, water was "open access" for nomadic pastoralists (Tisdell, 2003). They would come upon a watering point, take what they needed and moved on. Until the mid 1950s, pastoralists would only visit the Ferlo region of Senegal in the rainy season due to lack of permanent watering points (Valenza, 1975). Boreholes began being built in 1954, and by 1955, 50 wells could be found along the major herding routes throughout the Ferlo (Thompson, 1958). [I am unsure if the borehole in Widou Thiengoly was a part of this original digging frenzy, but multiple village sources reported the age of the well to be between 50-60 years old.] Nomadic pastoralists could then expect year-round access to water in the region and many began settling around the new boreholes (Valenza, 1975).

At this point, water was still deemed "open access"—free for anyone to use however he/she needed it. To help prevent conflict between settlers and nomads, the government declared that all subterranean water should be state property and also should be free (UNDP, 2013; Thompson, 1958). This declaration compelled the government to pay for all the fuel, repairs and staff required for each borehole, but it also equalized all users' rights to water access.

Water management has since changed dramatically in rural Senegal, especially in the Ferlo region. By the 1980s there were over 180 wells, and the national government could not finance all their operations. It then handed control of water to local communities who created committees to manage the water system (Thompson, 1958). Users began to be charged for their water consumption in order to help cover the costs of borehole maintenance and operation. This system is more or less still governing water distribution in Widou Thiengoly. Recently, in November 2013, the government announced that it would turn to private industry for maintenance and management of rural borehole system (PEPAM, 2013). Implications of this new policy upon Widou are not known.

Instituted within this more formalized agreement among water users is customary law based on the norms and traditions of an Islamic, pastoralist society. The Qur'an recognizes the importance of water for all existence, while also declaring it as a merciful gift from Allah that should be used but not exploited, "He sends down saving rain for them when they have lost all hope and spreads abroad His mercy" (Qur'an 25:48) and "Eat and drink from the provision of Allah, and do not commit abuse on the earth, spreading corruption" (Qur'an 2:60). A fundamental part of Islamic tradition is the purification practice before each of the five daily prayers— Allah does not accept prayers said in a state of impurity (Murad, 2006). Even in areas where water is especially difficult to obtain (possibly taking up to three days), like in Widou Thiengoly, community members adhere to this religious doctrine and collect enough water for their daily purification rituals. For this reason, Islam places a high priority on fair and equitable access to water.

Water is also deeply fundamental in pastoralist societies. Cows, goats and sheep are like bank accounts. All efforts to allow these assets to survive are taken. In the rainy season they drink from seasonal lakes. In the hot season, the herd is taken directly to the borehole to be watered. Here, family members distribute water to the herd before filling their own basins.

Many of these customs vary temporally, based on the season. During the rains, alternative access points for water are quite common. There are rainy-season lakes from which to withdraw water for laundry, watering animals, etc. It is also not as hot in this season, so animals and humans require less drinking water. Most households also practice rain catchment for domestic use whenever possible. Such practices alleviate pressures on the borehole system. During the hot season, everything needs more water and no alternative to the borehole system exists, creating increased pressure on the resource. Certain adaptations take place in order to accommodate this more stressful acquisition of water. Animals drink only every few days. Laundry is done less often. Gardening gets postponed until the rainy season. There is no written law mandating these practices, but this particular society recognizes their importance in order to ensure equity in water access for all people and their religious and livelihood needs.

Existing customary institutions are influenced when 'newcomers' enter the system (Meinzen-Dick, 2005). The dynamics of the new system will depend on power relationships. If the incoming entity enters an area with more power than the existing institutions, the system as a whole will change. If the incoming entity comes into the system with less power than the existing institutions, the system as a whole will stay intact.

Because GGW is a top-down approach to natural resource management and is run through the government of Senegal, it entered the area with much more power than the existing, traditional institutions. Because it held more money and influence, GGW was capable of shifting the power over water away from village-level needs in order to ensure its own success. The Human Development Report (UNDP, 2006) explained that, in times of water scarcity, it is the people who do not have a voice in the allocation decisions who first feel the effects of reduced supplies. Multiple community members, including village chiefs, showed evidence of this theory and spoke about the lack of transparency in the project: *I don't know what it* (GGW) *is doing or why it is happening. It needs to be transparent but it is* *not. It is taking our resources* (interview with village chief of Loughere Thiolly, translated from Pulaar). The village leaders had no part in this decision-making process. GGW was sent to them without consultation. They accepted its presence, and have consequently been water stressed by its existence—an ironic paradox of the first goal, which aims to "improve the living conditions of the people within the Sahel."

Access to a resource includes the ability to secure a minimum amount based on need (Gupta and Lebel, 2010). For international reporting purposes, access to water is defined as "at least 20 L/day of clean water from a source less than one kilometer from home" (UNDP, 2006). GGW has altered this access for many by taking massive amounts of water out of the borehole system at Widou Thiengoly to care for the seedlings in the tree nursery. The pump cannot keep pace with demand. The competition between the trees, humans, and animals is now too steep to fulfill all needs. Consequently, many families must wait up to three days to fill their cisterns and provide drink for their animals—most negatively impacting those families who come from several kilometers away to get water.

In the realm of health, less access to water leads to more instances of domestic water shortages. During such water scarce times, families often furlough certain domestic duties that are also considered preventative health measures, such as proper hygiene.

Water allocation refers to the sharing of water as a resource, including its burdens and risks (Gupta and Lebel, 2010). GGW has affected this landscape in multiple ways. It has diminished the overall quantity of the resource to be shared, leaving less for the general population, and has unevenly distributed allocation difficulties onto the village population. Because villagers are spending more time waiting for water, typical daily activities are delayed, creating a sense of "time poverty." "Time poverty" refers to the limitations and consequences of the time demand it takes to do labor activities that are essential for daily life (UNDP, 2006). By spending more time getting water, children and teachers are out of school longer, and economic activities are delayed, linking time poverty to income poverty. Currently there is no formal contestation by the villagers towards the administration of the GGW. When asked about their hard times getting water, most villagers (including those who were most passionate against the GGW) merely claimed, "ko aduna tan" (that is the world). Although quite vocal about the problem, they do not seem to be actively protesting the presence of the GGW or its power over the water system.

Alternatively, because this project is on the ground in this area and because it must have water to be successful, there is a greater interest in keeping the water system functioning. The government is now more invested in the area than it was before the implementation of GGW. When something in the water system malfunctions or breaks, there is likely to be a quicker response to getting it fixed.

Gardens

The women who worked in the gardens seemed quite proud of their work. The presidents of the groups of women gardeners in both Widou Thiengoly and Loughere Thiolly spoke of enjoying their work within the garden. The president in Widou comes in from two kilometers away to participate in the garden functions, and the president in Loughere Thiolly continued to be active in her garden plot, despite its distance from the water source. Such viewpoints seem to indicate a general desire to have and to be active in this part of GGW. Each day I spent in the garden at Widou, as many as 20 women would come to water the plants and harvest its crops, spending at least 1-2 hours there. In this culture, women rarely have jobs outside the home. Their days typically consist of cooking, getting water, and taking care of family members—they rarely have free time. That women are spending these hours every week at the garden is an indication of the positive impact this aspect of GGW is having on the villages.

Women are willing to take on the extra work of gardening for the prospect of better food for their families. I saw them divvy up the harvest of onions and eggplants, each woman getting enough for at least the next few days—proof that this aspect of GGW is affecting villager nutrition. My conversations about GGW with the women in the garden were mostly positive. No one I spoke to in a garden ever mentioned any problems GGW had brought to the village, although some did mention issues with access to water and lack of economic opportunities for the villagers. They did not, however, associate these social issues with the entrance of GGW to the area. For this reason, I believe their perception of GGW was either (a) heavily influenced by the production/presence of the garden or (b) kept to themselves, as expressing personal opinions is uncomfortable and atypical of a Senegalese, Pulaar woman.

Grazing

One reason that may explain my rare encounters with the guards is the massive expanse of land they are expected to patrol. One parcel can encompass hundreds to thousands of hectares, making a circuit of it time consuming and difficult.

Village perception about how much land is now closed to public access is relative, based on the person answering the question. It was difficult for villagers to quantify how much land they no longer had access to when I asked them how their grazing patterns had changed.

In regard to the lack of village participation in the permit system, I made several observations. One day, I became lost in an unfamiliar parcel. In trying to make my way back to my study sites, I noticed several downed fences, spanning many meters. Such open access would make secret grass-grabbing quite easy. I cannot say if this happened, as no villager admitted to doing so. Another possible explanation is that the information about the permit system is not well known in the village. Certain parts of the population may not be privy to its existence. The people with whom I did speak, were knowledgeable yet extremely unenthusiastic about it. I did not speak, however, to the entire village population about this issue.

A more likely explanation for the lack of use of the permit system is the deliberate disregard by the villagers who choose to ignore the opportunity the system presents. Reasons for this disregard can be varied. This system was imposed upon these pastoralists; it was not planned *with* them, effectively leaving them feeling disempowered. Land, along with other natural resources such as water and wood, in pastoralist culture is typically considered open access. [Agro-pastoralist society is a little different in that herds are typically kept off of producing cropland.] In a Senegalese pastoralist society, however, a herd takes what it needs, and there is no exchange or payment necessary to a landowner. The visiting herd's manure helps to fertilize the field for the following rainy season. Typically, ownership of a land in rural Senegal is not decreed by a legal document or title, but, instead, village elders decree it in a patriarchal fashion, making "ownership" more of a relative term rather than a legal contract.

Exclosured spaces not only severely limit the prospect of finding grass nearer to the village, but the system as a whole changes the very culture in which Senegalese pastoralists operate. It challenges the tradition-based ideologies behind land ownership and open access to natural resources, resulting in a population that feels marginalized by the presence of the GGW in its space.

Economics

The perception of economic impact by the GGW in the area is quite varied among the villagers. Positive viewpoints typically came from stakeholders who have directly benefited from the presence of the GGW, namely, its workers and the shopkeeper whose store was closest to the Eaux et Forets center. The store of the woman merchant who saw no impact from the GGW was across the village from the Eaux Forets center. This distance could be a determining factor when the GGW workers or visitors are choosing a place to purchase items, thus influencing her perception of overall economic impact by the GGW. Interestingly, this businesswoman had solidified her place in the market with the local population by setting up a solar panel and using its energy to run a refrigerator, thus becoming capable of selling cold drinks.

The argument that the GGW workers brought cell phone service to the area is debatable. I did not have a chance to meet with an employee of Orange to ask why the company had entered the area. It is possible that the GGW administration in Dakar helped to influence Orange's arrival to the area, but cell phone reception is still a growing market in Senegal. Even today, it has not reached all villages, but it has grown tremendously in the recent past, making cell phone reception quite common throughout the country. Widou

Thiengoly is the location of the area's weekly market and medical services. Phone companies often place cell phone towers in these kinds of villages. The continual influx of visitors to the markets and health posts is an indicator of a strong and dynamic customer base. This case has proven true in Widou and the surrounding villages, as most of the villagers (men and women) have cell phones and most shops sell cell-phone credit.

Time Cognizance

One of the reasons for the increased recognition of time in a village associated with the GGW is the work schedule for the GGW workers. Their days are much more structured than those of the regular pastoralist life. Work hours ran from 8:00 AM to 1:00 PM, with a break for lunch and prayer (Widou is predominantly Muslim), and then again from 4:00 PM to 7:00 PM. The community garden worked a little differently. The women involved would trickle in to work at different times in the morning, usually after having served breakfast to their families, but they knew all work needed to be finished by noon each day, as that was the schedule put in place by the GGW-employed garden manager.

Perceptions

Overall perceptions of the project were quite varied between administrators and villagers. Most villagers with whom I spoke had an overall negative opinion on the project, citing water to be the biggest issue since GGW entered the village area. One villager stated to me early on in my stay there that for every positive sentiment I hear about GGW, I would hear two negative ones. He was not wrong.

The village stakeholders with negative viewpoints seemed to associate the presence of the GGW with certain problems in the village. Village stakeholders with positive or indifferent opinions did not see these same relationships, were benefiting economically from the GGW, or were afraid to speak of their true sentiments.

Administrators and the GGW field staff expressed positive sentiments about how the project was being conducted. Word travels very quickly in small villages, so ground-level workers know what problems exist in the village. They know that water is hard to get and that grazing lands have been limited. They may not fully understand, however, the impact that the GGW has had on these villagers' daily lives due to the fact that, as GGW field staff, they received the benefits of the new job creation and also were not responsible for their own water or food needs.

Chapter 6: CONCLUSIONS

<u>Environmental Impact of the GGW</u>

The environmental results of this study can be summarized as follows: 1) The shade provided by the trees planted as part of the GGW is beginning to impact their surrounding environments and these changes can be quantified. 2) The young *Acacia senegal* trees as a part of the GGW are already stabilizing the air temperature beneath their canopies by decreasing maximum temperatures and increasing minimum temperatures. This decrease in fluctuation of air temperatures, due to the shade effect, has the potential to be conducive to other herbaceous life, and thus increase overall soil fertility. 3) Land surface temperatures taken beneath the GGW tree canopies are lower compared to the temperatures taken out in the open. This microenvironmental change can also help to decrease rates of evaporation, and thus increase water retention in the soil. 4) Trees decrease overall rates of received near–ground radiation. 5) Comparatively mature *Acacia senegal* trees have more impact on their surroundings than the young *Acacia senegal* trees of the GGW. Their increased impact is indicative of the potential future influence possible by the trees of the GGW.

Although these trees are still quite young (not quite six years old) and these measurements were taken in the transition to leaf–on season, the GGW trees are already influencing the surrounding environment by stabilizing near–ground temperatures and amounts of incident solar radiation. In these terms, restoration is starting to occur. The impact of the older *Acacia* trees in the study sites indicates potential for future influences by the GGW trees.

An important consideration that was not taken into account in this study is the annual tree mortality rate. Rainfall influences tree survival rates annually, and a study of these rates is recommended to more fully model the actual effect of GGW trees on the land. Additionally, to more holistically quantify the impacts of GGW on the ground and assess its progress towards the goal of improved ecosystem health and resilience, future research is encouraged on changes in albedo, herbaceous undergrowth, soil moisture, and soil fertility.

Social Impact of the GGW

The social ramifications of the GGW can be seen in changes to daily life for the villagers. As hypothesized, these changes especially revolve around participation in the community garden, increased economic opportunities for some, changes in grazing patterns for animals, changes in water accessibility, and overall perceptions of the project.

Lack of access to water was a central theme in all my conversations in Widou. In the hot season, GGW removes great amounts of water from the one water source in the village. The pump is not capable of keeping up with demand from the project as well as with demands from the population. Because the GGW comes from the government, its needs from the water system take precedence over the demands from the population. It has effectively hydrologically marginalized the village population, instigating a sense of time poverty by elongating their quest for water and diminishing time for other potentially economically beneficial pursuits, such as education, business, or improved health. This change in daily life was oftentimes passionately touted as the major problem of the GGW presence in the area.

The presence of the garden allows for improved nutrition as well as increased economic opportunities for women. Most women view the garden as the major impact of the GGW.

Grazing patterns have changed due to decreased available land surrounding the villages. It is possible to get a permit to remove grass from within a GGW parcel, but this permit is either fictional, not well publicized, or given nepotitiously. For these reasons, many men in the village have negative perceptions on the role of the GGW in the village

Economic opportunities have increased since GGW has been implemented on the ground, although quantifying these impacts was difficult in only a short time in the study area. Increased jobs include tree nursery workers, maintenance men, cooks, and cleaners. Cell phone reception is new to the area (since 2011) and has brought increased phone usage as well as the sale of pay-as-you-go minutes to the area's businesses. Perceptions on why the cell phone company entered the area differ depending on the level of stakeholder. People working for the GGW believe that their presence in the area influenced the company to come, while other stakeholders believe that it was a matter of having clients in the region. Most shop owners did not recognize any growth within their particular shops. Only one shop owner spoke of positive changes, and those have been only in small amounts.

Time cognizance appears to have increased since the presence of GGW. Importance on time is not typical of Pulaar or Senegalese culture; therefore, the current importance of work schedules for the GGW represents a departure from traditional culture.

Perceptions about the project differ greatly between those who work for GGW and those who live in the villages in which it is happening. Administrators and GGW workers (especially those who are originally from different cities/towns) have more positive viewpoints towards the initiative, while most people in the villages see it as an instigator of major problems. Optimistic villagers believe it can be improved with better access to water as well as increased job opportunities for local people.

Future research is encouraged on these social aspects, with an emphasis on how they change throughout the year. Water problems have the potential to be alleviated during the rainy season, as seasonal lakes offer a secondary source of water for animal needs and other domestic uses, such as laundry. Also, cooler temperatures will decrease the amount of water needed for drinking water. Additionally, once the older parcels have trees mature enough to remove the enclosing fences, grazing lands will increase, allowing pastoralists easier access to grasses for their herds. With improvement in these problems, perspectives on the presence of GGW may change. Finally, a closer study on the economic effects of the GGW in the area is recommended to better help quantify its direct impact.

The presence of the GGW trees is having several impacts—positive and negative. In the end, it is the environmental aspects of the GGW that will most likely prove sustainable. When the GGW is finished and its money and resources exit the area, the jobs it created will be lost. The villagers who worked these GGW jobs will return to pastoral livelihoods, a major component of their culture. Tourism dollars will decrease as memory of the project fades. The women may continue gardening during the rainy seasons, but as access to water is difficult, hot season gardening will probably be abandoned. Grazing areas, however, will be returned with an added benefit of the fruits and fodder provided by the GGW trees. Such increase in vegetation can be used domestically or sold in market, helping to improve Sahelian livelihoods through an increase in ecosystem health—exactly meeting the first two goals of the GGW.

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APPENDICES

APPENDIX A: PRE-TRIP GRANTS/PROPOSALS

IRB Proposal

I. Identification of Project
   a. Principal Investigator: Anna Alsobrook
      i. Address: 916 Luttrell St. Apt#5 Knoxville TN 37917
      ii. Phone Number: 901.487.2716
      iii. Email: aalsobro@utk.edu
   b. Faculty Advisor: Dr. Carol Harden
      i. Address:
      ii. Phone Number:
      iii. Email: charden@utk.edu
   c. Project Classification: Thesis
   d. Title of Project: A multidimensional analysis of the Great Green Wall in Senegal: a study of the physical and ecohydrological effects of afforestation and its impacts on a human landscape
   e. Starting Date: July 18, 2013
   f. Estimated Completion Date: August 21, 2013
   g. External Funding
      i. McClure Scholarship deadline March 6, 2013

II. Project Objectives: Quantifying the microenvironmental effects of tree canopies. 2). Comparing these effects with studies on fully matured trees to see at what rate soil properties are sustainably being ameliorated. 3) Using data from national and private sources to determine the effects of these young trees on the area's water balance; and 4). Interviewing appropriate stakeholders including government officials, local farmers, women and children who have participated in the planting/upkeep of the trees.

III. Description and Source of Research Participants: Research participants will primarily include women and men of local, surrounding villages of the Great Green Wall for the Sahara and Sahel Initiative. They are of the Fula culture whose livelihoods are dependent upon subsistent farming and pastoralism.

IV. Methods and Procedures: Methods will exclusively include interviews. I will go to at least three villages directly affected by this project, and speak with the local chief in each one. I will ask him to direct me to people who are directly involved in the GGWSSI project, or people who have been affected by it or its presence. From there, I will visit the households mentioned, and conduct the interviews with the appropriate people there.

V. Specific Risks and Protection Measures: Risks in this project are limited. There will be essentially no risks to the participating stakeholders. As the investigator and a woman, I will take care to conduct interviews in the presence of multiple people. I also intend to employ a local student to help with aerial knowledge, directions, and data recording.

VI. Benefits: In this semi-arid area of the world, any instance of vegetation change is capable of rapidly tipping the water balance from positive to negative; thus, having the potential to alter the hydrologic cycle. Because the water balance in these arid ecosystems is so fragile, studies that quantify the ecohydrological processes, especially in terms of woody encroachment, are important. In the case of the Sahel, most agriculture is rain-fed and any stress on the water system will inevitably lead to increased concerns over food security. GGWSSI has essentially been a top-down approach to natural resource mitigation (although several pieces of GGWSSI literature declare it as a grass-roots initiative). It is the stakeholder group directly affected by the project, the rural poor that has been left out of the decision-making process. From an efficiency and scholarly standpoint, it is commonsensical that their role in the decision making process be limited. At the development scale, they have neither the scientific background, nor the financial bearings to be of much use. They do, however, have labor and historical areal knowledge that could and do come into play. Unfortunately, by being marginalized, their lifestyles and cultural traditions are at risk of being dismissed.

VII. Methods for Obtaining "Informed Consent from participants: Most villagers in this region can neither read nor write. To obtain "informed consent," I will merely ask for permission to speak with them about the project. Should they agree, the student who is helping me with data gathering will then mark the stakeholder's name on a sheet, indicating that they have indeed consented. Should a stakeholder decline an interview, efforts at questioning will subsequently be dropped.

VIII. Qualifications of the Investigator to Conduct Research: The main researcher of this assignment (Alsobrook) has previously lived in Senegal. She has much experience living in the Fula culture and is capable of speaking Pulaar, the language of the villages in which the GGWSSI project in Senegal is happening. Additionally, she has much direct experience with tree propagation and transplantation, as well as training Senegalese nationals in such practices.

IX. Facilities and Equipment to be used in the Research: No facilities will be needed as interviews will be conducted in villagers' homes. No equipment will be needed, except for a recorder in order to more accurately depict stakeholders' statements during the time of analyzing the results.

X. Responsibility of the Principal Investigator: By compliance with the policies established by the Institutional Review Board of The University of Tennessee the principal investigator(s) subscribe to the principles stated in "The Belmont Report" and standards of professional ethics in all research, development, and related activities involving human subjects under the auspices of The University of Tennessee. The principal investigator(s) further agree that:

a. Approval will be obtained from the Institutional Review Board prior to instituting any change in this research project.
b. Development of any unexpected risks will be immediately reported to Research Compliance Services
c. An annual review and progress report (Form R) will be completed and submitted when requested by the Institutional Review Board.

d. Signed and consent documents will be kept for the duration of the project and for at least three years thereafter at a location approved by the Institutional Review Board

IRB Consent Basis

GGWSSI is a massive tree-planting project aimed to protect the lives of rural people. The aim of this research is to document your involvement with GGWSSI and how the initiative as a whole affects your daily life. It involves interviews and participant observations, and should not take much of your time. I will merely ask you some questions and make notes about some of your daily activities. Your story will be documented so that other nations facing the same problems can see an example of how such a large project can work. In documenting your story, I will never reveal your identity. Everything you say will remain anonymous. All my records will be safely stored and no one but me will have access to them. If at any time, you wish to remove yourself from the study, you have the right.

Pulaar Translation:
Ton woni projet ko mawni. Yimbe resde lekki ko heewi, doo haa leydi Djibouti. Jom projet wad murialle lekki por remde yimbe be e wurooji. Mi yiddi jangude projet o e windude ma histoire e projet o. Mi yiddi andude liggey ma e projet e nden non projet o wadi changement e ma temps/liggey e nwalma o. Mi namdoto ma e mi ndarat ma heen tan. O waddata waktuuji ko heewi. Mi hebata sarriche por ma waktu kono aan e histoire ma waawi waluude leydi gordo so o hebbi cadeele e environment, leydi ndi woni selaani, wala leydi ndi hebata lekki hay dara. Aan e histoire maa waawi walude be. Innde ma wonna cadeele. Hay gorto ngadat innde ma, ko miin tan. Fof, kan halat, waddi importance kono hay gorto ngadat maa. Mi moptat tindle ma e ko miin tan hebat chabbi ki. So a yidda non, a waawi yaltat walaa so a yidda namdol, a waawi halata.

McClure Scholarship Proposal

Paralysis of entire nations, collapse of economic sovereignty, destabilization of geopolitical regions—the powers of drought have historically proved daunting. No place is more cognizant of this than the Sahelian region of Africa. The 1970s-1980s brought the worst droughts of the 20th Century to the Sahel (Gaulter, 2012). A reported 100,000 people died and over 750,000 subsequently became dependent upon food aid (Wittig et al., 2007). These droughts stemmed from a multitude of natural, anthropogenic, and political causes.

The Sahel is a dry zone of transition between the Sahara Desert and the tropical rainforests of Central Africa. Traditionally, nomadic pastoralists roamed the area to find water in the semi-arid climate. Colonial powers severely altered this lifestyle by drawing national borders, thus limiting nomadic movement. Herders began settling, forming new villages in the region. Their agricultural practices quickly exhausted the soil of its nutrients, and overgrazing further decreased the area's vegetative cover. As sedentary populations grew, so did demands for firewood, agricultural land, and fodder; trees were cut down, further depleting soil health and productivity (Stewart, 2008).

Land degradation is linked to the desertification of the region, which in turn threatens the livelihoods of millions of people. In 2005, Nigerian president, Olusegun Obasanjo, introduced his vision to combat the degradation: a literal green wall of trees to span the continent (15km wide, 7,600km long). The proposal was met with profound acceptance and soon morphed into an integrated, ecosystem management approach with three principal aims:

1) Improve the living conditions of the people in the Sahel and enhance resiliency to climate change, climate variability, and drought;
2) Improve the state and health of ecosystems and their resiliencies to climate change, climate variability, and drought;
3) Create collaborations and partnerships between international and national stakeholders (FAO-EU Partnership, 2011).

The African Union approved the Great Green Wall for the Sahara and Sahel Initiative (GGWSSI) in 2007 (Johnkingsley, 2011).

Abdoulaye Wade, former president of Senegal, was the project's first major advocate. The country led the initiative into action by starting to plant trees in 2008. Since then, 50,000 acres of trees have been planted, roughly equating to 2 million trees each year (Hertsgaard, 2011). Senegal has fronted $2.1million (US) for its section of the project, but several international agencies have promised funding (Barbier, 2011). In 2011, the Global Environment Facility agreed to $115 million (US), citing the potential for it to become a carbon sink (Johnkingsley, 2011). Additionally, the World Food Programme has provided food for the community villagers who donate their time to plant and maintain the trees (Johnkingsley, 2011). The World Bank has also contributed $1.1 billion (US) (Bascombe, 2012).

The physiological processes of trees have long been credited for improving soil conditions, promoting greater water retention, improving nutrient levels, and increasing biodiversity (Charreau & Vidal, 1965; Grouzis & Akpo, 1997; Allen & Chapman, 2001; Chauhan, 2003; Deans & Munro, 2004; Farley et al. 2005; Fuchs, 2005; Jackson, 2009). Tree root systems play an important role in sequestering water and nutrients (Deans & Munro, 2004). Additionally, tree shade reduces the level of solar energy, thus cooling the ground and decreasing rates of ground evaporation (Fuchs 2005). In Senegal, soil water retention rates were upwards of 43% higher under canopies of a certain *Acacia* species (Charreau & Vidal, 1965). These differences reflect less extreme climatic conditions as well as greater soil fertility.

Western development policies stress the need for participatory and integrative approaches when dealing with the conservation of natural resources (Li, 2006; Margles, 2010; Nath & Inoue, 2010). The GGWSSI is saturated with stakeholders of all levels (e.g. the rural poor, intergovernmental organizations, scientists), certainly creating daily complexities. The cohesiveness of these stakeholder relationships directly affects the attainability of the goals for GGWSSI; therefore, an assessment of how these relationships are working and affecting each other is a primary goal of this study.

Especially important is the role of the village stakeholder in the project. While they lack scientific knowledge of afforestation, they bring invaluable familiarity of the land and its resources. By voluntarily planting and watering the trees, they are the ones effecting the ecological change the project aims to achieve. Their story, however, has yet to be written. The impact of GGWSSI upon them and their impact upon it is undocumented, yet insights about this interaction could be important for other developing nations facing similar natural resource problems.

The objective of this study is to assess what physical and social impacts have already emerged from GGWSSI as it pertains to Senegal. I will analyze whether the presence of the tree wall has created any cultural or physical shifts of the communities involved and quantify the physiological impacts these young trees are having on the microenvironments beneath their canopies. These objectives assess progress toward the first two goals of the GGWSSI.

Having recently lived in Senegal as a Peace Corps Volunteer, I know the region and the Fula culture well. I also speak Pulaar, the language of the villages in which the GGWSSI is happening. Additionally, I have a strong background in French, and a decent understanding of Wolof (other prominent languages in Senegal). I have held community meetings, conducted baseline surveys, and am quite familiar with the politics and dynamics of rural, Pulaar villages. I have Senegalese and Peace Corps contacts all over the country and have contacted the initiative's director in Senegal (Colonel Matar Cisse) and an involved scientist (Dr. Aliou Guisse), who have expressed interest in the topics I am addressing and have offered to be of assistance. Additionally, I have direct experience with tree propagation and transplantation, and have trained Senegalese nationals in such practices. The project will provide an extension of professional and personal development, as well as a continued cultural exchange for myself and for the Senegalese involved.

The study will take place for five weeks from mid June to mid July 2013. This will partially be during the Islamic holiday of Ramadan, an advantageous time for holding stakeholder interviews, as people are less likely to be working in the fields. Qualitative analysis at different stakeholder levels will be done with semi-structured, personal interviews and participant observations. Community stakeholders will be found by travelling to local villages and speaking with the chiefs and women's group leaders to understand who is involved. All levels of stakeholders will be interviewed, but questions for each stakeholder group will vary slightly, depending on their involvement with the project. IRB permission is pending. Travel to sites and villages will be by public transportation.

The physical effects of the green wall will be studied in Widou, Thiengoly, Senegal. The first trees were planted there in 2008, making them viable for physical measurements. Field research will be conducted under the canopies of commonly planted tree species to quantify the effects of the trees on the microenvironments beneath them. These measurements will be compared with measurements taken approximately 5m from the tree, so as to be in sun-only environments.

Four sites will be studied within the confines of GGWSSI project area. Each location will be documented with GPS. I will measure width, height and canopy breadth of 100 trees, classify soil texture using an on-site soil hand test, and document the presence or absence of any ground cover with photographs and site descriptions. At pairs of tree-covered and sunny sites, I will measure air and soil temperatures twice daily (early morning and mid afternoon) and soil moisture once. Differences in incident solar radiation between sun and shade will be measured once a day when sun is at its highest (mid-afternoon).

This study will enhance the literature of reforestation/afforestation as a means of combating land degradation and desertification. It will be unique in that it is an in-progress assessment of the project's first two goals (1: improved livelihoods 2: restored ecosystems). A study of GGWSSI effects can be useful in other parts of the developing world currently being faced with climate change and natural resource issues. GGWSSI is an African-led initiative that is capable of having immeasurable abstract and tangible impacts upon the continent. Should it be successful, Africa's ravaged history of chaos and instability could be replaced with a new era of increased collaborative strength and resiliency.

Materials:
Campbell HydroSense Time-Domain-Reflectometer
Light meter (?) Pyranometer (?)
300 meters string
Camera
Recorder
GPS
Digital air temperature thermometer
5 soil thermometers
Measuring tape
Paper
Pens

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APPENDIX B: IN-COUNTRY ITINERARY AND INTERVIEW QUESTIONS

Itinerary

21 May:	Arrive Dakar
22 May:	Interview with environmental health staff of Peace Corps
23 May:	Meeting with Louga region Peace Corps Volunteer
24 May:	Travel to Linguere, Senegal
25 May:	Return to Dakar to meet with OHM directors Profs. Boetsch & Guisse
27 May:	Travel to Widou Thiengoly
28 May:	Travel to GGW parcels near Tessekere
29 May:	Tour of the Widou GGW center, tree stands, and community garden
30 May:	Travel to Mbar Toubab for interviews
31 May – 14 June:	Conduct tree measurements and interviews in Widou Thiengoly
15 June:	Travel to Loughere Thiolly and Lagbar for observations & interviews
17 June – 26 June:	Personal travel
27 June:	Travel to Dakar
28 June:	Meet with Profs Boetsch, Guisse, Col. Matar Cisse, and Papa Sarr
1 July:	Return to America

Village Level Questions

1. What is this project?
2. What does it do?
3. Who is in charge?
4. Who is involved (organizations)?
    a. Why them?
    b. What do they do?
5. Have you been trained/or trained others about the project?
    a. What organization did your extension agent work for?
    b. Who did you train? How did you train them?
6. Has this project benefitted you somehow?
    a. How?
    b. When?
7. Has the project hurt you somehow?
    a. How?
    b. When?
8. How has the project changed your daily life?
9. How has the project changed your routine?
10. Has the number of visitors to the area increased or decreased since the project's beginning?
    a. How have they impacted the village?
    b. The market?
11. What are the strengths of the project?
12. What are the weaknesses of the project?
13. Why is this project happening?
14. Have you seen any differences in the levels of biodiversity in the buffer zone around the wall?
15. Has any village/personal land been lost?
    a. If so, was there any compensation?
    b. Any resistance?
    c. Have you had to change the places where you find fodder for goats/cattle?
    d. What about firewood?
16. Who actually does the tree planting and maintaining?
    a. When?
    b. How often?
    c. Why them?
    d. What are they not doing when they are instead volunteering?
17. What opportunities has this project provided to you/your village?
18. What is something that will keep this project from being successful? (a threat)
19. What is climate change? Land degradation? Desertification?

Interview Questions for GGW-Employed Stakeholders:

Questions for Government Officials/NGO Workers/Scientists:

1. What is this project?
2. Who is in charge?
3. Does it provide environmental services?
4. Who is involved (organizations)?
    a. Why them?
    b. What do they do?
5. Have you noticed a diversification of the local economy?
    a. Who?
    b. How?
    c. Who are the most likely risk takers?
    d. Increased tourism? People coming to help plant trees? Study trees?
    e. Increased bean sandwich ladies/ceeb shacks?
    f. Renters?
6. What are the strengths of the project?
7. What are the weaknesses of the project?
8. Have you been trained/or trained others about the project?
    a. What organization did your extension agent work for?
    b. Who did you train? How did you train them?
9. What is climate change? Land degradation? Desertification?
10. Why is this project happening?
11. Have you seen any differences in the levels of biodiversity in the buffer zone around the wall?
12. Has any village/personal land been lost?
    a. If so, was there any compensation?
    b. If so, was there any resistance?
        i. When?
        ii. How?
        iii. How was it resolved?
13. Who actually does the tree planting and maintaining?
    a. When?
    b. How often?
    c. Why them?
    d. What are they not doing when they are instead volunteering?
14. What opportunities has this project provided to surrounding villages?
15. What is something that will keep this project from being successful? (a threat)

APPENDIX C: FIELD DATA

Elevation, Lat/Long, Trunk Circumference, Height, Canopy Breadth, and Slope

Z1 Sample	Elevation (ft)	Lat (N)	Long (W)	Height (m)	Canopy Breadth (ft)	Slope (%)
101	179	15.96035	15.25366	2.5	12	-4
102	169	15.96042	15.25383	2	8 ft 5 in	-2%
103	176	15.96061	15.25395	2	8 ft 6 in	-7
104	175	15.96069	15.25413	1.5	9	-4
105	176	15.96085	15.25403	3	10 ft 7 in	-5
106	180	15.9608	15.25357	2	12	-6
107	183	15.96079	15.25349	2.5	7 ft 10 in	-5
108	172	15.96099	15.25333	3	9 ft 1 in	-6
109	173	15.96069	15.25326	4	12	-4
110	176	15.96059	15.25327	3.5	12	-4
Z1 Balanite	162	15.96066	15.25368	28	23 ft 4 in	-6
Z1 BIG ACACIA	176	15.96107	15.25369	30	19 ft 5 in	-5
Z2 Sample	Elevation	Lat (N)	Long (W)	height (m)	Canopy Breadth (ft)	Slope (%)
201	157	15.962	15.25263	4	14 ft 4 in	-3
202	157	15.96207	15.2526	3	7 ft 7 in	-3
203	159	15.96211	15.25244	2.5	10 ft 10 in	-5
204	164	15.96225	15.25235	1.5	6ft 5 in	-3
205	162	15.96238	15.25211	4	16 ft 4 in	-6
206	157	15.96247	15.25199	2.5	10 ft 9 in	-8
207	161	15.96225	15.25181	3	10ft 5 in	-5
208	154	15.96207	15.25178	>2	11 ft 9in	-5
209	156	15.96203	15.25195	2.5	11 ft 10 in	-4
210	157	15.96187	15.25199	3	16 ft 10 in	-9
Z2 Balanites	186	15.96219	15.25217	30	31 ft 10 in	-3
Z2 BIG ACACIA	150	15.96275	15.2543	32	21 ft 4 in	-5
Oseau Forets Center	Elevation	Lat (N)	Long (W)			
	213	15.99366	15.32035			
	Soil Texture	Soil Color				
Site 01	Sandy Loam	7.5yr 6.4				
Site 02	Sandy Loam	7.5yr 5.2				

Volumetric Water Content in GGW Parcel

8-Jun-13	Volumetric Water Content		
Soil Moisture			
	In 1	In 2	Out
101	1%	1%	1%
102	1%	1%	1%
103	1%	1%	1%
104	1%	1%	1%
105	1%	1%	1%
106	1%	1%	1%
107	1%	1%	1%
108	1%	1%	1%
109	1%	1%	1%
110	1%	1%	1%
Z1 Balanites	1%	1%	1%
Z1 Big Acacia	1%	1%	1%
201	1%	1%	1%
202	1%	1%	1%
203	1%	1%	1%
204	1%	1%	1%
205	1%	1%	1%
206	1%	1%	1%
207	1%	1%	1%
208	1%	1%	1%
209	1%	1%	1%
210	1%	1%	1%
Z2 Balanites	1%	1%	1%
Z2 BA	1%	1%	1%

Trunk Circumference at 1 Foot, measured 10 June 2013. All values are in feet.

	Trunk circumference@ 1ft	
	dbh	notes
101	3.3	
102	4	
103	3.4	
104	1.6/1.3	
105	3.56/3.7	
106	3.7	
107	2.6	
108	2.8	
109	3.4	
110	n/a	unattainable
Z1 Balanites	23	
Z1 Big Acacia	6.8/11.95	
201	3.8	
202	2.8	
203	2.45	
204	3.7	
205	4.2	
206	1.8	
207	3.8	
208	3.2	
209	4	
210	3.9	
Z2 Balanites	15.95/15.72	
Z2 Big Acacia	19.7	

Land–surface Temperature Data in Degrees Celsius

Tree	N	S	E	W	Out N	Out S	Time
101	52	47	42	49	54	53	Afternoon
102	40	37	37	41	46	42	Afternoon
103	40	42	44	42	43	43	Afternoon
104	47	43	40	46	48	49	Afternoon
105	43	41	41	46	48	51	Afternoon
106	44	42	44	44	51	46	Afternoon
107	39	41	42	47	49	42	Afternoon
108	43	45	40	42	48	45	Afternoon
109	44	41	41	45	47	45	Afternoon
110	44	43	40	43	49	46	Afternoon
Z1 Mature Acacia	39	39	36	38	43	40	Afternoon
201	34	35	35	37	37	40	Evening
202	36	34	34	35	39	37	Evening
203	37	35	38	37	38	42	Evening
204	37	40	37	41	41	42	Evening
205	37	38	36	36	37	46	Evening
206	34	34	36	38	41	41	Evening
207	38	37	34	34	43	42	Evening
208	34	37	36	34	38	40	Evening
209	34	37	33	35	40	37	Evening
210	37	35	37	36	39	37	Evening
Z2 Balanites	37	36	35	40	44	41	Evening
Z2 Mature Acacia	37	36	35	40	45	41	Evening
101	41	46	43	46	59	60	Afternoon
102	41	42	41	46	53	62	Afternoon
103	48	37	38	37	61	60	Afternoon
104	45	46	41	30	56	61	Afternoon
105	42	46	42	43	59	59	Afternoon
106	50	42	42	44	63	61	Afternoon
107	46	45	40	54	61	57	Afternoon
108	51	37	45	39	64	61	Afternoon
109	47	48	52	44	60	51	Afternoon
110	43	41	43	38	61	63	Afternoon
Z1 Balanites	38	37	35	38	38	58	Afternoon
Z1 Mature Acacia	40	37	40	36	58	55	Afternoon
201	41	45	42	45	57	52	Afternoon
202	51	51	43	49	56	57	Afternoon
203	39	41	40	39	56	56	Afternoon
204	46	48	43	44	61	58	Afternoon
205	49	49	51	47	54	57	Afternoon
206	39	40	40	41	54	56	Afternoon
207	36	39	37	38	55	60	Afternoon
208	37	45	43	37	59	56	Afternoon
209	48	42	47	42	59	55	Afternoon

210	49	43	46	40	50	48	Afternoon
Z2 Balanites	31	34	35	37	59	58	Afternoon
Z2 Mature Acacia	37	38	35	48	55	55	Afternoon
101	40	39	40	39	45	49	Evening
102	38	37	37	36	45	43	Evening
103	41	38	39	38	41	42	Evening
104	38	37	37	37	44	45	Evening
105	40	37	35	39	43	44	Evening
106	39	41	39	41	46	42	Evening
107	42	42	37	40	44	42	Evening
108	36	38	37	38	39	43	Evening
109	38	38	38	41	41	44	Evening
110	37	37	35	36		42	Evening
Z1 Balanites	35	34	36	36	44	48	Evening
Z1 Mature Acacia	36	35	36	40	43	43	Evening
201	38	38	37	38	41	41	Evening
202	37	37	37	38	41	42	Evening
203	37	38	38	37	39	38	Evening
204	37	38	38	37	41	40	Evening
205	35	36	36	36	39	42	Evening
206	35	36	35	36	40	40	Evening
207	37	36	36	36	41	40	Evening
208	35	35	35	37	38	41	Evening
209	36	37	36	38	38	40	Evening
210	37	37	37	38	40	41	Evening
Z2 Balanites	35	34	34	34	40	39	Evening
Z2 Mature Acacia	33	34	33	37	38	38	Evening
101	40	40	41	41	42	44	Evening
102	42	42	40	41	41	41	Evening
103	42	42	40	42	43	44	Evening
104	40	40	43	41	41	43	Evening
105	41	41	41	41	41	43	Evening
106	40	40	40	40	40	42	Evening
107	41	39	40	40	42	41	Evening
108	40	39	40	40	43	42	Evening
109	40	39	39	39	41	41	Evening
Z1 Balanites	38	39	38	39	40	40	Evening
Z1 Mature Acacia	39	39	39	41	41	40	Evening
201	39	39	38	38	39	39	Evening
202	38	39	39	38	40	40	Evening
203	39	39	38	38	41	38	Evening
204	38	39	38	38	40	39	Evening
205	41	40	37	41	38	39	Evening
206	38	39	38	39	40	38	Evening
207	38	38	38	38	38	38	Evening
208	39	38	38	38	39	39	Evening
209	38	38	38	38	38	38	Evening

210	38	38	38	38	39	37	Evening
Z2 Balanites	40	38	38	37	41	39	Evening
Z2 Mature Acacia	37	38	41	37	39	40	Evening
101	47	46	45	53	50	51	Afternoon
102	45	47	44	43	50	52	Afternoon
103	44	43	44	44	50	50	Afternoon
104	45	45	43	45	52	55	Afternoon
105	44	46	50	45	45	47	Afternoon
106	44	44	43	44	49	46	Afternoon
107	43	40	42	43	49	43	Afternoon
108	43	43	42	43	49	51	Afternoon
109	44	42	44	43	47	46	Afternoon
110	42	41	45	41	47	45	Afternoon
Z1 Balanites	40	39	38	40	46	42	Afternoon
Z1 Mature Acacia	42	38	40	40	42	46	Afternoon
201	43	43	42	42	44	45	Afternoon
202	46	42	44	42	43	45	Afternoon
203	43	43	44	43	48	45	Afternoon
204	41	43	43	43	51	44	Afternoon
205	45	44	44	44	50	47	Afternoon
206	44	44	44	43	49	46	Afternoon
207	43	42	42	43	47	46	Afternoon
208	46	43	43	43	47	45	Afternoon
209	42	42	42	41	44	49	Afternoon
210	46	41	44	43	51	42	Afternoon
Z2 Balanites	41	38	43	43	45	43	Afternoon
Z2 Mature Acacia	41	41	40	49	47	48	Afternoon
101	34	34	34	34	33	34	Evening
102	34	35	34	33	34	35	Evening
103	34	33	34	34	34	34	Evening
104	33	33	34	35	34	34	Evening
105	35	34	34	34	34	34	Evening
106	33	34	34	36	36	34	Evening
107	34	34	35	35	36	35	Evening
108	33	34	36	34	34	37	Evening
109	34	34	34	35	34	36	Evening
110	33	33	33	33	34	35	Evening
Z1 Balanites	33	34	34	33	37	35	Evening
Z1 Mature Acacia	34	33	32	33	35	34	Evening
201	34	34	34	34	35	36	Evening
202	34	33	34	33	35	33	Evening
203	36	34	35	35	37	36	Evening
204	36	34	34	33	36	37	Evening
205	35	34	33	37	35	37	Evening
206	33	34	34	33	37	38	Evening
207	33	34	33	34	36	38	Evening
208	33	33	33	33	39	37	Evening

209	35	33	33	34	35	34	Evening
210	35	35	37	35	35	37	Evening
Z2 Balanites	33	33	33	34	37	38	Evening
Z2 Mature Acacia	34	34	33	34	38	35	Evening
101	41	41	42	41	46	50	Afternoon
102	39	42	41	42	47	42	Afternoon
103	37	40	39	42	47	42	Afternoon
104	46	40	39	40	47	48	Afternoon
105	45	45	41	40	42	49	Afternoon
106	39	40	36	38	43	39	Afternoon
107	41	43	41	43	45	41	Afternoon
108	40	43	39	43	44	46	Afternoon
109	40	44	41	40	39	47	Afternoon
110	37	40	38	42	43	48	Afternoon
Z1 Balanites	37	35	37	38	45	40	Afternoon
Z1 Mature Acacia	45	43	41	41	45	42	Afternoon
201	39	39	39	41	46	41	Afternoon
202	39	39	40	40	43	42	Afternoon
203	44	39	38	41	45	45	Afternoon
204	37	38	35	39	42	42	Afternoon
205	41	39	38	43	45	43	Afternoon
206	37	38	38	38	45	40	Afternoon
207	40	39	37	40	46	39	Afternoon
208	41	38	37	38	44	37	Afternoon
209	42	39	38	41	43	41	Afternoon
210	40	39	40	44	45	44	Afternoon
Z2 Balanites	36	35	36	38	45	41	Afternoon
Z2 Mature Acacia	39	38	38	39	42	39	Afternoon
101	38	37	37	38	38	40	Evening
102	37	37	38	37	38	37	Evening
103	40	38	38	38	38	36	Evening
104	40	37	36	37	37	40	Evening
105	37	36	37	38	37	37	Evening
106	36	36	36	36	36	36	Evening
107	36	36	37	37	37	39	Evening
108	35	36	36	36	35	39	Evening
109	35	37	36	36	38	37	Evening
110	35	35	35	35	36	37	Evening
Z1 Balanites	35	35	34	36	37	35	Evening
Z1 Mature Acacia	36	34	34	35	37	37	Evening
201	35	35	35	34	35	35	Evening
202	36	35	35	35	35	35	Evening
203	35	35	35	34	38	35	Evening
204	35	35	35	34	36	33	Evening
205	36	36	35	35	36	37	Evening
206	35	35	35	35	37	36	Evening
207	35	35	35	35	36	37	Evening

208	34	35	35	35	36	35	Evening
209	35	35	35	35	37	35	Evening
210	35	36	36	35	36	35	Evening
Z1 Balanites	35	35	34	36	37	35	Evening
Z2 Mature Acacia	34	35	34	37	38	36	Evening
101	47	49	53	43	54	58	Afternoon
102	48	50	50	52	48	51	Afternoon
103	48	46	45	45	55	51	Afternoon
104	46	48	47	49	52	58	Afternoon
105	47	47	49	50	50	53	Afternoon
106	42	46	46	42	53	49	Afternoon
107	48	53	47	56	49	50	Afternoon
108	45	45	46	48	46	54	Afternoon
109	51	48	46	50	50	54	Afternoon
110	44	44	43	44	60	51	Afternoon
Z1 Balanites	41	42	41	42	54	60	Afternoon
Z1 Mature Acacia	44	42	42	46	54	52	Afternoon
201	48	44	44	48	47	48	Afternoon
202	50	46	43	44	53	57	Afternoon
203	45	45	44	47	48	55	Afternoon
204	43	47	45	46	47	50	Afternoon
205	46	40	43	49	52	51	Afternoon
206	43	42	42	42	48	51	Afternoon
207	46	44	42	46	48	49	Afternoon
208	44	44	43	48	55	50	Afternoon
209	45	46	45	54	50	50	Afternoon
210	47	48	44	52	45	56	Afternoon
Z2 Balanites	40	40	39	41	50	46	Afternoon
Z2 Mature Acacia	49	42	41	53	58	58	Afternoon
101	47	47	45	47	47	58	Afternoon
102	46	41	43	46	46	51	Afternoon
103	46	47	43	43	43	50	Afternoon
104	44	42	45	50	50	44	Afternoon
105	44	43	45	44	44	47	Afternoon
106	42	42	45	43	43	48	Afternoon
107	42	47	42	50	50	51	Afternoon
108	42	47	45	44	44	52	Afternoon
109	42	45	48	49	49	46	Afternoon
110	42	41	39	40	40	47	Afternoon
Z1 Balanites	39	36	38	39	39	43	Afternoon
Z1 Mature Acacia	42	39	39	38	38	43	Afternoon
201	41	41	40	45	45	47	Afternoon
202	41	41	42	41	41	49	Afternoon
203	45	42	44	44	44	48	Afternoon
204	40	44	40	43	43	49	Afternoon
205	45	44	41	43	43	47	Afternoon
206	40	39	41	41	41	50	Afternoon

207	39	41	38	40	40	44	Afternoon
208	47	42	43	45	45	52	Afternoon
209	47	41	42	40	40	47	Afternoon
210	42	41	44	47	47	50	Afternoon
Z2 Balanites	38	38	36	39	39	45	Afternoon
Z2 Mature Acacia	43	39	38	42	42	41	Afternoon
101	38	36	37	40	39	38	Evening
102	36	37	36	37	38	41	Evening
103	37	37	37	36	37	37	Evening
104	37	36	37	38	41	43	Evening
105	36	36	35	36	37	42	Evening
106	35	37	37	35	41	37	Evening
107	35	37	35	38	37	40	Evening
108	36	38	38	36	36	38	Evening
109	36	36	35	39	37	37	Evening
110	36	36	34	34	36	36	Evening
Z1 Balanites	35	35	34	35	39	36	Evening
Z1 Mature Acacia	36	35	35	36	38	39	Evening
201	36	35	35	37	38	39	Evening
202	38	35	35	36	37	39	Evening
203	37	36	36	35	38	35	Evening
204	34	35	34	34	38	38	Evening
205	37	36	35	36	36	35	Evening
206	35	35	34	35	38	35	Evening
207	34	35	34	35	38	37	Evening
208	34	34	34	36	38	37	Evening
209	36	34	34	36	37	38	Evening
210	36	34	36	34	39	37	Evening
Z2 Balanites	34	34	33	35	35	38	Evening
Z2 Mature Acacia	35	34	33	37	36	37	Evening

Maximum and Minimum Air Temperature (in Degrees Celsius)

5-Jun-13			
Air Temp	Min	Max	Notes
101	27	42	
108	22	N/A	needed fixing - fixed
Z1 Balanites	21	40	
Z1 Big Acacia	22	38	
Z1 No Tree	22	45	
203	21	40	
205	23	N/A	needed fixing - fixed
Z2 Balanites	24	41	
Z2 Big Acacia	23	40	
Z2 No Tree	25	N/A	needed fixing - fixed
7-Jun-13			
Air Temp	Min	Max	Notes
101	26	48	
108	23	45	
Z1 Balanites	22	42	
Z1 Big Acacia	23	44	
Z1 No Tree	26	48	
203	21	45	
205	N/A	N/A	no therm available, fixed
Z2 Balanites	22	45	
Z2 Big Acacia	23	45	
Z2 No Tree	22	48	
8-Jun-13			
Air Temp	Min	Max	Notes
101	28	44	
208	27	41	
Z1 Balanites	26	40	
Z1 Big Acacia	26	41	
Z1 No Tree	25	46	
203	25	44	
205	28	46	
Z2	29	44	

Balanites			
Z2 Big Acacia	28	41	
Z2 No Tree	24	47	
9-Jun-13			
Air Temp	Min	Max	Notes
101	26	46	
108	26	44	
Z1 Balanites	27	39	
Z1 Big Acacia	22	40	
Z1 No Tree	23	45	
203	26	43	
205	29	46	
Z2 Balanites	28	43	
Z2 Big Acacia	27	40	
Z2 No Tree	23	49	
10-Jun-13			
Air Temp	Min	Max	Notes
101	26	47	
108	24	44	
Z1 Balanites	27	45	
Z1 Big Acacia	25	42	
Z1 No Tree	24	49	
203	24	45	
205	26	48	
Z2 Balanites	24	45	
Z2 Big Acacia	26	45	
Z2 No Tree	21	49	
11-Jun-13			
Air Temp	Min	Max	Notes
101	22	47	
108	26	44	
Z1 Balanites	27	46	
Z1 Big Acacia	28	44	
Z1 No Tree	26	48	
203	26	44	
205	29	>50	
Z2 Balanites	29	44	

Z2 Big Acacia	28	41	
Z2 No Tree	25	45	
12-Jun-13			
Air Temp	Min	Max	
101	27	45	
108	26	44	
Z1 Balanites	21	42	
Z1 BA	25	42	
Z1 No Tree	25	49	
203	25	44	
205	25	45	
Z2 Balanites	29	43	
Z2 BA	27	43	
Z2 No Tree	22	> 50	

APPENDIX D: EMAIL EXCHANGES WITH SENEGALESE OFFICIALS INVOLVED

(Director GGWSSI in Senegal)
To:

cissematar@angmv.sn
Sent Items
Tuesday, February 05, 2013 4:16 PM
Cher Monsieur Cisse,

Je m'excuse, je parle très peu le français. De 2010-2012, j'ai vécu dans un petit village pulaar dans la région de Tambacounda, et ont depuis commencé des études supérieures en géographie, de retour aux États-Unis. Mon objectif est humain-environnement des interactions. Pour mes études supérieures, je suis devenu très intéressé par l'étude des effets des micro-environnementales et écohydrologique du projet Grande Muraille Verte qui se passe au Sénégal. Mes méthodes sont sans impact, à savoir des relevés de température, etc je peux vous envoyer ma proposition, si vous souhaitez le lire. Quels sont les processus ou les canaux dois-je faire pour obtenir la permission d'étudier ces arbres?

Je vous remercie sincèrement pour votre temps,
Anna Alsobrook

serigne mbodji <serigne.mbodji@gmail.com> Mar 13 (7 days ago)
to me, Matar, SARR, clotilde

Dear Anna,
Thank you for your interest for Great Green Wall. You are welcome in our field in Senegal. You can send your proposal so that we can appreciate better your project.
I am sending this message on behalf Mr Cissé.

...

Anna Alsobrook <anna.alsobrook@gmail.com> Mar 19 (1 day ago)
to serigne, Matar, SARR, clotilde

Dear Serigne,

Thank you for getting back to me, and in English! My French is not very good. I am in the middle of editing the proposal, but will send it to you as soon as it is finished. Thanks again! Hope all is well.

Anna

...

serigne mbodji 11:57 AM (21 hours ago)
to me, Matar, SARR, clotilde

Hi Anna,
Well noted. Thanks for your answer. Back to you as soon as the proposal is ready. Good luck

...

To:

Alsobrook, Anna E

Thursday, February 28, 2013 3:23 AM

Bonjour Anna Alsobrook
J'ai reçu votre courrier ce matin à mon retour du ferlo lors d'une réunion sur les terres arides, et j'étais avec le Colonel Matar Cissé; vous travaillez sur un thème intéressant, et qui nous intéresse beaucoup aussi ; par conséquent si vous êtes intéressé pour prendre ce volet en charge, vous êtes le bienvenu.
Je dois vous dire qu'à ma connaissance, personne ne travaille ici sur le rôle de la canopée ou l'impact de la plantation sur le cycle hydrologique et sur le micro environnement local. Par contre, nous avons des sociologues et des anthropologues qui s'intéressent aux aspects les implications et les intérêts de populations pour le projet.
Les données de l'OHM bien sûr sont disponibles (nous sommes en train de finaliser et de réactualiser notre site web) et nous partageons les articles qui sont publiés, malheureusement beaucoup de données ne sont pas encore disponibles du fait que les équipes sont encore en train de les exploiter.
Voilà ce que je peux vous dire pour le moment, et je reste à votre disposition pour de plus amples informations.

Pr Aliou GUISSE
00 221 77 638 96 69

De : Alsobrook, Anna E [mailto:aalsobro@utk.edu]
Envoyé : mercredi 27 février 2013 02:43
À : aliou.guisse@ucad.edu.sn
Objet : Concernant la Grande Muraille Verte, Senegal

Alsobrook, Anna E

Sent Items
Tuesday, February 26, 2013 9:43 PM

Cher Monsieur Aliou GUISSE,
Pardon mon francais, s'il vous plaît-- je suis Américain. Je vous écris à propos de votre travail avec la Grande Muraille Verte pour le Initiative du Sahara et Sahel. Je suis en train de travailler sur mon diplôme de maîtrise en géographie à l'Université du Tennessee à Knoxville, aux États-Unis. Ayant vécu en Sénégal pendant deux ans, je suis très intéressée par GMVSS et les effets qu'elle peut avoir sur le paysage. Ma thèse envisage de se concentrer spécifiquement de la manière que la canopée des arbres modifient les microenvironnements au-dessous d'eux, comment, ou si, les arbres eux-

mêmes ont un impact sur le cycle hydrologique local, et comment le projet entier affecte, ou est affecté par, les populations locales.
Y a-t-il des études déjà réalisées dans ce domaine qu'appartient à l'un de ces spectres? S'il y en a, pourriez-vous me diriger vers quelqu'un approprié avec qui je peux être en contact?
En outre, est-ce que OHM partage ses données? Si oui, comment puis-je y accéder?
Finalement, j'ai essayé de contacter M. Cissé à propos d'obtenir permis pour étudier les environs, mais je n'ai reçu aucune réponse. Pourriez-vous m'expliquer le processus d'obtenir un permis pour faire des recherches là-bas.
Je vous remercie sincèrement pour votre temps,
Anna Alsobrook
Etudiant diplômé
Departement Geographie
University of Tennessee, Knoxville

VITA

Anna Eugenia Alsobroook was born in Memphis, TN to the parents Richard and Adrien Alsobrook. She is the third of four children, with three brothers: Alan, Mark and William. She attended St. Louis School in Memphis, TN until 8th grade and went on to high school at St. Benedict at Aurbundale, also in Memphis, TN. After graduating high school, she pursued her undergraduate degree at the University of Tennessee, Knoxville, majoring in Global Studies and minoring in Geography. During that time she spent six months studying abroad in Stellenbosch, South Africa, with a focus on community development and service learning. She completed her Bachelors of Arts degree in May 2009. After receiving her degree from Honorary Doctorate Dolly Parton, she spent 2010-2012 in Saare Boyli, Senegal serving in the United States Peace Corps. Upon her return to the US, she entered the graduate program for Geography at the University of Tennessee, Knoxville. She graduated with a Masters of Science degree in May 2014. She is continuing her education through life experience.