



**CATIE** Tropical Agricultural Research  
and Higher Education Center

## **Global Change Group**

### **PROJECT**

**TROPICAL FORESTS AND CLIMATE CHANGE ADAPTATION  
(TROFCCA-Central America)**

**SECOND ANNUAL REPORT  
Period June 2006 – August 2007**



Photo by Carlos J. Perez (February, 2007)



Photo by Carlos J. Perez (June, 2007)

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## **Annual Report - Trofcca Central America June 1<sup>st</sup>, 2006 – August 31<sup>st</sup>, 2007**

### **1. Introduction**

This documents reports activities and progress achieved by the Project Tropical Forests and Climate Change Adaptation –Trofcca- in Central America, during the period from June 2006 – August 2007. The corresponding financial report covers the period from August 2006 – August 2007. Following the agreements reached during the general meeting in Indonesia in April 2007, it is expected that for Year III both reports, the narrative and financial, will cover the same period.

In Central America, climate change and climate variability are expected to have an impact in several socio-economic sectors. Water resources will not escape the effects of these impacts. The vulnerability of the population and sectors depending on water sources for their sustainability will be a function of the sensibility of the water resources and the adaptive capacity of the population or sectors. Forest ecosystems and other land uses provide different ecosystem goods and services to water users. Determining the location and extent of different land uses and their provision of ecosystem services is relevant for designing adaptation policies and strategies. Trofcca decided to conduct investigations on the relevance of forest ecosystems as providers of goods and ecosystems services through a meta-analysis, and studies at the national level on two key socio-economic sectors (drinking water and hydroelectric power). These sectors were selected during the Regional Kick Off meeting performed in April 2006.

The strategy followed by the Project to conduct the studies has included the invitation to graduate students to conduct the studies under the supervision of scientific advisors working in CATIE and other institutions of higher education. Consultants are also hired for specific studies in highly specialized subjects (i.e., the energy sector in Central America). In the case of Nicaragua, two M. Sc. graduate students from CATIE were in charge of conducting studies to identify tropical forests providing ecosystem services to hydropower and drinking water sectors. A similar approach was used in Honduras, where a single M. Sc. from the National Autonomous University conducted research under a collaboration agreement between Trofcca and that education center.

The products generated by Trofcca C.A. during this period are varied. For our purposes, we are considering products the following: thesis finalized by M. Sc. or Ph.D. level students; reports from consultancies; articles that have been either submitted or accepted in regional or international journals. When appropriate, these products have been uploaded in the website of Trofcca being managed either by CIFOR or by CATIE. An effort has been made to provide a summary of each of the products available during this reporting period.

### **2. Trofcca Staff Meetings**

During this period, Trofcca staff members from the different regions (South East Asia, Central America and West Africa) were mobilized across regions to either attend kick-off meetings or to participate in staff discussions on methodological issues.

**The kick-off meeting of Trofcca in West Africa was organized from 5 – 9 of June 2006 in Ouagadougou, Burkina Faso.** The three regional coordinators and the Global Trofcca Coordinator were invited to participate. The agenda included the contribution of each regional coordinator to the different kick-off meeting activities and the participation in a field visit to farmers in the Sahel, and forest south of Ouagadougou, where there is a Project executed by the state to extract firewood from a forest ecosystem of 20,000 ha. The state forestry office has designed a cycle of extraction of 15 years. It is unknown if this forest will be able to recover after 15 years.

At the end of the kick-off meeting the topics selected for Trofcca's activities in the region were: water, bio-energy and food security. From the field visit in Burkina Faso, it could be observed the potential effects of drought on agriculture and the reposition of trees for fuel wood. It became apparent that the work for Trofcca in West Africa is very challenging. However, since there is a forest gradient coming from Ghana to Burkina and then to Mali, this could provide Trofcca in the region with an excellent ground for its research agenda.

Despite the challenges posed by climate factors in the region, during the field visit we could observe several tree species that survived very well the dry season (8 – 9 months / year); the following species were observed green and shiny: mangoes, Karite, neem, mahogany, *Cassia siamea*, acacia, among others. It is likely that soil and water conservation programs are sorely needed in the region for food security and to slow down the needs from farmers and villagers to depend on fuel wood to survive.

Additionally, this visit of all three regional coordinators, created the opportunity for a planning meeting including Trofcca staff from West Africa, the global coordinator, the Regional Coordinator of Trofcca in Indonesia and the homologue from Central America.

**Trofcca staff members from the three regions were invited to participate in the Regional Workshop organized by CIFOR in April 2007, Bogor, Indonesia.** The primary goal of this meeting was to review the approaches, methods and tools in the methodologies being elaborated by each region. The primary concern was to share methodologies used for vulnerability assessments of the selected sectors, which were determined during the regional kick-off meetings. The workshop also provided the opportunity for planning for CoP13, to be held in Bali, Indonesia in December 2007, and explore ways of increasing/improving current activities and visibility of the project. While all staff members were invited to participate physically, it was decided that the videoconference technology would be used by members of the team from Central America and those participating directly in the workshop, mainly to reduce GHG emissions and to reduce travel costs. The technology worked, thus creating a precedent on how to reduce travel costs. It was cheaper to acquire the videoconference equipment than the investment that otherwise would have been needed in travel.

From the side of Trofcca Central America, a presentation was made on the research activities undertaken by the team in the region. It was stressed that Trofcca C.A. is working on three main subjects: Identification of forest ecosystems relevant for socio-economic sectors, mainly drinking water and hydroelectric power generation; Assessing the vulnerability and impact of CC on forests; and the role of society on adaptive management of forests. Regarding the identification of forest ecosystems relevant for the drinking water and hydroelectric sectors, at the time of the workshop,

progress has been made in completing the work in Nicaragua; by May 2007, the work will be completed for Honduras and Costa Rica.

The subject on vulnerability and impact of CC on forest ecosystems, Trofcca C.A. is working three main subjects: i) Climate change and its effect on hydrological services of forests in Central America (Pablo Imbach presented the methodology of this study); ii) CC and the dynamics of forests pests, taking the Pine-Bark Beetle as a system, taking the examples of Nicaragua and Honduras (Carlos J. Perez presented the methodology guidelines of this study); iii) CC and its effects on the dynamics of forest fires in Central America (Bruno Locatelli presented the methodological aspects of this study which will begin in July 2007); and iv) CC and shifts on optimal zones for commercial forest plantations (Pablo Imbach presented the methodology of this study). Within this subject, a literature review was conducted on the relationship of forest and water and a meta-analysis on forests and hydrological services.

In the case of the third subject, five main activities are being undertaken by Trofcca C.A.: i) The improvement of Payment for Ecosystem Services for hydroelectric power generation including different land uses (forests, agriculture, agro-forestry and pasturelands); ii) Network analysis of institutions and policy design, looking at opportunities for mainstreaming adaptation in the development agenda; iii) Community based adaptation through PES at the local level to promote assisted forest regeneration; and iv) Changes in ecosystem services and the reaction of society towards those changes.

The reaction from colleagues from other regions (i.e., Johnson Nkem) were that it would be interesting to also conduct research on forest insect pests and forest fires in West Africa. In Indonesia, some work has been conducted by CIFOR on forest fires, and is part of the agenda of Trofcca in Indonesia. One subject that seems common to Central America and West Africa is that on hydrological services of forest ecosystems. However, it is not clear if methodologies can be extrapolated. Another subject with common interest, at least in Central America and West Africa is that on policy network analysis to mainstream adaptation into the national development agenda.

A high interest was expressed by other colleagues regarding the studies on identification of relevant forest ecosystems for hydroelectric power generation. According to Heru Santoso and Johnson Nkem, this has become a sector of major interest in all regions due to potential vulnerability of the sector to CC and social interventions (i.e., communities and agricultural producers are placed in the upper watersheds, thus contributing to sediments in the dams). It is possible that CIFOR and CATIE undertake some initiatives on this subject.

**The regional workshop on “Decision making and policy networks in forestry-dependent development sectors: mainstreaming adaptation to climate change into policy”. This was held in Ouagadougou, Burkina Faso, from 14 – 19 of May 2007.** Trofcca’s general goal is to integrate climate change adaptation into policies for development in the countries of intervention. This goal requires an understanding of the policy arena to effectively achieve this aim, and also, to develop a methodology that could eventually be used for adaptation to climate change in other areas of interest. This workshop in Ouagadougou aimed at conducting an open discussion and harmonization of the conceptual approach in policy research, and a revision of the methodologies, techniques and variables that will be used for data collection and analysis. Since West Africa and Central America

are engaged in this type of analysis, it is feasible to conduct a comparative analysis across countries and across regions. The staff of Trofcca C.A. was represented by Raffaele Vignola, who will start field research activities during the second semester of 2007, while Maria Brockhaus and Kalame Fobissie did it for Trofcca West Africa. It is expected that field work will be conducted in both regions during 2008. The methodology requires existing data on the bio-physical and the socio-economic vulnerability assessment which are currently on-going. A full report is available containing the conceptual framework and the elements for elaborating the methodology in each region.

### 3. Collaboration with partners

**Collaboration between Trofcca & IUCN to improve a payment for ecosystem services in Costa Rica in the hydro energy sector.** Hydropower production in Costa Rica represents almost 80% of energy source. This type of energy production depends strongly on the hydrological dynamics in the watersheds. In this respect the most relevant environmental pressures occurring upstream are climate and land use. Indeed, observed (Aguilar et al. 2005) and projected (Hulme, 2005) climate change in the region identifies increasing occurrence of precipitation extremes and also of the amount of rainfall per event. This hydrological dynamic combines with land use change and land management practices in upstream landscapes to determine the level of current land degradation. In this respect, Trofcca, in collaboration with the National Institute for Hydroelectricity (ICE), identified a case study of relevance in the Reventazon Watershed, where 30% of hydroelectric power for Costa Rica is generated. This case study has been co-financed by the Fund for Environmental Policy of IUCN-Mesoamerica. The goal is to contribute to local and national discussion on a Payment for Ecosystem Services scheme that would benefit both the demand (e.g., from downstream Hydropower plants) and the supply (upstream land users and forest owners) of hydrological services. The project is exploring the utility function of supply and demand of hydrological services to design a sustainable financing scheme for erosion and sediment transport control. This action entails a series of activities that include the systematization of existing information from the watershed, understanding technology adoption and current land management practices, and several policy dialogue meetings with stakeholders. Although activities have started during the first semester, most of the results will be coming out during the second semester 2007 and first trimester 2008. Trofcca assigned the coordination of this study to Raffaele Vignola.

**Collaboration Trofcca – Both ENDS for community based adaptation documentation.** In February 2007, Trofcca C.A. and Both ENDS<sup>1</sup> joint efforts to systematize a local experience of community based adaptation to climate variability and change in agriculture and water resources in the dry tropics of Nicaragua. This experience emphasizes the importance of forest ecosystem restoration for improving resilience in agriculture and water resources. The case refers to the municipality of San Pedro del Norte, in northern Nicaragua, located in the dry tropics of Central America. The study included a revision of the information available from key documents in the municipality of San Pedro del Norte, and documents and references published elsewhere. Additionally, three meetings (workshops) were organized during the third week of February 2007: i) with farmers acting as suppliers of ecosystem services; ii) the water users as part of the demand for

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<sup>1</sup> Both ENDS is a non-governmental organization from the Netherlands working on Environment and Development Service; more information from [www.bothends.org](http://www.bothends.org)

those services; and iii) local authorities. Questionnaires in the three meetings were directed toward fact finding in the subject of past, present and future climate related risks, and natural resources management. Also, a joint analysis was performed of local and national policies influencing local adaptive capacity.

In San Pedro del Norte (SPN) several climate extreme events, such as Hurricane Mitch and various episodes of droughts have caused major socio-economic damages. Droughts are recurrent climate events that have affected agricultural production and water availability, particularly for the urban population. Upon the drought of 2001, authorities decided to implement a pilot project on payment for ecosystem services to restore vegetation in a micro watershed. Since 2003, negotiations with upstream farmers have induced natural forest regeneration in 13 ha, and the introduction of other soil and water conservation practices such as stone ditches and stone rows. Additionally, there has been a horizontal (farmer to farmer) discussion on the importance of not practicing slash-and-burn for land clearing before planting food crops. A new Municipal Environmental Ordinance was approved in August 2006, with special consideration of forest fire avoidance, and the acquisition of slash-and-burn permits by farmers. The reduction of land degradation and ecosystem restoration is at the top of a list of measures to ensure water resources conservation and management.

The local scheme of payment for ecosystem services has strengthened local organizational capacity, and other inter-institutional links that are favorable towards increasing social capital. Overall, resilience to climate variability is improving but resources (financial and human) are still short compared to the investments stated in the Municipal Development Plan. Inter-institutional coordination will be highly important to have better chances of policy changes at the national level, to call the attention of national institutions to invest more resources in the area to enhance infrastructure, technical assistance and improve the current policy for transferring funds from the national treasury to municipalities. Climate change scenarios officially reported suggest that the area will be drier and hotter, increasing the risks of food security and water availability. Climate variability and climate change should be integrated into local and national policies, prioritizing those areas like SPN that are located in the Pacific Basin, and with similar projections of climate change and climate variability. A major challenge will be to access funds at the international level to invest in improving resistance and resilience to climate related risks. The local experience of payment for ecosystem services has proven to be an effective way promoting forest regeneration. Additionally, hillside farmers are planting trees for forage and seeds as food source. Both ENDS is considering this and other nine local experiences to contribute to the international dialogue on adaptation policies.

**A Workshop on Adaptation to Climate Change in the Hydroelectric, Water and Agricultural Sectors was organized in Nicaragua on November 30, 2006.** Participants to this workshop were representing the National Office for Clean Development Mechanism and Climate Change -ONDL- and from the National Energy Commission –NEC-.

Three presentations were performed by Trofcca- project, and one from a representative of the ONDL: i) Identification of forest ecosystems relevant for climate change adaptation of the hydroelectric power sector of Nicaragua; ii) Identification of forest ecosystems relevant for climate change adaptation of the drinking water sector of Nicaragua; iii) A methodological proposal to evaluate farmer's adaptation to climate variability, mainly drought, in watersheds of Central

America; and iv) The preparation and content of the II National Communication to the UNFCCC by Dr. Freddy Picado from ONDL.

For Trofcca it was very important to hear the comments from the representatives of ONDL and NEC. For the work conducted by Efrain Leguia, comments were very positive and of high value for a socioeconomic sector that is being highly prioritized by the Nicaraguan government. The conclusion was that the work on identification of forest ecosystems relevant for the hydroelectric sector could become part of the Adaptation Strategy of the sector, and should become part of the II National Communication. For the representative from the NEC, it was very clear that the management plans of the upper watersheds were highly important, and added that every hydroelectric project, actual or future, should integrate the importance of forest landscapes ecosystem services and implement the ecosystem's management plans. The work performed by Cliserio González was also of high interest for the II National Communication because drinking water is a strategic sector, and is linked to the Millennium Development Goals. For the representatives of ONDL this work is innovative in Central America and should be integrated into the II National Communication to the UNFCCC before March 2008 when the document is due.

**In Costa Rica, a Workshop on Adaptation to Climate Change was organized jointly between Trofcca C.A. and the National Meteorological Institute (NMI), on December 13, 2006, in San José.** Participants to the workshop were invited by NMI, representing the National Fund for Forest Financing (FONAFIFO), the Costa Rican Electricity Institute (ICE), the Institute for Biodiversity Conservation (INBIO), and NMI. Two presentations were performed by Trofcca-project: i) Identification of forest ecosystems relevant for climate change adaptation of the hydroelectric power sector of Nicaragua; and ii) Identification of forest ecosystems relevant for climate change adaptation of the drinking water sector of Nicaragua. The study on identification of forest ecosystems relevant for the provision of ecosystem services to the hydroelectric sector is highly relevant and could eventually become an important tool for ICE. In Costa Rica, 80% or more of the electric power is generated by hydroelectric plants and upper watersheds need to be managed adequately to enhance or maintain the provision of ecosystem services. For the work that will be done in Costa Rica, ICE could provide the information that ICE has already available and hence facilitating the work that Trofcca will perform in the country. The representatives from ICE requested another presentation of Trofcca's work in January 2007, for ICE's personnel. For the representatives of FONAFIFO, the studies presented, particularly the methodology, are quite relevant because the institution will be in charge of assigning financial resources for forest ecosystem management under a scheme of Payment for Ecosystem Services. The water tax in Costa Rica will soon be implemented and a study like the one presented by Trofcca is quite relevant. FONAFIFO is willing to provide Trofcca with information for the work that will be executed and concluded during the first trimester 2007 for this country.

**Also in Costa Rica, the meeting with Trofcca requested by ICE personnel during the workshop at NMI (see above) was finally organized at ICE's Office in San Jose on January 18, 2007.** This meeting had two major objectives: i) To inform ICE staff on the work that Trofcca is doing concerning tropical forests and climate change adaptation, and the relevance of ecosystem services provided by forests to the hydroelectric sector in Central America; and ii) Upon sharing the work of Trofcca in Nicaragua, obtain ICE's support to gather relevant and reliable data for the study in Costa Rica that would be conducted during the I semester of 2007. Presentations from the Trofcca side were: i) An overview of Trofcca, its approach and lines of research by Carlos J. Perez, Regional

Coordinator in Central America; ii) Identification of forest ecosystems relevant for climate change adaptation of the hydroelectric power sector of Nicaragua; its application in Costa Rica and information needed; and iii) Contribution of Trofcca to the design of a Payment for Ecosystem Services in the Reventazon Watershed involving various soil uses and various actors (CATIE, Trofcca, ICE and UMCRE). The latter has already been discussed elsewhere in this report.

The work performed by Trofcca in Nicaragua and the progress done in Costa Rica was welcomed by most participants that work in the hydrology department. One of the most important aspects of this interest was the letter sent by Mr. Carlos Obregon Quezada the Vice President of ICE, to welcome Trofcca's work and offer the support from the institution when requested.

Following the above meetings, the NMI has invited Trofcca to three meetings on adaptation to climate change in the water resources sector. It's also relevant to mention that in Costa Rica is where the government is more advanced in policies towards climate change mitigation and adaptation, and is reflected in the national development plans. NMI, IUCN and ICE have become major partners for Trofcca in this country.

**In Honduras, a workshop was organized jointly between Trofcca and the National Program on Climate Change from the Ministry of Natural Resources and the Environment, in Tegucigalpa, on February 27 – 28, 2007.** The main objective of this workshop was to present Trofcca's results in Honduras, and perform an analysis with participants of the relevance of the findings. Two presentations were performed by Trofcca: i) An overview of Trofcca and the research being conducted in Honduras and other countries, and ii) the results of the study on "Identification of forest ecosystems providing services to hydroelectric and drinking water sectors in Honduras" (see above). Attendants to this event were representing the Ministry of Natural Resources and the Environment (SERNA), the National Service on Drinking Water and Sanitation (SANAA), the National Forestry Corporation (COHDEFOR), and the National Electricity Enterprise (ENEE). Participants welcomed the results of the work performed by Trofcca and there was consensus that both sectors are dependent on ecosystem services provided by forests. However, it also became apparent that the information on forest cover and land use was not up-to-date. This discussion was relevant because the representatives from COHDEFOR took note of the relevance of performing an inventory of forest cover and land use at least every five years. It was also important that the representative from SERNA and the National Program on Climate Change agreed to integrate these results into the II National Communication to the UNFCCC, which is in preparation and should be delivered in 2008. Another important partner in Honduras is the National Autonomous University, particularly the Latin American Program for Social Studies.

**Trofcca contributes to mainstreaming climate change adaptation in the regional agenda.** The Ministries of Agriculture, Health and Environment have agreed upon an initiative to design and implement the Agro-environmental Regional Strategy (ARS). The definition of "agro-environmental" includes agriculture and forests, and the corresponding links between agricultural sector, environment and health. The ARS initiative aims at developing a regional agenda on four main subjects: i) Sustainable Land Management; ii) Climate change and climate variability; iii) Biodiversity; and iv) Markets for agricultural and forest products with an ecological label. There are several organizations contributing to the design of the ARS: The Central American Commission on Environment and Development (CCAD), The Regional Council on Agriculture (CAC), the Inter-American Institute for Agricultural Cooperation (IICA), the Tropical Center for Agricultural

Research and Higher Education (CATIE), FAO, the Regional Unit for Technical Assistance from the World Bank (RUTA), The Global Mechanism, International Union for Conservation of Nature (IUCN), and others. All these institutions have been organized into the Inter-Agency Consultative Committee (IACC) to which CATIE is a member. The Regional Coordinator of Trofcca joined the efforts made by CATIE to contribute with two subjects: climate change and climate variability. One first presentation was made during the meeting of the IACC meeting of July, where the subject of climate change and climate variability was first introduced, and was scheduled for an additional presentation in September 2007, during the first meeting of representatives of the ministries of agriculture, environment and health from the seven countries of Central America. Trofcca will continue to support this effort and contribute to the design of the ARS which will include climate change and climate variability at the highest level in the region.

**The VI Inter-American Dialogue on Water Management (6-IDWM) was held in Guatemala City, Guatemala from August 12 – 17, 2007.** Participants to this event come from almost every country in Latin America and the Caribbean. Subjects covered include: people and water; water, environment and climate change; water, economy and commerce; sustainable use of water; Infrastructure, technology and services related to water.

The Project Tropical Forests and Climate Change Adaptation –Trofcca- was invited to give a conference on tropical forests and water. The presentation emphasized the research agenda covered by the project on hydrological ecosystem services provided by tropical forests to relevant socio-economic sectors (drinking water and hydroelectric power generation). It was also stressed the vulnerability of forest ecosystems to climate change, that will be noticed as an increased observation of insect pest outbreaks, increase occurrence of forest fires, and projected shifts of optimal zones for certain forest species of commercial value. Trofcca's contribution to this 6-IDWM reinforced the science side of adaptation of water resources to climate change, within the frame of the session entitled "Adapting to climate change" held during the 12 and 13 of August. Presentations during this session covered the climate change scenarios for Central America, new initiatives on the science of water resources and CC, and two cases of national strategies (NSCC): one case presented by the Minister of the Environment and Energy (MINAE) of Costa Rica and the CC Commission from Mexico who is also a member of IPCC.

The case of Costa Rica was particularly relevant for the audience because it showed a clear link between science and policy. The President and Ministers have decided that the country will become Carbon-neutral by 2020. The political will to integrate climate change mitigation and adaptation into the National Development Plan was clear. It was particularly relevant that the NSCC of Costa Rica shows specific financial mechanisms to implement adaptation measures for water resources management. This mechanism includes management of forest ecosystems providing hydrological services for water resources. Trofcca's participation in this event brings guidance for better direction of the research agenda in the region. Additionally, the experiences from Costa Rica and Mexico provide good elements to support other countries that are willing to design their own NSCC. One aspect that was pointed out by most of the almost 100 participants was the fact that communication to the public on climate change matters is very poor and actions have to be taken immediately to improve building bridges between science and the public. It was also welcomed the participation of several journalists who also mentioned that need training on the subject of climate change mitigation and adaptation to better address the problem in their countries. In the future, Trofcca also will need to design and implement a strategy to communicate its results to a wider audience.

## 4. Program of activities

### 4.1 Research Activities and Progress

During this period, Trofcca devoted efforts to conduct research in two ways. First, it is very important for the Project to achieve a better understanding of the relationship between forest and water. Thus, an in-depth analysis of the existing literature on the relationship between forest and hydrological ecosystem services was conducted applying a methodological approach leading to a meta-analysis. Second, another study was conducted through a consultancy to better understand the electric sector, with an emphasis on hydroelectric power generation and the opportunities for Trofcca. A position article was also written in order to have a better understanding of the vulnerability of forests to CC and potential adaptive management. The summaries of the results of these studies are shown in **Annex 1**.

Also, Trofcca C.A. made progress in conducting research in three lines of actions: i) Identifying forest ecosystems that are important for the drinking water and hydroelectric power sectors. In **Annex 2** are summarized the efforts on validation of methodologies for identification of forest ecosystem that provide services to hydroelectric power and drinking water sectors, and contribute to climate change adaptation in the corresponding sectors.

ii) For determining the vulnerability of forest ecosystems to climate change, the focus was on three areas of research: i) Understanding potential ecological shifts that may affect competitiveness of the timber industry; ii) Studying the dynamics of insect pest outbreaks and forest fires under varying climate parameters and host conditions. In **Annex 3** are the summaries of studies being conducted to better understand the vulnerability of forest to CC, either through shifts in ecological conditions; disturbances to forests, such as insect pests or forest fires; and the threat to hydrological ecosystem services.

iii) The third line of action for Trofcca C.A. is “strengthening participation of society in adaptation”. This aims at performing a series of studies to better understand the underlying mechanisms to involve society into adaptation activities. The strategy that Trofcca is implementing includes research in territories by selecting case studies, in-depth policy network analysis in selected socio-economic sectors and an analysis of current mechanisms of payment for ecosystems services as valuable tools to enhance adaptive forest ecosystem management from the perspective of society. The progress within this line of action is summarized in **Annex 4**.

### 4.2 Outreach activities

**RIOCC, October 2006.** The Project Trofcca (Represented by the Regional Coordinator in C.A.) participated in the 3rd annual meeting of the Ibero-american Network of Offices of Climate Change (RIOCC), organized by the Ministry of the Environment from Spain in Santa Cruz de la Sierra (Bolivia), from 4 – 6 October 2006. This event was attended by representatives from the climate change offices and programs from most Latin-American countries. RIOCC is considered a platform

that allows the exchange of experiences; disseminate information concerning current projects and programs in any of the countries; and the formulation of position documents that are eventually brought to the Convention of the Parties. Trofcca was presented in plenary session and was welcomed by the audience. Studies conducted under the Ibero-american Program for Climate Change (PIACC), conducted by the Spanish Ministry of the Environment, came to the conclusion that agriculture, water resources and health are the most vulnerable sectors to climate change. Other sectors considered vulnerable are: forestry, coastal areas, energy, biodiversity, and others. During March 2007, the RIOCC called for a revision of Chapter 20, section 20.8.1, page 32, of the IPCC WG2 which would meet in Brussels 2-5 April 2007. Trofcca C.A. sent its contributions to this revision. A similar meeting is expected sometime in October 2007.

**AEA, October 2006.** Another presentation on the “Importance of forest ecosystem services for the hydroelectric power sector” was given by Trofcca C.A. Regional Coordinator during the “Meeting of the European Union and Latin-America on Renewable Energy”, organized by the Central America Alliance on Energy and Environment”, in Panama City, Panama, from 9 – 11 October 2006. Several leaders of the energy sector throughout Central America and South America attended to this meeting. During the course of the event, it was observed that the interest on bio-fuels is very strong, and that in Central America, there is a strong interest to increase the generation potential of renewable energy, mainly hydropower, followed by geothermal and wind power. It was concluded that the selection of the hydropower sector as an area of research for Trofcca in the region was appropriate, given the strategic significance of this sector and its connection with forest ecosystem services. Additionally, the strong interest on bio-fuels (ethanol, biodiesel) may become stressful for forest ecosystems if the areas planted to sugar cane, oil palm, or other crops, are to be expanded in the region. Planning will be critical to avoid effects on food crops and forest ecosystems providing ecosystem services to society.

**CoP 12, November 2006.** The Regional Coordinator of Trofcca C.A. was assigned by the Global Change Group of CATIE to attend the CoP 12 in Kenya Nairobi, held from November 6 through 17, 2006, more precisely, attendance was from 8-13 November. Trofcca C.A. participated more actively during the side event on “*Development and Adaptation Days*”, organized by the International Institute for Development Economics (IIED) and took place during the weekend of the 11 and 12 November. The presentation by Trofcca C.A. was entitled “**Importance of Tropical Forest Ecosystems for Climate Change Adaptation in two socio-economic sectors: drinking water and hydroelectric power generation**”. Following is the quotation published by the International Institute for Sustainable Development -IISD- reporters in the Development and Adaptation Days Bulletin Vol. 99, No.3, Tuesday, 14 November 2006. Or the IISD website <http://www.iisd.ca/climate/cop12/DAD/> Quote: “Carlos Perez, Tropical Agricultural Research and Higher Education Center (CATIE), Costa Rica, presented a project on tropical forests and adaptation taking place in Asia, Central America and West Africa. He stressed the increasing importance of hydroelectric power generation given the high cost of oil, adding that hydroelectricity potential in Central America is relatively high, therefore making it critical to manage water sources. He said that ecosystem services, such as regulation of water flows and soil erosion reduction, and identification of relevant forest ecosystems are crucial for adaptation. In conclusion, he stressed: the increasing importance of hydroelectric power generation; the importance of forest ecosystems services; reduced water availability resulting from climate change; the need for adaptive management and financial mechanisms for implementation (of adaptive management); and forests as key to carbon sinks and adaptation”.

### 4.3 Capacity Building

**Raffaele Vignola represented Trofcca C.A. during the II International Latinamerican Congress on Forestry and Policies, organized by the group IUFRO/INFOR/FAO, in La Serena, Chile, from 18 – 25 October 2006.** The aim of Trofcca's participation was to acquire background information and elements that are critical to mainstreaming adaptive forest management into the climate change adaptation policies. Trofcca's research on forests and climate change should be socialized at different stages of the research and not wait until the end. Identifying appropriate hubs or platforms for delivery of the scientific information is critical to making the linkage between science and policy design. This conference was key to strengthening the decision of Trofcca C.A. to go into policy network analysis as an essential component of the research agenda.

#### **Developing strong links with higher education centers from Switzerland and Netherlands.**

Over all, Trofcca's research on policy network analysis for mainstreaming adaptation to climate change has required in-depth capacity building and discussions. Besides the participation of R. Vignola in the II International Latin-American Congress of Forestry and Policies (see above), additional actions on capacity building within the subject required the participation in meetings at the Institute for Environmental Decision-Making, ETH –Zurich, Switzerland, from 20 to 23 of June 2007, and the participation on the “Conference on Earth System Governance: theories and strategies for sustainability”, held in the University of Amsterdam, the Netherlands from 24 – 26 May 2007. Trofcca's participation in these two higher education centers has allowed developing instruments for surveys in the upper watershed of the Reventazon watershed in Costa Rica, where the project, in collaboration with IUCN is conducting research for the improvement of a payment for ecosystem service. One relevant outcome of the above participation is the participation of at least three professors from the ETH-Zurich in the policy network research in Reventazon watershed for hydroelectric power generation with application of innovative payment for ecosystem services.

**Two members of the Trofcca staff in C.A. (Pablo Imbach and Bruno Locatelli) represented the Project during the workshop “Tropical Forests & Climate Change”, organized by the Group on Forest Ecosystems of Public Interest, within the School of Forestry in Montpellier, France, from 19 – 27 May 2007.** Subjects covered of great relevance for Trofcca's activities, were (but not limited to): water cycle and carbon; remote sensing techniques for ecosystem studies; current knowledge on past, present and future climate scenarios for tropical forests in Latin-America and the Caribbean and Africa; and several aspects of tropical forest management. Attendance to this workshop was relevant to better design the methodology that Trofcca C.A. will design for research on forest ecosystems and hydrological services under climate change. Contacts were made with other scientists from the forest sector of France and the possibility came apparent to organize a workshop like this in Central America in the future, under collaborative efforts between Trofcca C.A. and ECOFOR. This remains to be decided.

## 5. Products

Below is a matrix summarizing the products (Articles, thesis and reports) that have been prepared with the support of Trofcca C.A., and the corresponding status of the document.

<b>Document title</b> (titles in original language)	<b>Author (s)</b>	<b>Date due</b>	<b>Status</b>	<b>Contribution of the product to working package (WP)</b>	<b>Potential user of product</b>
<b>Thesis:</b> Identificación de bosques importantes para la adaptación del sector agua potable en Nicaragua	Cliserio González	December 2007	Available online in CATIE's library	WP3	- Drinking water enterprises at the national or municipal levels in Nicaragua - The National Office for Climate Change, for the II National Communication to the UNFCCC
<b>Article:</b> Identificación de bosques importantes para la adaptación del sector agua potable en Nicaragua	González, C. Locatelli, B. Imbach, P. Vignola, R. Perez, C. J.	March 2007	Submitted to the Journal of Natural Resources and Environment from CATIE	WP3	The scientific community
<b>Thesis:</b> Identificación de bosques importantes para la adaptación del sector energía hidroeléctrica en Nicaragua	Efraín Leguía	December 2007	Available online in CATIE's library	WP3	- The Ministry of Energy of Nicaragua - The National Office for Climate Change, for the II National Communication to the UNFCCC

<b>Article:</b> Identificación de bosques importantes para la adaptación del sector energía hidroeléctrica en Nicaragua	Leguía, E. Locatelli, B. Imbach, P. Vignola, R. Pérez, C. J.	March 2007	Submitted to the Journal of Natural Resources and Environment from CATIE	WP3	The scientific community
<b>Consultancy report:</b> Sector eléctrico e hidroeléctricidad en América Central	Oscar Coto, Ph.D.	September 2006	Available online	WP5	Useful for Trofcca's orientation in the region
<b>Thesis:</b> Identificación de bosques importantes para la adaptación del sector hidroeléctrico y agua potable en Honduras	Najarro, Tania	June 2007	In review	WP3	<ul style="list-style-type: none"> <li>- The National Drinking Water Enterprise, The Ministry of Environment and Natural Resources</li> <li>- The National Office for Climate Change, for the II National Communication to the UNFCCC</li> </ul>
<b>Report:</b> Zonas edafoclimáticas aptas para especies forestales bajo escenarios de cambio climático: un estudio de caso en Costa Rica	Cervi Ferez, Ana Paula	January 2007	In review	WP1	<ul style="list-style-type: none"> <li>- Forest enterprises or farmers' organizations</li> <li>- Extension agents</li> <li>- FONAFIFO</li> </ul>
<b>Report:</b> Bosques e hidroenergía en Costa Rica	Leguía, E. Locatelli, B. Imbach, P.	June 2007	In final review before up loading online	WP3	<ul style="list-style-type: none"> <li>- FONAFIFO</li> <li>- ICE and others within the hydroelectric power sector</li> <li>- MINAE: Ministry of Environment and Energy</li> </ul>

<b>Article:</b> Importancia de los bosques tropicales en las políticas de adaptación al cambio climático	C. J. Pérez B. Locatelli R. Vignola P. Imbach	May 2007	Submitted to the Journal of Natural Resources and Environment from CATIE	WP4	The scientific community
<b>Article:</b> Forest hydrological services in developing countries: the need for more science (results from a meta-analysis)	Locatelli, B. Vignola, R.	May 2007	In final review before submission to Forest, Policy and Economics	WP4	The scientific community
<b>Article:</b> Spatial priorities for the payment for ecosystem services (PES) in Costa Rica	Imbach, P. Pedroni, L. Koellner, T.	May 2007	Submitted to the Journal of Land Use Policy	WP3	- FONAFIFO - MINAE
<b>Report:</b> Community based adaptation in the dry tropics of Central America	Perez, C.J. Vignola, R. Perez E., H.	April 2007	Prepared for an international position paper on community based adaptation	WP2	- Both ENDS - International Community working in CC impact on livelihoods at the local level

## 6. Staff devoted to activities of Trofcca in Central America

<b>Name of Trofcca personnel</b>	<b>Activities during 2006 – 2007</b>	<b>Comments</b>
Ana Paula Cervi Ferez	Conducted research on Optimal soil and climatic conditions for forest species of commercial interest under CC scenarios	Exchange student from the University of Sao Paulo, Brazil
Andrea Cedeño	Global Change Group Administrator	Works 50% for Trofcca
Ligia Pérez	Global Change Group Secretary	Works 50% for Trofcca
Tania Najarro	Conducted research in Honduras to identify forest ecosystem relevant for the hydroelectric and drinking water sectors	M. Sc. Student at the National Autonomous University in Honduras
Angela Díaz	Conducted research in Costa Rica, on determinants of societies' adaptation	M. Sc. Degree student in CATIE
Cliserio González	Conducted research in Nicaragua and Costa Rica on forest ecosystems relevant for the drinking water sector	M. Sc. Degree student in CATIE
Efraín Leguía	Conducted research in Nicaragua and Costa Rica on forest ecosystems relevant for the drinking water sector	M. Sc. Degree student in CATIE
Milton Rivera Rojas	Conducted research in Nicaragua and Honduras on pine bark beetle outbreaks and climate parameters	M. Sc. Degree student in CATIE
Dr. Thomas Köellner	Consultant and Scientific Advisor on Goods and Ecosystem and innovative financial mechanisms	Part time
Dr. Oscar Coto	Consultant, Energy Specialist; conducted studies on the electric and hydroelectric sector in three countries	Part time
Dr. Bruno Locatelli	Scientific Advisor for Ecological Modeling; develop methodologies for studies in three countries	Works 50% for Trofcca under an agreement with CIRAD and CATIE
Raffaele Vignola, M. Sc.	Research Associate, worked on meta-analysis of forest and water relationships; coordinated the work on PES between Trofcca – ICE and IUCN in Costa Rica	Works 100% for Trofcca
Pablo Imbach, M. Sc.	Geographical Information Systems specialist; provided GIS support to all M. Sc. students listed above	Works 50% for Trofcca

Luis Guillermo Molina Carpio	GIS Consultant, worked on geospatial database management	Part time
Carlos J. Pérez, Ph.D.	Regional Coordinator of Trofcca	Works 100% for Trofcca
Marcos Otárola, M. Sc.	Consultant, work on initial systematization of information on the Reventazon watershed	Only for three months during I semester 2007
Oswaldo Corella	Partially conducting studies for Trofcca on commercial forest plantation distribution in Costa Rica	M. Sc. Degree student in CATIE

## 7. Actions planned for year III of Trofcca Central America

### Overview of activities for Year III

In Central America, Trofcca's research program and validation of methodologies will be consolidated during the third year, because several results and products will be achieved during the period running from July 2007 through August 31<sup>st</sup>, 2008. Additionally, the collaboration with national partners to integrate results into the national communications to the UNFCCC and other policies will intensify. It is also expected that Trofcca will contribute to knowledge sharing on the science of adaptation to climate change through articles, conferences, seminars and workshops at various levels: national, regional and international.

The following are initiatives that either have started during Year 2 of Trofcca and will continue or begin actions during Year 3:

- A study on impact of climate change on forest plantations of commercial interest will be conducted at the regional level from May to December 2007. This study will produce maps of suitable areas for selected forest species for future planning of plantations and adaptation measures. The methodology will comprise the use of climate change scenarios for the region, soil and climate requirements for optimal growth of selected forest species, and ecological conditions on the ground. At the end, it is expected that current optimal areas will change due to global warming.
- Climate change and outbreaks of the southern pine bark beetle *Dendroctonus frontalis* (Coleoptera: Scolytidae) in Nicaragua and Honduras. The products of this study are expected to be available during the I Trimester of 2008.
- The study on the dynamics of forest fires in Mesoamerica under climate change scenarios will begin in July 2007 and the results of these investigations are expected during the I Trimester of 2008. A methodology will be designed and validated to develop a forest fires risk index considering climate change scenarios. This initiative will combine data on human factors, classification of fuel types, and climate parameters associated with forest fires.
- Evaluating the impacts of climate change on ecosystem functions providing hydrological services in the Mesoamerican region by modeling the actual and future distribution of the functions and services. This started in January 2007 and is expected to go until the I Trimester of 2009.

- Collaboration between Trofcca & IUCN to improve a payment for ecosystem services in Costa Rica in the hydro energy sector. This initiative will be consolidated during the Year 3 of Trofcca. It is anticipated that graduate students from Spain and the Netherlands will join this project to contribute in filling the scientific information needed to achieve results. In particular, collaboration with the Polytechnic University of Madrid, will contribute to a better understanding of the contribution of different soil uses to the hydrological services and soil erosion control. This information, linked with the studies on technology adoption, will lead to the design of different scenarios for reduction of sediments that interfere with hydropower generation.
- Response from society to changes in ecosystem services. As stated above this study entitled “Determinants of social decisions for landscape management as and adaptive response to changes in the provision of hydrological ecosystem services in Costa Rica”, has been conducted by Trofcca C.A. since January 2007 and results are expected by the I Trimester 2008.
- Decision making and policy networks in forestry-dependent development sectors: mainstreaming adaptation to climate change into policy. A methodological approach for this action has already been discussed during the workshop in Burkina Faso in May 2007 (see above). The field phase of this research will begin during the last trimester of 2007.

During Year 3, site selection for Nicaragua and Honduras will be completed. In Costa Rica the site has already been selected and field work is under way through the collaboration between Trofcca, ICE and UICN in the Reventazon Watershed. The latter was selected due to the strategic importance of this watershed, which produces about 35% of the hydroelectric power in the country, and also provides drinking water to 600,000 people. In Nicaragua, initial contacts have been made with the National Office for Clean Development Mechanism and Climate Change, and the National Electricity Enterprise to determine if Trofcca should invest resources in a watershed that is relevant for hydroelectric power generation and agricultural production with different irrigation methods. In the case of Honduras, initial contacts and discussions will be conducted until a decision is reached during third trimester of 2007. In both cases (Nicaragua and Honduras) studies in specific sites should be designed and started during the fourth trimester 2007.

As outreach activities, Trofcca C.A. will participate in CoP13 to be organized in Bali, Indonesia, in December 2007. Other outreach activities will be organized with the Offices of Climate Change in the countries where Trofcca is working in the region. Additionally, Trofcca will disseminate results participating in seminars and conventions organized at the national, regional and international levels by different organizations that require the dissemination of knowledge being acquired through the work performed by Trofcca.

By the end of Year 3, Trofcca C.A. will have reached significant progress towards a set of methodologies that will contribute to the knowledge base on forest adaptive management, from the perspective of society or relevant socio-economic sectors.

**Annex 1: in depth study of the relationships between forest and water, and a study for better understanding of the electric sector in Central America**

**Forest hydrological services in developing countries: the need for more science. This is a meta analysis on forest and water. The manuscript is being prepared for submission by B. Locatelli and R. Vignola. 2007.**

**Summary.** The hydrological services provided by forest ecosystems are critical to human well-being. An increasing number of valuation studies and experiments of payment for ecosystem services have been dealing with the role of ecosystems in regulating water quantity. However, several are based on misconceptions of the role of forests in the hydrological cycle, despite the publication of many review papers by hydrologists. This paper applies a meta-analysis on field studies at watershed scale in developing countries for contrasting the belief systems and the scientific findings regarding the effects of forest cover change on hydrology. The paper shows that forests do not provide the same hydrological services as it is often believed. Because of uncertainties and natural variability, scientific knowledge is a critical challenge for valuation and payment for ecosystem services.

**Understanding the energy sector in Central America and opportunities for Trofcca in the region; summary of a consultancy report by Dr. Oscar Coto**

This work has the principal objective of providing an up-dated review on the situation of the electric sector in Central America. In order to do so, a documentary and interviewing process was conducted in the period from January-February 2007, in order to gather data, as well as to understand the most important trends in the electricity markets in the region. Most of the data presented has been systematized to the year 2006, since most of the more recent information for 2007 has not been officially released by agencies and institutions operating in those markets.

The information is presented from four principal perspectives:

1. Sector wide as well as country specific data characterizing the operation of the sector, from the regulatory and business operation as well as supply-demand relationships.
2. Presentation of state of reform processes and institutional development in each country from the perspective of potential participation by new players in the business sphere.
3. Presentation of forecasts for power and energy demand in the different countries, followed by an assessment of the potential market share for renewable energies in grid connected applications.
4. Present perspectives on the role of hydroelectricity in the context of recent and expected future developments in the energy markets in the region.

Hydroelectric power in Central America has been placed high in the energy agenda of several countries in the region. As one of the sectors selected by the Project in the region, during 2006 and

2007, a study was conducted to better understand the energy demands and current policies in the sector. The study revealed that the electricity sector is coming out of a transitional period, through the 90s, characterized by a series of reforms of first and second generation, comprehending not only private sector participation in generation, through the signing of PPAs; but the implementation of open wholesale electricity markets in Guatemala, Nicaragua, El Salvador and Panamá. Only Costa Rica, and Honduras have not implemented this kind of open market arrangements, although due to different sets of national circumstances.

The region's installed capacity in 2005 was 8.889,6 MW, of which 4.753,3 MW for a 53,4% was supply capacity based on renewable energy resources. Hydroelectricity represents 3.804,3 MW for a 42% of the installed capacity in the region. Electricity generation accounted for 34.272,7 GWh of which the private sector generated around 59,86% showing the importance of the private sector in the region. Renewable energies generated on the order of 61% of the total generation and hydroelectricity accounted for a total of 49,85% that is 17.086,6 GWh. Nevertheless having an important contribution from renewable energies, most of the most recent capacity additions, have been based on fossil fueled generation technologies, with the exemption of Costa Rica at the country level and some particular technologies that seem to be finding small but interesting niches for installation like wind in Costa Rica and geothermal plants in Nicaragua and El Salvador.

There is a wide variety of institutional and market arrangements in the sector across the region, which is presented through the document. The business sphere especially in the area of generation, shows the largest numbers of market agents; therefore special attention is given to understand the relevant issues related to entry conditions as well as market power share in the hand of different sets of players in the market. Information is presented on sets of indicators for understanding power concentration, that indicate that the different markets are still qualified as medium to concentrated markets, where power is still in relatively few hands and entry conditions are not necessarily easy for new market agents.

Detailed information is presented on the policy and regulatory aspects of the markets in the different countries in the region, in order to show similarities as well as key fundamental differences that can influence investment in capacity additions.

Energy pricing is presented for Guatemala, El Salvador, Nicaragua and Panamá, via an evaluation of the volatility observed in the different markets in order to assess the relative importance of the types of sub markets operating and the effect of different variables in the cost of energy in the open markets. In the case of the other countries, information is presented on the current estimates of marginal cost of electricity as it is reported by the planning agencies in Honduras and Costa Rica.

Demand growth continues to be around a 5-6% annually, signaling that by 2005, energy consumption will grow to a 22% from the observed values in 2001 and 2014, there will be a 52% increase in energy consumption.

Central America needs to add in the range of 2189 MW of new capacity by 2005. It is expected that nearly a 62% of that capacity is going to be fossil fuel based (based on current expansion plants as well as investment trends in the industry), with the remaining being renewable (mostly hydro and geothermal). On the long run, for the period 2006-2014, it is estimated that capacity additions in the level of 5000-5700 MW will be needed. In such a framework of time, different simulation models

call for a participation of renewable energy resources in the order of 50-63%, signaling that annual investments in renewable energy projects may be in the order of 300-350 MW regionally compared to a current trend of about 160 MW per year.

Presentation is made of initial results from a non-formal interview process conducted with different members of networks associated with hydroelectricity generation in Costa Rica, with respect to different issues related to forest and water relationships in the hydro sector.

The stakeholders interviewed are clear in their assessment of the relationships of hydroelectric generation and ecosystem services from the forest, in particular the developers of projects impressions on the services of regulation provided by the forest in the management of water drainage and flow in upper watersheds. Nevertheless the stakeholders contributed in identifying issues, and that the country has an on going process for devising a national strategy for adaptation of water resources, there seems to be a need to foster dialogue in the hydroelectricity sector and long term adaptation to climate change.

The interviews conducted point into the direction of identifying several opportunities to conduct specific watershed and systemic exercises and experiments that can contribute to enhance the stakeholders capacities to join in coalition formation and participation in the national adaptation discussion, as well as fostering knowledge exchange with respect to the adaptation in the hydro sector, which can ultimately have an impact in the policy process in this subject in Costa Rica.

**The importance of tropical forests in climate change adaptation policies. 2007. Manuscript submitted to the Journal of Natural Resources and Environment in May. By Carlos J. Pérez<sup>2</sup>, Bruno Locatelli<sup>3</sup>, Raffaele Vignola<sup>1</sup>, Pablo Imbach<sup>1</sup>**

**Summary** Tropical forests are important for sustainable development due to the goods and ecosystem services they provide to society. Despite the vulnerability of forest ecosystems to climate change, few adaptation plans incorporate tropical forests, or, they are even considered as an asset separate from society. Climate change impact on forests could exacerbate the vulnerability of society to these environmental changes. In this document, we argue that socio-economic sectors that depend on forest ecosystem services should participate in policy decisions and strategies for adaptive management of forests. The vulnerability of these ecosystems could be reduced with practices and measures that improve forest adaptive capacity. The project “Tropical Forests and Climate Change Adaptation” illustrates an approach to facilitate adaptive management of forest ecosystems driven by the interest of society or socio-economic sectors.

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<sup>2</sup> Grupo Cambio Global, CATIE 7170, Turrialba, Costa Rica

<sup>3</sup> CIRAD UPR Forest Resources, Montpellier, France; CATIE Global Change Group, Turrialba, Costa Rica

**Annex 2: validation of methodologies for identification of forest ecosystem that provide services to hydroelectric power and drinking water sectors, and contribute to climate change adaptation in the corresponding sectors**

**Nicaragua**

**Identification of forests and agro forestry systems important suppliers of ecosystems services for the drinking water sector in Nicaragua. M. Sc. Thesis, CATIE, Turrialba, CR, 135 p. By Gonzalez H., C. 2006.**

**Summary** Water resources are considered an essential component in the economic growth and social development of nations. The tropical forests and agroforestry systems play a very important role in the regulation of water flow and quality. In the context of climate change and utilizing a method that examined the interaction between these ecosystems and society, we identified the areas of forest and agro forestry that are important in the provision of potable water for Nicaragua. This method considered criteria of vulnerability of potable water sector, the location of the users, soil use types and the capacity of these soil use types to generate ecosystem services. Utilizing a Geographical Information System (GIS), we created maps of forest ecosystems and agroforestry areas that are important in the provision of potable water and we also determined the area of important forest below the protected areas. The results indicated that approximately 37, 804 km<sup>2</sup> and 1,722 km<sup>2</sup> of forests and agroforestry systems respectively, are of high to very high importance for potable water sector. The majority of these areas are found in the Central North and Pacific regions, where the highest population densities occur. Most of the agroforestry systems in the Central North region coincide with an important coffee growing zone of the country. There are approximately 7,600 km<sup>2</sup> of important forest located in protected areas, which represents 20% of the total area of protected forests. For the decision makers, this study constitutes an instrument of analysis that can contribute to the design and implementation of adaptive management strategies for forests and agroforestry systems, which must consider the relation between society and these ecosystems with the purpose of guaranteeing their permanence and the ecosystems services that lend to the society. The full document can be downloaded from the following site: <http://orton.catie.ac.cr/repdoc/A1307E/A1307E.PDF>

**Identification of forest ecosystems providing relevant ecosystem services to the hydroelectric power sector in Nicaragua. M. Sc. Thesis. CATIE, Turrialba, Costa Rica. 110 p. By Leguia, E. 2006.**

**Summary.** Tropical Forests produce important ecosystem services for hydroelectric power generation. Nicaragua is promoting investments for utilizing renewable sources of energy, particularly hydroelectric power generation. The objective of this study was to identify forest ecosystems providing ecosystem services relevant for climate change adaptation of the hydroelectric sector in Nicaragua. A model based on geographical information system was developed. This model considers vulnerability criteria at the watershed level, position of the hydroelectric plants according to the projected installed capacity (MW), land uses (ha), drainage system and micro watersheds, a matrix relating ecosystem services production and land use, and a matrix of utility of ecosystem services for hydroelectric plants. The results of the study demonstrated that 35% of upstream forest landscapes relevant for hydroelectric power generation are located in areas with high sensibility to

climate events. Approximately 8,300 and 1,425 km<sup>2</sup> of forest landscapes and perennial crops, respectively, are considered of high and very high importance for ecosystem services to hydroelectric power projects or plants. Most forest ecosystems relevant for hydroelectric sector are located in the Rio Grande de Matagalpa watershed, in the central region of the country, and the Rio Coco watershed. Agroforestry systems based on coffee were the most important perennial crops producing ecosystem services. Additionally, <10% of forest landscapes producing ecosystem services for hydroelectricity are outside the protected areas system of Nicaragua. The results of this study indicate that it is important to link ecosystem service users with the forest ecosystem providing those services, thus improving the adaptive capacity of the ecosystems of interest and the provision of ecosystem services for the future. The full document can be downloaded from the following website: <http://orton.catie.ac.cr/repdoc/A1061E/A1061E.PDF>

## **Honduras**

**Identification of forests providing ecosystem services for socio-economic sectors vulnerable to climate change: drinking water and hydroenergy in Honduras. M. Sc. Thesis. National Autonomous University, Tegucigalpa, Honduras. By Najarro, Tania. 2007.**

**Summary** In Honduras, climate variability and climate change will have an impact on society and several socio-economic sectors, as has been witnessed with passed extreme events like droughts and hurricanes. Among the impacted sectors, those relying on water resources are of particular interest, like the drinking water and hydroelectric power. Both sectors are of strategic importance for sustainable development. This study aims at identifying forest ecosystems providing goods and services to the above sectors. The methodology of this investigation includes a tool relying on geographical information systems, watershed maps, potential for ecosystem services provision by land use, and the adaptation capacity of the population across the country. The results of this study indicate that in the western region of Honduras, where water consumers total >1,342,411 inhabitants, forests are the major providers of ecosystem goods and services for the drinking water sector. These ecosystems are important for reducing vulnerability of the population to water problems by reducing the sensibility of the sector to climate variability and climate change. The adaptive capacity of the population showed the lowest index in this region, suggesting the increased importance of forest ecosystems for vulnerability reduction. In the south-central region of the country, agriculture is the most important land use and is correlated with low soil cover. In this region, current soil use results in a poor ecosystem service provision for the drinking water sector. Country wide, 88.3% of total drinking water connections are supplied with superficial sources, mainly by gravity. Compared to ground sources, superficial water sources are more sensible to climate variability and climate change, thus affecting the vulnerability of the sector. The high percentage of superficial water users requires several measures to improve land use practices and policies to enhance forest ecosystem goods and services provision for water resources.

In the case of hydroelectric power, there are currently 16 hydropower plants with a generation capacity of >386 MW. Considering 71 new projects, it is expected that Honduras will have an installed capacity 1,070 MW. Currently, 30% of the area covered by forests is of high importance to at least 436 MW of hydropower generation potential. However, in the northern region of the country, several of the power plants are or will be located in watersheds with up-land use delivering poor quality ecosystem services, particularly due to wide distribution of degraded pasture lands. These

degraded ecosystems contribute poorly, when compared to forests, to sediment reduction. Sediments increase the vulnerability of the hydroelectric power sector to climate change and climate variability, because sediments reduce the generation capacity of this renewable energy.

Discussions with stakeholders and representatives of the two sectors involved in this study lead to defining some recommendations for policy design and integration of forest ecosystems to enhance adaptive capacity of both sectors. Current and new policies for the drinking water and hydroelectric power sectors should be designed to promote increased forest cover and forest management. The national program for reforestation could be re-directed to prioritized regions of higher sensibility to climate change and climate variability, and where land use should be enhanced or managed to deliver better quality goods and services. Payment for ecosystems services is one of the mechanisms that could be implemented, and is already considered in the National Forestry Program (PRONAFOR). Another line of policy within the forestry sector is the programming of an inventory of forest cover and other land uses every five years. The law of territorial planning should consider land uses that are important for ecosystem provision to the above sectors. International conventions like the UNFCCC and UNCCD, of which Honduras is already a member, can become synergistic in some of the regions where land degradation prevails and affects water resources. The strategy for poverty reduction should also prioritize actions and programs based on the lowest adaptation capacity of the population and where actions and programs could contribute to strengthening management of forest ecosystems providing ecosystems services for the drinking water sector. The next national communication of Honduras to the UNFCCC should also prioritize the drinking water and hydroelectric power sectors into the CC adaptation policy.

## **Costa Rica**

### **Tropical forests and hydroelectric power in Costa Rica. 2007. A report prepared by Efraín Leguía H.<sup>4</sup>, Bruno Locatelli<sup>5</sup>, and Pablo Imbach<sup>1</sup>**

**Summary** Tropical forests provide important ecosystem services (ES) for hydroelectric power generation. One important step towards adaptive management of forests is to identify those ecosystems relevant for the sector. In this study, we validated a methodology to identify those forest ecosystems relevant for the hydropower sector of Costa Rica. The analysis is based on the linkages between power plants and ES such as: erosion reduction, maximum flow reduction, minimum flow conservation and water yield in the watershed. It is assumed that these ES improve the adaptive capacity of the hydropower sector under climate change. A model was developed combining geospatial information, power generation potential and land use information. Additionally, the model considers vulnerability criteria for each watershed, land or soil use (ha), location of the power plant downstream given its power potential (MW), a matrix of ecosystem services production and corresponding utility for the hydropower plant. The installed capacity of hydropower plants in Costa Rica (2,340 MW) is distributed across 93 micro watersheds that benefit from ecosystem services produced from 12,527 km<sup>2</sup> of different land uses. Forests are the most important land cover (52%)

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<sup>5</sup> *CIRAD UPR, Ressources Forestières, Montpellier 34398 Francia; CATIE, Grupo Cambio Global, Turrialba, Costa Rica.*

upstream. Most important forests are located upstream of Rio Grande de Terraba (697 km<sup>2</sup>), this is the watershed with the major area covered by perennial crops important for hydroelectric power generation. The watershed of Rio Reventazon is the second with forest cover (529 km<sup>2</sup>), but the most important in terms of power generation potential (638 MW). We estimated that 32% of forests relevant for the sector are located within protected areas. An in-depth study is needed on an individual watershed basis to better discriminate among different land uses and the ES they provide, particularly for the reduction of sediments. This methodology may be useful for fine-tuning the implementation of a payment for ecosystem services provided by forests and other ecosystems, and that would enhance the adaptive capacity of the hydroelectric sector in Costa Rica.

**Spatial priorities for the payment for ecosystem services (PES) in Costa Rica. 2007. Imbach, P. L. Pedroni, and T. Koellner. May. Manuscript submitted to the Journal of Land Use Policy.**

**Abstract** Payment for Ecosystem Services (PES) is a promising approach for preserving ecosystem services that are critical for sustaining human societies. A variety of schemes involving PES have been implemented around the globe and new initiatives are starting in many places. One of the key issues in the design of such schemes is deciding which lands and land-use activities should be compensated for the ecosystem services that they provide in order to make the payments more efficient. Here we present a methodological framework for identifying spatial priorities for PES.

Using a Geographical Information System (GIS), we developed a spatial model that calculates priorities depending on two main criteria (i) the level of provision of ecosystem services (ES) at given location (e.g. a pixel), and (ii) the risk of losing the provision of such services at that same location due to land-use change. A multi-criteria decision structure was used to combine different indicators of provision of ES and risk of land-use change. The model was implemented in Costa Rica, where a nation-wide PES scheme is functioning since more than one decade. In 1996, Costa Rica's new Forest Law established which ES are of interest to the society, which land-use activities provide them, and how land owners have to be compensated for implementing these land-use activities.

Accordingly, the provision of ES was evaluated for biodiversity conservation, carbon storage, scenic beauty and water provision for human consumption, irrigation and hydro-electric generation. The risk of losing the provision of ES was evaluated as the risk of deforestation in forested area, and as the risk of land-use change from less to more intensive land-uses in non forested areas. The level of provision of ES and the risk of land-use change were combined to obtain an indicator of priority for PES. We found that the priorities for each service have distinctive spatial distribution and that services of local use (different water uses and scenic beauty) have a high spatial correlation. This indicates that in Costa Rica, the payment for one service will ensure the provision of another since higher priorities share the same places.

Our methodology is flexible as it can be adapted for different objectives, for instance a separate priority evaluation for each ES or for particular groups representing different value perceptions regarding the importance of services or risk factors. Further work has to be done in order to evaluate results in the field and the methodology robustness.

**Annex 3: summaries of studies conducted to better understand the vulnerability of forest to CC, either through shifts in ecological conditions; disturbances to forests, such as insect pests or forest fires; and the threat to hydrological ecosystems services**

**Variations in optimal plantation areas for forest species of commercial use under climate change scenarios in Costa Rica. Tropical Agricultural Research and Higher Education Center –CATIE–. February 2006. By Cervi F., Ana P.**

**Summary** Climate variability and climate change may cause shifts in optimal sites for competitive production of different forest tree species. This study explored the variation of current optimal soil and climatic conditions for five forest species of commercial value in Costa Rica: *Tectona grandis* L. f., *Gmelina arborea* (L.) Roxb., *Cordia alliodora* (Ruiz & Pav.) Oken, *Hyeronimia alchorneoides* Allemao, and *Vochysia guatemalensis* (Donn. Sm.). The study consisted of developing a tool that could be used for planning and adequate site selection considering climatic variables, actual and future under climate change scenario for year 2100. A review of bio-ecological requirements of the above species was conducted; digital maps of soil type's distribution, climate parameters, etc., were collected from national institutions. Climate scenarios were derived from the I National Communication to the UNFCCC. Interviews were conducted to obtain actual locations of current plantations of the above species. The study shows that current optimal areas for commercial plantations suffer geographical shifts under the climate change scenario used. Meanwhile, optimal areas for *T. grandis*, *C. alliodora* and *H. alchorneoides*, decrease by 19.5%, 13.7% and 30.8%, respectively. For *G. arborea* and *V. guatemalensis*, optima areas increase 4.5% and 21.1%, respectively. The study concludes that selection of appropriate plantation sites will require the consideration of climate change scenarios otherwise the competitiveness of timber production may be at stakes. Further efforts are needed to allocate digital positioning coordinates for forest plantation sites and trees used as seed sources. This will enable a better evaluation of the potential of current plantations and future site selection. The study was conducted by Ana Paula Cervi Ferez with technical support by the GIS specialist from the Global Change Group in CATIE.

**Key words:** forest plantations, climate change, shifts of optimal conditions

**Insect pest outbreaks** Forest's insect pest outbreaks are considered major disturbances that tropical forests will face due to climate variability and climate change. Trofcca C.A. has undertaken the work "Climate change and outbreaks of the southern pine bark beetle *Dendroctonus frontalis* (Coleoptera: Scolytidae) in Nicaragua and Honduras. There are several species of pines in Honduras and Nicaragua, but the most extended are *Pinus oocarpa* and *P. caribea*. The system "pine-*D. frontalis*", was selected due to the major extensions of pine in the region and the history of pest outbreaks that have been devastating in some years, particularly 2001-2002 in both countries. Since January 2007, Trofcca C.A. has devoted efforts towards designing the methodology and collecting data from relevant institutions in both countries. In Nicaragua, the National Institute of Forestry (INAFOR), the Institute of Territorial Studies (INETER), the National Autonomous University, the Municipalities of San Fernando and Jalapa, were important collaborators and provided relevant data. In Honduras, the Honduran Forestry Forum, the Forestry Development Corporation (COHDEFOR), the School of Forestry Science (ESNACIFOR) and the Ministry of Natural Resources and the Environment, were also key collaborators providing relevant information. There are significant differences between countries in monitoring the attacks of *D. frontalis*. In Honduras, data on timber

losses have been gathered since 1982 whereas in Nicaragua, the data were collected a major pest outbreak occurred in 2001-2002. Major timber losses have been recorded since 2001 in Honduras. This study is looking at the relationship between climate variables (temperature, precipitation, etc.) and insect pest outbreaks. Additionally, one of the interactions to study is the correlation between forest fires and the subsequent occurrence of pest outbreaks in pine plantations, since it is possible that forest fires weaken the trees and make them more susceptible to insect attacks. This study is being conducted by the graduate student Milton Rivera, a M. Sc. candidate within the Graduate Program in CATIE. The results of these investigations are expected to be delivered by the end of 2007.

**The provision of forest ecosystem's hydrological services is of major importance for sustainable development.** Climate change will have an impact on the distribution of ecosystems and the pattern and variability of precipitation. Consequently, the provision of hydrological ecosystem services is expected to change. We aim at evaluating the impacts of climate change on ecosystem functions providing hydrological services in the Mesoamerican region by modeling the actual and future distribution of the functions and services. Our results will help to develop adaptive measures at regional and national level.

The study will be applied at the regional scale in the Mesoamerican region from southern Mexico (Chiapas) to Panama. However, local studies will be developed in parallel by the Trofcca C.A. project to complement the regional modeling, for instance watershed hydrological modeling and socioeconomic studies about the users of hydrological services. This study will be performed by Pablo Imbach (M.Sc.) during the period January 2007 until the first trimester of 2009.



Photo by Carlos J. Perez (November 2006)

#### **Annex 4: strengthening participation of society in adaptation**

**Responses from society to changes in ecosystem services** One of the studies conducted by Trofcca since January 2007 has been entitled “Determinants of social decisions for landscape management as an adaptive response to changes in the provision of hydrological ecosystem services in Costa Rica”. This study has selected two case studies: 1) the creation of the Commission for territorial planning and management of the upper watershed of the Reventazon River –COMCURE-, mainly linked to hydroelectric power generation; and 2) the Commission for the recovery, protection and conservation of water recharge area of Los Santos, mainly for public water consumption. In this two cases, society and socio-economic sectors decided to create institutions and important decisions were made to change landscape management practices. The study is aiming at determining the sources of motivation, conditions, rules and steps made toward the creation of institutions. It is expected that this study will provide important lessons for adaptive landscape management, including forest ecosystems. During the period January - June 2007, the steps already performed include: designing the methodology based on Robert K. Yin (2002) “Case Study Research Design and Methods” and a model proposed by Selin & Chavez (1995) to study collaborative processes to Environmental Management and Planning; revision of key documents such as memoirs of meetings, annual reports, institutional missions, etc.; field visits to perform a series of interviews to different institutions and upper landscape dwellers. The study is being conducted by the graduate student Angela Diaz, a M. Sc. candidate within the Graduate Program in CATIE. The results of these investigations are expected to be delivered by the end of 2007.

**Community based adaptation to climate variability and climate change in agriculture and water resources in the dry tropics of Nicaragua: The Case of San Pedro del Norte. A Report prepared by Carlos J. Perez<sup>6</sup>, Raffaele Vignola<sup>1</sup> and Hernán Pérez E.<sup>7</sup> This work was performed in collaboration with Both ENDS a Non-Governmental Organization from the Netherlands ([www.bothends.org](http://www.bothends.org))**

**Summary** San Pedro del Norte (SPN) is the northern-most municipality in the Department of Chinandega, Nicaragua, bordering with the municipality of San Marcos de Colón in Honduras. The zone falls into the category of dry tropical forest, with hillsides as the prevailing topography. Several climate extreme events, such as Hurricane Mitch and various episodes of droughts have caused major socio-economic losses.

Upon a severe drought occurred in 2001 the municipality decided to undertake actions in order to ensure ecosystem management for water sources conservation. Droughts are recurrent climate events that have affected agricultural production and water availability in both, urban and rural populations. Following four years of implementation of a local scheme of payment for ecosystem services (PES), a follow up was organized during the third week of February 2007 to investigate lessons learned; three workshops were organized with local stakeholders: i) with farmers acting as suppliers of ecosystem services; ii) the water users as part of the demand for those services; and iii) local authorities. Questionnaires in the three meetings were directed toward fact finding in the

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subject of past, present and future climate related risks, and natural resources management. Also, a joint analysis was performed of local and national policies influencing local adaptive capacity.

Contracts signed with upstream farmers have allowed the introduction of managed natural forest regeneration in the upper micro watershed. Additionally, different soil and water conservation technologies (i.e., stone ditches and stone rows) have been adopted. After four years of implementing the local PES scheme, several positive impacts have been observed: water availability has improved, particularly relevant during the dry season months; farmer-to-farmer discussions on the importance of not practicing slash-and-burn for land clearing before planting food crops has increased adoption of better practices; the importance of trees and forests increased among growers and decision makers; a new Municipal Environmental Ordinance was approved in August 2006, with special consideration of forest fire avoidance, and the acquisition of slash-and-burn permits by farmers. The reduction of land degradation and ecosystem restoration is at the top of a combination of measures to ensure water resources conservation and management.

Altogether, soil and water conservation technology adoption, improved local organization, conflict resolution over natural resources management, better inter-institutional links that are favorable towards increasing social capital, have resulted in improved adaptive capacity to climate change and climate variability. Overall, adaptive capacity to climate change and variability has improved but resources (financial and human) are still short compared to the investments stated in the Municipal Development Plan to increase conservation of natural resources in time and space. Inter-institutional coordination will be highly important to improve chances of policy changes at the national level, and technical assistance will be needed to have access to funds at the international level (i.e., funds for adaptation). Climate change scenarios officially reported suggest that the area will be drier and hotter, increasing the risks of food security and water availability.

**Key words:** water availability, ecosystem services, droughts, municipal laws