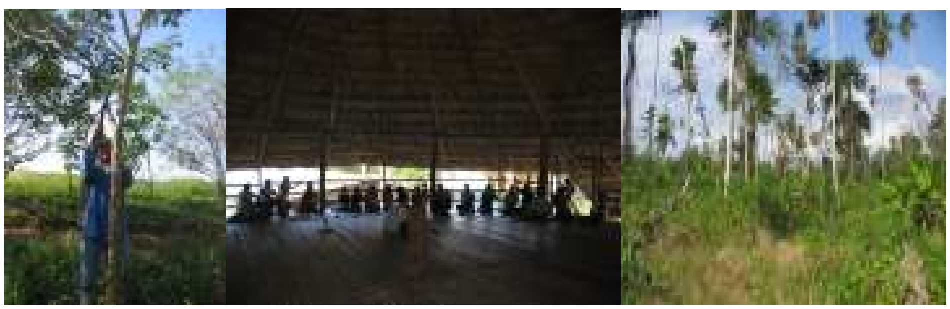
Tropical Reforestation and Carbon Neutralization: Implementation of a Small-scale Project and Research in an Experimental Plantation in Eastern Panama.

Reforestación Tropical y Neutralización de Carbono: Implementación de un proyecto de pequeña-escala y las investigaciones en una plantación experimental en Panamá del Este



April 27, 2007

Final Report

Jessica Hawryshyn and Alexandra Senikas

Supervisor: Dr. Alain Paquette

ENVR 451

Presented to Roberto Ibáñez

Acknowledgements:

We would like to give our sincere gratitude and thanks to Dr. Alain Paquette for his excellent supervision and incredible support. Thank you to Dr. Catherine Potvin for her tremendous help as well. We want to express our thanks as well to the community of Ipeti-Embera, especially Bonarje and Alba, Nesar, Reineidio, Rigoberto and Olga, and Pablo.

Other thanks to Dr. Roberto Ibáñez for his supervisión throughout our internship; to José Montesa y Lady Mancilla in Sardinilla; to Jefferson Hall and the staff at PRORENA for all their help; and to Ultiminio Cabrera of Dobo Yala for his legal assistance.

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Executive Summary:

The general goal of our project was to look at carbon sequestration through high diversity tropical reforestation. Our project involved two different approaches to investigating our general goal: 1) a community reforestation project establishing a small scale carbon sequestration high diversity plantation; 2) a scientific study of the impacts of pruning on tree growth and carbon sequestration in a high diversity experimental plantation.

The reforestation project was established in the community of Ipeti-Emberá in order to offset the climate impact of research and teaching in Panama, by the PFSS program and the Panama Consortium, composed of staff and students of McGill University, Université Laval and Université du Québec à Montréal. Seed nurseries were set up with involved community members with native timber species valuable to the Emberá community in order to be able to establish a high diversity plantation in an undercover setting (*rastrojo alto y bajo*) on Ipetí-Emberá collective lands.

The scientific work was carried out at the Sardinilla high diversity plantation and preliminary statistical analysis found significant differences between tree species in quality in terms of tree formation growth and the amount of biomass required to be pruned. Some species have higher tendencies to higher quality classes, whereas others have tendency to lower quality classes.

With regards to the carbon neutralization project in Ipeti, we hope that our efforts will provide general visibility of the impacts of air travel on carbon emissions and global climate change, especially within the academic sector. In addition, we hope that the carbon initiative in Ipeti presents an alternative sustainable source of income for

community members, and that it attracts future potential investors interested in offsetting carbon.

Resumen Ejecutivo:

El tema general del proyecto es el estudio del secuestro de carbono por la reforestación tropical de alta diversidad. El proyecto usa dos enfoques para investigar ese tema: 1) un proyecto de reforestación en una comunidad indígena estableciendo una plantación de alta diversidad a pequeña escala para fijar carbono atmosférico; 2) un estudio científico de los impactos de poda sobre el crecimiento de árboles y el secuestro de carbono en una plantación experimental de alta diversidad.

El proyecto de reforestación estuvo establecido en la comunidad de Ipetí-Emberá para contrarrestar los impactos climáticos de las investigaciones y las enseñanzas en Panamá de los programas de PFSS, NEO y Consortium de Panamá conformados por empleados y estudiantes de las Universidades McGill, Laval y de Québec à Montréal (UQAM). Los semilleros fueron construidos por algunos miembros de la comunidad involucrados en el proyecto, utilizando especies nativas maderables que tienen un gran valor para los Emberá. Por lo tanto esta plantación tendrá una alta diversidad y estará colocada debajo de la cobertura vegetal en rastrojo alto y bajo en parcelas de Tierra Colectiva de Ipetí-Emberá.

El trabajo científico se hizo en la plantación de alta diversidad en Sardinilla y un análisis preliminar estadísticos realizado nos señalo que hay cuatro diferencias significativas entre las especies de árboles acerca de la formación arborezca y la cantidad

de biomasa a podar. Algunas especies tienen tendencia a subir las clases de calidad, mientras que otras tienden bajar las clases de calidad.

Acerca del proyecto de neutralización de carbono en Ipetí, esperamos que nuestros esfuerzos provean una visibilidad general de los impactos del pasaje en avión sobre las emisiones de carbono y el cambio climático global, especialmente en el mundo académico. Además, deseamos que la iniciativa de secuestro del carbono en Ipetí sea una fuente alternativa de ingreso para la gente de la comunidad, y que a traiga a esa área inversiones potenciales futuras.

Time spent on the internship (Number of days of both students)	
Number of days spent at the desk	Number of days spent in the field
33	15

Host Institution Information

We are working under the supervision of Dr. Alain Paquette, a post-doctorate at the Centre d'études de la Forêt at UQAM, and Dr. Catherine Potvin, a professor at McGill University. Dr. Potvin has been working with the Ipeti community for a decade, and is also involved in the Sardinilla plantation. We are also collaborating with various members of the Ipeti community. Finally, the reforestation organization PRORENA, headed by the Smithsonian Tropical Research Institute (STRI) and the Yale Tropical Resources Institute are providing native seeds, some tools and technical advice.

Information for Thank You notes:

Dr. Alain Paquette
alain.paquette@gmail.com

Centre d'étude de la forêt (CEF)
Université du Québec à Montréal
Pavillon des Sciences biologiques
141 Président-Kennedy, bureau SB-2987
Montréal (Québec) H2X 3Y7 Canada

Dr. Catherine Potvin
catherine.potvin@mcgill.ca

Department of Biology
McGill University
Stewart Biology Building, W6/8
1205 Docteur Penfield
Montreal, Quebec
Canada H3A 1B1

(for Dr. Potvin, could also be mailed to Tupper, STRI)

1. Introduction

Carbon Sequestration in the Global Context

Since the Kyoto Protocol's creation in 1997, global environmental attention has been focused on reducing green house gas (GHG) emission rates out of concern for world climate change. The Protocol projected the reduction of minimum 5% of 1990 GHG emissions during the commitment period of 2008-2012 (UNFCCC). With the Protocol's ratification by many countries in February 2005, the issue of stabilizing GHG emissions has become even more of a concern.

This accord permits the trading of "certified emissions reductions (CER)" produced from carbon-reducing or carbon-avoiding projects known as "Clean Development Mechanisms (CDM)", usually financed in Less-Developed Countries (UNFCCC). At the smaller scale, CDM includes the following projects:

- Reforestation, that is "direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested, but that has been converted to non-forested land" (UNFCC);
- Aforestation, defined as "direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources" (UNFCCC).

Such schemes can consist of agroforestry, community forest plantations, forest regeneration, and improved fallows. In order for these projects to be recognized, they must: (a) not produce leakage, in which other areas would be deforested to offset the project and there would be no net aforestation; and (b) not cause additionality, in which the area proposed would have been reforested anyway (UNFCCC).

While the official carbon trading market along Kyoto guidelines is being established, a voluntary market has already existed since the 1990s for individual groups or events to be carbon-neutral (Climate Care 2005). An advantage of the voluntary market is that it requires less investment, thus allowing the development of smaller-scale projects that have more direct positive impacts on the social, economic and health sectors of people and communities involved (Climate Care 2005). Many companies have taken on the provision of this service, and the Climate Care Organization provides a reputable example.

Reforestation in Panama

For a country such as Panama, which possesses inadequate resources to finance its own small-scale sustainable forestry practices, CDM-like projects provide a significant opportunity to pursue such sustainable land use and store atmospheric carbon over the long term (Potvin et al, unpublished). Avoiding deforestation of established forests remains the most efficient way of storing carbon in this region (Kirby and Potvin, submitted). However, Kraenzel et al. (2003) analyzed the carbon storage of various 20 year old teak plantations in Panama, and found that such a land use allowed the storage in trees of roughly two thirds of that of primary forest of the same area, measured in Potvin et al. (unpublished). Another option for land-use change and carbon sink in Panama involves sustainable agroforestry, where only ephemeral tissues are collected and trees sequester carbon over a longer period, but stores about half as much carbon as the teak plantation calculations and is thus less efficient on a per area basis (Potvin et al., unpublished). Most reforestation initiatives in Panama up to now have used exotic species, mostly teak (*Tectona grandis)*; for instance, out of the 18 965 ha reforested in Panama up to date, 14 700 ha have been devoted to teak monocultures (Campos 2006). In fact, close to 95% of trees planted in Panama are exotic species and, other than teak, Caribbean pine (*Pinus caribea*), "Cedro espino" (Bombacopsis quinata), *Acacia mangium* and African mahogany (*Khaya ivorensis*) are mainly used (Campos 2006). This type of reforestation is often undertaken on old pastures or clear-cut soils in an intensive high external input monoculture fashion to render the highest output of timber per area.

Although tree diversity of plantations does not impact the amount of carbon stored *per se* (Kirby and Potvin, submitted), plantation techniques and diversity may have an impact on the tree growth and health and hence the amount of carbon stored. For instance, in tropical forests, a meta-analysis of undercover planting reveals that trees survived best in an intermediate shelterwood (Paquette et al. 2006). This type of plantation environment refers to "residual forest cover under which natural or artificial regeneration is managed after a partial cut" (Paquette et al 2006). Studies in other parts of the world have found that high diversity plantations could be more productive than monocultures (Erskin et al. 2006). Furthermore, tree diversity in the Sardinilla plantation project in Panama is currently being researched to analyze its impact on tree growth and carbon storage (Potvin 2003).

In general, very little is understood about tropical reforestation and the growth and ecology of native tree species. Most forestry research in Latin America and globally has concentrated on the production of exotic species introduced in this region. For instance, in Costa Rica, the grand majority of research projects produced in the reputable "Instituto de Investigación y Servicios Forestales" from the National University of Costa Rica concentrates on teak or Caribbean Pine with regards to production, wood quality and chemical inputs, but virtually no work of the same quality can be found on native species (INISEFOR). Costa Rica being at the forefront of forestry in Central America, Panamá can thus be expected to have even less support for native species planting and care at the national level.

Local Context

In the indigenous community of Ipetí-Emberá located in Eastern Panama, reforestation with native species has been studied because of the many positive externalities brought in through the CDM framework (Potvin et al., unpublished). These externalities include increasing biodiversity through increased forest cover and long-term economic benefits to owners of the land in the form of valuable timber (Kirby and Potvin, submitted; Tschakert et al. 2006). Furthermore, in terms of ongoing research, undercover plantation strips of various native trees were established in the plots of 2 households in the Ipetí-Emberá village in Panama in 2003 in "rastrojo alto", that is, high fallow older than 5 years, and are currently being measured for growth and mortality.

Although agroforestry is a traditional Emberá agricultural practice, cattle ranching has become the fastest growing livelihood in this community, and is contributing to deforestation in the area and to global warming as part of a larger accumulative process (Potvin et al, unpublished; Kirby and Potvin, submitted). In addition, ethical concerns of such a practice must be seriously considered, as financial differences within the community may be exacerbated by such projects by being more easily accessible to diversified and higher income households (Tschakert et al. 2006).

In Sardinilla, a high diversity plantation has been established on degraded old pasture, and is currently serving as a research site for scientists from all over, with interests ranging from biophysiological matters to large scale impacts of species diversity on carbon sequestration. The stand was planted in 2003 and pruning cuts have begun on some parcels in February 2007.

2. Objectives

The general goal of our project is to look at carbon sequestration through high diversity tropical reforestation. Our project involves two different approaches to investigating our general goal: 1) a community reforestation project establishing a small scale carbon sequestration high diversity plantation; 2) a scientific study of the impacts of pruning on tree growth and carbon sequestration in a high diversity experimental plantation. The reforestation project will be carried out in the community of Ipetí-Emberá in order to offset the climate impact of research and teaching in Panama, by the Panama Consortium and composed of staff and students of NEO and PFSS programs (involving McGill University, Université Laval and Université du Québec à Montréal). It will involve the planting of native timber species valuable to the Emberá community in an undercover setting (“rastrojo alto y bajo”). Our specific objectives are:

1) To assist in the measuring and pruning of tropical tree species in the existing high diversity plot in the open field plantation of Sardinilla in Panama;

2) To analyze the pruning data from the Sardinilla plantation and determine the factors affecting the amount of biomass pruned (species, tree quality, etc.);
3) To establish a wood decomposition study in the Sardinilla plantation understanding the effects of tree stand diversity on wood decomposition:
4) To assist in the establishment of a small-scale carbon sequestration reforestation project in Ipetí with emphasis on community participation, in order for the community to become autonomous in seed collection and seedling production;
5) To draft a contract between the Panama Consortium, involved Ipetí-Emberá community members, and third party monitors in order to a) establish a long-term monitoring effort to ensure the maintenance of the high diversity plantation for carbon sequestration and valuable timber growth; b) establish a written agreement for payment for the ecosystem service:
6) To provide a means of public information about the plantation in Ipetí through a web site.

This report summarizes the methodology, the results obtained during the execution of the various objectives, and provides an overview of actions carried out during the PFSS internship. Final products in document form are included in the appendices.

3. Implementation of a Small-Scale Carbon Sequestration Plantation with Undercover Strip Planting of Native Tree Species in Ipetí-Emberá

3.1 Study Site

The Emberá indigenous community of Ipetí-Emberá is located in the watershed of Alto Bayano, in the Chepo District in the Province of Panama (78°30'–78°34' W, 8°55'–9°00' N; Tschakert et al. 2006). A geographical map of the village location is found in appendix i-1. The community landholding is composed of 3,168 hectares of communal land known as "Tierra Colectiva", which is subdivided in "parcelas" managed by individual households, which can range from 1 to 100 hectares of area (Tschakert et al. 2006). In 2004, the community was composed of 71 households, representing about 550 individuals (Tschakert et al. 2006). The main economic activities of Ipetí include swidden-fallow subsistence agriculture, cattle ranching, day labor and crafts; as such, while presenting some dependency on external markets and cash income, most households are still highly reliant on the environment for their livelihoods (Tschakert et al. 2006). The median annual household income in the village, incorporating both wages and individual household subsistence production, is about 1100$ (Tschakert et al. 2006).

Historically, the Emberá settled in the Bayano region in the 1950s, arriving from Columbia (Tschakert et al. 2006). More specifically, Ipetí originates from a relocation of sparse Emberá family settlements present in this region between 1972 and 1976 following the flooding of Lake Bayano for hydroelectric damming (Potvin et al, unpublished).

3.2 Methods

The project in Ipetí is multi-faceted and demands methodological considerations in scientific, socio-economic and legal aspects. As such, this section summarizes the actions carried out during the internship.

3.2.1 *Conceptual Framework*

The Ipetí carbon sequestration project is modeled after the Clean Development Mechanism (CDM) of the Kyoto Protocol in the sense that it strives towards a common goal: the sequestration of atmospheric carbon emitted by industrialized countries through atmospheric carbon diminishing development projects in developing areas (UNFCCC). The CDM Executive Board coordinates carbon sequestration projects in the latter areas into Certified Emission Reduction Credits, which are then bought by industrialized country firms or governments to mitigate their climate impacts. However, our project aims to directly offset the emissions of students and researchers in an efficient way, and also provide a socially responsible and environmentally sustainable project with economic opportunity for an indigenous community.

Discussions with experts in the field, such as Dr. Potvin and Dr. Paquette, helped determine the general frame, timeline and feasibility of the logistical and legal aspects of this enterprise. Various points considered in these deliberations included the nature and number of Ipeti participants involved (individual versus collective arrangements), basis for payment (ecological services, opportunity cost of land, or reforestation), quantity and modalities of payments. The type of plantation, that is an undercover strip high diversity plantation, was determined by Dr. Paquette as part of an experimental framework in his post-doctoral research.

3.2.2 *Calculations*

The atmospheric carbon emitted by the Panama Field Study Semester, Panama Consortium and NEO program was estimated using the Climate Care Calculator for carbon emission of air travel, as recommended by Dr. Potvin in a personal communication. This calculator was developed by Climate Care from the findings of the Environmental Change Institute at Oxford University on climate impacts of aviation, commissioned by the Climate Care organization[1]. The calculator accounts for various variables including average fuel burned per flight, average number of seats, average amount of freight carried and circling distance between airports (Climate Care). However, the type of aircraft or the amount of stopovers is not included in the calculations (Climate Care). Finally, the calculator yields the average amount of atmospheric carbon emissions based on the physical distance between sites traveled by airplane (Climate Care).

The amount of hectares of land to be forested to neutralize these emissions was then calculated and the necessary number of trees to be planted was estimated based on the teak plantation carbon storage estimates of Kraenzel et al. (2003; see appendix i for calculations). The conversion from amount of land estimated to number of trees to be planted was necessary because of the nature of the plantation type, which leaves strips of intact vegetation between planted strips of trees, therefore occupying more space (Paquette, personal communication). Included in these calculations is an estimate of

[1] For the original report, see Jardine, Christian. 2005. *Calculating the Environmental Impact of Aviation Emissions*, Part1. Environmental Change Institute at Oxford University Centre for the Environment, Oxford. Report commissioned by Climate Care.

necessary work time and wages for the establishment and maintenance of the plantation in the first three years.

3.2.3 *Native Species Selection, Growth and Planting*

The native tree species to be planted were decided based on the choices from the Ipetí Emberá community members and the availability of seeds. The seeds were provided by PRORENA, an organization directed by the Center for Tropical Forest Science at STRI and the Yale Tropical Resources Institute at The Yale School of Forestry and Environmental Studies. The PRORENA project is concerned with reforestation of deforested land in Panama with native species, and runs a seedling nursery and seed storage facility in Gamboa (PRORENA).

In addition, PRORENA has staff with much experience in seed collection. As such, a seed collection workshop is planned for the Ipetí participants so that the carbon project can become independent in the future and not require seeds from an outside source.

In terms of seedling growth, Dr. Paquette provided information and training on the construction of basic seed nurseries, and seedling care. Dr. Potvin provided additional information on materials already available in Ipetí and what should be brought for the project.

The diversity plantation will be set as undercover strips in land parcels with high fallow. Such a method maintains most aspects of natural forest cover and structure and preserves beneficial ecological services to the plantation, such as microclimate moderation, optimal light and competition conditions, and reduced herbivory (Paquette et al. 2006). As such, they require less maintenance while yielding good productivity.

3.2.4 *Working with the Ipeti Community and Ethical Considerations*

As the project unfolded, regular communication between the Ipeti community and the students was maintained with close attention to ensure proper dissemination of the project process, and transparency and legitimacy on account of the internship students. Such communications were carried out either through collective meetings, in which the themes to discuss were presented in Spanish and ideas were exchanged in the format of an open discussion between all. An Embera translator was present in most of these instances, and carried out translation to ensure proper communication. Telephone conversations with an active community leader, Bonarje, were also employed when time did not permit travel to the community to ensure that the information would be properly communicated. Finally, all decisions made in Panama City were reviewed with participating community members and adpated if need be by means of direct feedback stemming from group discussion with participating Ipeti individuals. All documents produced during the course of the internship, excluding the final report, and all photographs have been assessed and approved by the latter as well. All material and information not approved has been removed from this report or any other document produced and will be discarded. As such, the methods comply with the mandate set forth by the McGill Ethical Code with regards to work with indigenous peoples.

3.2.5 *Legal Aspect*

Because the project involves a long-term financial transaction between international partners, legal foundations are necessary to validate the project. Consultations with Ultiminio Cabrera, an Emberá lawyer from Ipetí Emberá who works with the Dobo Yala Foundation, were carried out to produce a contract and other legal documents binding parties involved.

3.2.6 *Media Communication and Publicity for the Carbon Sequestration Project*

A web page will be created to document and give public access to information about the carbon plantation project in Ipetí Emberá. The web page should consist of a basic summary of the project in its main aspects and provide some photos of what has been accomplished throughout the internship. All materials in the web page have been reviewed and approved by participating parties.

3.3 Results

3.3.1 *Project Framework*

The carbon sequestration project involves establishing high diversity undercover strip plantations of five different native tree species in high and low fallow. Since this type of project is relatively uncommon and has few well-documented precedents, the methodology is based on collaboration and exchanges between various actors. Based on the development of such exchanges, an experimental process was developed throughout the duration of the internship.

Due to the high level of interest amongst Ipetí community members in the carbon sequestration project observed during the month of January at a community meeting, four families per year are considered instead of only one. However, the agreement should not be viewed as collective, but rather as individual agreements between individual households and PFSS.

Interest also increased from other researchers in Panama. At the onset of the project, only PFSS and the Panama Consortium were to be neutralized by this project. Later on, Dr. Andrew Henry, Director of the McGill Neotropical option at McGill (NEO), expressed great interest in the project and has given his approval for the payment towards carbon neutralization. As such, the NEO group has been added into our calculations.

Payment for carbon sequestration is based on the opportunity cost of land, derived from the most profitable economic activity in the area, cattle ranching (Coomes et al 2006). This payment represents $63.88 USD per hectare per year. This figure was adapted to discount the ecological services provided by the conservation of fallow strips, so as to include only the planted area in the form of number of trees planted. In addition, the plantation type requires less maintenance than the intensive monoculture (Paquette, personal communication).

The carbon sequestration period, which represents the duration of the contract, is 21 years. This decision is due to the fact that most small-scale plantation studies are based on the 21 year timeline (Potvin, personal communication).

Various payment strategies were considered. Dr. Potvin will manage the fund over the contract time and deliver yearly payments. Initially, annual equal payments of the total sum based on land opportunity cost were considered because they could yield interest and provide benefits over a long time span. However, upon feedback from participating community members, this option was rejected because of the risks taken by the latter in investing time and money into an uncertain future. As such, although a final payment plan has not been developed completely, it is strongly recommended that future efforts in the project consider larger payment in the first years from labor input, which can then be subtracted from the rest of the total sum for carbon sequestration.

Yearly evaluation of the plantation will be carried out by Dr. Hector Barrios from the University of Panama for the next 7 years at a minimum. After this time, another evaluator will be selected by the latter. Payments will be given based on satisfactory results. In terms of evaluation methods, two options have been elaborated, but have not been selected as of yet. One involves the business approach, which demands that tree mortality be the basis for evaluation, in the sense that payment is exchanged for the service of carbon sequestered in each tree in a transaction. Another view stems from the experimental forestry approach, in which participants are responsible for data collection of their actions on the plantation, but cannot be held accountable for tree mortality because the design is not theirs. It is important to note that the latter was initially presented to the community. However, the final choice of approach remains unresolved as of this year.

All in all, the advancements made during 2007 will be built upon in the following year with the new PFSS internship cohort.

3.3.2 *Carbon Calculation Results*

Calculations summarized in Appendix ii and iii yield that 320 trees must be planted to neutralize PFSS, which should cost $540 USD over 21 years, assuming that no other investment is made in the project other than payments for opportunity cost of land. The Panama Consortium and NEO should both require $270 USD to neutralize their travel emissions. Calculation results are represented on a total and per family basis in Table i. Moreover, time and wage estimated during the first three years have been projected to total $270 USD, and are presented in Table ii. Calculations for this table are present in Appendix iv. It is interesting to note that only estimated time and wages for the initial three years present 25% of the total payment for carbon sequestration for 21 years, thus requiring a lot of investment at the beginning.

Table i. *Total and per household tree number and associated opportunity cost (payment) necessary to sequester carbon from various participating programs*. Tree number adapted from Kraenzel et al. 2003. Detailed calculations found in Appendix ii. Four households are considered.

	Total			*Per household*	
Programs	Necessary area according to teak monoculture (ha)	Necessary Tree Number	Total sum paid for Carbon sequestration during 21 years ($USD)	Necessary Tree Number	Total sum paid for Carbon sequestration during 21 years ($USD)
PFSS	0.4	320	540	80	135
Panamá Consortium	0.2	160	270	40	67.50
NEO McGill	0.2	160	270	40	67.50
TOTAL	0.8	640	1080	160	270

Table ii. *Estimated work time and labor wages for the establishment of the plantation during the first three years*. Time and wage estimates from teak monoculture planting from Kirby and Potvin (submitted). Detailed calculations found in Appendix iii. Individual households not considered.

Program	Planting time (# days, assuming 1 team of 6 workers)	Clearing Time (# days, assuming 1 team of 6 workers)				Total work time (# days, assuming 1 team of 6 workers)	Wage associated to total work time ($USD)
		Year 1	Year 2	Year 3	Total		
PFSS	0.5	1.0	1.5	1.5	4.0	4.5	162
Panama Consortium	0.25	0.5	0.75	0.75	2.0	2.25	81
NEO	0.25	0.5	0.75	0.75	2.0	2.25	81
Total	0.8	2.0	3.0	3.0	8.0	9.0	324

3.3.3 *Plantation design, Seed Nurseries and Seedlings*

The organization of seedling production in Ipetí unfolded remarkably well. Upon inspection of available land, Dr. Paquette developed an undercover plantation design based on the state of fallow development. Suitable plantation sites were thus established for the June 2007 planting season. The design can be found in Appendix v.

Native tree species were chosen based on their availability from PRORENA and relative ease/fast rate of germination through a participatory manner with participating villagers. Species to be planted in 2007 are:

- Caoba[2] (*Swietenia macrophylla*, fam. *Meliaceae*)
- Cocobolo[3] (*Dalbergia retusa,* fam. *Fabaceae-Papilionoideae*)
- Corotu (*Enterelobium cyclocarpum*, fam. *Fabaceae-Mimosoideae)*
- Carbonero (*Colubrina glandulosa*, fam. *Rhamnaceae*)
- Guachapali Rosado (*Samanea saman*, fam. *Fabaceae-Mimosoideae*)

Seeds were distributed twice to participating families during the internship. The first instance occurred during mid-February, where some 600 caoba seeds were split between the four participants. Materials for substrate were gathered and black plastic seedling bags were distributed as well. General directions for the construction of a seed nursery were also explained and written copies were left in the village.

The seed nursery trial was assessed a month later, upon delivery of remaining seeds. The visual review examined in which ways the seed nurseries had been constructed, watering frequency and germination rates. Our initial estimate of 50% seed

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[2] Seeds were collected independently by authors during the fruiting season around Clayton and Balboa in the City of Panama.

[3] Cocobolo is also a valued hardwood by the Emberá, as it is used in traditional wood sculpture (Alain Paquette, personal communication, 2007). Around Ipetí Emberá, this tree has notably become sparser because of its frequent use; this factor motivated its inclusion in addition to the rest of the criteria.

mortality was in the end conservative, as only Nesar's seeds had a higher rate, that is 61%, versus 47%, 47% and 23% for the others. One of the reasons possibly explaining this outcome involves the initial substrate used: when using chicken manure, it is preferable to let the mixture compost for 25 days, as the decomposition process yields high acidity, which can rot the seed or the roots of seedlings (Riviett, PRORENA, personal communication). More detailed observations and pictures available in the assessment summary located in appendix vi.

Upon the second assessment of all seed growth at the end of April, production of seedlings was deemed successful, in consideration of previous attempts of seedling production in the village conducted by Dr. Potvin and Dr. Paquette. Please refer to Table iii for a summary of seedling numbers produced and germination rates. A total of 842 seedlings were produced, although not all of them have been transferred into plastic bags and many were still very young. Reneidio and Nesar's seedlings have been put into the bags, and are older than Rigoberto and Olga's seedlings, thus are deemed usable for the June planting. Rigoberto and Olga have only the caoba seedlings in the bags. As such, we confirm that approximately 766 seedlings will be ready for the planting season.

In terms of germination rates, our initial estimate of 50% seed germination rates has been accurate. Each species has germinated on average between Nesar, Reinedio and Rigoberto and Olga at that rate (see Table iii). However, when looking at species germination rates per individual family, wide differences in success are present. For instance, Nesar was much more consistent than the other two households; his seed nursery was surrounded by chicken wire, which protected his seedlings from herbivory from chickens, which was observed to be a considerable problem with Reneidio and

Rigoberto and Olga's seedlings. In addition, some rates were very close to or above 100%. This can be explained by extra seeds having been given, but not counted at the onset of the seedling production. In addition, seeds may have been given by Pablo from his share during the project. All in all, the seed nursery establishment is a success in the community, and provides important milestones for the future advancement of native tree reforestation in Ipetí.

Table iii. Seedlings produced and Germination rates according to species and participants as of April 22 2007. Arithmetic means were calculated. No distinction between seedlings in plastic bags or in early stage.

Number of seedlings produced out of number of seeds initially given						
Participants	Cocobolo (/50 seeds)	Guachapali rosado (/75 seeds)	Carbonero (/125 seeds)	Caoba (/175 seeds)	Corotu (/125 seeds)	Total seedlings available
Nesar	33	44	125	111	80	393
Reneidio	5	77	38	121	77	318
Rigorberto and Olga	26	12	38	55	Not planted	131
Total	64	133	201	287	157	842
Germination rate of each species (%)						
Participants	Cocobolo	Guachapali rosado	Carbonero	Caoba	Corotu	Average germination rate per participant
Nesar	66	59	100	63	64	70
Reneidio	10	103	30	69	62	55
Rigorberto and Olga	52	16	30	31	N/A	32
Average germination rate per species	43	59	53	54	63	

The seed collection workshop with Jose Deago from PRORENA was cancelled due to unforeseeable events, and will thus be postponed until next year. However, training was obtained by the students from staff at the PRORENA seed nursery in order to insure basic technical support for seedling production in Ipetí. In addition, substrate alternatives for the plastic bags were discussed, as our previous efforts in Ipetí were insufficient in terms of volume and also the required materials needed to be transported by truck. The new approach involves germinating seeds in sand for the most part, and then transplanting them in black bags filled with black earth and rice peels, instead of planting the seeds directly in plastic bags filled with a non-composted mix of black earth, sand, chicken manure and rice peels (see appendix vi for more substrate details). Thus, the change in soil mix may account for the good germination rates observed as well. It also requires less labor for the collection of mix components and will produce lighter seedlings that can be more easily transported. In the end, the Gamboa visit proved to be successful and a good foundation for discussion of practical components of tropical reforestation, and is thus recommended for students in the next internship cohort.

3.3.4 *Partnerships and Outcomes*

Three of the four households in Ipetí have expressed their enthusiasm to continue with the project as of April 22 2007. Pablo, who chose to drop out, nevertheless has lent his support in group discussions and has expressed interest in including his Caoba seedlings in the June plantation. However, the final outcome of the Ipetí partnership will be determined more specifically at this time.

The number of seedlings acceptable for planning produced over the last months is not sufficient to neutralize all three organizations' carbon emissions. Although the available seedlings tabulated in Table iii are numerically sufficient (842 seedlings counted, 640 seedlings needed), we are not confident that all will be ready for the plantation period. In addition, Rigoberto and Olga appear hesitant to continue with the project, and at the time of writing it cannot be confirmed if they will continue in the future as well. As such, we have informed the NEO program that we will not be able to sequester their carbon emissions for 2007, but that they will be included in the initial calculations in the following year. A final count of trees planted in June will then provide a better estimate of necessary seedling production in 2008.

3.3.5 *State of the Contract*

An informal contract in Spanish was drafted in two parts and reviewed by Nesar, Reinedio and Olga either orally or through text. The first part, found in Appendix vii, summarizes the concept. The second portion outlines contract specifications, and is only available in Spanish (see Appendix viii and ix). The evaluation method specified in this section involves payment for data collection, and was presented as the final evaluation method to the participants. However, upon consultation with Dr. Potvin, a measure for tree mortality accountability was deemed necessary as well, and should be incorporated in this framework in the future.

Because of time constraints of consultations with the Emberá lawyer Ultiminio Cabrera, a legally formatted version of the contract was not produced. As such, no contract will be signed for 2007. Nevertheless, live seedlings will be planted in June and labor wages will be paid for by Dr. Potvin, and so PFSS and Panamá Consortium carbon emissions for the year 2007 will be neutralized. The contract will be reviewed and formatted by students taking over this internship in 2008, and will include the trees planted in 2007 with associated payments for the 21 years. If the contract is not signed, then the Ipetí participants who plant the trees in 2007 will not be bound by any legality and trees will become their property.

3.3.6 *Web page design*

In order to ensure visibility and publicity for sequestration of air travel carbon emissions, the text for a web page has been drafted in English and Spanish and is included in Appendix x. The web page will be linked to the Panamá Consortium website. Once the final text is approved, a French version will be created as well. Proposed photographs for the web page have not been reviewed as of yet by the Ipetí members, and are thus not included in the appendix. The web page will be finalized in September 2007 by the internship students in Montreal, and should function online shortly after this point.

3.4 Discussion of Project Design, Conceptual Framework and Results

Since this is the first year of the carbon sequestration initiative in Ipetí, many aspects were pursued in order to give a proper foundation to project for the years to come. The project in itself mandated the creation of a carbon sequestration project using reforestation of native tree species in an undercover setting for PFSS, and ensure that it be self-sustainable. The main tasks involved developing an appropriate design and framework on which to build a long term partnership between Ipetí and McGill PFSS students to sequester carbon and provide a fair and sustainable income opportunity for members of the community.

During the course of the project, a preliminary analysis comparing teak plantations to high diversity undercover plantations for carbon sequestration was carried under the Millennium Ecosystem Assessment (MA) framework (see appendix xi). This analysis served to provide a general background on reforestation under two management types, the high diversity undercover design used in this project, and the most common type in Panamá, the intensive teak monoculture. It also listed the possible effects of these management options on the ecological services in Ipetí, on which the population is highly dependent (Tschakert et al 2007). Such an analysis predicts that high diversity plantations, while achieving carbon sequestration, maintain more integrally these services. In addition, the assessment incorporates the elaboration of future scenarios, in which high diversity plantations appear to provide the most economic and social benefit in the long term. Such an analysis is preliminary, but nevertheless provides a holistic argumentation for the management choice of the plantation in this project, in light of the socially and environmentally responsible goals set forth.

Further goals involved organizing the logistical progression of the project in Ipetí between various actors, more specifically with seed collection and seed nurseries, the establishment of a contract to assure fairness and transparency in the payments, long term monitoring, and promote awareness about the environmental cost of air travel. Overall, these tasks were attained and the outcome of this year's trial for the project provides a positive outlook for the future. Various points of discussion encountered during the process are enumerated below to serve as project contextualization for the next cohort.

Choosing to work with individual households simplified greatly relationships between Ipetí community members and the project. The political organization of *Tierras Colectivas* in Ipetí renders individual households the decision-makers and managers of their own *parcela*, as such this form of arrangement lies in respect of established land tenure systems (Tschakert et al. 2007).

Furthermore, since the project is set to run for at least the next three years, the choice to split each year's carbon sequestration budget between four individual families will insure equity between all interested community members. The list of remaining interested families is conserved in appendix ii and will serve in the selection of next year's participants. For 2007, participants were chosen on the basis of *parcela* proximity, that is, between each *parcela* and to the main entrance road to the village, due to time constraints in assessing the sites of each household during the passage of Dr. Paquette in Ipetí. As for the 2007 participants, only 3 chose to remain with the project until the end of April 2007: Nesar Dumasa, Reneidio Casama, and Rigoberto and Olga Casama. The fourth household did participate enthusiastically at the beginning, but eventually changed interest. One of the reasons may be because this particular owner has already high investment in cattle ranching (Potvin, personal communication), and thus does not see sufficient returns in carbon sequestration in comparison to this economic activity, as has been outlined in previous research (Tschakert et al 2006). Rigoberto and Olga Casama also show some hesitation in continuing to participate, but rather due to time constraints.

The basis for payment of the project was developed taking into account experimental, economic and practical feasibilities. Undercover enrichment planting being an experimental forestry method in the tropics (Paquette, personal communication), the outcome is uncertain. However, considering that a similar technique was used in the *parcela* of another Ipetí family (Juvenal) three years ago with considerable success (Potvin, personal communication), good results are projected. In addition, this technique yields many advantages over intensive monocultures of exotic species such as teak (*Tectona grandis)* and may even be more productive. For instance, Erskin et al. (2006) find that species richness significantly increased individual tree basal area in Australian tree plantations of the humid tropics. In addition, native tree enrichment planting maintains closer natural forest composition and function, and thus retains various ecological services such as water and various foods for the Ipetí community (Paquette, personal communication). This characteristic may reduce the usual increase of dependency on the external market for food and fiber provision predicted from CDM projects (Potvin et al, unpublished).

As such, to simplify payment strategies for carbon sequestration, paying the opportunity cost for land used over the length of the contract was the optimal solution. The data for the region was already available from Coomes et al (2006), who carried out a cost-benefit economic analysis of a CDM, cattle ranching and avoided deforestation in Ipetí Emberá. It is a relatively easily calculable and perceivable sum that in general appeared to be well understood by participants in Ipetí. As such, the contract could be seen in the future as leasing land with certain demands with regards to its use.

Payment for ecological services may present a more accurate value of the carbon sequestration, but on the other hand is much more complicated to develop and translate into economic terms. In addition, although this project is on the one hand experimental, the business aspect much still be considered and should incorporate a fair exchange between parties.

Finally, payment for avoided deforestation also holds much promise with regards to the possibility of obtaining recognition as an official CDM project, although it has yet to be officially recognized by the CDM board of executive (Coomes et al 2006). This option could be integrated into the framework of the project, as strips of fallow including large trees are left between plantation lines in Dr. Paquette's plantation design and could thus count towards the carbon sequestration count. However, it is important to note that the carbon stored in these strips will be not be protected once the contract time is over, and may thus be returned to the atmosphere rapidly without any legal means of protection (for instance, after clearing, the land owner could decide to burn the field). That is why the soil and litter carbon storage was excluded from the carbon calculations for the project, as their carbon-storing performance is dependent on the presence and age of trees (Kraenzel et al. 2003). In parallel, the Climate Care organization has progressively declined investing in forest carbon sequestration over the last two years unless it could legally protect them at a longer time scale, such as reforestation investments in degraded areas of the Kibale National Park in Uganda (Climate Care 2005). With the planted trees, however, most carbon is stored in the bole of the tree, which, if transformed into relatively more permanent functions, such as furniture or construction, could store carbon at a much longer time scale (Kraenzel et al 2003).

Payment modalities will have to be closely looked through and evaluated in the following year, as the costs of planting and clearing the plantation in the first three years represent a quarter of total payment for carbon sequestration. A fair and economically profitable manner must be defined in order to insure the repeatability of the project for the future.

Finally, it is interesting to compare Climate Care's prices to sequester the same amount of carbon as what this project sets forth. To sequester the emissions of PFSS, Panamá Consortium and NEO, the organization commissions a price of $1,142.62 USD. The price predicted by our project, based solely on payments from land opportunity cost, is $1080 USD. Thus, if future budget surpluses are less than $62.20 USD, then this direct method can be deemed extremely successful in that it is more cost efficient. However, due to the non-economical goals also pursued by the native tree plantation, it is most likely that the final budget will pass this figure. However, this will also mean that the social and ecological goals of the project will also have been attained.

3.5 Limitations and Obstacles Encountered

Relatively few large problems were encountered during the Ipetí project. Most constant obstacles involved logistical aspects. For instance, Ipetí only has one phone line, provided through a public phone, and is widely used when working by the villagers or not in function. As a consequence, regular communication was difficult. In addition, providing adequate supplies for the seed nursery proved to be a challenge. As the material quantities needed were estimated before our visits, they often had to be re-adjusted once they were brought to the field, and hence caused some delays. In addition, appropriate means of transport for these materials were often missing, such as a pick-up truck, and so we had to either adapt or post-pone some activities. Finally, the drafting of a legal contract ended up demanding more professional assistance that initially thought, and thus based on time constraints and irregular communication, the contract could not be formatted with Ultiminio Cabrera.

After getting to know Ipetí better and how social relations functioned there, some equity issues were discussed as well. As mentioned in the methods section, we worked closely with Bonarje in setting up this project, and this close tie may have biased our interactions towards his friends or family. However, he is nonetheless an important community figure and is used to working with foreigners, and provided us an incredible amount of help in getting to know community members.

Other challenges were also encountered in our relation with PRORENA. Firstly, there was miscommunication about the quantity of seeds necessary to our enterprise. This resulted in low seed availability for Cocobolo from the start, the most important species for our project due to its socio-economic and ecological value. Bureaucratic tensions were also encountered, as PRORENA presents a clear hierarchy, but the nature of our work demanded we work with all levels, and as such there were communication problems between our interactions with various staff members.

Finally, when the seed collection workshop was cancelled, we tried to quickly find another solution to deliver on time the information needed for the seed nurseries to Ipetí. Going to PRORENA's Gamboa seed nursery proved to be a beneficial solution, as much information was gathered from experts in native tree reforestation in Panama and was then shared with Ipetí.

From a more general perspective, most obstacles during this project lied in coordinating various efforts with various actors in a relatively small amount of time. Working with indigenous peoples requires a different way of proceeding, and to include this difference into coordinating between a variety of academic and economic interests mounted a tedious task. Nevertheless, as our learning curve increased during our stay, we managed to stay flexible and adapt within the context to ensure the success of our project.

4. Pruning and Wood Decomposition Studies carried out in an experimental high diversity tree plantation in Sardinilla.

4.1 Study site

The Sardinilla plantation is located in the town of Sardinilla (9°19’30”N, 79°38’00”W) in the Buena Vista Region in the central part of Panama. It is a long term research facility administered by STRI and involves many international academic partners such as McGill (Potvin 2003). The diversity plantation was established in 2001 to study the effects on carbon fluxes of the transition from pasture to a tree plantation, and the effect of community richness and identity of tree species on carbon accumulation and cycling (Potvin 2003).

4.2 Pruning Experiment

4.2.1 Methods

Field Methods

The pruning treatment in the High Diversity Plots was carried out in six of the eight blocks of trees. The other two blocks had almost no surviving trees of the selected species, therefore could not be included in the experiment. The blocks differ by number of species, however were all planted at the same time in 2003. The tree species chosen for treatment were those at sufficiently high survival rates for statistical significance. The species chosen were: *Anacardium excelsum* (AE), *Cedrela odorata* (CO), *Pachira quinata* (PQ), *Tabebuia rosea* (TR) and *Tabebuia guayacan* (TG). Trees were assigned quality levels and the qualities were classified as follows: A) no formation problems below two meters, no formation cuts necessary, B) single leader (leading trunk) but formation branching below 2 meters, C) multiple leaders, D) single leader but formation branching at ground level (<30cm), and E) multiple leaders at ground level (<30cm) (Figure 1). On a tree by tree basis, three trees were chosen of the same species and of relatively similar quality, condition and height for the three treatments: (1) pruning in the dry season; (2) pruning in wet season; and (3) no pruning. Maps were designed in order to assist finding the appropriate tree for pruning in the field.

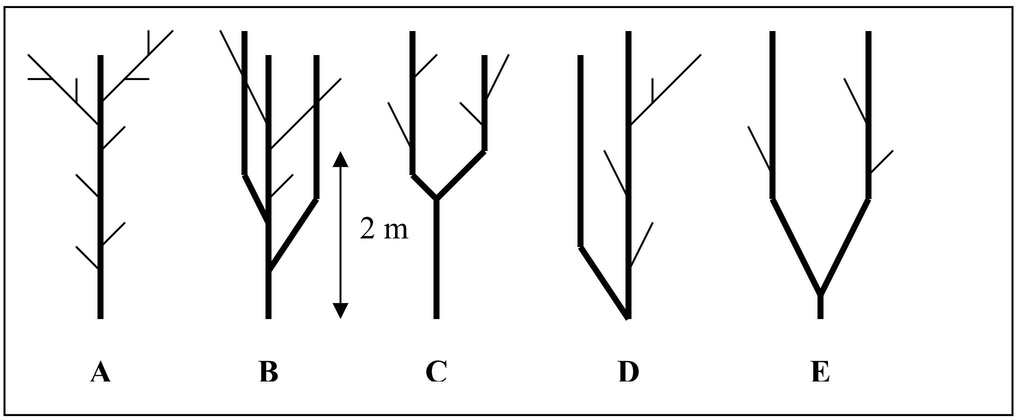

Figure 1. *Tree Quality categories.*

The pruning treatment carried out in the dry season occurred during early February, during the visit of Dr. Alain Paquette and us February 6-8, 2007. During the pruning process, branches were cut cleanly to avoid infection using saws and alcohol. Branches were cut in order to maintain at least half of the canopy and balance of the tree. The types of pruning cuts performed were recorded for each tree: the number of formation cuts (branches competing with the main leader) and pruning cuts (branches of smaller size with greater insertion angles). Those branches pruned were further cut into pieces and weighed. Small cross section samples of branches representative of the biomass cut were weighed and kept for later measurement of dry weight.

The second set of pruning will occur in the wet season and further analysis will be carried out at this time.

Statistical Analysis

Contingency analysis was performed in order to test the null hypothesis that species relative frequencies are the same for tree quality (alternative hypothesis: species relative frequencies are not the same for tree quality). Both a contingency table and mosaic plot were created. Due to the fact that not all tree qualities were represented for each species, statistical analysis could not be performed on the original table. In order to perform statistical contingency analysis, tree qualities were first re-organized into functional categories describing the location of branching problems. Quality A trees (Figure 1), which present appropriate form below 2 m were classified in ">2m". Quality B and C trees, showing problematic stems below 2m were put together in the "High" category. Finally, quality D and E, showing branch growth and formation problems at ground level (<30cm) of tree height were classified in the "Low" category. With this re-organization, a statistically valid analysis was made possible using a contingency table and Pearson Chi-square test that the distribution of quality classes is the same across each species (Legendre and Legendre, 1998; p. 217-218).

Statistical contingency analysis was also performed on the data re-organized so as to group tree qualities A, B and D into a category of single leader (trees with only one leading trunk) and tree qualities C and E into a category of multiple leaders (trees with more than one leading trunks) (see figure 1).

One-way Analysis of Variance (ANOVA) was performed for several responses tested across species (X): amount of biomass pruned, number of formation cuts, and total number of cuts (Y). One-way ANOVA was also performed for every species of biomass removed (Y) per class of quality (those re-organized into “High”, “Low” and “>2m”) (X) as well as per class of quality (those re-organized into “Single” versus “Multiple” leaders) (X). The Kruskall-Wallis non-parametric comparison of means test, followed by the Tukey-Kramer Honestly-Significantly-Different (HSD) analysis, were performed in all three cases.

4.2.2 Results

The initial contingency analysis of tree quality across species was not statistical; however inferences can still be made from the contingency table (Table 1) and mosaic plot (Figure 2). The sample size, N, was 155, including all trees in the experiment, those pruned, not pruned and those to be pruned in the wet season. Significant proportions of the trees of *T. rosea* (TR) (n=51) and *T. guayacan* (TG) (n=43) were classified as quality A. Half the trees of *P. quinata* (PQ) (n=18) were classified as quality B. Nearly half of the trees of *C. odorata* (CO) (n=12) were classified as quality C and another half were classified as quality D. The trees of species *A. excelsum* (AE) (n=31) were relatively consistently distributed across tree quality classes.

In the statistical contingency analysis of the re-organized data (N=155), the results obtained were similar to those of the initial contingency analysis, as can be seen in the contingency table (Table 2) and the mosaic plot (Figure 3). Since the class of “>2m” includes only trees of Quality A, again substantial proportions of trees of *T. guayacan* and *T. rosea* were found to have no branching under 2m. In addition, all species were found to have consistent and substantial proportions of the functional category “High” (ranging 33-60%). As for the functional class of “low”, species *C. odorata* has the highest proportion of this class at 50%. The Pearson statistic was found to be 36.603 with a high level of significance of less than 0.0001.

Table 1. *Initial Contingency Table of Tree Quality across Species.*

Count Row %	A	B	C	D	E	
A. excelsum	8 25.81	6 19.35	7 22.58	9 29.03	1 3.23	31
C. odorata	0 0.00	1 8.33	5 41.67	6 50.00	0 0.00	12
P. quinata	3 16.67	9 50.00	2 11.11	3 16.67	1 5.56	18
T. guayacan	17 39.53	3 6.98	15 34.88	5 11.63	3 6.98	43
T. rosea	33 64.71	6 11.76	11 21.57	1 1.96	0 0.00	51
	61	25	40	24	5	155

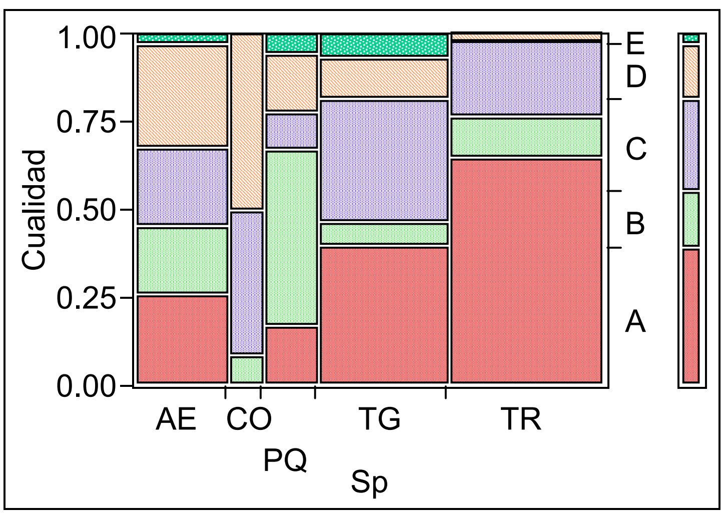

Figure 2. *Initial Contingency Mosaic Plot of Tree Quality across Species*. Species: *Anacardium excelsum* (AE), *Cedrela odorata* (CO), *Pachira quinata* (PQ), *Tabebuia rosea* (TR) and *Tabebuia guayacan* (TG). See Figure 1 for tree quality categories.

The results of the contingency analysis of the tree quality data re-organized into the groups single or multiple leaders (N=155) were found to be non-significant. The contingency table (Table 3) and the mosaic plot (Figure 4) show variable proportions across species. The Pearson statistic was found to be 7.235 with a significance value of 0.1240.

Table 2. *Contingency Table of re-organized tree quality classes (Low, High, >2m) across species.*

Count Row %	>2m	High	Low	
A. excelsum	8 25.81	13 41.94	10 32.26	31
C. odorata	0 0.00	6 50.00	6 50.00	12
P. quinata	3 16.67	11 61.11	4 22.22	18
T. guayacan	17 39.53	18 41.86	8 18.60	43

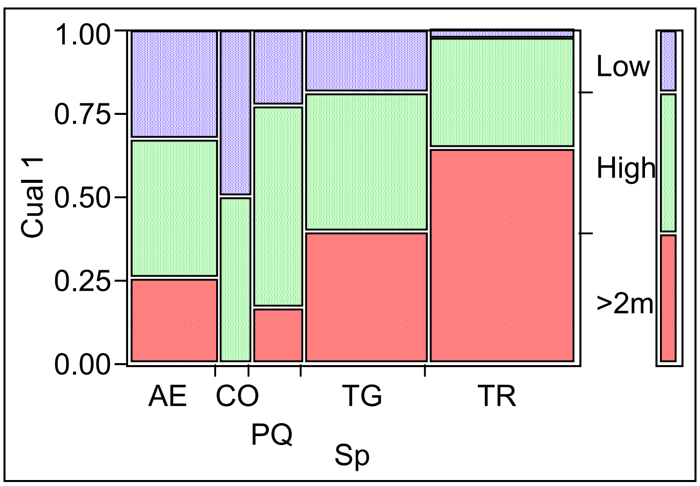

Figure 3. *Contingency Mosaic Plot of re-organized tree quality classes (Low, High, >2m) across species* (see Methods for description). See Figure 2 for species names.

Table 3. Contingency Table of re-organized tree quality classes (single or multiple leaders) across species.

Count Row %	multiple	single	
A. excelsum	8 25.81	23 74.19	31
C. odorata	5 41.67	7 58.33	12
P. quinata	3 16.67	15 83.33	18
T. guayacan	18 41.86	25 58.14	43
T. rosea	11 21.57	40 78.43	51
	45	110	155

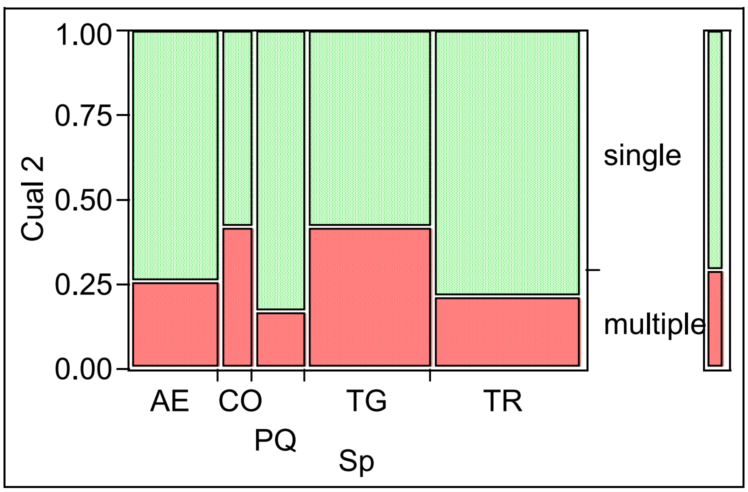

Figure 4. *Contingency Mosaic Plot of re-organized tree quality classes (single or multiple leaders) across species*. See Figure 2 for species names.

The one-way ANOVA of biomass by species (N=55) was performed only on those trees that were pruned, therefore the sample size is smaller (Table 4). The Kruskal-Wallis test found tree species to significantly differ in the amount of biomass pruned (P=0.0065). The Tukey-Kramer HSD comparison of means found *P. quinata* to be significantly different from *T. rosea*, but not from *A. excelsum*, *T. guayacan*, or *C. odorata*.

Table 4. *Statistics of one-way ANOVA for biomass by species.*

Species	N	Biomass removed (mean)	Tukey-Kramer test
A. excelsum	11	2183.70	AB
C. odorata	4	614.22	AB
P. quinata	8	3761.59	A
T. guayacan	14	1146.01	AB
T. rosea	18	694.18	B
Global test	55	K-W $Chi^2 = 14.27$	$p>Chi^2 = 0.0065$

The one-way ANOVA of number of formation cuts by species also finds significant differences (Table 5). The Kruskal-Wallis test found tree species to significantly differ in the number of formation cuts (P<0.0001). The Tukey-Kramer HSD comparison of means found *P. quinata* to differ significantly from *A. excelsum, T. guayacan*, and *T. rosea*, but not *C. odorata; A. excelsum* was found to differ significantly from *P. quinata* and *T. rosea*, but not *C. odorata* or *T. guayacan*; *C. odorata* does not differ significantly from any other species (due to small sample size); *T. guayacan* only differs significantly from *P. quinata; T. rosea* differs significantly from *P. quinata* and *A. excelsum* but not *C. odorata* or *T. guayacan*.

Table 5. *Statistics of one-way ANOVA of number of formation cuts by tree species.*

Species	N	Number of formation cuts (mean)	Tukey-Kramer test
A. excelsum	11	2.09	B
C. odorata	4	2.00	ABC
P. quinata	8	3.75	A
T. guayacan	14	0.86	BC
T. rosea	18	0.72	C
Global test	55	K-W $Chi^2 = 24.73$	$p>Chi^2 <0.0001$

The one-way ANOVA of total number of cuts by species also finds significant differences (Table 6). The Kruskal-Wallis test found tree species to significantly differ in total number of cuts (P<0.0001). The Tukey-Kramer HSD comparison of means found *P.*

quinata to differ significantly from *C. odorata, T. rosea* and *T. guayacan*, but not *A. excelsum; A. excelsum* was found to differ significantly from *T. rosea* and *T. guayacan*; *C. odorata* differs significantly only from *P. quinata*; and both *T. rosea* and *T. guayacan* differ significantly from both *P. quinata* and *A. excelsum*.

The one-way ANOVA of biomass removed per class of quality (those re-organized into "High", "Low" and ">2m") found no significant differences, due to small sample size. Biomass removed did not vary between quality classes for any species (ANOVA; $p>0.05$), except for T. rosea ($p=0.0184$ if your using Fisher, 0.155 if KW) for which a significantly heavier biomass was removed on trees with formation problems located high (classes B and C) as compared with those of class A (no trees of that species were in the "low" category (classes D and E). Biomass removed on T. guyacan was quite large on those trees with problems located low (classes D and E) when compared with the other classes, but that was not significant ($p=0.0980$ or 0.0711) probably due to low sample size. The one-way ANOVA of biomass removed per class of quality (those re-organized into "Single" versus "Multiple" leaders) also found no significant differences in biomass removed between trees with single versus multiple leaders in any species.

Table 6. *Statistics of one-way ANOVA of total number of cuts by tree species.*

Species	N	Total number of cuts (mean)	Tukey-Kramer test
A. excelsum	11	6.55	AB
C. odorata	4	3.75	BC
P. quinata	8	10.00	A
T. guayacan	14	0.86	C
T. rosea	18	0.89	C
Global test	55	K-W $Chi^2 = 33.32$	$p>Chi^2 <0.0001$

4.2.3 Discussion

The initial non-statistical contingency analysis indicates several trends of tree quality in species. The high proportions of *T. rosea* and *T. guayacan* in quality A indicate that this genus grows relatively straight in open pasture and requires little pruning in the first years of growth. However, there are about a third of *T. guayacan* trees in quality C, indicating that some formation problems may also be present during early growth years for this species. Furthermore, the low proportion of *P. quinata* individuals in quality A and the high proportion of trees in class B suggests that this species usually does not present formation problems in its early growth stages but does require regular pruning. The presence of the majority of *C. odorata* trees in either class C or class D indicates that this species often requires formation cuts in early stages of growth as well as regular pruning. The regular distribution of species *A. excelsum* trees throughout the quality classes indicates that there is no evidence of a trend in early growth of this species in open pasture.

The statistical contingency analysis indicates several trends consistent with those found in the initial analysis. The trees of species *T. guayacan* and *T. rosea* tend to have good formation growth. All species had substantial proportions of trees in the functional category of “High”, therefore it can be inferred that a substantial proportion of trees for all species fall in the intermediate range of tree quality. Half the trees of species *C. odorata* fall in the functional class of “Low”, indicating that half the trees of this species are of low quality and poor trunk formation, requiring heavy formation cuts and pruning low on the trunk. The highly significant likelihood ratio indicates that some species have much higher probabilities of having poor quality with multiple stems at the base while others have high probabilities of having high quality with no problem below the 2 m height line.

The contingency analysis of the tree quality data re-organized into the classes of single or multiple leaders found variable proportions across species and a non-significant likelihood ratio. Therefore, it can be inferred that no differences were found between species in terms of tendency to have single (qualities A, B, D) or multiple (qualities C and E) leaders.

The one-way ANOVA of the amount of biomass pruned by tree species found significant differences. The finding that species *P. quinata* is significantly different from *T. rosea*, but not from *A. excelsum*, *T. guayacan*, or *C. odorata*, is consistent with the mosaic plots of the contingency analyses that show the differences in proportions of tree qualities across species. The finding of significant differences between species in terms of both number of formation cuts and total number of cuts is also consistent with the other findings of significant differences in quality across species, since more formation cuts are required in trees of poorer quality, with formation problems in early growth. However, which species differ significantly from which changes between the two ANOVA's. Therefore, it is important to look at both the results of both the contingency analysis and ANOVA's since the ANOVA's indicate which species differ significantly from each other, and the contingency analysis provides information regarding which species have tendencies to which qualities.

In conclusion, it can be said that there are significant differences between tree species in terms of tendencies of formation growth and tree quality, consequently, the amount of biomass that must be pruned, the number of formation cuts that must be done and the total number of pruning cuts required. From this preliminary analysis, *T. rosea* and *T. guayacan* tend to have good formation during early growth and require less pruning, whereas the species *C. odorata* tends to have poor quality and formation and therefore require substantially more pruning. However, most species also have high proportions of trees that are of intermediate quality, therefore requiring intermediate levels of pruning.

The amount of pruning required and the amount of biomass removed has implications for the tree growth, value and carbon sequestration. The more pruning required means there is more “damage” incurred on the tree, and more vulnerability to pest invasion and disease infection. In addition, there are implications for timber trees, as they are most valuable when they have a straight single leader, therefore in order to maintain good formation growth and high value, certain species need high levels of maintenance and pruning. Furthermore, when biomass is removed from a tree, sequestered carbon is released, however, the pruning also initiates new (possibly greater) growth, allowing more carbon sequestration. In the long term, this experiment will provide insights into this question of whether pruning improves carbon sequestration of trees, or if there is net release of sequestered carbon. It is also important to understand more about when during early tree growth is it optimal to prune. In the tropics, plant growth is so rapid that early tree growth occurs in a short span of time; therefore pruning must be done early. It is possible that our pruning treatment was done on trees already too mature.

As previously mentioned, the biomass that is pruned is carbon released from the tree, however that carbon is recycled. If the pruned biomass is left on the ground for decomposition, the carbon will be cycled back into the soil. It is important to consider the full cycle of carbon, from atmospheric carbon to that sequestered by the tree, to that recycled into the soil. The following section regarding the wood decomposition study will address this subject in further detail.

In addition, it is interesting to note that prior to our project, quality of the trees was not seen as important (bad cuts were actually done intentionally on the trunks). Teaching the methods and importance of quality were also major objectives of this project. With training of permanent staff at the Sardinilla plantation, and due to the long-term continuation of this project, it is believed that these goals are in the process of being achieved.

4.2.4 Problems Encountered

In the field, several problems were encountered. Some species were not able to be used because of high mortality rates in the plantation; this also meant that several blocks could not be used. Consequently, as already mentioned, sample sizes were fairly small for statistical significance to be obtained. With a larger sample size, there could be higher statistical power.

4.3 Wood Decomposition Study

4.3.1 Methods

The experimental design of the wood decomposition study involved literature review and consultation with Dr. Alain Paquette. Literature pertaining to wood decomposition was used to determine the standard definition of fine and coarse woody debris, the standard wood piece sizes used, and the standard forms of controls. Consultation with Dr. Alain Paquette and use of maps of the Sardinilla plantation allowed experimental layout and detailing.

4.3.2 Results

The experiment was designed and translated into Spanish for implementation. Permanent Sardinilla staff and a University of Panama student were trained to carry out the experiment. The experimental design is attached as Appendix xi.

4.3.3 Discussion

The wood decomposition study is an important component of the research in Sardinilla as it may contribute to the understanding of tropical carbon cycling. The pruning experiment pertains to the above ground carbon sequestration of tropical native tree species and attempts to understand how to optimize tree growth and carbon sequestration. The wood decomposition study uses wood from the pruning experiment in order to understand how plantation diversity affects decomposition of woody debris of different tree species. Since the biomass pruned is carbon released, it is important to understand the process of decomposition that follows.

5. Conclusion

The carbon sequestration plantation project in Ipeti-Embera was successfully established. Seedling germination rates were high enough in order to plant a sufficient number of trees to offset the carbon emissions of the PFSS and Panama

Consortium programs. Planting will occur in June of this year. Based on analysis done by Paquette et al. (2006), establishing a high diversity tree plantation in an intermediate shelterwood (or undercover, such as *rastrojo alto* in Ipeti) will have a higher growth rate and survival of trees than in an open plantation. The trees are found to grow straighter as well, therefore producing higher value wood. Furthermore, this type of plantation conserves forest structure and biodiversity and will provide greater versatility for its users (hunting, material and food, water retention, etc.). Keeping intact forest also allows for the conservation of carbon stocks in both the remaining biomass and soils, whereas large amounts of C are released from soils with the complete removal of forest cover. In addition, the species to be planted in the reforestation project are to be indigenous species of high value to the Embera community, some of which are locally extinct or threatened.

With regards to the carbon neutralization project in Ipeti, we hope that our efforts will provide general visibility of the impacts of air travel on carbon emissions and global climate change, especially within the academic sector. In addition, we hope that the carbon initiative in Ipeti presents an alternative sustainable source of income for community members, and that it attracts future potential investors interested in offsetting carbon.

The experiments carried out at the Sardinilla plantation were also successfully established. The pruning experiment was carried out and statistical analysis was done, finding significant differences in quality between species with respect to tree growth and formation. The wood decomposition study was initiated after careful experimental design and training of Sardinilla staff and involved researchers.

The two projects represent different aspects of tropical reforestation. The Sardinilla work represents the scientific and experimental dimension of trying to understand how native tropical timber species grow in a high diversity plantation, how carbon is stored in the system, and how to manage tree growth in order to optimize carbon sequestration and timber value. Meanwhile, the work in Ipeti-Embera represents the practical and applied dimension of trying to actually establish a carbon sequestration high diversity plantation in a community, in order to offset emissions but also to develop a project beneficial to the community. The work in Sardinilla will help improve projects such as those in Ipeti-Embera to improve plantation management and therefore carbon sequestration and tree value.

In reflection, the implementation of carbon sequestration projects involves various dimensions including legal, social, economic, and scientific. Therefore, there are difficulties in balancing these dimensions and in coordination of different interests. It is important to try to establish at the beginning of such a project how much attention must be focused on different dimensions and be mindful of all involved participants and their interests.

Furthermore, it is important to understand that there exist many uncertainties in the future and such projects, especially since tropical reforestation is still not fully understood, are subject to changes. Therefore it is important to be adaptable and flexible and try to mitigate vulnerabilities and make the project resilient and adaptable to changes. In addition, it is important to recognize how such projects are inherently experimental and iterative. Because this type of project is new and tropical reforestation of this sort (with native species in fallow) is not well understood, we have to work in an experimental framework and be prepared to trouble-shoot successively. Working with a community and with social and legal dimensions is an iterative process of continual consultation, re-working and further consultation. Thus, although it is a complicated process, the key to success of tropical reforestation for carbon sequestration lies in the integration and harmony of the various dimensions together with the active participation of the people involved.

With this in mind, we strongly recommend that the project with Ipeti-Embera be continued during the following PFSS year of 2008. We recommend that next year's group focuses on the legal dimension, primarily the contract, in order to ensure management and monitoring of the plantations and to secure financial commitments. We strongly recommend even closer work with the Ipeti-Embera community in order to ensure active involvement of community participants and to attempt to make the community as self-sufficient as possible in terms of establishing the plantations. See Appendix xii for more specific recommendations for next year's PFSS cohort.

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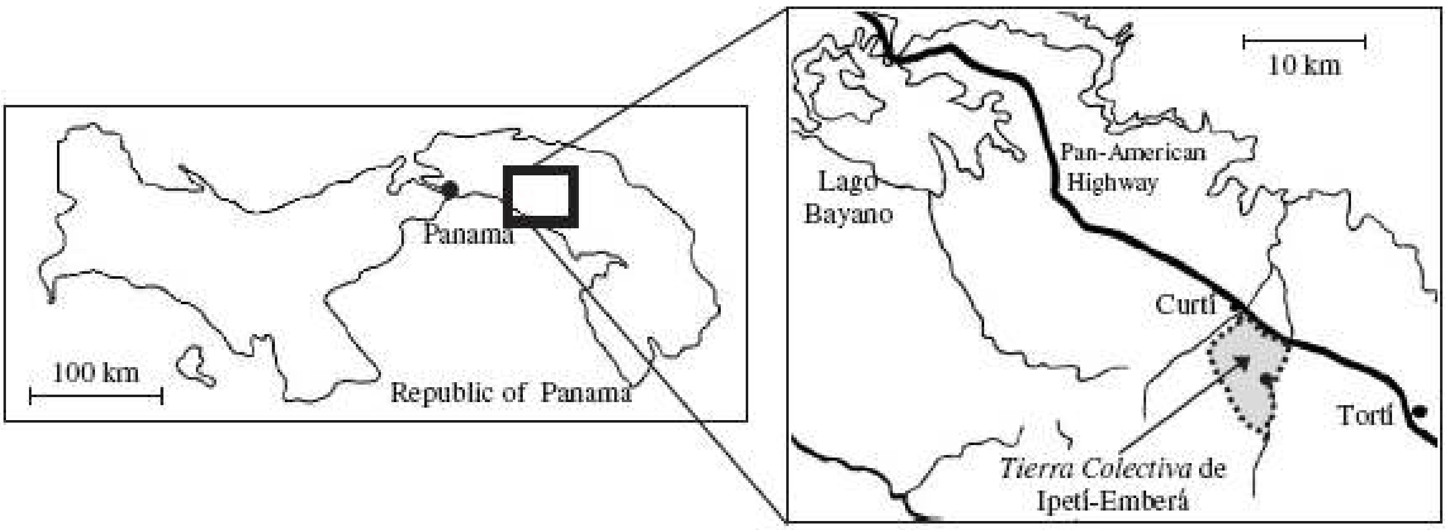
Appendix i-1: Geographical Map of Ipeti-Embera[4]



Original caption :

Map illustrating the location of the Tierra Colectiva of Ipetí–Emberá in eastern Panama.

[4] Figure adapted from Tschakert, Petra, Oliver T. Coomes, and Catherine Potvin. 2007. Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics* 60: 807-820.

Appendix i: List of Ipeti Households interested in the carbon plantation project, written during a community meeting on January 21st 2007.

Participants selected for 2007

- Nesar Dumasa
- Reneidio Casamá
- Rigoberto and Olga Casamá
- Pablo (who has since removed his participation with the project)

Other participants for future years, not in any particular order

- Victor Deguisa
- Nene Ruiz
- Bregel Bailarin
- Bonifacio Flaco
- Antonio C.
- Arcindo
- Breanki
- Eligio
- Cajare
- Leonel
- Fulgencio
- Mauricio
- Juan Casama
- Julio
- Lisando Flaco

Appendix ii: Calculations for the Amount of Trees Needed to Sequester Carbon Emissions of PFSS, Panama Consortium and McGill NEO

a) *McGill Panama Field Studies Semester*

- Total Number of plane roundtrips from Montreal, Canada, to Panama City, Panama: **34**
  - 25 for students
  - 1 for Nilka Tejeira
  - 2 for McGill professors Uli Locher and Tom Meredith
  - 4 for Dr. Catherine Potvin, PFFS professor and coordinator
- Climate Care estimate for atmospheric carbon emissions based on the Climate Care calculator: **38.62 tons** of emissions
- Climate Care price for the neutralization of this amount of emissions: £289.71 = $571.31 USD
- Kraenzel et al. (2003) estimate that a harvest-age (21 years) teak plantation sequesters 120 tons/ha (excluding soil, litter and undergrowth compartments). As such, the necessary area to sequester the carbon emitted by PFSS if it were an intensive teak plantation is:
  38.62 tons ÷ 120 ton/ha = 0.321298 ha ~ **0.32 ha**
- To account for natural tree mortality during planting and tree growth, 25% extra land is added (Potvin, personal communication):
  0.32 ha * 1.25 = **0.40 ha**
- Assuming that an average teak plantation in Panama holds 800 trees/ha (Potvin, personal communication), we determine that the following number of trees need to be planted to ensure that the PFSS carbon emissions be neutralized. 0.40 ha * 800 trees/ha = **320 trees**

b) *Panama Consortium*

- Number of roundtrips from Montreal, Canada, to Panama City, Panama: **17** (Potvin, personal communication)
- Climate Care price for the neutralization of this amount of emissions: £144.86 = $285.66 USD
- This quantity is half of PFSS, thus **160 trees** are necessary to sequester the carbon emissions from the Panama Consortium.

c) *McGill-STRI Neotropical Environment Option (NEO)*

- Estimated as the same number of roundtrips from Montreal, Canada, to Panama City, Panama: **17** (Potvin, personal communication)
- Climate Care price for the neutralization of this amount of emissions: £144.86 = $285.66 USD
- This quantity is half of PFSS, thus **160 trees** are necessary to sequester the carbon emissions from the Panama Consortium.

Appendix iii: Budget for Carbon Sequestration based on opportunity cost of land in Ipeti-Embera

a) *Budget for PFSS*

- Opportunity cost of land in Ipeti-Embera is based on the most profitable land use activity in the area, cattle ranching, and consists of $1597 USD/ha for 25 years, thus **$63.88USD/ha per year**[5].

- For 0.4 ha of land calculated from appendix i, the yearly opportunity cost should be $25.68 USD per year
- As such, for the 21 years of duration for the contract, the total money to disburse for the opportunity cost of land will be $539.28 USD **~ $ 540 USD.**

b) *Budget for Panama Consortium*

- Should be half that of PFSS (Potvin, personal communication), therefore $269.64 USD ~ **$270 USD**.

c) *Budget for NEO*

- Should be half that of PFSS (Potvin, personal communication), therefore $269.64 USD ~ **$270 USD** as well.

[5] Opportunity cost calculated in Coomes, Oliver T., Franque Grimard, Catherine Potvin and Philip Sima. 2006. The Fate of the Tropical Forest: Carbon or Cattle? Unpublished commentary, April 21.

Appendix iv: Projected Work Time and Wages for the Establishment of the Plantation During the First Three Years, based on time estimates from Teak plantation[6]

a) *Planting time and necessary for PFSS*

- Planting assumes 1 team of six men for 1 day per hectare
- Planting assumed to be identical for timber plantation and agroforestry plantation
- 25% Tree mortality assumed in calculations

- Using 0.402 ha (from teak estimate in appendix i), planting time = **0.4 day for 6 workers ~ 0.5 days**

b) *Clearing time necessary for PFSS*

- Cleaning assumes 2.5 days of the 6 men team per hectare in yr 1 and 3.5 days of the 6-men team in year 2 and 3

- Cleaning time = **1.005 day for 6 workers for year 1 ~ 1 day**
  1.407 days for 6 workers for year 2 ~ 1.5 days
  1.407 days for 6 workers for year 3 ~ 1.5 days

c) *Estimates of wages of planting and clearing work for the first 3 years for PFSS*

- If we estimate 4.5 days in total of planting and cleaning time, that is 27 workers = 27 "work days" paying $6/day = **$162 USD**

d) *Summary table of planting and cleaning times and associated wages for PFSS, Panama Consortium and NEO*

- Assume Panama Consortium and NEO are both half the amount of PFSS (Potvin, personal communication)

Program	Planting time (# days, assuming 1 team of 6 workers)	Clearing Time (# days, assuming 1 team of 6 workers)				Total work time (# days, assuming 1 team of 6 workers)	Wage associated to total work time ($USD)
		Year 1	Year 2	Year 3	Total		
PFSS	0.5	1.0	1.5	1.5	4.0	4.5	162
Panama Consortium	0.25	0.5	0.75	0.75	2.0	2.25	81
NEO	0.25	0.5	0.75	0.75	2.0	2.25	81
Total	0.8	2.0	3.0	3.0	8.0	9.0	324

[6] Calculations are based on data obtained from Kirby, K., and C. Potvin. Variation in carbon storage among tree species: implications for the management of a small-scale carbon sink project. *Forest Ecology and Management*, submitted. Data provided by Dr. Potvin.

Appendix v: Ipeti plantation design (Paquette)

Instructions for the 2007 under-cover enrichment plantation at Ipeti-Embera

The instruction for the construction and maintenance of the nursery, if available, can be copied here

Four plantations are to be established in June 2007. Four families participate by:

1. Growing their own seedlings in a nursery during the dry season
2. Preparing their parcela for the plantation in May
3. Planting the seedlings in June
4. Caring for the plantation for 25 years afterwards; which mostly involves keeping the lines open for the first 5 years or so.

The families are:

- Nesar
- Reinedio
- Rigoberto

In 2007, two plantation plans are possible according to the height of the vegetation in the chosen parcela. For a rastrojo bajo such as that of Nesar, plan A should be applied. For a rastrojo alto such as that of Pablo, use plan B.

General rules:

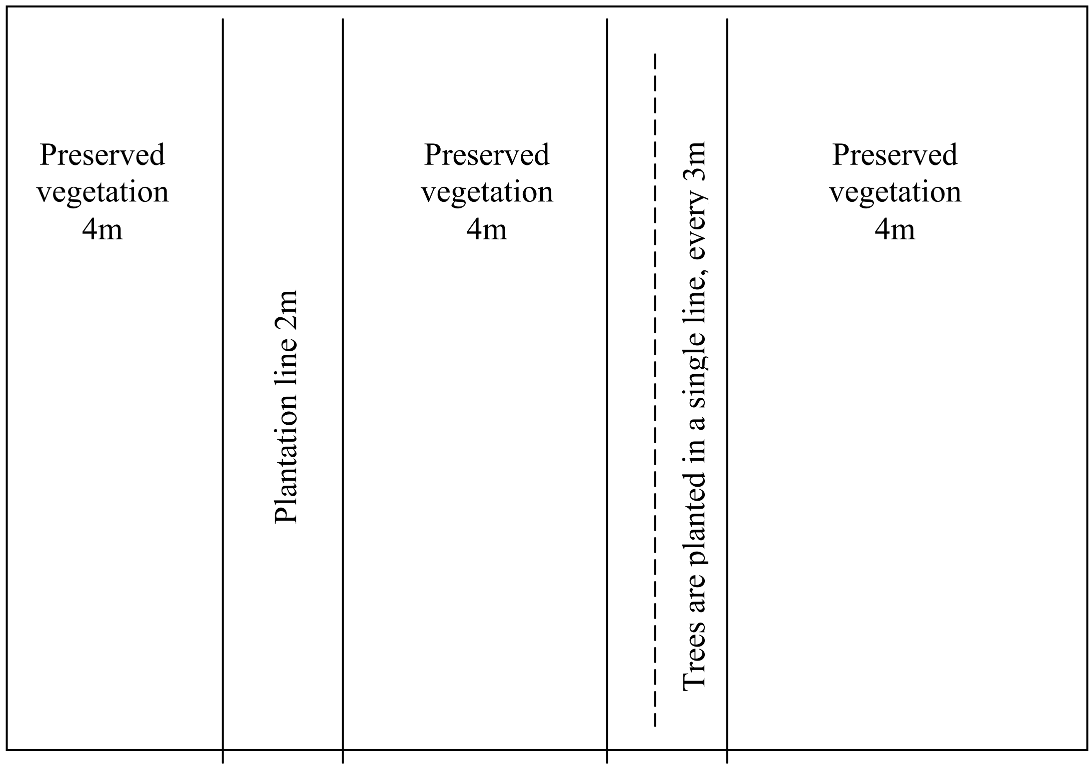
- Do not remove trees, palms, or other plants that are valuable.
- Seedlings are to be planted so as to alternate between species (e.g. 1, 2, 3, 4 ,1, 2, …).
- The planted trees are to be kept free of above competition and grass. The seedlings should be cleaned 3 to 4 times a year and the strips re-opened completely every year.

Strips are to be opened at the start of the rain season, and trees planted no more than two weeks after that.

A: Rastrojo bajo (Low fallow)

Dominant vegetation is between 2 and 4 meter high. Do not consider tall but sparse trees or palms (such as the high palms on Nesar's parcela).

The vegetation type on these parcelas is much different than on taller sites. Gramináceas (grass) are still present and will require more regular limpiezas. Grass should never be allowed to grow within 1m from the planted seedlings until they reach at least 3m in height.

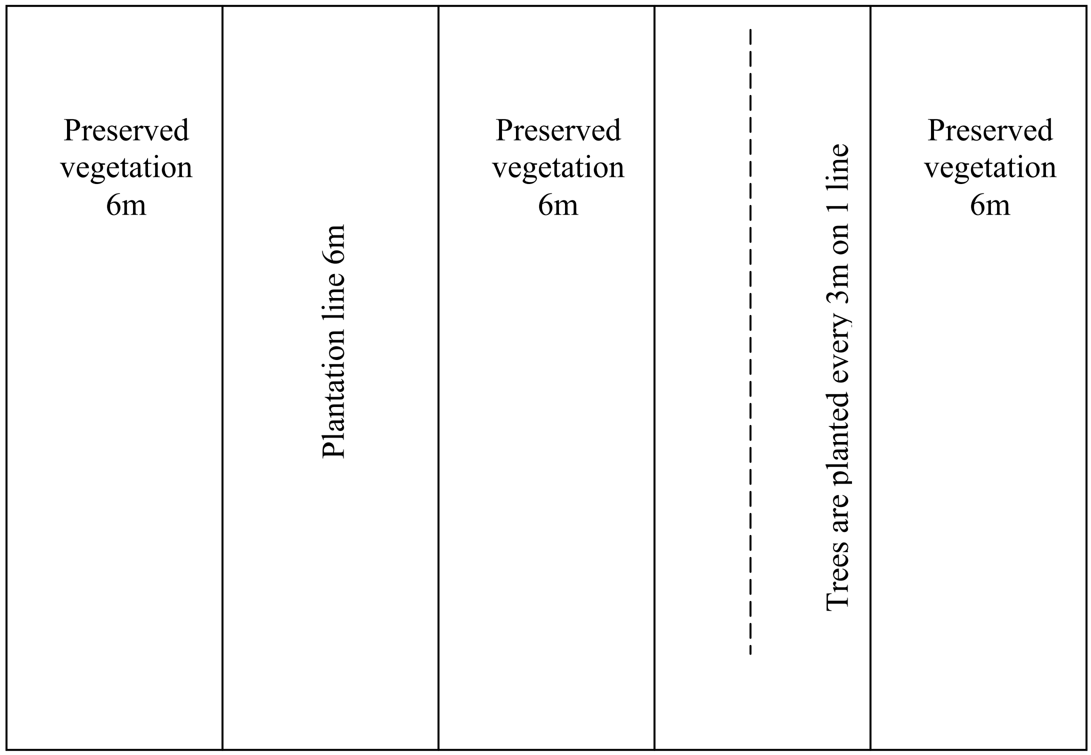


Trees are planted in a single line every 3 meters. Species alternate on the line. A total length of 1500 meters of opened lines is necessary to plant 500 trees.

B: Rastrojo alto (High fallow)

Dominant vegetation is over 4 meter high. Do not consider tall but sparse trees or palms (such as the high palms on Nesar's parcela).

The vegetation type on these parcelas should not be grass as the cover is denser.



Trees are planted every 3 meters on 1 line. The lines are separated by 2 meters from the preserved vegetation. Species alternate on each line. A total length of 1500 meters of opened lines is necessary to plant 500 trees.

Appendix vi

UPDATE FROM OUR VISIT TO PRORENA AND IPETI (March 9/10/2007)
(originally ATTN: Alain Paquette)

We traveled to Gamboa and Ipeti last Friday and Saturday to check up on the viveros and bring the black bags and new seeds.

<u>PRORENA at Gamboa</u>

Because Jose Deago was sick, we decided it would be best to get some on-hand training from at Gamboa. Adriana Sautu (PRORENA) burnt us a copy of a database on the care and growth of native trees of Central America (the language is not too technical and it is all in Spanish, so we can bring copies to Ipeti on our next trip).

We then contacted Riviett at Gamboa and she agreed to meet with us on Friday morning in Gamboa. For two hours she gave us a rundown on basic vivero set-up, soil alternatives and care for plants and specifics for each species. One important point she mentioned is that seeds in general had a much higher germination rate when they germinated in sand only. After becoming sturdy enough they could then be transplanted into the substrate of the black bags. The sand can just be contained in a "sand box", watered twice a day, and seeds are planted very close to the surface.

For alternatives to the soil we were using before Riviett explained that using gallinasa and black earth at the same time were not necessary, and also that sand could be replaced with more rice peels, and would decrease the weight of the bags. She also mentioned that when using gallinasa, the mix must be composted before planting to avoid rotting of roots of the plantones. These are the alternatives she gave us for the soil mix:

1) 1 part black earth + 1 part rice peels
2) 1 part red earth + 1 part gallinasa + 1 part rice peels + some water
   * The mix must be composted for 25 days under ideally plastic covering or palm leaves, and must be turned over 3 times a week for this period. This is the mix used at Gamboa.

In terms of seed availability, we had some difficulty obtaining the seeds for cocobolo and T. rosea or guayacan. We ended up taking more than 5 species because of insufficient seed numbers, uncertain long-term availability of wanted seeds and possible germination problems. In addition we bought a pair of low quality hand pruners for seed preparation. These are the seeds we obtained and the necessary care for germination:

1) **Cocobolo (*Dalbergia retusa,* fam. *Fabaceae-Papilionoideae*)**
   - Quantity: 200
   - All the seeds for cocobolo have been reserved or planted at Gamboa; we barely managed to obtain the 200. Because of Jose's illness he may not

be able to collect anymore for the next month, but the plantones are available for the moment if need be (we would need to know quickly if we need to reserve them…).

- Care: Seeds must be soaked from 3 to four hours and then planted close to the surface in sand. They must be watered twice a day, and covering up the sand with dried herbs can help preserving moisture.

2) ***T. rosea* or *guayacan* (roble or huyacan)**
- Not available when we left but trees will be seeding in 2 weeks and they will be available sometime then. We plan to return to Gamboa to pick them up and send them out to Ipeti with associated instructions.
- Both species germinate quickly so this set-back should not affect the planting in June.

3) **Corotu (*Enterelobium cyclocarpum***, fam. *Fabaceae-Mimosoideae)*
- Quantity: 500
- The tip of the seed opposite the hilum must be cut (with hand pruners) then soaked in water for 2 hours. The seed can then be directly planted in the black bags with the cut end sticking out of the soil.

4) **Carbonero (*Colubrina glandulosa***, fam. *Rhamnaceae*)
- Quantity: 500
- Seeds must be sanded down with "lija de agua" (sand paper, grain 150-220) until the seeds become dull. This will accelerate the germination process.
- The seeds must then be soaked in water for 12 hours and then planted close to the surface in sand.
- These seeds may take up to 20 days to germinate (they are the slowest of all the seeds obtained).

5) **Guachapali Rosado (*Samanea saman***, fam. *Fabaceae-Mimosoideae*)
- Quantity: 300
- Not on the short species list from PRORENA but on the long list.
- The tip of the seed opposite the hilum must be cut (with hand pruners) then soaked in water for 12 hours. The seed must then be planted in sand with the cut tip sticking out of the sand.

<u>Ipeti-Embera Visit</u>

Our two goals in Ipeti were to assess the current state of the viveros (germination rates for caoba and general observations), and distribute seeds and instructions for the new seeds we brought with us. We achieved the latter in a group meeting with all the participants. We also hand-copied the above mentioned instructions and left a copy for each participant. We then built a sand box with Pablo, who is in charge of helping others to do the same.

Sand box built by Pablo during our visit

Here is a list of the quantity of seeds received by each family:

Corotu: 125
Cocobolo: 50
Guachapali Rosado: 75
Carbonero: 125
275 black bags each
Sand paper for each, 1 hand pruner to be shared by all

VIVERO ASSESMENT (09/03/2007)

Germination rates of caoba

Family	Germination rate of caoba (%)	Total number of seedlings
Nesar C.	47%	81
Pablo G.	61%	82
Reinedio Casama	47%	47
Rigoberto C.	23%	23

Observations

1) **Nesar**

- Germination rate: 58/100. also planted extra seeds: 23/74
- Built on slope, under a tree with many leaves.
- Appeared to be watered regularly.
- Bags are directly on soil.

2) **Pablo**

- Germination rate: 82/134
- Built beside bathroom-showering area.
- Pieces of tin roof as roof.
- Bags are directly on soil.
- Appeared very well-watered.

3) **Reinedio Casama (Lana)**

- Germination rate: 47/100 planted at beginning. Other set planted one week later: 0/80.
- Bags are directly on soil.
- Under a very large tree.

4) **Rigoberto and Olga**

- Germination rate: 23/100

- Seeds were planted very deep in the bags, almost touching the bottom.
- Directly on the ground under the crests of 3 large trees.
- Appears watered regularly.
- This is the worst outcome out of the four. Are the seedlings taking longer to germinate because of their depth, or will they germinate less, or is it due to the fact that our soil mix was not composted properly before?

Appendix vii. Informal contract, Part 1: Summary

Contrato de neutralización de carbón para el ¨Panama Field Study Semester¨ 2007

Resumen:

- Introducción
- Personas involucradas
- Tareas especificas de involucrados
- Aspecto financiero y manejo a largo tiempo
- Planes futuros (mínimo de 3 años)

Nosotros, el Semestre de estudios de campo en Panamá de la Universidad de McGill en Montreal, Canadá (PFFS), y el Consortium de Panamá, queremos neutralizar las emisiones de carbón producidas por el transporte en avión en ida y vuelta de Montreal hasta Panamá. Las personas incluidas en el PFSS son 25 estudiantes de McGill, profesores y empleados. Las personas involucradas en el Consortium son varios profesores y investigadores de las universidades siguientes: Universidad de Québec en Montreal (UQAM), McGill y la Universidad Laval, ubicadas en la provincia de Québec, Canadá. En total, hay 34 viajes de ida y vuelta en avión para el PSF y 17 para el Consortium de Panamá. Para compensar las emisiones de carbón, queremos establecer una plantación de árboles nativos en la comunidad de Ipetí-Emberá en el distrito de Chepo en la Provincia de Panamá. La plantación será establecida en las tierras colectivas de Ipetí-Emberá, pero en las parcelas de tierra respectivas a hogares individuales. Por este año 2007, las tres familias participando en el contracto son las de Nesar, Juan Pablo, Reinedio Casama y Rigoberto. Cada hogar será responsable para:

1. La siembra, germinación y crecimiento general de plantones de árboles en un vivero mientras la estación seca;
2. La preparación de su parcela para el periodo de plantación en mayo 2007;
3. La plantación de los plantones en Junio 2007;
4. La limpieza de hiervas y el cuidado general de la plantación para los próximos 21 siguientes.

La mayoría del mantenimiento ocurre en los primeros cinco anos. Sin embargo, los participantes deben cuidar la sobreviva de los árboles hasta el fin del contrato. Al fin del periodo descrito, los árboles se vuelven propiedad de los hogares participantes respectivos, y se pueden usar según sus preferencias. Los detalles de plantación y cuidado de la plantación son descritos al fin del contrato en el apéndice.

Dos estudiantes del PFSS, Jessica Hawryshyn y Alexandra Senikas, están encargadas de establecer el proyecto en la comunidad por el año 2007. Ellas aseguran la transmisión de información, comunicación y seguimiento con la comunidad. Además, el investigador post-doctoral Alain Paquette, de UQAM, proveerá de pericia técnica dos veces al año acerca del mantenimiento de plantones y de la plantación. La profesora Dra. Catherine Potvin, de la Universidad de McGill, también proveerá de suporto general y supervisión del desarrollo del proyecto para los años a venir.

Los hogares involucrados serán pagados una vez al año una suma especifica durante el periodo del contrato según. El método de evaluación falta ser escogido todavía. La cantidad pagada esta basada sobre el cuesto de oportunidad del área de tierra usado concordando al uso lo más rentable actual, lo cual es la ganadería[7].

Para asegurar el bueno crecimiento de la plantación de árboles y la secuestración optima de carbono, Dr. Héctor Barrios de la Universidad de Panamá coordinara la evaluación anual de las plantaciones antes de administrar el pagamiento. Dra. Potvin se encargara del manejo del fundo de financias del contrato.

[7] Tschakert P, OT Coomes, and C Potvin. 2006. Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics*, articulo en prensa.

Appendix viii. Informal contract, Part 2: Additional Clauses.

Cláusulas adicionales al Contrato 2007

Periodo del contrato
El contrato es de 21 años al final.

Monitorio de la plantación
El Dr. Héctor Barrios de la Universidad de Panamá se encargará del monitorio por al mínimo los 7 próximos años. De allí, el seleccionará una otra forma para seguir la tarea si ya no pueda hacerla el mismo.

Manejo del fundo por el periodo del contrato
Dr. Catherine Potvin manejara el fundo del contrato, incluyendo a los intereses.

Detalles del pago

- Los cálculos de pago son basados por cantidad de árboles plantados. Del estudio de Tschakert et al. 2006[8], se había determinado que el costo de oportunidad de 1 hectárea en Ipeti era de 61$ USD al año[9]. Esa cifra estuvo calculada en una plantación de teca intensiva, que cuenta aproximadamente 800 árboles por hectárea. Así adaptamos la cifra por área a una cantidad de árboles, como la plantación de Ipetí es de alta diversidad y en línea, abajo rastrojó alto o bajo. La plantación tomará mas espacio que una de teca intensiva, pero también toma menos trabajo y lleva muchos ventajes como recursos procurados por bosque natural como agua, comida, etc.

- Con esa cifra, calculamos que cada familia tiene que plantar 200 plantones para que sobrevivan 160 árboles para secuestrar el carbono necesario[10]. Al momento, esa cifra incluye las emisiones de PFSS (80 árboles/familia), Panamá Consortium (40 árboles/familia) y el programa NEO de McGill (40 árboles/familia). A cada familia, le hemos dado un poco más que 500 semillas de 5 varias especies, y cada una recibirá también 100 plantones de cocobolo y 50 plantones de caoba antes del periodo de plantación.

- Catherine Potvin y Alain Paquette se ocuparan de traer los plantones en la tercera semana de Junio 2007, al mismo tiempo que el periodo de plantación.

- Para esa cantidad, el pago será de 1080$ sobre 21 años a compartir entre las cuatro familias mientras el periodo.

[8] Tschakert P, OT Coomes, and C Potvin. 2006. Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics* 60: 807-820.
[9] El pago esta basado de la valor del USD en 2007.
[10] Estamos estimando una tasa de mortalidad de 25% de los plantones después la plantación.

	Total			*Por Familia*	
Grupos Involucrados	área necesaria según monocultivo de teca (hectáreas)	# de árboles necesaria	Pago ($USD) durante los 21 años	# de árboles necesaria	Pago ($USD) durante los 21 años
PFSS	0.4	320	540	80	135
Panamá Consortium	0.2	160	270	40	67.50
NEO McGill	0.2	160	270	40	67.50
TOTAL	0.8	640	1080	160	270

Modalidades de pago
Una cosa segura: el pago será anual. De aquí, tenemos dos opciones que, según sus consejos y la encuentra con los participantes, podamos escoger y si a caso, modificar.

1. Dividir el 270$ en rentas anuales iguales, sea de 12.86$ al año mientras 21 años, mas los intereses adicionales que llevaran el fundo de dinero manejado por Dr. Catherine Potvin. El pago será dado después la evaluación.

2. Dar una parta más alta en los cinco primeros años del contrato, porque esos años requieren mas trabajo manual que el resto del tiempo del contrato. Proponemos en esa opción dar 20$ anuales por los 5 primeros años, y por años siguientes 10.63$ más los intereses adicionales que llevaran el fundo de dinero manejado por Dr. Catherine Potvin. El pago será dado después la evaluación.

Forma de evaluación
La evaluación será hecha por medio de tomada de datos de la parte de cada participante. Los datos describen el estado general de de limpieza de las líneas e información relativa a su mantenimiento, más específicamente:

- Fecha de limpieza
- Duración de cada limpieza
- Numero de gente involucrada en cada limpieza
- Observaciones sobre el estado general de árboles o proceso de limpieza.

Los participantes son encargados de registrar sus acciones en la plantación en un libro de datos procurado por el PFSS, cuales acciones están ubicadas en el apéndice del contrato.

El evaluador notara los datos y revisara si todo la información requerida este y concuerda con el estado de la plantación. Se tomara también en nota mientras la evaluación la tasa de mortalidad de los árboles según cada especie y el estado de limpieza de las líneas para objetivos académicos. Para terminar, por los cinco primeros años del contrato, la evaluación tomara en cuenta también el respeto de las dimensiones y frecuencia de limpieza y claro de las líneas especificado en las “reglas generales” del apéndice del contrato por cada participante. El pago será administrado en función del respeto general de esas variables, lo cual será juzgado *in situ* por el evaluador.

Appendix ix

Instrucciones para la plantación 2007 de alta diversidad en rastrojo en Ipetí-Emberá

Cuatro plantaciones serán establecidas en la tercera semana de Junio 2007. Las cuatro familias participaran en los aspectos siguientes:

1. Crecimiento de sus propios plantones en un vivero mientras la estación seca.
2. Preparación de su parcela en Mayo para que este lista para el tiempo de plantación.
3. Plantación de los plantones en Junio.
4. Mantenimiento de la plantación por los 21 años del contrato, involucrando la limpieza y el claro de las líneas en los primero cinco años.

Por 2007, dos planes de plantación son posibles en función de la altura de vegetación en la parcela escogida. Para un rastrojo alto, por ejemplo como lo de Nesar, el plan A debería estar aplicado. Para un rastrojo bajo, en el caso de Pablo, el plan B puede estar utilizado.

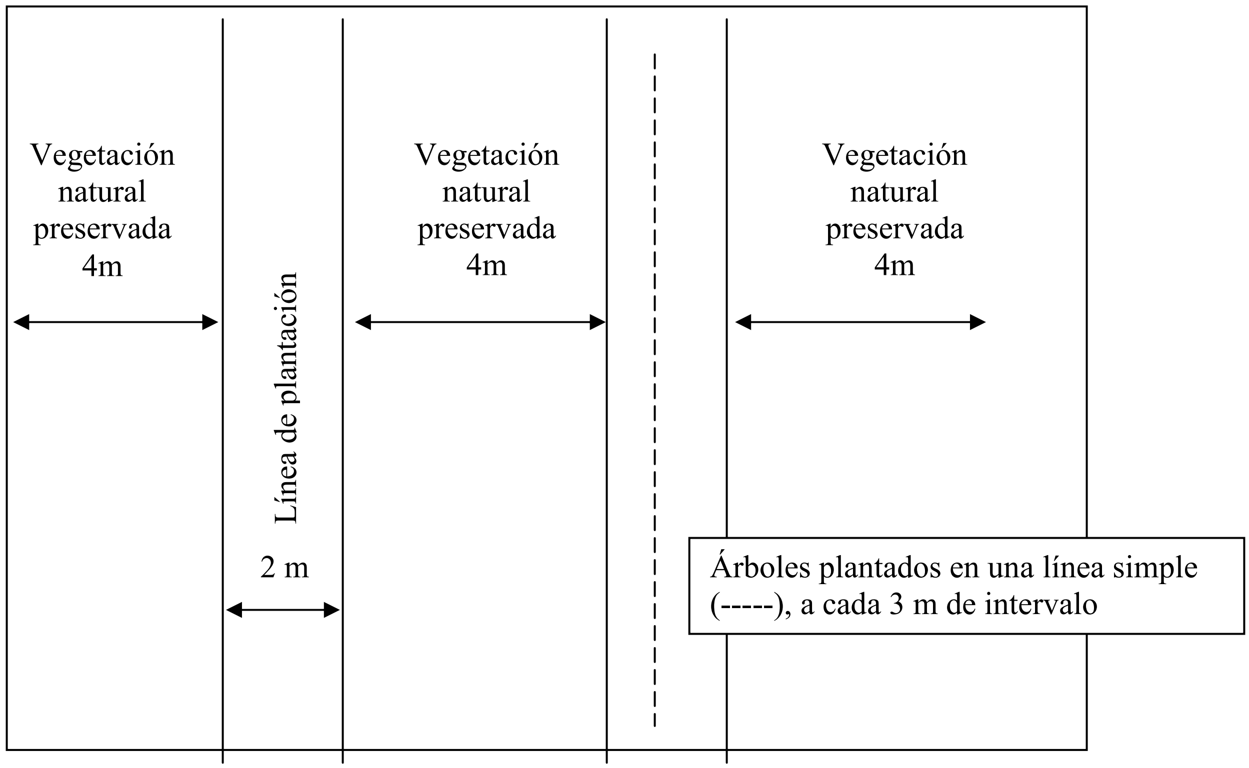
Reglas generales para la plantación

- No sacar árboles, palmas u otras plantas de valor.
- Plantones deben estar plantados de manera a alternar especies en las líneas. Por ejemplo, el orden seria 1, 2, 3, 4, 5, 1, 2, …
- Los árboles plantados deben estar libre de arriba de competición (para que entre luz) y de hierbas. Los plantones deberían estar limpiados de esas hierbas de tres a cuatro veces al año, y las líneas abiertas completamente una vez al año.
- Para la plantación de 2007, las líneas se abren al inicio de la estación de lluvia y los plantones necesitan estar plantados no más que dos semanas después.

A: Rastrojo bajo

La vegetación dominante mira entre 2metros y 4 metros de altura. No considerar vegetación alta y escasa (como las palmas en la parcela de Nesar).

La vegetación presente en ese tipo de parcela es muy diferente que la de otros sitios. Hierbas se encuentran mucho y requieren limpieza más regularmente. La hierba no puede crecer al entro de 1 m del plantón hasta que tengan 3 m de altura.

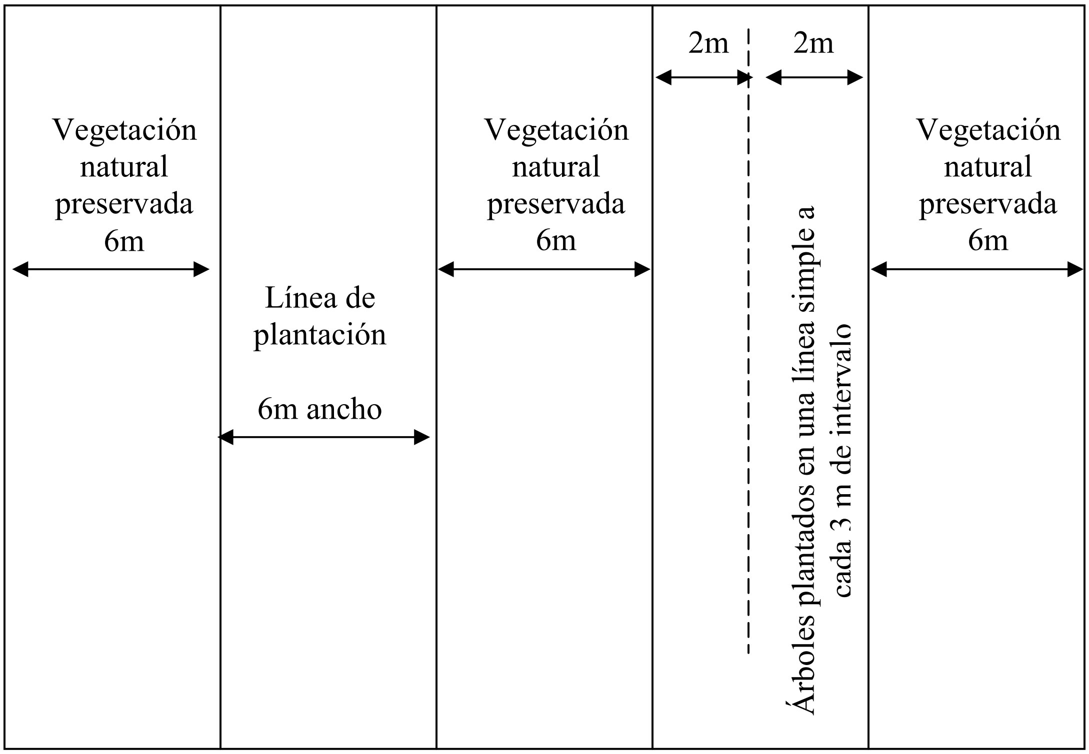


Los árboles son plantados en una línea simple, a cada 3 m de intervalo. Especies alternan en la línea. Un largo de 600 m en total son necesarios para plantar 200 árboles.

B: Rastrojo alto

La vegetación dominante mira más que 4 metros de altura. No considerar vegetación alta y escasa (como las palmas en la parcela de Nesar).

Los plantones también se plantan cada tres metros en una línea única. El tipo de vegetación en esas parcelas no deberían ser hierbas, pero una vegetación más densa.



Los plantones están plantados cada 3 metros en una única línea. La línea esta separada por 2 m de la vegetación natural preservada. Un largo de 600 m en total son necesarios para plantar 200 árboles.

Appendix x: Web Page Text draft

a) *English version*

Tentative titles:

1. Diminishing the climate impact of international environmental research: Carbon Neutralization in partnership with an indigenous community in Eastern Panama
2. Avoiding Environmental Hypocrisy: Carbon neutralization of international environmental research with an indigenous community in Eastern Panama
3. Research with a conscience: a small scale initiative in Eastern Panama to reduce the climate impacts of international travel

Project Definition:

A carbon sequestration native tree plantation will be established in the community of Ipeti-Embera in order to offset the travel emissions of research in Panama produced by students, professors and researchers of the PFSS program, the Neotropical graduate program(link), and the Panama Consortium(link) (McGill University, Université Laval and Université du Québec à Montréal).

Context:

Since the Kyoto Protocol's creation in 1997, global environmental attention has been focused on reducing green house gas (GHG) emission rates out of concern for world climate change. The Protocol projected the reduction of minimum 5% of 1990 GHG emissions during the commitment period of 2008-2012 (UNFCCC). With the Protocol's ratification by many countries in February 2005, the issue of stabilizing GHG emissions has become even more of a concern. It now allows the trading of "certified emissions reductions (CER)" produced from carbon-reducing or carbon-avoiding projects known as "Clean Development Mechanisms (CDM)", usually financed in Less-Developed Countries (UNFCCC). At the smaller scale, CDM includes reforestation and aforestation projects such as agroforestry, community forest plantations, forest regeneration, and improved fallows.

While the official carbon trading market along Kyoto guidelines is being established, a voluntary market has already existed since the 1990s for individual groups or events to be carbon-neutral (Climate Care 2005). An advantage of the voluntary market is that it requires less investment, thus allowing the development of smaller-scale projects that have more direct positive impacts on the social, economic and health sectors of people and communities involved (Climate Care 2005). Many companies have taken on the provision of this service, and the Climate Care Organization provides a reputable example (link). In that sense, this native tree plantation pursues the same endeavor.

Objectives:

Our small-scale project is being done with the twofold objective of:

1. Offsetting travel atmospheric carbon emissions produced by a group of researchers doing environmental work in Panama on a long-term basis
2. Providing a socially responsible and environmentally sustainable project with economic opportunity for an indigenous community.

3. Conserving natural-like forest cover, structure and functions in an area of increasing deforestation caused by destructive cattle grazing and growth-intensive teak plantations.

An International Partnership:

Jessica Hawryshyn and Alexandra Senikas, two students of the McGill Panama Field Studies Semester 2007 (PFSS) (link) have taken part in this project in the context of an academic internship, under the supervision of Dr. Alain Paquette (link), a post-doctorate at the Centre d'études de la Forêt (CEF) (link) at UQAM, and Dr. Catherine Potvin (link), a professor at McGill University. The project is in collaboration with the community of **Ipetí-Emberá**, where will take place this initiative. The reforestation organization PRORENA (link), headed by the Smithsonian Tropical Research Institute (STRI) and the Yale Tropical Resources Institute are providing materials and technical advice. Finally, Dr. Hector Barrios from the University of Panama is lending his support through monitoring the project in Panama over the years to come

Ipetí-Emberá:

The plantation is set in the indigenous community of **Ipetí-Emberá** in Eastern Panama. It is located in the watershed of Alto Bayano, in the Chepo District in the Province of Panama (78°30'–78°34' W, 8°55'–9°00' N). The community landholding is composed of 3,168 ha of communal land known as Tierra Colectiva, which is subdivided in parcels managed by individual households (Tschakert et al. 2006). The main economic activities of Ipeti include swidden-fallow subsistence agriculture, cattle ranching, day labor and crafts (Tschakert et al. 2006). In 2004, the community was composed of 71 households, representing about 550 individuals (Tschakert et al. 2006). **Ipetí-Emberá** has a recent history of collaborating with international students under the supervision of Dr. Potvin, who has been working with the community for more than a decade.

Project Process:

To begin, the atmospheric carbon emitted by the researchers was estimated using the Climate Care Calculator for carbon emission of air travel, available on the Climate Care website (link).

From there, the land area needed and necessary number of trees to sequester these carbon emissions were calculated based on the local teak carbon storage research in Kraenzel et al. 2003. Work with **Ipetí-Emberá** and other collaborators has involved organizing the community families to be involved, setting up seed collecting workshops, starting seed nurseries, preparing land for planting, creating a contract for plantation maintenance and payment, and determining a long-term third party for monitoring. Tree species were chosen by the Embera participants.

The carbon emitters (researchers) and the involved **Ipetí-Emberá** community members will be bound to a 21 year contract during which the native trees will be grown in order to sequester atmospheric carbon, the community members will be paid for plantation maintenance. Dr. Barrios will ensure the long-term monitoring of the plantation in Panama.

The native tree species being used in this project are:

- Caoba (*Swietenia macrophylla*, fam. *Meliaceae*)
- Cocobolo (*Dalbergia retusa,* fam. *Fabaceae-Papilionoideae*)
- Corotu (*Enterelobium cyclocarpum*, fam. *Fabaceae-Mimosoideae)*
- Carbonero (*Colubrina glandulosa*, fam. *Rhamnaceae*)
- Guachapali Rosado (*Samanea saman*, fam. *Fabaceae-Mimosoideae*)

Many of these species are also of traditional value to the Emberá, especially Cocobolo. The wood from this species is carved into beautiful sculptures in the creation of handicrafts.

The diversity plantation will be set as undercover strips in land parcels with high fallow. Such a method maintains most aspects of natural forest cover and structure and preserves beneficial ecological services to the plantation, such as microclimate moderation, optimal light and competition conditions, and reduced herbivory (Paquette et al. 2006). As such, they require less maintenance while harnessing good productivity.

References

Climate Care. 2005. *Annual Report 2005*. http://www.climatecare.org/about_us/index.cfm?content_id=E16C4841-C5D2-7D65-199DAF1C0FC73542

Kraenzel, Margaret, Alvaro Castillo, Tim Moore and Catherine Potvin. 2003. Carbon storage of harvest-age teak (*Tectona grandis*) plantations, Panama. *Forest Ecology and Management* 173: 213-225.

Paquette, Alain, Andre Bouchard, and Alain Cogliastro. 2006. Survival and growth of under-planted trees: a meta-analysis across four biomes. *Ecological Applications* 16(4): 1575-1589.

Tschakert, Petra, Oliver T. Coomes, and Catherine Potvin. 2007. Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics* 60: 807-820.

United Nations Framework Convention on Climate Change (UNFCCC). “Kyoto Protocol”, http://unfccc.int/kyoto_protocol/items/2830.php

b) *Spanish version*

Titulo:

A determinar.

Definición del proyecto:

Una plantación de árboles nativos será establecida en la comunidad de Ipeti-Embera para neutralizar emisiones de carbono atmosférico producidas por el transporte en avión de estudiantes, profesores e investigadores del PFSS, del programa NEO y el Panamá Consortium (McGill, Universite Laval y UQAM).

Contexto:

Después la creación del Protocolo de Kyoto en 1997, la vigilancia medio-ambiental global se ha concentrado sobre el tema de reducciones de gases a efectos invernaderos acerca de cambios climáticos internacionales. El Protocolo proyectaba reducciones de al mínimo 5% de las emisiones de 1990 mientras el periodo de compromiso 2008-2012 (UNFCCC). Con la ratificación del Protocolo por varios países in Febrero 2005, el tema del estabilizo de tales emisiones se han vuelto una preocupación mas grande ahora. El sistema permite ahora el Comercio Internacional de Emisiones (CE) producidas por proyectos bajando emisiones de carbono conocidos por Mecanismo de Desarrollo Limpio (MDL), normalmente financiados en países en desarrollo económico. A más pequeña escala, MDL incluye proyectos de reforestación y aforestacion como agropastorale, plantaciones de árboles de comunidades, regeneración de bosque y rastrojos mejorados.

Mientras que el comercio oficial de Kyoto estuvo estableciéndose, un comercio voluntario ya existió desde la decena 1990 para que grupos individuales o eventos estén neutrales acerca de sus emisiones de carbono (Climate Care 2005). Uno de los ventajes del comercio voluntario es que requiere menos inversión, permitiendo el desarrollo de proyectos más pequeños que tienen impactos positivos más directos sobre los aspectos sociales, económicos y de salud de la gente y comunidades involucradas (Climate Care 2005). Muchas compañías han usado ese servicio, y el suceso de la organización Climate Care presente un buen ejemplo. En ese sentimiento, nuestro proyecto persigue un fin similar.

Objetivos:

El proyecto persigue los puntos siguientes:

1. Compensar las emisiones de carbono atmosférico producidos por un grupo de investigadores haciendo estudias ambientales en Panamá a largo tiempo.
2. Proveer una oportunidad económica al entro de un proyecto que sea responsable al plano social y sostenible al nivel del medio ambiento para una comunidad indígena.
3. Preservar una cobertura y estructura boscosa con funciones naturales en un área más y más deforestada por actividades de ganadería y plantaciones intensivas de teca.

Colaboración Internacional
Jessica Hawryshyn y Alexandra Senikas, dos estudiantes de McGill participando en el PFSS 2007, han tenido parte en ese proyecto en el contexto de su pasantilla académica, a bajo de la supervisión de Dr. Alain Paquette, post-doctora al Centro de estudio del Bosque a UQAM, y la Dra. Catherine Potvin, profesora a la Universidad de McGill. Este proyecto esta en colaboración con la comunidad de Ipeti-Embera, donde esta ubicado el proyecto. La organización de reforestación PRORENA, manejada por el Instituto de investigación tropical Smithsonian (STRI) y el Instituto de Recursos tropicales Yale están proveyendo materiales y ayuda técnica. Finalmente, el profesor Dr. Héctor Barrios de la Universidad de Panamá presta apoyo en asegurando el monitorio del proyecto en Panamá por los años a venir.

Ipeti-Embera:
La plantación esta ubicada en la comunidad indígena de Ipeti-Embera en el este de Panamá. Se encuentra en la cuenca de Alto Bayano, en el Distrito de Chepo en la provincia de Panamá. La tenencia de terrena de la comunidad esta compuesta de 3,168 hectáreas de tierra colectiva, subdividida en parcelas manejadas por hogares individuales (Tschakert et al. 2006). Las actividades económicas de Ipeti son agricultura, ganadería, obra diaria y artesanía (Tschakert et al. 2006). En 2004, la comunidad tenia 71 hogares, representando a 550 personas (Tschakert et al. 2006). Ipeti-Embera tiene una historia reciente de colaboración con estudiantes internacionales a bajo de la supervisión de Dr. Potvin, la cuala tiene más de una decena trabajando con esa comunidad.

Referencias

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United Nations Framework Convention on Climate Change (UNFCCC). “Kyoto Protocol”, http://unfccc.int/kyoto_protocol/items/2830.php

Appendix xi: Wood Decomposition Study Plan 2007

1) Tree pruning

Three monoculture plots will be pruned: Plot CM1, TR1 and AE2. In each of these plots all trees in every third columns will be pruned (pruned column 1, 4, 7, 10 and 13).
*we have already started to prune trees in TR1-1 along column 1 on Wednesday this week, to give Lady an example… Trees from lines 1 to 4 in column 1 are now pruned)

All the branches cut during pruning will be put in a bag identified with the tree number and weighted. A small segment of wood for 10 individual trees of each species will be cut, weight and brought to STRI to be dried in the drying oven. The wood section will be re-weighted after drying for three days.

*PLEASE NOTE THAT THE TREES USED BY DR SCHWENDENMANN SHOULD NOT BE PRUNED. Mark them in the data sheets as not prunable.

2) Wood decomposition

- Three species (AE: *Anacardium excelsum*, TR: *Tabebuia rosea*, CM: *Cedrela odorata*)
- The study will consider sticks of wood of these species as Fine Woody Debris[11] (described in b).

a) Calculations (See Sardinilla Layout at end of document)

- 10 sticks per species per line. 1 line (or array) per subplot, 4 subplots per plot: 10 X 4 = **40 sticks per species per plot.**
- 40 sticks/species/plot X 6 plots per species = **240 sticks total for each species**
- There 3 species. So 240 sticks X 3 species = **720 sticks to be collected from pruning wastes**
- Each array of a particular species within each subplot will be come with an array of dowels. 10 dowels per subplot X 4 subplots/plot X 6plots/species X 3 species = **720 dowels total**

b) Stick considerations:

- We will be finding standard pieces of wood from long straight branches (those pruned in part 1, from a common pool), and with the intention of cutting ones that are about 10 cm long and about 1.0-2.0 cm diameter.
- All pieces will be taken back to the lab to be dried for 3 days and weighed before being set up in the field.

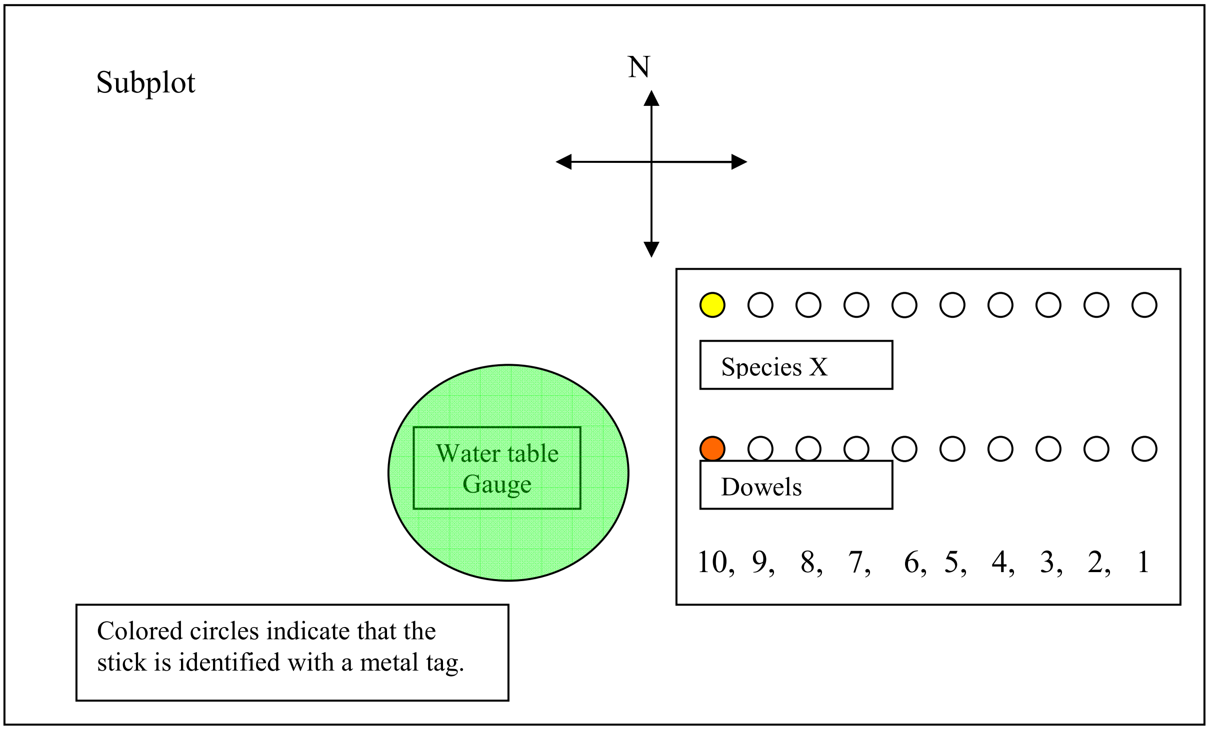
c) Dowel considerations

[11] As defined in Harmon, M. E. et J. Sexton. 1996. Guidelines for Measurements of Woody Detritus in Forest Ecosystem LTER Network Office, University of Washington, Seattle, WA.

- Dowels should be cut to10 cm in length and be approximately 13 mm in diameter[12]
- Must be purchased from the same lot or batch as much as possible
- Each dowel must be dried and dried-weighed before being put in the field.

d) Stick emplacement

- The arrays will be set up in each subplot in the following way:



- The pieces of wood will be buried half into the ground, in lines.
- The arrays will be placed east
- The samples will read from right to left in the east array.
- The #10 samples, the last ones with the tags, are located next to the WTG, 10 cm to the East of where the natural grass begins; each sample is separated by 2cm, and each row by 5cm
- Rows will be assigned randomly in subplot.

- Proposed labeling system for each piece:
  In label: Plot #, subplot #, replicate #, species name/code, and piece #.

TR 1 – 1, TR, 10

eg: plot TR1, subplot 1, species *Tabebuia rosea*, stick 10; D will be for the dowel.

---

[12] As used by the Long-term Intersite Decomposition Experiment Team (LIDET), http://www.fsl.orst.edu/lter/research/intersite/lidet/lidet_meth/lidet.htm .

* The metal tags are pre-numbered; those should be considered lab numbers, with correspondence in the table or plan described above
* After drying the pieces they will temporarily be labeled with masking tape before being placed in order out in the field plots, numbering 1-10 for each species.
* In the field, a metal tag can be used to fully label just the LAST piece of the sets of 10.

e) Sampling

- Every month, one piece from each species, each replicate, each plot/treatment will be taken for weighing, drying (for 3 days), and dry-weighing. The sticks are labeled in chronological order, 1 being the first, 10 being the last sampled.

- At this same time, a soil sample will be taken at each replicate and plot in/surrounding the replicates to be wet-weighed, dried, dry-weighed. The weighing of the humid soil may be carried out in 2 ways:
  1) On-site weighing of soil
  2) Sample is bagged in Zip Lock bag, brought to STRI and weighed in a small paper bag (soil will be dried in bag, and dry-weighed with the bag as well)
- Quantity of sample: a few grams, for instance a table spoon's worth.
- Sampling method: the soil sample can be taken every time between, say row # 1 and 2, at the level of the sample being taken (1, 2, 3 …). The hole should be filled back with soil taken just outside the replicate.

Sardinilla Layout, established July 2001

12 Monoculture plots, 6 triplets, 6 six-species plots, 225 trees/plot, 45 m X 45 m
A= high diversity plot (6 spp); T= 3 spp: every subplot (dashed lines) has a water table gauge.

Green circle is WTG (pizometer)
Blue line is TR (1 array of 10 sticks)
Pink line is AE (1 array of ten sticks)
Purple line is CM (1 array of 10 sticks)
Brown lines are dowels (1 array of 10 sticks)

The plots to be pruned: AE2, CM1, TR1.

a) **CM** sticks will go in CM1, CM2, T1, T4, A3, A6. (N=240 sticks total)

b) **AE** sticks will go in AE1, AE2, T2, T3, A2, A4. (N=240 sticks total)

c) **TR** sticks will go in TR1, TR2, T5, T6, A1, A5. (N= 240 sticks total)

d) 1 array of **Dowels** will accompany each line of sticks, for a total of 720 dowels.

Appendix xii: Recommendations for next year's PFSS cohort:

- Meet with community participants early in order to see how the plantations are doing, and initiate communication.
- Meet with PRORENA right away as well, in order to discuss seed and seedling availability and, most importantly, in order to set up and prepare for a workshop in the Ipeti-Embera community on seed collection and nursery care and maintenance.
- Meet with Ultiminio, the Embera lawyer from Ipeti, who works in the city, in order to initiate the legal work required for the contract.
- Develop a clear and thorough financial and time budget in order to allot money and time to the various aspects of the project. It is foreseeable that the legal work on the contract may require financial investment, as well as the workshop and purchase of seeds/seedlings from PRORENA. A significant proportion of time should be allotted to being in the Ipeti-Embera community, working more with participants, ensuring progress, open communication, clear understanding between all parties.
- In appendix IIIi is the list of participants and community members interested in participating in future years. An effort should be made to work with interested community members from a different part of the community, of different families, to try to equitably distribute the project benefits in the community. A Master's thesis done by Casima should be looked at since it related to the social structure of the community.