Clean Energy and Healthy Watersheds in El Bote, Nicaragua

A Case Study

By:

Association of Rural Development Workers-Benjamin Linder (ATDER-BL) and Green Empowerment
with the Center for the Understanding of Nature (CEN)

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ABBREVIATIONS & ACRONYMS

APRODELBO	Association for the Development of Bocay Electric Service
ATDER-BL	Association of Rural Development Works--Benjamin Linder
CATIE	Tropical Agricultural Research and Higher Education Center
CO_2	Carbon Dioxide
CEN	Center for the Understanding of Nature
DISNORTE	Electricity Distribution Company
EU ETS	European Union Emissions Trading Scheme
GE	Green Empowerment
GHG	Greenhouse Gas
INE	Nicaraguan Energy Institute
IUCN-NL	International Union for Conservation of Nature—Netherlands
km	Kilometer
km^2	Square kilometer
kW	Kilowatt
kWh	Kilowatt hour
MADECASA	Central American Timber LLC
MARENA	Ministry of Environment and Natural Resources
MASL	Meters above sea level
MEM	Ministry of Energy and Mining
mWh	Mega watt hour
NGO	Non-governmental Organization
SINIA	National Environmental Information System
tCO2	Tonnes of carbon dioxide
VAT	Value Added Tax

ACKNOWLEDGEMENTS

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We welcome any comments, questions, or criticisms readers of this report would like to share. Please address all correspondence to Caitlyn Peake at caitlyn@greenempowerment.org

I) Executive Summary

Since 1997, Green Empowerment and the Association of Rural Development Workers-Benjamin Linder (ATDER-BL) have worked together with local communities and governments to implement community-based renewable energy, potable water, and watershed conservation projects to alleviate rural poverty and environmental degradation in Northern Nicaragua. Since 2006, a large component of that work has been an integrated hydroelectric, watershed and forest conservation project in the community of El Bote, El Cuá, Jinotega. A 900kW hydroelectric plant was constructed to power homes, schools, clinics and businesses, and now provides reliable electricity to approximately 22,000 people. The health of the watershed supplying the plant was realized as critical to its long-term viability. Considering the decades of deforestation in surrounding primary rainforests, we recognized the opportunity to pilot a multidimensional approach to biodiversity and watershed conservation in tandem with improving the wellbeing of rural communities. Now, after eight years of implementation, this case study was developed with the support of the International Union for Conservation of Nature-Netherlands (IUCN-NL) in order to share with policy makers, peer organizations, and other rural communities the benefits and challenges of employing this type of integrated model to address the dual challenges of rural poverty and environmental degradation in threatened rainforest ecosystems.

Quantitative and qualitative data were collected and analyzed from the hydroelectric plant, local households, and the forest reserve in order to assess and document the social, environmental and economic impact of the El Bote project. While limited baseline data presented a challenge, we have found that overall, the direct link between a basic household need (electricity), and the natural resource that provides it (water), helps transform the concept of ecosystem services from nebulous to concrete and tangible, mobilizing local residents to actively participate in watershed conservation efforts and protect upstream forests. With dedicated, professional technical assistance readily available, farmers are motivated to adopt agroforestry practices such as cultivating shade-grown coffee, live fencing, tree planting, and riverbank reinforcement which in addition to their environmental benefits, can improve incomes. Concurrently, the 956 hectare forest reserve continues to be supported and managed by the El Bote community itself, permanently protects vital rainforest habitat, provides a biological corridor for the critical BOSAWAS Biosphere Reserve, and reinforces water quality for downstream use.

Initial investment in the project was $1.7 million for construction and equipment for the 900 kW hydroelectric plant and $ 1.4 million in building the distribution lines to the first group of communities in the project impact area. Of this funding, US$ 1.3 million was secured from a World Bank loan and the balance was obtained from local in-kind contributions and donations from various international sources. Since then, further investments have been made to extend the electric supply grid to additional rural communities, and in the watershed program described in this case study. The high operation and maintenance costs of the plant, particularly when including depreciation and excluding carbon offsets and other ecosystem services, means that reaching financial

sustainability can require 10 years. Yet with certain adjustments to the financial model, we feel that the project ultimately demonstrates a holistic approach to sustainable development that is replicable and adaptable to other rural communities seeking to address basic needs while strengthening environmental stewardship.

II) About ATDER-BL and Green Empowerment

II.a. ATDER-BL

In November 1985, a young North American electromechanical engineer, Benjamin Linder, led the installation of a micro-hydroelectricity plant in the community of La Chata, Jinotega, Nicaragua. The 44 kilowatt (kW) system provided electricity for the first time to the community and the adjacent town of El Cuá. In April 1987, Ben was killed by the Contras while evaluating a future micro-hydro site in San José de Bocay. The same year his colleagues formed the non-governmental organization ATDER-BL to continue his work and honor his legacy. Directed by Rebecca Leaf who leads a staff of 30, ATDER-BL has since implemented dozens of small hydroelectric, watershed conservation, and potable water projects across Jinotega and Matagalpa to improve the socioeconomic and environmental wellbeing of rural Nicaraguans.

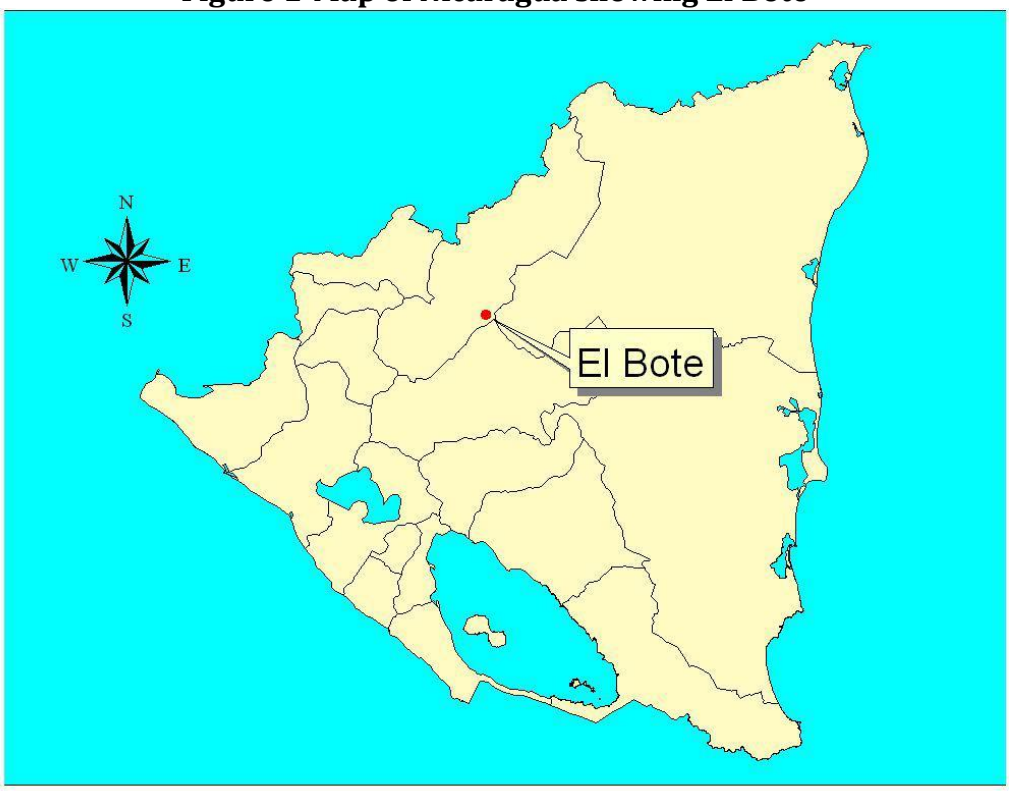
II.b. Green Empowerment

Since 1997, Green Empowerment has partnered with ATDER-BL in these efforts, providing technical, financial and organizational assistance. Green Empowerment is an international NGO that works with local partners around the world to strengthen communities by delivering renewable energy and safe water. Since 1997 we have worked with marginalized communities in 10 different countries to improve health, the environment, and economic opportunities by utilizing appropriate water and clean energy technologies. These projects, sustained by our enduring partnerships with local NGOs and the communities they serve, have resulted in 217,240 people served by newly electrified health clinics and schools; 10,883 people with water delivered to their homes; 24,062 households with clean lighting, and 1,445 hectares of critical rainforest protected. Our programs and partnerships in Nicaragua reach back to our foundation, and are now led by Nicaragua Program Coordinator Caitlyn Peake, who works closely with ATDER-BL on project development, research, monitoring, evaluation and reporting. Caitlyn holds a BS in environmental science and manages multiple community development projects throughout Nicaragua.

III) El Bote, El Cuá, Jinotega, Nicaragua Context

The community of El Bote is located in a remote mountainous area of Central Northern Nicaragua, in the municipality of El Cuá, department of Jinotega. El Bote lies along the El Bote River, whose watershed comprises an area of 25 square kilometers (km2) and is a tributary of the Bocay River and the greater Coco River. The geographic coordinates of the project area are 13° 23’ latitude north and 85° 33’ longitude west.

Figure 1-Map of Nicaragua showing El Bote



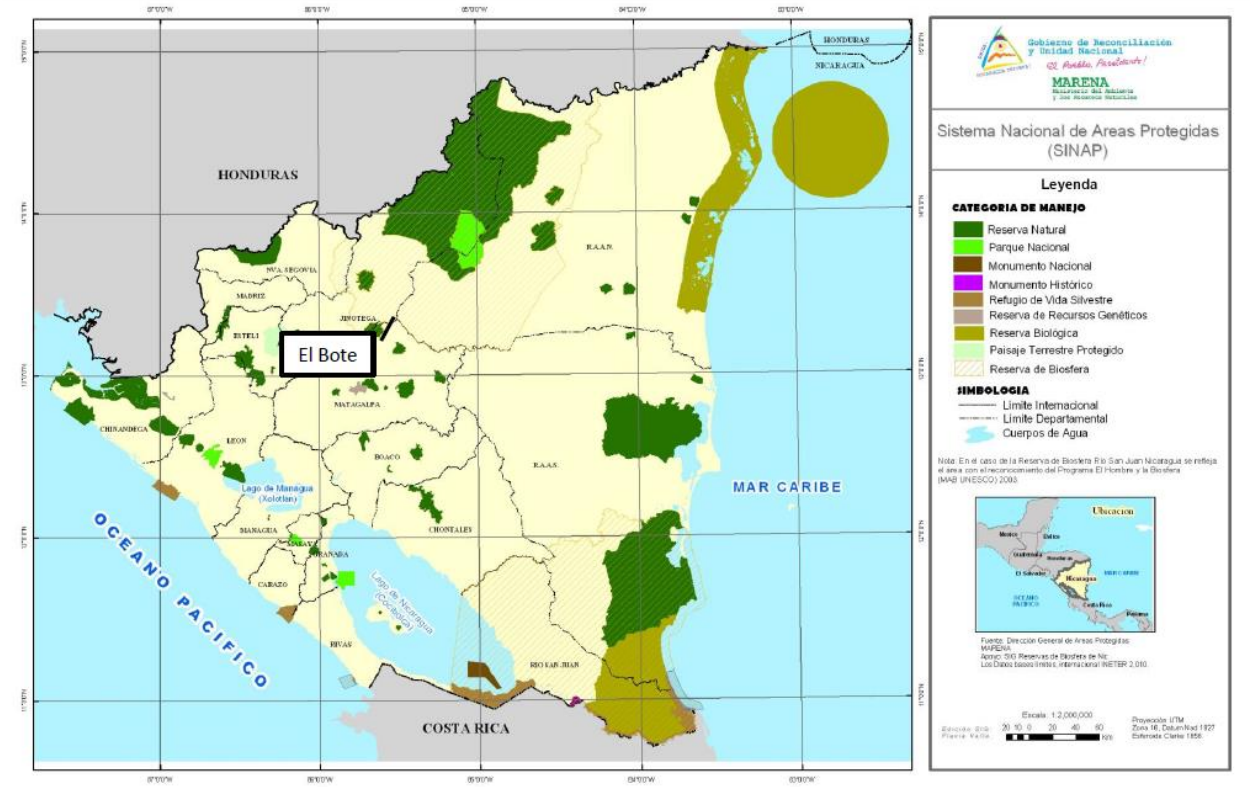
The region is dominated by mountain ranges and dense primary tropical rainforest. Elevation of the project site varies from 670 meters (m) to approximately 1,200 m above sea level (MASL). Two dominant eco-regions exist in the community: sub-tropical humid forest and sub-tropical cloud forest. The climate is generally defined as sub-tropical moist with distinct dry and wet seasons. The majority of rainfall occurs from May to early November with average precipitation varying from 1,000 millimeters (mm) to 1,800 mm.[1] The tropical climate contributes to relatively small seasonal variations in temperature with the average daily temperature ranging from 16 degrees centigrade (°C) to 27 °C.

The ecological characteristics of the region are defined by some of the greatest biological diversity of flora and fauna in the world. The El Bote Forest Reserve lies within the boundaries of the official buffer zone of the BOSAWAS biosphere reserve, which was declared an international Biosphere Reserve by UNESCO in 1997. The BOSAWAS Biosphere Reserve consists of the "nucleus," which is a protected area, surrounded by the "buffer zone," which is defined by the outer borders of the municipalities that have any territory within the nucleus. The reserve is part of the Central American Biological Corridor stretching from southern Mexico to Panama and is second in the world only to tropical Andean rainforests in its biological wealth. Within the Biosphere Reserve and greater region, there is a confluence of flora and fauna from North and South America with a tremendous variety of plant and animal life. More than 7,000 species of plants and 270

[1] "Características del Clima de Nicaragua" *INETER.* Date accessed: November 30, 2013. http://webserver2.ineter.gob.ni/Direcciones/meteorologia/clima%20nic/caracteristicasdelclima.html

species of trees and bushes have been identified, including rare tropical varieties such as mahogany and Spanish cedar. Between 100,000-200,000 insect species, 600 species of amphibians and reptiles, and 700 types of birds, including 100 species of North American migrant birds call the BOSAWAS region home. The project area is home to some of the last populations of Central American endangered species such as Baird's Tapir, Jaguar, Ocelot, Harpy Eagle, Resplendent Quetzal, Giant Anteater, Spider Monkey, and the American Crocodile.[2]

Figure 2- Map of Protected Areas of Nicaragua



Dark green indicates natural reserve. El Bote is identified in the Buffer Zone of the BOSAWAS (indicated in light striped yellow) and falls as part of the biological corridor between the BOSAWAS and the Peñas Blancas Massif. *Source: Ministerio del Ambiente y los Recursos Naturales Nicaragua (MARENA)*

Beginning in the 1960s, El Bote and the surrounding region became the agricultural frontier of Nicaragua. The Somoza government granted lumber exploitation contracts to foreign companies and provided free land to anyone willing to homestead in the region. Logging companies built access roads all over what is now the BOSAWAS buffer zone, including the primary road to El Bote still used today. Driven by population growth and free land incentives, many Nicaraguans migrated from drier, less fertile parts of the country. However tropical soils are very thin and once deprived of forest cover are eroded by heavy rains that leach their fertility. Farmers then attempt to combat lower yields by cutting more forest to expand plots, thus beginning a vicious cycle of continuous poverty

[2] "Mayangna–Bosawas Biosphere Reserve, Nicaragua," *UNESCO.* Date accessed: May 15, 2012. www.unesco.org/new/en/natural-sciences/priority-areas/links/resource-management/projects/mayangna/.

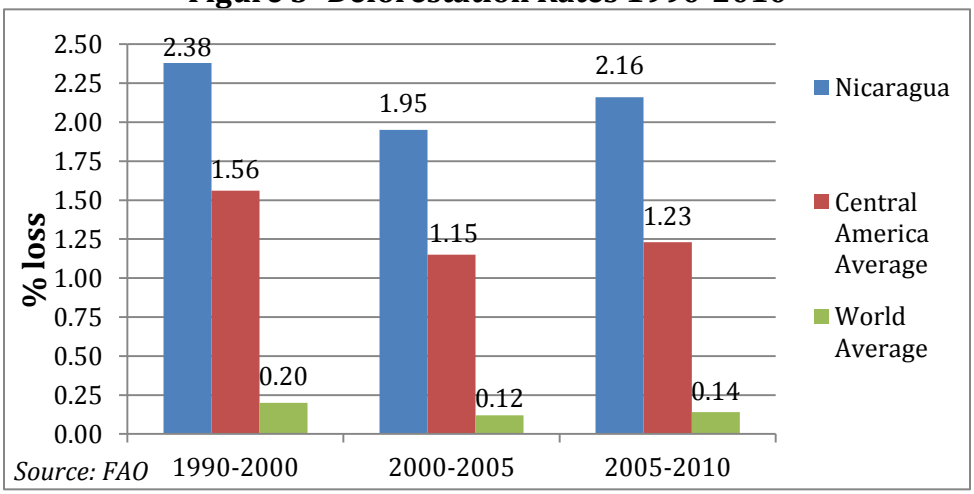
Clear cut forest near El Bote

and deforestation. Meanwhile, Central American Timber, LLC (MADECASA) and other timber companies harvested precious tropical hardwood tree species from the area, including in the El Bote watershed.

However in the early 1980s, due to the increasing intensity of the civil war, MADECASA closed its operations, leaving tracts of primary forest in the upper reaches of the El Bote watershed intact. Starting in the late 1990s, the government also made efforts to slow agricultural expansion, no longer providing free land grants and attempting to keep new homesteaders out of the BOSAWAS Biosphere Reserve. Yet continued pressures from impoverished smallholders, both new and existing, as well as renewed commercial logging operations, have maintained deforestation rates at alarmingly high levels into the 2000s, as can be seen in

Figure 3 below. From 2005-2010 Nicaragua lost 70,000 ha of forest annually, or 2.16%--significantly higher than the global average or even the Central American one, already the highest regional average in the world.[3] Indeed only seven countries in the world have a higher rate of deforestation.

Figure 3- Deforestation Rates 1990-2010

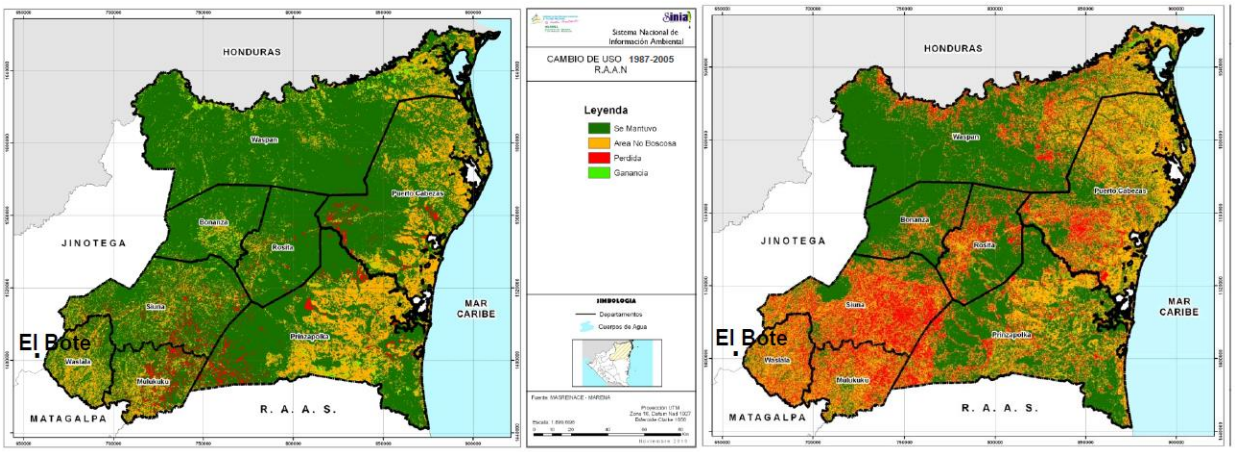


[3] "Global Forest Resources Assessment 2010," *Food and Agriculture Organization of the United Nations,* December 17, 2012*. Date accessed: Nov 28, 2013.* <http://www.fao.org/forestry/fra/fra2010/en/>

Figure 4 below shows the more localized manifestation of this trend, with increasing incursion into the BOSAWAS Reserve despite tighter enforcement.

Figure 4-BOSAWAS Reserve Land Use Change Map 1987-2005

AVANCE DE LA FRONTERA AGRÍCOLA – INCURSIÓN A LA RESERVA DE BIÓSFERA "BOSAWÁS"



Dark green indicates forested areas, yellow indicates non-forested areas, red indicates deforested areas, and light green indicates reforested areas. *Source: Sistema Nacional de Informacion Ambiental (SINIA)*

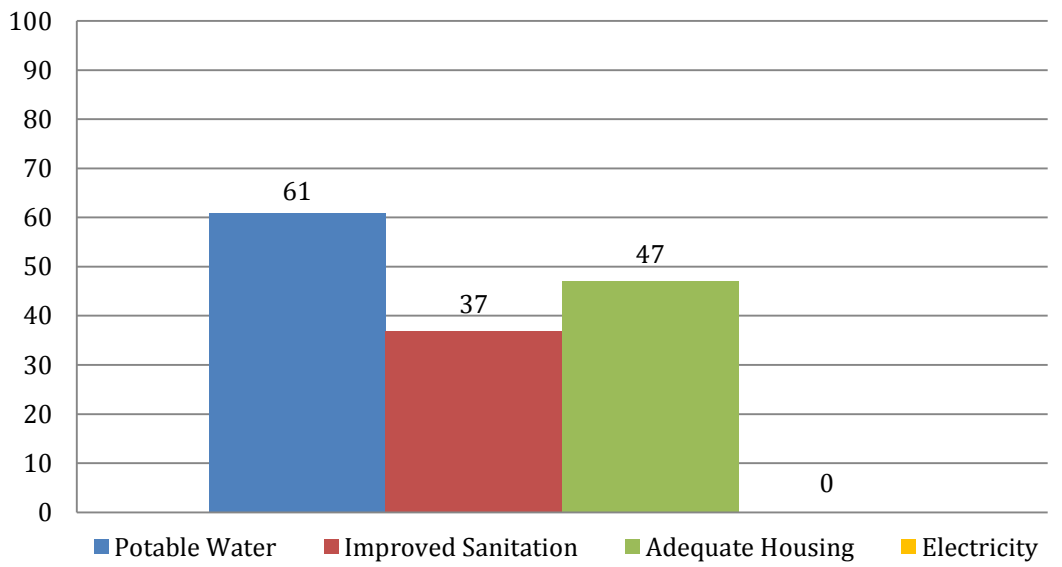
In the El Bote watershed in 2000, conditions were also similar, with individuals in the pursuit of wood and forest products for auto-consumption (fuel, home and fence construction) or for small-scale timber trade and sale, deforesting an average of 35 hectares (ha) a year, or 2% of the watershed.[4] Preference was given to those species most resistant to humidity and insects: Rosewood, Walnut, Guava, Black Wood, Mampas, Oak, San Rafael, Quebracho, and Mountain Pine.[5] Slash and burn practices were widespread, with a mere 17% of household heads alleging they were familiar with the concept of soil conservation (and of those, only 36% claiming they applied related techniques).[6] Climate change and increasingly frequent severe weather events have further exacerbated the vulnerability of the unique, fragile ecosystem of the El Bote area, and combined with human pressures have resulted in dwindling virgin rainforest, destruction of critical wildlife habitat, and increasing erosion, flooding, topsoil loss, and deterioration of water supplies.[7]

These deteriorating environmental conditions are particularly problematic for El Bote residents who rely almost entirely on subsistence agriculture.[8] In the year 2000, the town

[4] Ruiz, Gutavo Adolfo. *Conservacion de la Microcuenca y Generacion de Energia Hidroelectrica en El Bote,* (Nicaragua: Center for Understanding of Nature, 2013).
[5] Ruiz, Gutavo Adolfo.
[6] Municipality of El Cuá. "El Bote Household Survey." Survey. December 2000.
[7] Centro del Agua del Trópico Humedo para America Latina y el Caribe [CATHALAC] (2009). Consideraciones Generales para el Desarrollo de una Estrategia de Adaptación de los Ecosistemas Forestales al Cambio Climático en Nicaragua. Comisión Centroamericana de Ambiente y Desarrollo [CCAD] and Sistema de la Integración Centroamericana [SICA] (2010). Estrategia Regional de Cambio Climático. Documento Ejecutivo.
[8] Muncipality of El Cuá,

and surrounding watershed had a population of approximately 110 households, with few families living above the poverty line. Families owned an average of 21.9 ha, of which typically a third was utilized for crop cultivation (coffee and basic grains being the most popular) or cattle grazing. The remaining 67% of the land was left as primary forest or *tacotal*.[9] Homes were rudimentary structures with dirt floors, and roughly half lacked access to basic services and facilities, including potable water, improved sanitation, and electricity. 47% of children did not attend school. According to a 2005 national census, 73.2% of families were living in extreme poverty.[10] Poor and distant healthcare facilities struggled to provide care, and few farmers received technical or financial assistance for their crops.

Figure 5- Percentage of El Bote Households with Access to Basic Services (2005)



Source: Instituto Nacional de Informacion de Desarrollo

IV) Project Background

Since as early as 1997, ATDER-BL and Green Empowerment have worked together with local residents and governments from the El Cuá area to implement community-based renewable energy, potable water, and watershed conservation projects to address the precarious environmental and socioeconomic situation described above. With rural electrification as a starting point (micro-hydro facility), the two organizations recognized an opportunity to pilot a multidimensional approach to biodiversity and watershed conservation in tandem with improving the wellbeing of rural communities, the three components of which are described below.

[9] A scrub brush landscape typically comprised of regenerating secondary forest on previously cleared agricultural land.

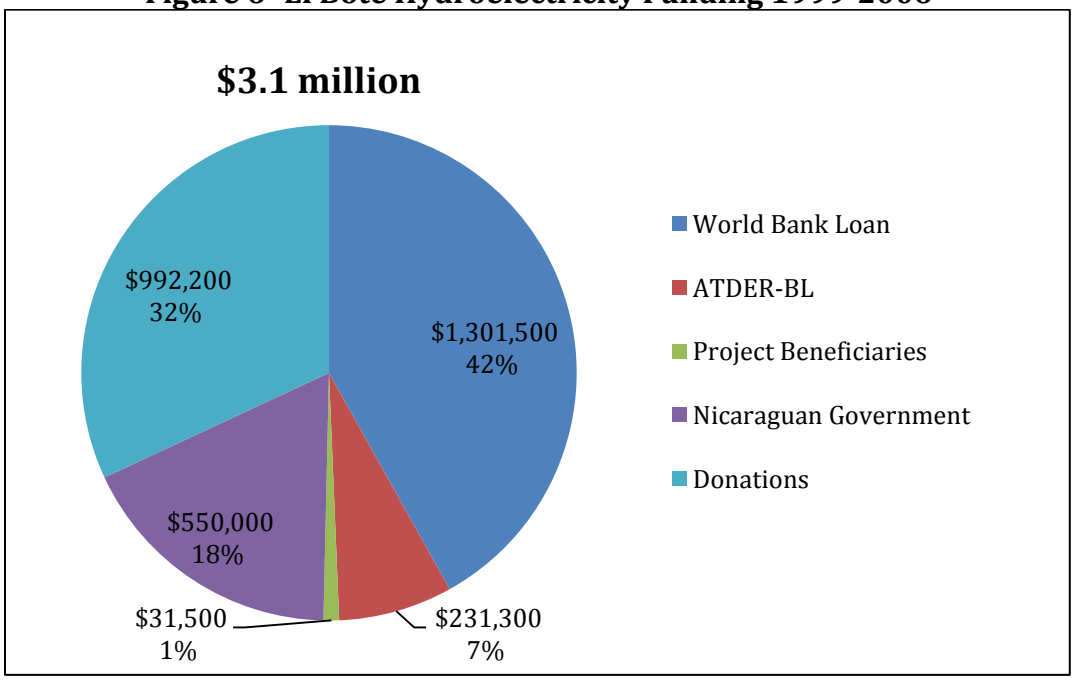
[10] "Municipio de El Cuá Barrios y Comarcas Pobreza Extrema," *Instituto Nacional de Información de Desarrollo*, 2005. Date accessed: Nov 28, 213. <http://www.inide.gob.ni/censos2005/CifrasMun/JinotegaTPDF/MaPElC%C3%BAa.pdf>

IV.a. El Bote Hydroelectric Plant

The municipality of El Cuá grew rapidly from a small town of 180 houses in the late 1980s to a regional center of 700 households by the year 2000. The local demand for electricity had quickly outgrown the capacity of the micro-hydroelectric plant in La Chata, propelling the local government to install a diesel generator in 2000 to provide power to just the town of El Cuá. However high diesel and transportation costs combined with regional instability meant the plant ran only 14 hours a day, and often went for weeks without diesel. With a 120 meter waterfall discovered two years earlier on the El Bote River, ATDER-BL began development of a 900kW hydroelectric plant to end energy poverty in the region utilizing renewable sources.

From 1998 through 2004 ATDER-BL developed surveys, feasibility studies, designs, and management plans, identified and secured funding, and obtained construction and commercialization permits. Initial investment in the project totaled $3.1 million; $1.7 million in the hydroelectric plant and $1.4 million in distribution lines. As can be seen in **Figure 6** below, project funding came from a variety of national and international sources: 42% from a World Bank loan administered through the Nicaraguan Ministry of Energy and Mining (MEM) to be repaid over 16 years with 5.5% annual interest; 32% from private donations and grants, including PANIF (government of Finland), Green Empowerment (USA), COSUDE (government of Switzerland), the Ben Linder Memorial Fund (USA), and Manos Unidas (Spain); and 18% from the MEM through the Rural Electrification and Rural Development Programs supported by the United Nations Global Environmental Facility and the Inter-American Development Bank respectively. ATDER-BL contributed 7% of total project costs, primarily through in-kind donations of its engineers' time for design and installation. Local residents from El Bote and the neighboring villages of El Galope, Chica Estrada, and Villa Nueva provided over 5,000 man days of volunteer labor during construction.

Figure 6- El Bote Hydroelectricity Funding 1999-2006



Machine house, El Bote hydroelectric plant

The construction of the diversion weir and intake began almost immediately, with significant volunteer labor contributions from local residents. The majority of the civil works, installation of electromechanical equipment and electrical lines occurred in 2005 and 2006. This included the installation of 485 meters of penstock, hydraulic turbines, generators, transformer banks, street lighting, and 75km of distribution lines. In 2007, the El Bote Hydroelectric Facility was inaugurated, powering homes, schools, clinics and businesses in the town of El Cuá and 10 neighboring villages including El Bote, bringing reliable electricity to 7,000 people for the first time. Additionally, the local grid was interconnected with the national grid and a neighboring grid managed by a sister organization, Association for the Development of Bocay Electric Service (APRODELBO) in 2006, providing clean power indirectly to an additional 30,000 people. Since the original installation in 2006, ATDER-BL has further extended the electrical lines an additional 100 km, serving a current total of 3,300 homes and businesses in 28 villages. Approximately $408,000 was invested in this expanded infrastructure, bringing total investments in the El Bote Hydroelectric Plant and regional grid to $3.5 million.

Since establishing the local grid in 2006, ATDER-BL has operated and administered the concession of electricity for the region of El Cuá under license by the Regulatory Authority of Nicaragua. The concession area begins approximately 17 km southwest of El Cuá where it connects to the national grid, and extends to the Santa Teresa River approximately 21 km northeast of El Cuá, where it connects to a grid managed APRODELBO. A detailed map of the concession area can be found in Appendix A.

For the dispersed, remote households in the El Bote watershed for which it was cost prohibitive to extend the grid from the hydroelectric facility, ATDER-BL provided the option to purchase solar PV systems with a 50% cost subsidy in order to ensure comprehensive coverage and full participation in watershed protection efforts. Forty households have participated in the watershed solar PV program, which was funded by the United Nations Development Program.

Remote house with solar PV system in the El Bote Watershed

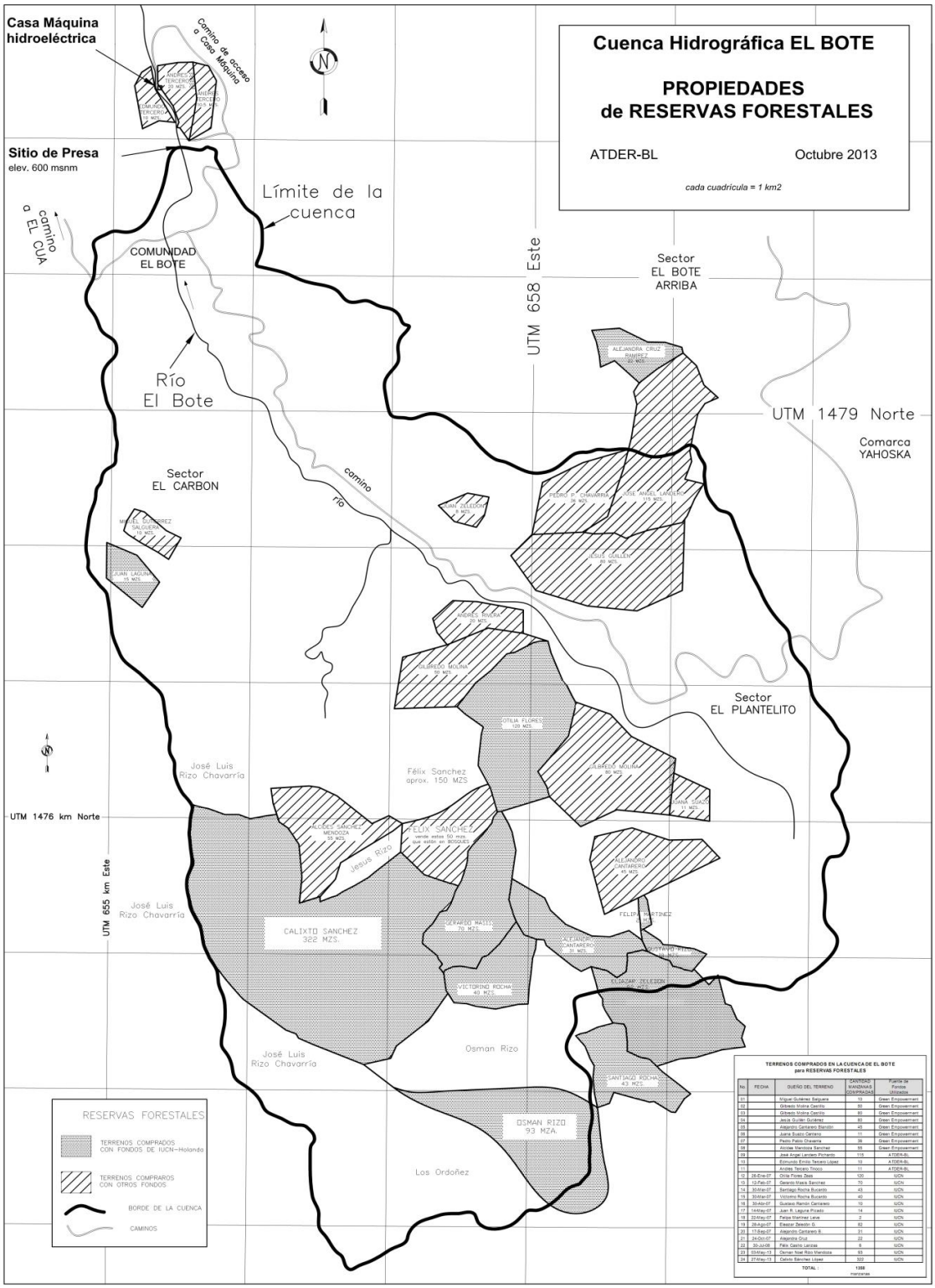
IV.b. Community Forest Reserve

Given the high levels of deforestation in the El Bote watershed, ATDER-BL understood early on that restoring and safeguarding its health would be critical to the long-term viability of the hydroelectric facility, in addition to providing valuable ecosystem services and livelihood opportunities in its own right. To this end ATDER-BL began working with the local community in 2001 to establish a community based forest reserve in order to protect the area's tremendous biodiversity and the upper reaches of the watershed. By securing El Bote's critical water resources (including the spring sources feeding the town's main drinking water system), sediment loads could be reduced and water infiltration increased, which, among other benefits, reduces the stress on the concrete weir of the hydro plant and erosion in the turbines, extending their life.

El Bote Forest Reserve at top of ridge

The El Bote community forest reserve sits at the top of the El Bote watershed and is comprised of 24 different land purchases from private owners between 2001 and 2013, as seen in **Figure 7** below.

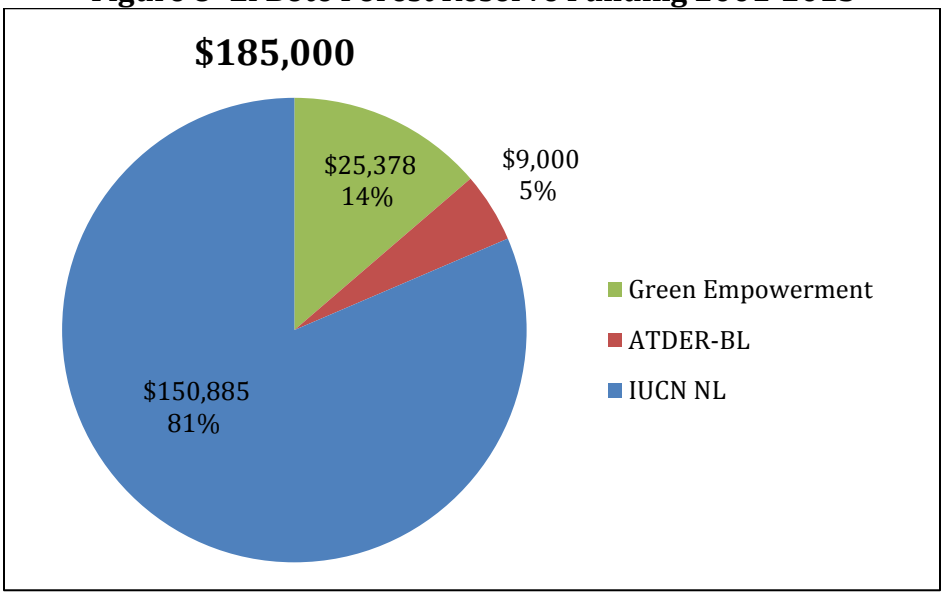
Figure 7- El Bote Forest Reserve 2001-2013



Gray indicates areas purchased through IUCN-NL funding; striped indicates areas purchased through Green Empowerment and ATDER-BL funds.

Property owners sold the higher, forested portion of their land into the Forest Reserve while retaining lower elevation farmland for their livelihoods, thus avoiding simply displacing agricultural expansion to adjacent watersheds. The reserve protects 956 hectares of primary sub-tropical rainforest (official registration is still pending with MARENA), which required a total investment of $185,000 over a 12 year period. As can be seen in **Figure 8** below, funding came from Green Empowerment, ATDER-BL, and IUCN-NL. The reserve is managed by the local Watershed Management Committee, which is comprised of local farmers and individuals from the town of El Bote who are committed to the health of the watershed in the region. They work entirely on a volunteer basis and have successfully managed and monitored the reserve for over ten years. ATDER-BL acts as the Watershed Management Committee's fiscal representative and has provided its members with basic equipment to monitor and patrol the reserve, assisted them to delineate and install proper signage, utilize and implement environmental laws and regulations, and educate residents about ecosystem services provided by the watershed and the importance of its protection. Through the establishment of the forest reserve, 38% (9.5 km^2) of the 25 km^2 watershed has been protected.

Figure 8- El Bote Forest Reserve Funding 2001-2013



IV.c. Agroforestry Activities

Limiting human impact on the area's fragile environment was seen as a critical element of protecting the El Bote watershed. To complement the electricity provision and forest conservation components of the project, ATDER-BL worked with more than 122 producers in the watershed to implement more sustainable agricultural techniques, increasing the diversity and value of local production while reducing erosion and agricultural pollution. With technical assistance from ATDER-BL (most critically from a full time agronomist who resides in the community), these families have reforested over 84 ha with native tree species; planted high value shade grown crops such as coffee, cacao, plantains, and taro; developed family vegetable gardens to enrich family diets; improved husbandry of chickens and pigs; worked with the Watershed Management Committee to install gabion walls to

strengthen riverbanks and prevent erosion, and build fences to restrict cattle from grazing in riparian zones. In 2013, ATDER-BL also piloted fuel efficient cookstoves with 16 families in the town of El Bote with the aim of reducing indoor air pollution and local demand for firewood within the watershed. ATDER-BL subsidized the cost of the stoves, which are designed to reduce fuel needs (firewood) by 50% and indoor air pollution by 90%. Due to the high interest from the community, ATDER-BL plans to continue with stoves in the future, gradually reducing subsidies and selling them in the local market. See **Table 1** below for a complete list of agroforestry and watershed conservation measures undertaken by ATDER-BL and the community since 2006.

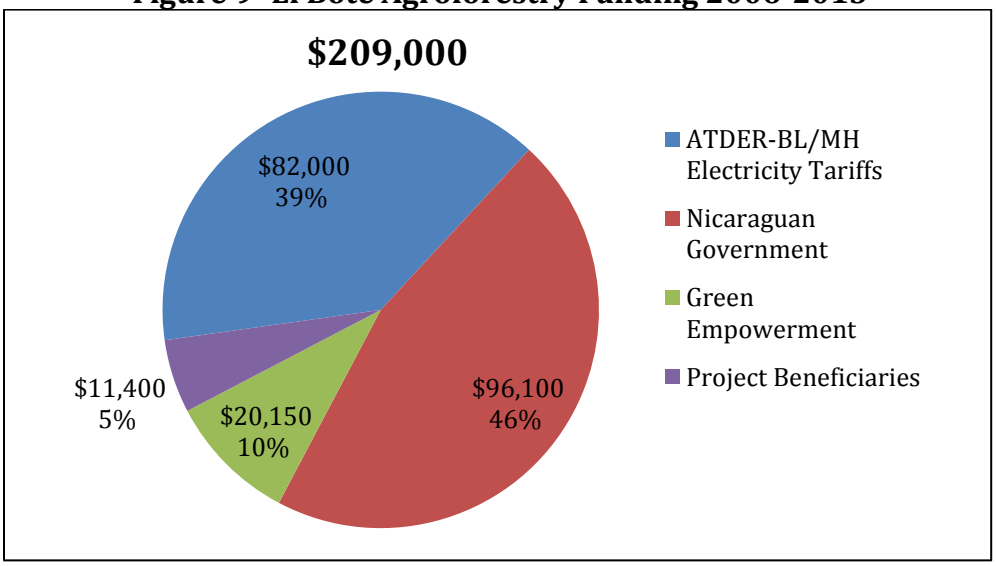
Table 1: Summary of Agroforestry Activities Implemented in the El Bote Watershed: 2006-2013

Activity	Unit of Measurement	Quantity
Rainforest protected in reserve	Hectares	956
Trees planted	Hectares	84
Shade-grown coffee cultivation	Hectares	253
Cacao cultivation	Hectares	12
Banana/plantain cultivation	Hectares	45
Taro root cultivation	Hectares	14
Basic grains cultivation with soil conservation barriers	Hectares	10
Mini Poultry Farms established	Farms	9
Family vegetable gardens established	Gardens	6
New pigs raised	Pigs	37
Live fencing planted	Meters	11000
Live vegetation barriers of vetiver grass planted	Meters	7500
Silvopasture established	Hectares	56
Fodder banks planted	Hectares	3.5
Organic composts established	Composts	10
Vermiculture practices employed	Composts	10
Riverbank dead wood erosion protection installed	Meters	500
River bank fencing established to protect against erosion	Meters	6000
Gabion baskets installed to prevent erosion	Gabions	30
Solar PV systems installed on homes in the upper watershed	Solar PV systems	40
Signs installed with environmental protection messages	Signs	80

Environmental management trainings conducted	Trainings	15
Experience exchanges conducted with residents of other watersheds	Exchanges	2
Fuel Efficient Improved Cookstoves Installed	Stoves	16
Technical assistance provided	Years	8

Investments in agroforestry activities in El Bote between 2006 and 2013 totaled $209,000. These monetary and in-kind contributions came from a variety of sources, including project beneficiaries, the Nicaraguan Government (through support from the Ministry of Energy via the United Nations Development Program), Green Empowerment (through funds from the New England Biolabs Foundation, Christadelphian Meal-a-Day Fund of the Americas, the Leiter Family Foundation and individual donations), and most importantly, ATDER-BL itself through electricity sales from the El Bote Hydroelectric Plant. This revenue has been able to support a highly trained, full time agronomist to permanently live and work in the community since 2006.

Figure 9- El Bote Agroforestry Funding 2006-2013



V) Project Impact

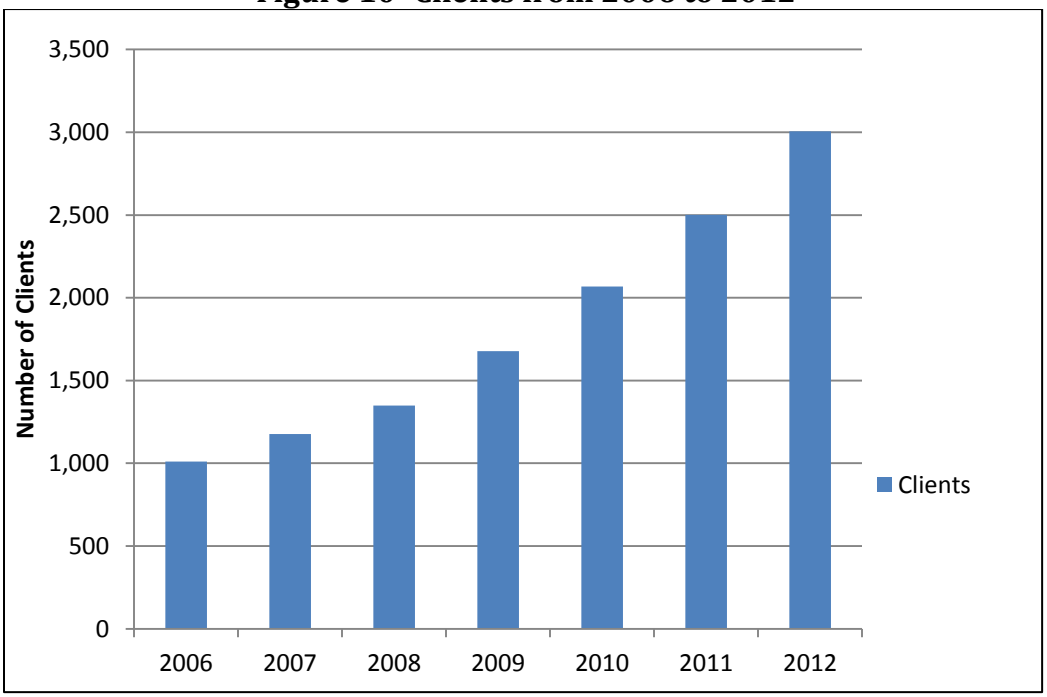
V.a. Hydroelectric Facility

The hydroelectric plant has a maximum capacity of 900 kW, corresponding to 21,600 kWh/day, and a maximum annual production capacity of 7,884,000 kWh (if full water flow is available all year round). Due to seasonal variations and available stream flow in the El Bote River, the plant has produced between 2,949,334 kWh/year and 3,701,979 kWh/year between 2008 and 2012 (average annual production was 3,344,769 kWh). Yearly maximum stream flow and thus electricity production is during the peak of the Nicaraguan rainy season (August-October) with the minimum stream flow occurring at the end of the dry season (April-May).

V.a.1 Socioeconomic Impact

According to a 2005 national census, 100% of El Bote households did not have access to electricity, utilizing candles, kerosene lanterns, or diesel generators for lighting.[11] By 2013 that number had decreased to 16%, with the majority of residents receiving power from the El Bote hydroelectric plant. The number of beneficiaries (electricity clients) in the municipality of El Cuá tripled from 1,100 in 2006 to 3,300 in May 2013. These clients are local families, schools, businesses, and health services that previously lacked access to electricity, and collectively amount to approximately 22,000 people directly benefited. Average annual electricity consumption per client has been 585 kWh, approximately one twentieth of the average annual household electricity consumption in the United States of America.[12]

Figure 10- Clients from 2006 to 2012



Clients' energy consumption is monitored by meters installed at each property and ATDER-BL staff is responsible for billing and collection of payments. The Nicaraguan Energy Institute (INE) regulates energy tariffs and sets the rates each utility or concession can charge based on electricity production costs presented by the entity. From 2006 to 2009, clients paid $0.21/kWh and from 2010 to present, $0.14/kWh. Families pay an accessible fee to connect (less than the initial meter and cable costs) and ATDER-BL has a constant stream of requests for additional connections. In the rural area, families with an average family size of 6.3 people per household are predominately the lowest energy consumers and many consume just the connection fee of $1.50 per month for basic household

[11] "El Cuá en Cifras," *Instituto Nacional de Información de Desarrollo*, March 2008, 30. Date accessed: Nov 28, 213. <http://www.inide.gob.ni/censos2005/CifrasMun/Jinotega/EL%20áA.pdf>

[12] "Frequently Asked Questions," U.S. Energy Information Administration, March 19, 2013. Date accessed: Nov 28, 2013. http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3.

illumination and appliances such as televisions, radios, and cell phone chargers. A household consuming the average monthly consumption would pay approximately $7 per month to meet all energy needs, including lighting and larger appliances like refrigeration and basic machinery. Residents previously utilized kerosene lamps, candles, and battery powered flashlights for lighting, while more affluent households and businesses had diesel generators. In addition to posing negative environmental and health effects, these energy sources could cost between $4 and $8 per month for basic kerosene lamps and batteries and based on the conservative consumption of 19 liters a month for diesel, $25 per month to power generators.[13]

Energy access has also provided additional income generating opportunities for local residents not previously possible, with more than 330 businesses utilizing electricity for the first time. These include small stores, restaurants, hotels, bakeries, carpentry shops, tire-repair shops, a dairy with refrigeration equipment, welding shops, gas stations, ice cream shops, tailors, 4 rural radio stations, and added value agricultural processing such as machines for corn grinding, rice husking, and coffee processing. Furthermore, public facilities such as schools and health centers have been able to extend and improve services. In the town of El Bote, since electricity service was extended to the school, they have added secondary school classes, graduating the first class of high school students in December 2012. Health services have significantly improved in the region with clinics now able to offer laboratory testing, power surgical equipment, refrigerate vaccines, and attend to emergencies past dark. The health center in El Cuá now functions as a mini-hospital, and there are plans to construct a hospital in Ayapal, a remote town along the edge of the BOSAWAS reserve which since 2012 has electricity from the El Bote plant via APRODELBO. Currently the nearest fully equipped hospital is in the department's capital of Jinotega, a 7 hour bus ride away.

Businesses powered by the El Bote Plant

[13] Average local price for 2-4 liters of kerosene per month plus 1-2 sets of batteries of a flashlight. Generator cost estimate based on 19 liters per month of diesel.

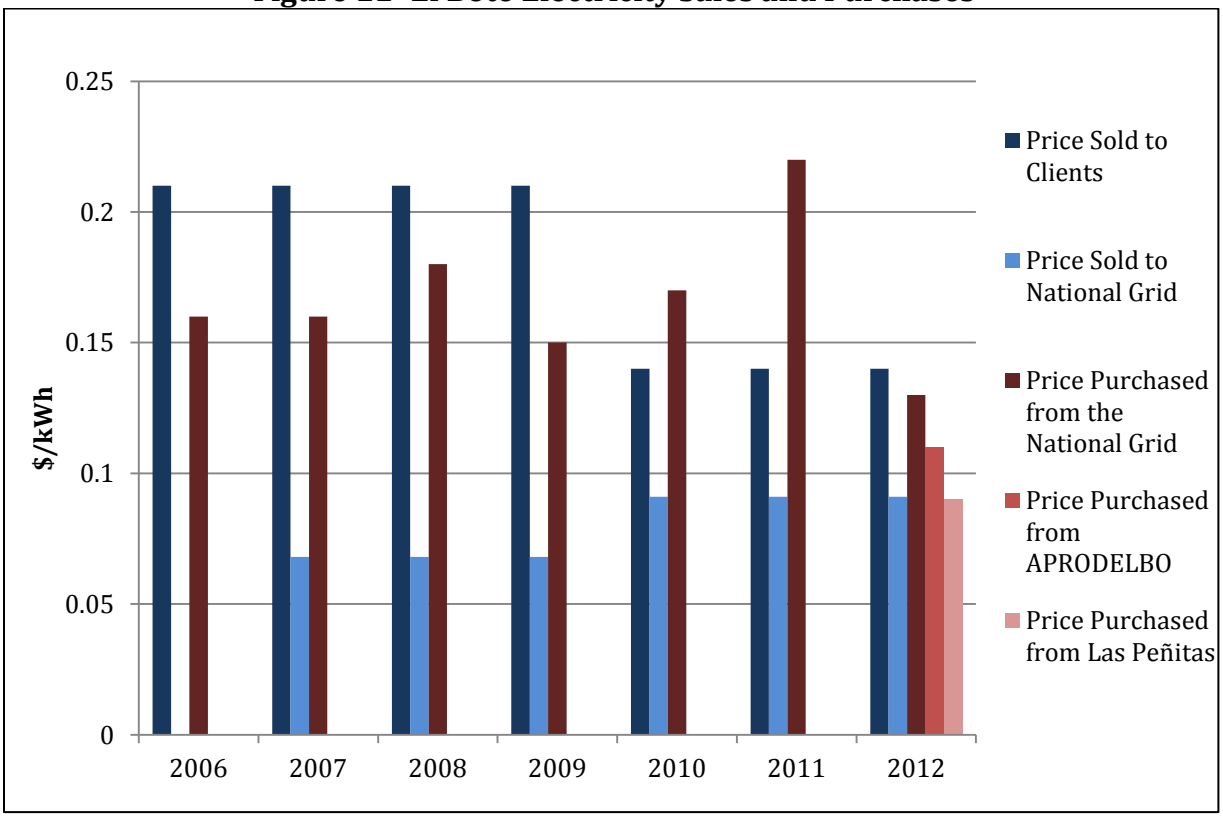
Businesses powered by the El Bote Plant

The hydroelectric plant itself also employs 17 individuals as operators, electrical line workers, meter readers/bill collectors, and cashiers, all of whom earn salaries 20% higher on average than the Nicaraguan minimum wage for equivalent positions. An office administrator, engineer in charge of the electric grids, and the agronomist in charge of the watershed conservation program are also employed through income generated from electricity sales and earn an average salary of $500/month. These talented young professionals have remained on staff without turnover for the entire seven year duration of the project. The long-term employment of the agronomist has been critical to increasing farming incomes and restoring watershed health in the El Bote area, as discussed below.

In addition to selling directly to their own clients, ATDER-BL sells surplus electricity to the national grid through the utility DISNORTE, and to a grid concession managed by APRODELBO. Due to Nicaraguan energy laws, which do not provide for feed-in tariffs, ATDER-BL must negotiate directly with DISNORTE to establish the price they will pay for electricity generated from the El Bote plant. ATDER-BL must convince DISNORTE of their energy production costs and it must be comparable or less than what DISNORTE pays for hydroelectricity from other sources. The agreement between ATDER-BL and DISNORTE is renewed each year and reviewed by INE before approval.

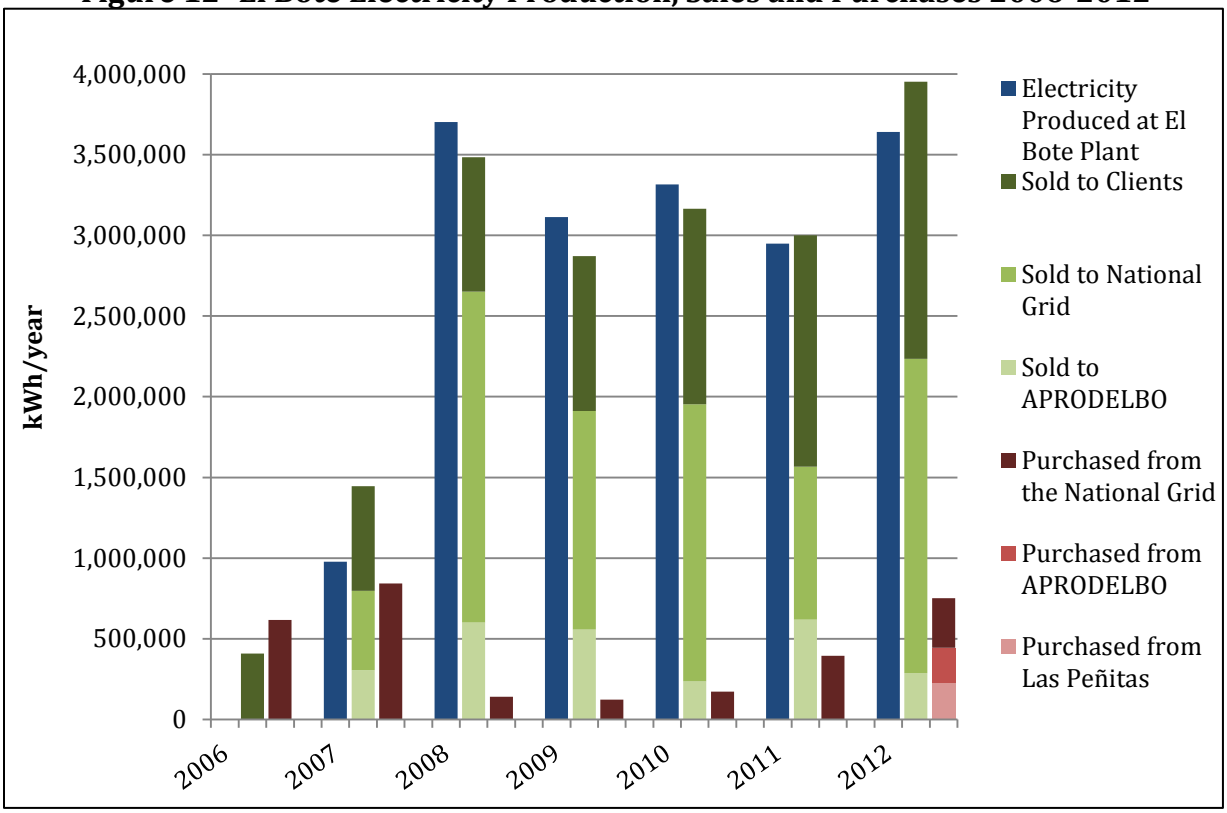
ATDER-BL also *purchases* electricity back from the national grid in instances where local demand cannot be met due to seasonal fluctuations in water resources and peak hour demand load. DISNORTE charges ATDER-BL a commercial electricity rate that is often significantly higher than the rate at which ATDER-BL sells to DISNORTE. Since the majority of DISNORTE electricity is generated from fossils fuels, their costs are high and reflected in their pricing, which is in turn sanctioned by INE. From 2007 to 2009, and again in 2011, DISNORTE charged ATDER-BL more than double the rate per kWh than that which they paid for electricity purchases from ATDER-BL. As DISNORTE has been able to diversify their electricity production, prices have begun to decrease, as can be seen in **Figure 11** below. Additionally, starting in 2012, ATDER-BL began to purchase electricity from APRODELBO and a small private hydroelectric system near El Cuá called Las Peñitas. These systems can supply electricity to ATDER-BL at a lower rate than DISNORTE.

Figure 11- El Bote Electricity Sales and Purchases



As seen in **Figure 12** below, in the beginning years of the project, electricity produced and purchased did not equal the amount of electricity sold as there were significant electrical line losses (20 to 30%). In recent years improvements to electrical lines mean that line losses and energy for public illumination have leveled off at about 9% of total electricity generated.

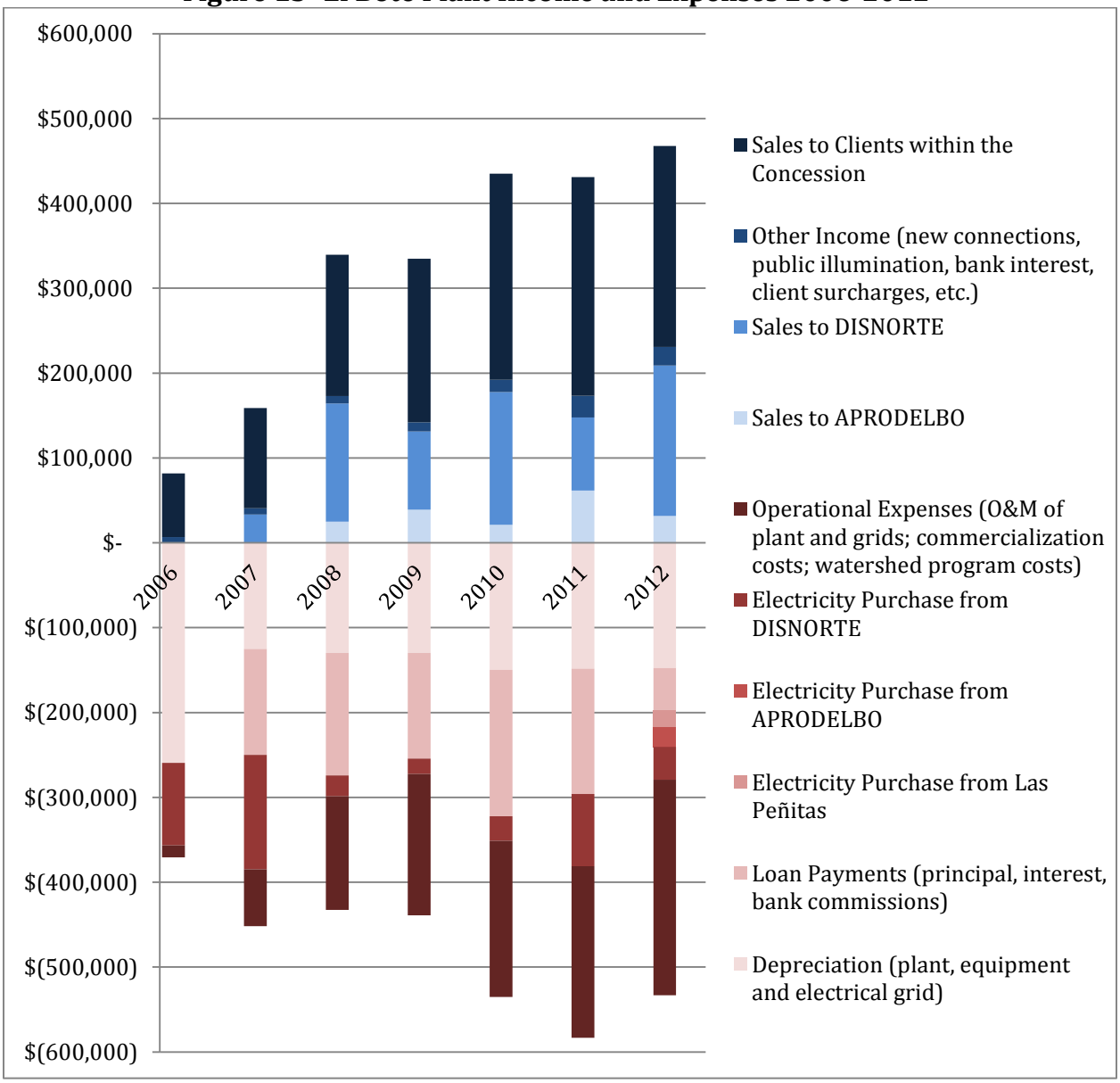
Figure 12- El Bote Electricity Production, Sales and Purchases 2006-2012



As shown below in **Figure 13**, total annual income from the above electricity sales and services has increasingly grown since 2006 to over $450,000 in 2012. Not taking into consideration depreciation costs, ATDER-BL has been able to cover all costs for the facility from electricity sales since 2008. However the costs of maintaining the plant's equipment and infrastructure alone are significant, and when capital depreciation costs are included, comprise almost 2/3 of all expenses. Therefore to date expenses continue to exceed income, though the gap is diminishing due to steady demand and a growing client base, stabilization of DISNORTE prices, and diversification of sources for energy purchases. Once repayments on the World Bank loan are concluded in 2017, it is estimated that income will exceed expenses for the first time, and remain relatively stable thereafter. Furthermore, income calculations do not include a monetization of the greenhouse gas emissions offset by the El Bote plant, a modest if indirect revenue source as seen below. Lastly, 50% of Nicaragua's electricity is generated from renewable sources, with a goal of 90% by 2020.[14] The policy environment is likely to become more favorable in the future as a result of the renewable energy sector and multilateral organizations proposing feed-in tariffs/subsidies discussions at the national level.

[14] "Nicaragua usa 52% de energía renovable," El Nuevo Diario: Nov 30, 2013. http://www.elnuevodiario.com.ni/economia/300982-nicaragua-52-de-energia-renovable

Figure 13- El Bote Plant Income and Expenses 2006-2012



V.a.2 Environmental Impact

The El Bote hydroelectric plant, as is the case with most small hydroelectric systems, is designed to have negligible environmental impacts. Unlike large hydropower projects which require flooding a large area to create a reservoir, micro-hydro plants intake and divert only a small portion of stream flow for a short distance before 100% of the water is returned to the source, in no way altering the water's physical properties. Civil structures also integrate erosion control as well as openings in the bottom of the weir structure to guarantee stream flow in the river meets ecological demand and further protect aquatic life.

El Bote weir and water intake (left) and water outlet (right)

However the primary environmental benefit of the hydroelectric plant itself is the reduced greenhouse gas emissions and local pollution from previously utilized diesel generators and household kerosene lamps. Emission offsets of the El Bote plant can be estimated at 0.506 tonnes of carbon dioxide (tCO_2) per MWh of electricity produced using the country's emission factor in electricity generation.[15] Therefore between 2007 and 2012, the El Bote hydroelectric facility has offset an estimated 8,956 tonnes of CO_2. This is approximately equivalent to the emissions of 15,630 barrels of oil.[16] Utilizing the four year historic average price for carbon emissions under the European Union Emissions Trading Scheme (EU ETS) ($16.21/$tCO_2$) this amounts to a rough estimate of $145,198 to date.[17,18]

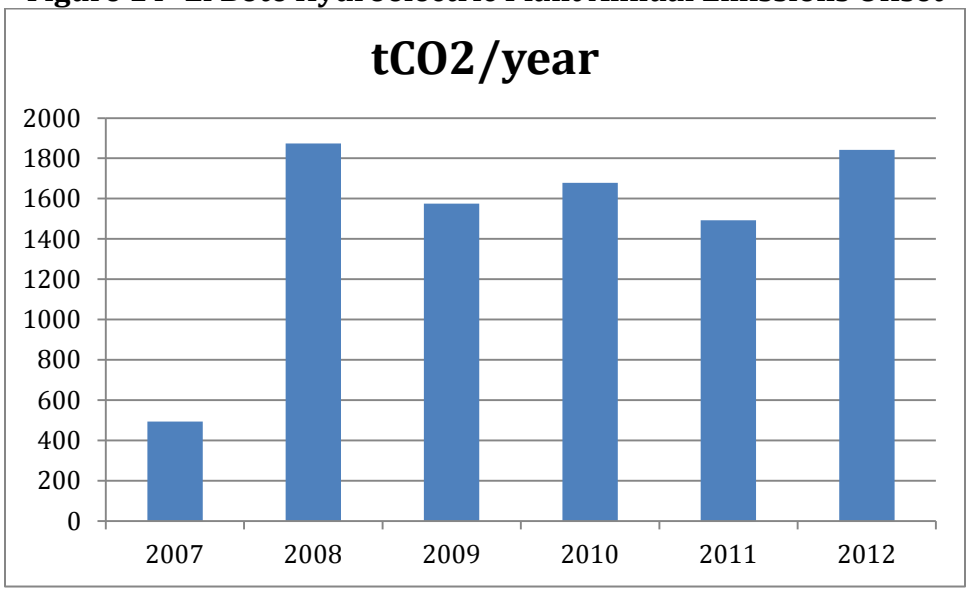
[15] "SUSTAINABLE ENERGY PROJECT SUPPORT (SEPS) Baseline Calculation," WISIONS. Date accessed: Nov 28, 2013. http://www.wisions.net/files/uploads/Baseline_Calculation_2013.pdf.

[16] "Greenhouse Gas Equivalencies Calculator," U.S. Environmental Protection Agency, November 26, 2013. Date accessed: Nov 29, 2013. <http://www.epa.gov/cleanenergy/energy-resources/calculator.html>

[17] "Carbon Emissions Historical Data." Date accessed: Nov 29, 2013. <http://www.investing.com/commodities/carbon-emissions-historical-data>

[18] Data was only available from October 1, 2009 on. An average was taken of the monthly price according to the above source and converted to USD based on the average exchange rate for the same period per www.oanda.com. The authors recognize the imprecise nature of this calculation and the instability and uncertainty associated with carbon pricing and trading schemes. It was used to provide a rough estimate only of the monetary value associated with the El Bote plant's emissions offsets.

Figure 14- El Bote Hydroelectric Plant Annual Emissions Offset



V.a.3 Challenges

While ATDER-BL has been successful at providing and extending clean, affordable energy to remote, rural homes and businesses, the operational challenges discussed above have so far impaired financial viability. One of the most significant has been the connection to the national grid, both in terms of price and quality. Every year ATDER-BL must renegotiate the rate at which it sells its electricity surplus to DISNORTE, often reaching suboptimal agreements. The prevailing rate for 2010-2012 was $0.091, and for 2013 ATDER-BL requested an increase to $0.11 per kWh, to which DISNORTE initially agreed. However, following management changes, a counteroffer of $0.10 per kWh was made and then withdrawn completely. As of November 2013, ATDER-BL had agreed to the previous price of $0.091 per kWh but was awaiting INE's review and approval. Furthermore, ATDER-BL had not received any payment for electricity sold to DISNORTE in all of 2013.

Similarly, the rates that ATDER-BL must pay for its electricity purchases *from* DISNORTE are also problematic. From 2007-2009 and again in 2010, DISNORTE charged ATDER-BL for electricity at more than double the rate they paid for electricity received from ATDER-BL due to DISNORTE's high production costs. In 2011, ATDER-BL was charged $0.22 per kWh, which was $0.08 per kWh more than ATDER-BL was regulated by INE to charge their customers ($0.14/kWh). In addition, ATDER-BL is subject to 15% value added tax (VAT) on all electricity purchased from DISNORTE, however under Nicaraguan National Law number 554, they cannot pass this tax onto those that consume less than 150 kWh/month, the majority of their customers. Thus, ATDER-BL pays for all electricity entering the concession from DISNORTE but does not recuperate the majority of this cost.

Furthermore, these exaggerated rates are paid for poor quality service. While improved in recent years, at the beginning of the project blackouts of the national grid were common, and would cause instability in the El Bote grid, damage plant equipment over time, and forced the hydroelectric plant to shut off. When the plant was shut off, it would take up to

20 minutes to restart and synchronize the system during which ATDER-BL would need to purchase power from DISNORTE to supply uninterrupted service to their users. Without these outages, El Bote would have produced their own power and required less from the more expensive DISNORTE. According to local users, this frequent grid instability additionally caused damage to household light bulbs and appliances.

Lastly, as a small organization, ATDER-BL's ability to quickly add new customers and therefore increase revenue is constrained by its small staff size. As of November 2013, ATDER-BL had a list of almost 400 households requesting new connections to the grid that had yet to be serviced.

V.b Agroforestry Activities

ATDER-BL continues to work with producers in the El Bote watershed to adopt more sustainable agricultural practices in order to reduce soil erosion and increase water infiltration while also improving livelihood opportunities. We believe adoption and participation rates have been so high (122 producers from over 90% of households approached have participated) in part due to the inherent incentives inspired by the micro-hydro system itself. Given their particular reliance on local ecology and resources, smallholder farmers have an innate vested interest in preserving them. ATDER-BL has helped make this link more apparent with consistent education and practice. However the tangible link between a basic household need (electricity), and the natural resource that provides it (water), creates even stronger incentives for protection. Preserving the village power source becomes another motivation for strengthening and formalizing community-based watershed and forest protection, which render a host of valuable ecosystem services for both local residents and downstream users on top of the emissions reductions achieved through the micro-hydro plant itself.

V.b.1 Socioeconomic Impact

In May 2013 ATDER-BL conducted a household survey of 63 randomly selected El Bote families in order to assess changes in the socioeconomic well-being of families participating in the project.[19] This data was then compared with that of a household survey conducted by the municipality in December 2000, before the project began, which contained similar questions relating to income and assets, agricultural production and prices, and environmental education. Results were compared utilizing t-tests and chi-squares analysis, with changes deemed statistically significant if surpassing the 1% level. It should be noted however that in making these comparisons, the authors do not claim to demonstrate a scientifically proven relationship between project activities and impact. Rather the principle of "significant contribution" – i.e., activities can be logically argued to contribute to an expected result, should be considered.

The primary economic activity of El Bote households remained the same in 2013 as 2000: raising animals and/or cultivating coffee and basic grains (corn and beans). Corn and bean cultivation remained consistent at an average of 6% of the property while pasture land increased from 19% to 23%. Many of these ranchers are working with ATDER-BL to

[19] Survey instrument available upon request.

establish silvopasture, live fencing, and fodder banks (*Brachiaria brizantha*), to increase fertility and productivity. However the most notable shift in agricultural production in the El Bote watershed in the last decade was the significant increase in coffee cultivation, particularly shade grown varietals mixed with banana, cacao, and other tree species. Households on average now dedicate 23% of their property (3.9 ha) to coffee cultivation, up from only 5% in 2000.[20]

Figure 15- Land Use in El Bote, 2000

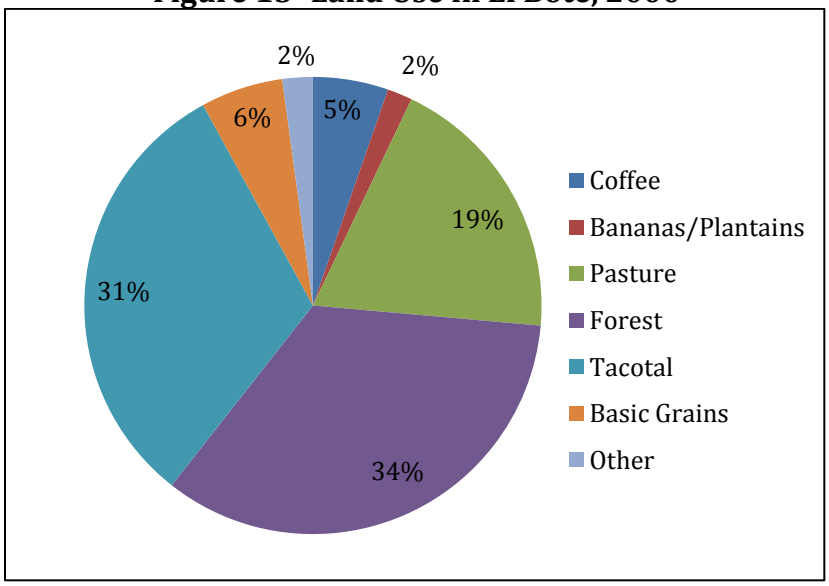
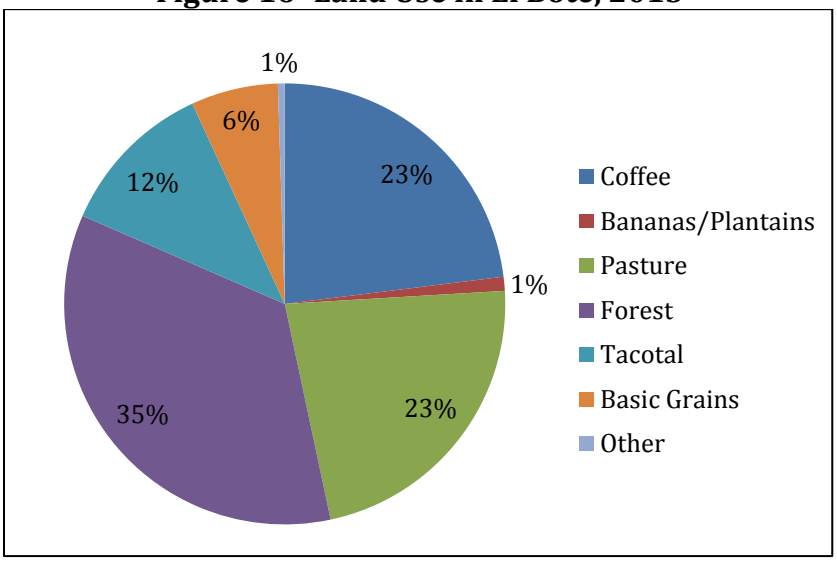


Figure 16- Land Use in El Bote, 2013

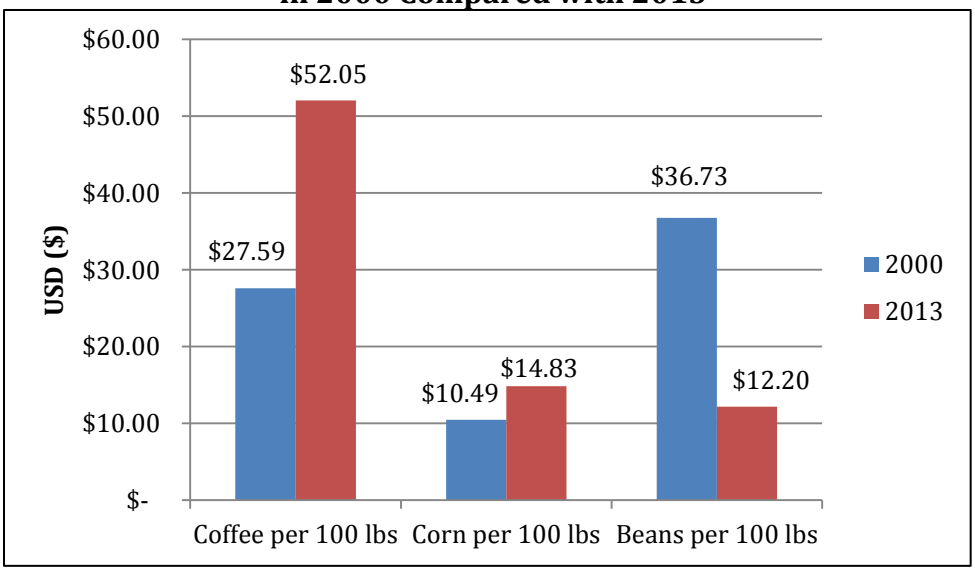


[20] Green Empowerment and ATDER-BL."El Bote Household Survey." Survey. May 2013.

These shifts in agricultural production are a reflection of changes in international market prices and the availability of technical assistance. In 2000, only 4 households in the El Bote area reported receiving technical assistance from any entity for their crops or livestock. Now 86% of households receive technical assistance, 94% of which came from ATDER-BL, whose full-time agronomist Boanegre Rocha lives in the community and works daily with producers. Much of this agricultural extension work has focused on expanding and improving cultivation of shade-grown Arabica coffee varietals due to their economic and environmental benefits (described below) over both sun-grown counterparts and other local crop alternatives. El Bote's climate and altitude are well suited for varieties, which can fetch high prices in the specialty coffee market. Indeed as can be seen in **Figure 17**, in 2013 producers in El Bote received over $0.50/pound of coffee—three times what was earned for corn and beans. Only 2% of households produce for self consumption alone, with 97% of producers selling between 75 and 100% of their harvest. These earnings have allowed 63% of respondents to invest in expansions or improvements to their homes or land during the project timeframe. A notable addition in this respect has been the increase in sanitation facilities. 90% of households now have access to a latrine or other improved sanitation facility, up from 68% in 2005.

Shade grown coffee in the El Bote watershed

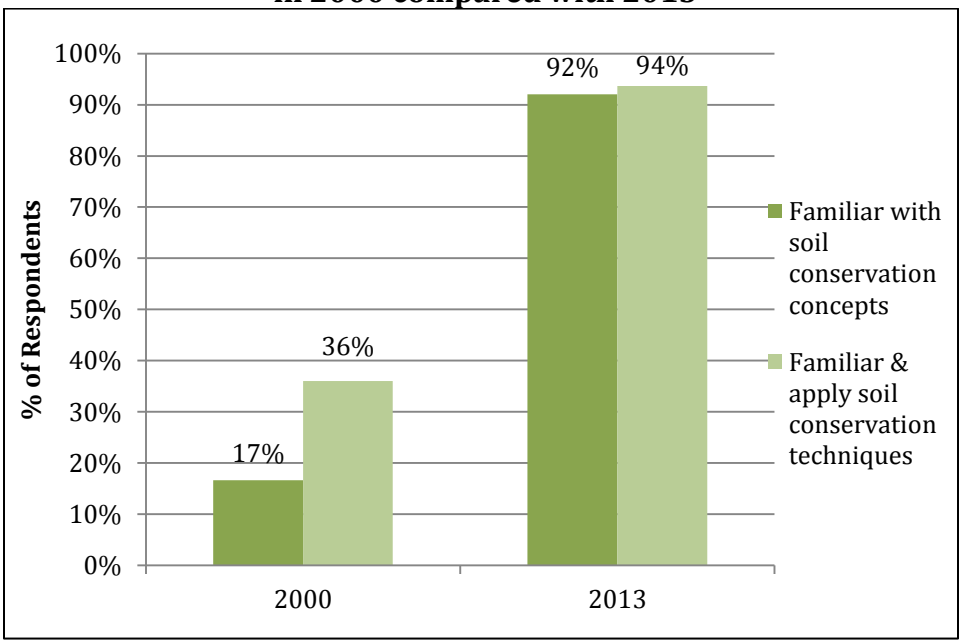
Figure 17- Average Crop Prices Received by El Bote Producers in 2000 Compared with 2013



V.b.2 Environmental Impact

The incorporation of agroforestry practices in agricultural production systems increases carbon storage, decreases soil erosion, enhances soil fertility, creates and enhances wildlife habitat, and diversifies species, among other benefits.[21] These practices, combined with live fencing and reforestation, augments the watershed's capacity to store carbon and provide habitat for local wildlife, including small mammals, birds and insect populations of high importance for crop pollination. Shade grown coffee cultivation in particular provides many of these benefits while also generating higher value for farmers. Intercropping with shade trees (especially fruit bearing varieties for additional food and income) generates greater oxygen and habitat, returns organic matter and moisture to soil, slows erosion, and hinders weed growth (which in turn reduces pesticide use), all of which extend the productivity and life of the coffee plant. Add composting, biofertilizer application, and improved water and soil management, precisely the types of assistance ATDER-BL has provided, and farmers can begin a virtuous cycle of restoring soil fertility for heartier crops with higher yields and quality beans. Indeed in 2013, 92% of producers stated that they were familiar with the concept of soil conservation and were able to cite a variety of related techniques. Before the project began, only 17% of households could do so. More importantly, of those that answered affirmatively, 94% attested they also apply these techniques, up from 36% in 2000.

Figure 18- El Bote Producers Familiar with Soil Conservation in 2000 compared with 2013



Other agroforestry and watershed restoration activities implemented during the project focused on erosion control and prevention given its importance for the hydroelectric system. Heavy siltation of the supplying waterway can quickly degrade turbine runners,

[21] "Coffee growing and agroforestry systems," CIRAD. Date accessed: Nov 28, 2013. <www.cirad.fr/en/content/download/3716/29835/.../2/.../agroforsheet.pdf>

and at times obstruct them completely. Turbine efficiency is directly tied to watershed health. Erosion control efforts focused on stabilizing stream banks though deadwood barriers, stabilizing roads and hillsides through gabion walls, fencing off riparian areas from cattle, and planting live vegetation barriers (vetiver grass).

Establishing live vegetation barriers (vetiver grass) (left) and live fencing (right)

Fodder bank (left) and silvopasture (right) established in El Bote

Constructing a gabion retaining wall (left) and deadwood erosion protection (right)

Ecosystem Services

ATDER-BL's years of educating, training, and working side by side with producers to implement the various activities and techniques described above have contributed not only to the direct economic gains for families previously described but has provided a host of ecosystem services that further benefit both local residents and downstream users, including carbon storage, erosion control, and water infiltration.

In an attempt to estimate the economic value of these services, an analysis was conducted according to the methodology established in the Intergovernmental Panel on Climate Change Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF) and Food and Agriculture Organization case studies (evaluation of non-timber forest products) developed by Barbier et al. (1994), in collaboration with the Tropical Agricultural Research and Higher Education Center (CATIE) and IUCN. The evaluation takes into account three important aspects of each ecosystem: production of goods, services and attributes. The prices assigned to each service were derived from previous literature on the subject or are the going market rate paid locally or four year historic average price for carbon emissions under EU ETS ($16.21/t$CO_2$).[22,23] Unfortunately the analyzable environmental services were constrained by the quantity and quality of available field data. With the field data currently available, only carbon storage and erosion control services could be evaluated. Additionally, the erosion control assessment focused on the value of the erosion prevented in terms of soil loss but was unable to be analyzed in terms of maintenance cost savings for the hydroelectric plant. The following agroforestry activities were analyzed, comprising a total area of 473 ha:

ACTIVITY	ha	m2	Km2
Silvopasture	56.49	564,931.86	0.56
Tree plantations	84.74	847,397.78	0.85
Shade grown coffee cultivation with mixed species	254.22	2,542,193.35	2.54
Basic grains cultivation with live soil conservation barriers	7.06	70,616.48	0.07
Cacao cultivation	12.00	120,048.02	0.12
Plantain cultivation	45.19	451,945.48	0.45
Taro cultivation	14.12	141,232.96	0.14
Total	**473.84**	**4,738,365.93**	**4.74**

As can be seen in the subsequent tables, these agroforestry activities resulted in 7,132 tonnes of carbon stored valued at approximately $115,623.33. Flows of sequestered carbon and erosion control generated a monetary value, a combined $1,289.64 annually. Other services such as increased water availability we were not able to quantify due to lack of pre-project baseline data.

[22] Intergovernmental Panel on Climate Change. Good Practice Guidance for Land Use, Land-Use Change and Forestry, (Kanagawa: Institute for Global Environmental Strategies, 2003).
[23] European Union Emissions Trading Scheme

Physical Carbon Inventory of Select Agroforestry Activities		
Area of Agroforestry Activities	473.84	ha
Average Basal Area of the different species	15	m2/ha
Average diameter of different species	0.1	m
Average Height	3	m
Basal area of trees	0.007854	m2/tree
Area density	1909.86	trees/ha
Total trees	90,4961.23	Trees
Volume	21,322.65	m3
IFC = V * FEB * D * FCC (V: total volume m3/ha, FEB: Biomass Expansion Factor, D: Wood density, FCC: Biomass conversion to carbon factor ~ 0.5.		
V	45	m3/ha
FEB	1.68	adim
Density	0.4	t/m3
FCC	0.5	adim
IFC	15.08	t/ha
Price in dollars per tonne of carbon	16.21	USD/t
Value of inventory of services generated	244.44	USD/ha
Total value of 473 ha	**$ 115,623.33**	

Flow of Carbon Sequestered Annually by Select Agroforestry Activities		
FFC = IAP * FCV * D * FCC (FFC: Physical flow of carbon (t / ha / year), IAP: Average Annual Increase (m2/ha/an), FCV: volume conversion factor (arithmetic ratio between the volume and basal area of different diameter classes), D: Wood density, FCC: Biomass conversion to carbon factor.		
Annual Increase	2.5	t/ha/year
IAP	0.166	
FCV	3	m

D	0.62	t/m3
FCC	0.5	
FFC	0.15	t/ha/year
Value of annual flow of inventory of services generated	2.43	USD/ha/year
Total annual value of 473 ha	**$1,1150.09**	

Erosion Control Provided by Select Agroforestry Activities		
Land inventory (IS: PS * A * DA (Ton / Ha), PS: arable soil depth (m) to area (m2), Yield: Bulk density (t/m3)		
PS	0.2	m
Da	1,350	t/m3
A	10000	m2/ha
IS	2700	t / Ha
Ground flow (E: R * K * LS * C), E: eroded n (Ton/ha/year), R: rainfall and runoff factor, K: soil erodibility factor, L*S: length factor and gradient of the slope, C: coverage factor and crop management.		
R	750,000	
K	0.15	
S	0.57	
L	0.501	
C	0.001	
E	0.032	t/ha/year
Price in dollars per tonne of topsoil	9,207	USD/t
Value of annual erosion control	0.295	USD/ha/year
Total annual value of 473 ha	**$139.54**	

V.b.3 Challenges

In the early years of the agroforestry program, it was at times difficult for ATDER-BL staff to secure participation in and commitment to the activities given unfamiliarity and uncertainty about both the concepts and the agronomist. However as producers observed initial successes, hesitation quickly waned, with more and more families wanting to participate. Furthermore, by residing full-time in El Bote, ATDER-BL's agronomist Boanegre Rocha quickly gained families' trust and confidence, and has since become a recognized and respected leader in the community. This is also owing to his superior social and technical skills as both a community organizer and agronomist. As of 2013, Mr. Rocha is providing ongoing technical assistance to over 120 small producers in the watershed.

V.c. Community Forest Reserve

The impact of the 956 ha community forest reserve has been primarily environmental through preventing deforestation, providing a refuge for diverse and endangered plant and animal life, sequestering vast stores of carbon, and strengthening soil and water resources. These in turn render economic benefits in the form of significant but difficult to monetize ecosystem services for the local community, hydroelectric plant, and surrounding area.

V.c.1. Socioeconomic Impact

The primary socioeconomic benefits of the forest reserve enjoyed by local residents are those generated by the ecosystem services it provides. The forest cover and root system ensure water infiltration to local rivers, control surface runoff and erosion, reduce sedimentation in water bodies (critical to the efficacy of hydroelectric plant equipment), prevent landslides on steeper slopes, and sequester significant stores of carbon—152,195 tonnes worth, with an approximate total value of $2,467,084.19. Flows of sequestered carbon and erosion control generate an additional combined value of $84,429.43 annually. Increased water availability is also an essential service provided by the forest reserve, supplying the wells of those families living in the middle and upper reaches of the watershed, drinking water to the town of El Bote, and stream flow in the El Bote River to power the hydroelectric plant. Unfortunately, due to lack of pre-project baseline data we are unable to quantify these important contributions.

Mini-intake that serves as the town of El Bote's drinking water source, within the El Bote forest reserve

Physical Carbon Inventory of 956 ha Forest Reserve		
Area of Agroforestry Activities	956	ha
Average Basal Area of the different species	43.8	m2/ha
Average diameter of different species	0.34	m
Average Height	7.0	m
Basal area of trees	0.09	m2/tree
Area density	482.42	trees/ha
Total trees	461193.5	Trees
Volume	293108.9	m3
IFC = V * FEB * D * FCC (V: total volume m3/ha, FEB: Biomass Expansion Factor, D: Wood density, FCC: Biomass conversion to carbon factor ~ 0.5.		
V	306.6	m3/ha
FEB	1.68	adim
Density	0.62	t/m3
FCC	0.5	adim
IFC	**159.2**	t/ha
Price in dollars per tonne of carbon	16.21	USD/t
Value of inventory of services generated	**2,580.63**	USD/ha
Total Value	**$2,467,084.19**	

Flow of Carbon Sequestered Annually by El Bote Forest Reserve		
FFC = IAP * FCV * D * FCC (FFC: Physical flow of carbon (t / ha / year), IAP: Average Annual Increase (m2/ha/an), FCV: volume conversion factor (arithmetic ratio between the volume and basal area of different diameter classes), D: Wood density, FCC: Biomass conversion to carbon factor.		
Annual Increase	2.5	t/ha/year
IAP	0.016	m2/ha/an
FCV	7	m

D	0.62	t/m3
FCC	0.5	
FFC	5.43	t/ha/year
Value of annual flow of inventory of services generated	**88.02**	USD/ha/year
Total Annual Value	**$84,147.41**	

Erosion Control Provided by 956 ha Forest Reserve		
Land inventory (IS: PS * A * DA (Ton / Ha), PS: arable soil depth (m) to area (m2), Yield: Bulk density (t/m3)		
PS	0.2	m
Da	1,350	t/m3
A	10000	m2/ha
IS	2700	t / Ha
Ground flow (E: R * K * LS * C), E: eroded n (Ton/ha/year), R: rainfall and runoff factor, K: soil erodibility factor, L*S: length factor and gradient of the slope, C: coverage factor and crop management.		
R	750,000	
K	0.15	
S	0.57	
L	0.501	
C	0.001	
E	0.032	t/ha/year
Price in dollars per tonne of topsoil	9.207	USD/t
Value of annual erosion control	0.295	USD/ha/year
Total Annual Value	**$282.02**	

Additionally, local families in El Bote rely heavily on local timber resources for fuel and household construction. For families in the upper reaches of the watershed, the community forest reserve periodically provides a source of timber from naturally fallen trees, which ATDER-BL and the community have agreed can be occasionally harvested. ATDER-BL has helped local residents, including Maria Llaguna Picado, pictured below, to reconstruct and improve their homes utilizing this resource, as opposed to felling trees.

Maria Llaguna Picado and family in their house constructed from salvaged downed wood from the forest reserve. Photo Credit: Tim Takaro.

Using the going local market price for timber, the total estimated commercial value of timber within the El Bote Forest Reserve is $21,103,891.20. Our calculation is based on the same volume of wood per ha as in the environmental services calculations above and utilizing local timber prices from ATDER-BL. The total estimated commercial value of the timber within the broader watershed, both the Forest Reserve and on private property (930 ha), is $41,633,827.20.

El Bote Watershed Timber Value					
	Size (ha)	Volume m^3 of wood per ha	Total m^3	Local value of 1 m^3 of wood ($)	Total value of timber ($)
Forested Land on Private Property	930	306.6	285138	$ 72.00	$20,529,936.00
El Bote Forest Reserve	956	306.6	293109.6	$ 72.00	$21,103,891.20
Total Value of Timber in the Watershed					**$41,633,827.20**

It is a testament to the education campaigns conducted by ATDER-BL, and the organization and commitment of the community itself, particularly the volunteer Watershed Management Committee, that despite the high timber prices available for local species, and

continued local demand for timber products, forest land area in the watershed has remained consistent over the last decade. As seen in **Figure 15** and **Figure 16** in Section IV.b.1, in 2013 households maintained over a third of their property as forest—the same as in the year 2000. This local deforestation rate of essentially 0% is even more impressive given that national rates accelerated during 2005-2010, reaching a staggering 2.16% annual deforestation rate.

V.c.2. Environmental Impact

In addition to the varied ecosystem services described above, the El Bote Forest Reserve also harbors a tremendous variety of plant and animal life. To date field research and species inventories to develop an accurate biodiversity count within the reserve itself have been limited. Therefore to assess local biodiversity value, the Center for the Understanding of Nature (CEN) and ATDER-BL relied on data from multiple sources: 1) the Peñas Blancas Natural Reserve and other cloud forests of Northern Nicaragua, whose proximity and similarities to El Bote make them reasonable proxies; 2) samples taken from two different sites within the El Bote forest reserve; and 3) observations of local residents.

The cloud forests of Northern Nicaragua, which include the El Bote forest reserve, are home to the greatest number of endemic plant species in the country—48 different plant species comprising 45.2% of all known endemic plant species in the country. In the region there are 249 plant species that have only been collected once in the Peñas Blancas Massif near El Bote, with another 332 species considered very poorly collected.[24] Within Peñas Blancas, at least 44 trees species (with an additional three species not yet identified), two species of tree ferns, 14 species of edible wild plants and 27 medicinal species have been documented.[25,26] Also documented within Peñas Blancas are 12 species of amphibians, including an endemic salamander (*Oedipinakohleri*), 31 species of reptiles, including four poisonous species, 24 mammal species (excluding mice and bats), and 136 species of birds (19 of which are migratory), belonging to 32 families.[27] Of these bird species, 12 are on the IUCN Red List of Threatened Species under various categories, including the Resplendent Quetzal *(Pharmoachrus mocinno)*.

To better understand the biodiversity value of the El Bote forest reserve, the CEN and ATDER-BL conducted an inventory of forest habitat at two field sites within the reserve. One sample was taken in a mature section of forest at 1099 meters above sea level (masl) and another in a more open section at 737 masl. In the sample plots, 21 and 22 species of trees were documented respectively, with basal areas of 48.18 m^2/ha and 39.3 m^2/ha. The basal area of the mature section of forest (48.18 m^2/ha) is greater than that recorded at a permanent monitoring plot in Peñas Blancas (44.88 m^2/ha), which in turn is greater than

[24] Ruiz, Gutavo Adolfo.
[25] Centro de Entendimiento con la Naturaleza. *Plantas Alimenticias de la Reserva Natural Macizo de Peñas Blancas,* (Managua: Centro de Entendimiento con la Naturaleza, 2013), 92.
[26] Bolt, A. *Algunas plantas medicinales, Área protegida Macizo de Peñas Blancas, BOSAWAS* (Centro de Entendimiento con la Naturaleza, 2013), 121.
[27] Díaz, F. and H. Herrera. *Evaluación del Jaguar y sus Presas, Aves y Tipos de Bosque en la Reserva Natural Macizo de Peñas Blancas, Reserva de BOSAWAS* (Centro de Entendimiento con la Naturaleza, 2012), 56.

documented basal areas for the cloud forests of the Maderas and Mombacho volcanoes.[28] The sample sites also contained three high value trees species: Oak (*Quercus*), Guayabo (*Terminalia amazonia*), and Quebracho (*Cocojobaarborea*). All have high quality timber and therefore high market value. However their genetic value is even greater, guaranteed by centuries of natural selection. 28% and 41% of sapling trees within the sample sites had a diameter at breast height less than or equal to 8 cm, demonstrating significant potential for regeneration.

Interviews with El Bote residents revealed the presence of at least three feline species (including jaguars and pumas) in the surrounding forests. These animals serve to keep herbivore populations in check, preventing excessive depredation of seeds and guaranteeing natural reproduction of the forest. Additionally, their size and solitary nature require extensive territory (upwards of 38 km^2), and therefore their presence is a positive indicator of ecosystem health and confirms the El Bote reserve is indeed functioning as a corridor to other national reserves such as Peñas Blancas, Cerro Kilambe, and the BOSAWAS, as envisioned.

Other unique species were observed in the forest understory. Small frogs including the strawberry poison-dart frog (*Oophaga milio*) breed in the moist pockets of the forest floor. Another resident is the red-headed woodpecker (*Dryocopuslineatus*), which drills holes in search of insects and to create nests. Once abandoned these nests are also used by toucans and quetzals, essential for their reproduction. Indeed the Resplendent Quetzal has been documented in El Bote and is known to nest in the highest and coldest parts of the Peñas Blancas Massif.[29] In April, at the end of the dry season when most of the wild fruits (mainly of the *Lauraceae* family) are depleted, the Quetzals and their young migrate to the lower slopes of the mountains, in search of additional fruits. The presence of these birds in El Bote indicates that these forests are part of their altitudinal migration. The tree species that provide Quetzal habitat are scarce, and their reproductive behavior is increasingly impacted by climate change, threatening their survival and therefore that of the Quetzal as well. These tree species are also highly sought after for their high value timber. Therefore their protection under the El Bote Forest Reserve is critical to ensuring the survival of the Quetzal and other native bird species.

The tremendous quantity and diversity of plant and animal species ostensibly benefiting from the El Bote protected area is one of its most significant contributions to the environmental health of the region. Ensuring habitat for important and threatened species that play a critical role as natural guarantors of broader ecosystem health is particularly valuable.

V.c.3. Challenges

One of the main challenges to establishing and replicating the community forest reserve has been the limited availability of funding for land purchase. International organizations

[28] Ruiz, Gutavo Adolfo.
[29] Ruiz, G.A. *Quetzales en el Macizo de Peñas Blancas: Cuantificación Ecológica Preliminar* (Centro de Entendimiento con la Naturaleza, 2012), 17.

that support land purchase for conservation are declining, with several major organizations such as The Nature Conservancy looking to land easements and other tools as preferable methods.[30] Unlike agroforestry or other multi-use land use practices which provide more direct and tangible user benefits, setting aside large tracts of land devoted purely to conservation is unlikely to be undertaken independently by local residents without financial compensation.

VI) Conclusions

The data gleaned from the interviews, surveys, accounts, site visits, and biodiversity assessments contribute to an overall picture that this integrated project is affecting a variety of socioeconomic and environmental improvements in El Bote, principally by providing clean, reliable electricity, protecting the area's forests and waterways, and enhancing the long-term value and diversity of agricultural production. Several key factors of success can be identified:

VI.a Factors of Success

1) The **long-term** nature of the project, and dedication of ATDER-BL staff and local leaders to carry out the activities, stand out among "development" programs, which often have short time horizons, narrow funding, and high staff turn-over. Project designers had a long-term vision that responded to multiple, interrelated needs of the community. ATDER-BL's long-term presence and follow-through during the early years of the program mobilized local residents and additional resources to bring about change. This commitment has been strengthened by the permanent nature of the hydroelectric facility and the diversification of funding sources for the project with revenue from electricity sales. Having a resident agronomist working side by side with producers on a long-term basis has been essential to the success of the agroforestry program.

2) **Community "buy-in"** has been a critical factor of success. It has been integral to our model to provide education and training so that families can grow sustainably within their existing natural environment, on the land where they currently live, selling just a portion of their property to be permanently protected. The hydroelectric plant was constructed almost entirely by volunteer community labor, and is run by local technicians who were trained to operate and maintain the system. It also helps inspire active community participation in forest and watershed conservation efforts. The direct, tangible link between electricity provision and water resources creates even stronger incentives for protection by local farmers who already have a vested interest in preserving local ecology and resources. Community members contribute on all of the agroforestry projects and share their experiences with each other. Additionally, field visits of community members to other sustainable development initiatives, and hosting visitors in El Bote, has helped the community recognize the value of their work, build self-esteem, and further motivation.

[30] "Land Purchase as a Tool for Conservation,"*World Land Trust.* Date Accessed: Nov 29, 2013. <http://www.worldlandtrust.org/about/how-we-work/policies/land-purchase-policy>

3) The **comprehensive approach** aimed to break the cycle of poverty which was compelling overuse and depletion of the very natural resources El Bote residents depend on for their livelihoods. Demonstrating the inherent interconnection of electricity provision, watershed protection, forest conservation, and income generation garnered an explicit respect for local ecosystems and created mutually reinforcing feedback loops that are the foundation for sustained, long-term impact.

IV.b Challenges

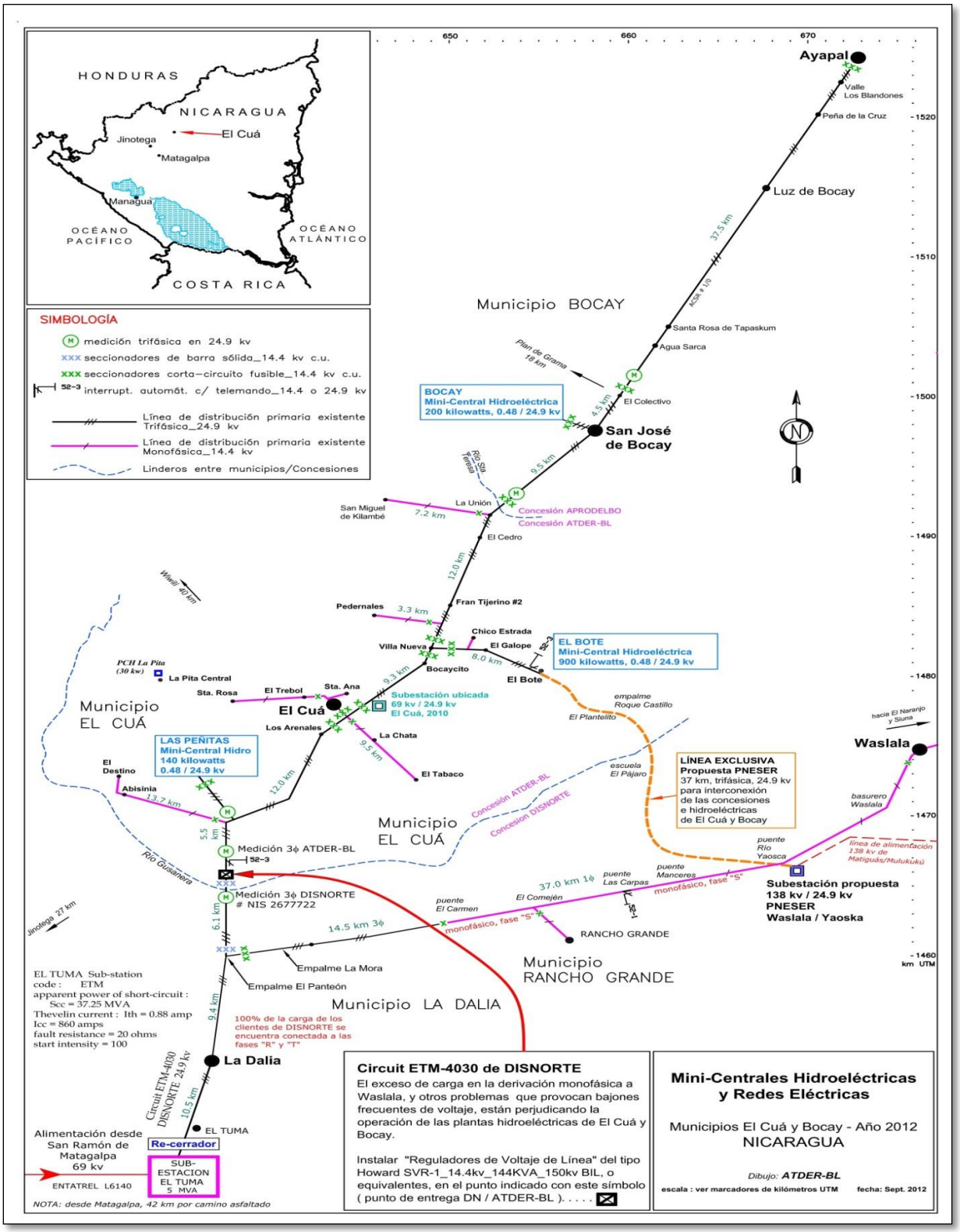
A primary challenge has been the operational and financial complexities of the hydroelectric facility. The significant costs associated with capital depreciation, along with an unsupportive policy and regulatory environment, mean that small electricity concessions such as ATDER-BL will struggle to become financially viable. This has implications for funding other components of the program that are financed by electricity sales, such as the agroforestry activities and land purchase. This is especially critical as international funding for land purchase diminishes. While ultimately the point at which income exceeds expenses appears near, most projects won't benefit from such lengthy time horizons, suggesting that piloting and documenting alternative financial models would be a worthwhile exercise.

Poor data availability, particularly pre-project, made quantitatively documenting impact attributable to the project difficult. While theoretical and anecdotal evidence is strong as to the economic improvement of families and businesses, and the valuable ecosystem services provided by project activities, the extent we were able to quantify and monetize these results was limited by data availability and resources. The valuation of the diverse ecosystem services provided by various project components would particularly benefit from further research and investigation.

IV.c Replicability and Scalability

With the effects of climate change only intensifying, and the world's poor at greatest risk, there is an urgent need for replicable, proven models for advancing economic well-being while minimally contributing to global warming and protecting natural resources for future generations. We feel that the experience of El Bote provides an example of one potential pathway to doing so. There are thousands of micro-hydro projects around the world, but few if any have put as much time and resources into the health of the surrounding watershed and its inhabitants. Further research and investigation could help to demonstrate the true value of ecosystem services generated by these types of comprehensive initiatives. There is great potential for adapting this approach to the needs of other rural communities around the world that confront the interrelated challenges of poverty and environmental degradation.

APPENDIX A


HONDURAS
NICARAGUA
El Cuá
Jinotega
Matagalpa
Managua
OCÉANO PACÍFICO
OCÉANO ATLÁNTICO
COSTA RICA
SIMBOLOGÍA
medición trifásica en 24.9 kv
seccionadores de barra sólida_14.4 kv c.u.
seccionadores corta-circuito fusible_14.4 kv c.u.
interrupt. automát. c/ telemando_14.4 o 24.9 kv
Línea de distribución primaria existente Trifásica_24.9 kv
Línea de distribución primaria existente Monofásica_14.4 kv
Linderos entre municipios/Concesiones
Ayapal
Valle Los Blandones
Peña de la Cruz
Luz de Bocay
37.5 km
Municipio BOCAY
Santa Rosa de Tapaskum
Agua Sarca
Plan de Grama 18 km
El Colectivo
BOCAY Mini-Central Hidroeléctrica 200 kilowatts, 0.48 / 24.9 kv
San José de Bocay
9.5 km
Río Sta. Teresa
La Unión
San Miguel de Kilambé
7.2 km
Concesión APRODELBO
Concesión ATDER-BL
El Cedro
12.0 km
Fran Tijerino #2
Pedernales
3.3 km
Chico Estrada
Villa Nueva
El Galope
EL BOTE Mini-Central Hidroeléctrica 900 kilowatts, 0.48 / 24.9 kv
Bocaycito
8.0 km
El Bote
PCH La Pita (30 kw)
La Pita Central
Sta. Rosa
El Trebol
Sta. Ana
9.3 km
Subestación ubicada 69 kv / 24.9 kv El Cuá, 2010
El Cuá
Municipio EL CUÁ
Los Arenales
La Chata
9.5 km
El Tabaco
empalme Roque Castillo
El Plantelito
escuela El Pájaro
LAS PEÑITAS Mini-Central Hidro 140 kilowatts 0.48 / 24.9 kv
El Destino
Abisinia
13.7 km
12.0 km
5.5 km
Medición 3ϕ ATDER-BL
Río Gusanera
Concesión ATDER-BL
Concesión DISNORTE
Municipio EL CUÁ
LÍNEA EXCLUSIVA Propuesta PNESER 37 km, trifásica, 24.9 kv para interconexión de las concesiones e hidroeléctricas de El Cuá y Bocay
hacia El Naranjo y Siuna
Waslala
basurero Waslala
línea de alimentación 138 kv de Matiguás/Mulukuku
puente Río Yaosca
Subestación propuesta 138 kv / 24.9 kv PNESER Waslala / Yaoska
puente Manceros
puente Las Carpas
37.0 km 1ϕ
monofásico, fase "S"
El Comején
puente El Carmen
RANCHO GRANDE
Medición 3ϕ DISNORTE # NIS 2677722
6.1 km
14.5 km 3ϕ
Empalme La Mora
Empalme El Panteón
Municipio RANCHO GRANDE
Municipio LA DALIA
Jinotega 27 km
Wiwili 40 km
EL TUMA Sub-station
code : ETM
apparent power of short-circuit : Scc = 37.25 MVA
Thevelin current : Ith = 0.88 amp
Icc = 860 amps
fault resistance = 20 ohms
start intensity = 100
100% de la carga de los clientes de DISNORTE se encuentra conectada a las fases "R" y "T"
9.4 km
La Dalia
Circuit ETM-4030 DISNORTE 24.9 kv
10.5 km
EL TUMA
Alimentación desde San Ramón de Matagalpa 69 kv
Re-cerrador
SUB-ESTACION EL TUMA 5 MVA
ENTATREL L6140
NOTA: desde Matagalpa, 42 km por camino asfaltado
Circuit ETM-4030 de DISNORTE
El exceso de carga en la derivación monofásica a Waslala, y otros problemas que provocan bajones frecuentes de voltaje, están perjudicando la operación de las plantas hidroeléctricas de El Cuá y Bocay.
Instalar "Reguladores de Voltaje de Línea" del tipo Howard SVR-1_14.4kv_144KVA_150kv BIL, o equivalentes, en el punto indicado con este símbolo (punto de entrega DN / ATDER-BL). . . . .
Mini-Centrales Hidroeléctricas y Redes Eléctricas
Municipios El Cuá y Bocay - Año 2012
NICARAGUA
Dibujo: ATDER-BL
escala : ver marcadores de kilómetros UTM
fecha: Sept. 2012