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Research Network for the Evaluation of Carbon Sequestration Capacity of Pasture, Agropastoral and Silvopastoral Systems in the American Tropical Forest Ecosystem

CIPAV- Universidad de la Amazonia -CIAT-CATIE-
Wageningen University and Research Centre.

The Netherlands Cooperation:
Activity CO-010402

CIAT

Project duration: 5 years
December 1, 2001 – November 30, 2006

Six-months Technical Report no. 8

June 1 – November 30, 2005

María Cristina Amézquita
Project Scientific Director

Presented to The Netherlands Cooperation through The Netherlands Embassy in Bogotá, Colombia. December 15, 2005.

CONTENTS

Acknowledgements

Participant Institutions, Project Executive Committee, Project members and Consultants.

1. Background

1.1 Project Executive Summary.
1.2 The Project: Main goal, objectives, expected products and research methodology.

2. Activities June 1 – Nov 30, 2005 in agreement with Annual Plan 2005

2.1 Technical and administrative coordination activities

- VI International Coordination Meeting, CIAT, Cali, Colombia, August 16-19, 2005; and 3-day Training Course on Green House Gasses (GHG) held at CIAT on August 22-24, 2005.
- Preparation of Technical and Financial Reports semester 2, year 4
- Preparation of Annual Plan 2006

2.2 Research Activities

- Statistical Analysis and interpretation of data from the 2nd Carbon Sampling (2005), Humid and Sub-humid Tropical Forest, Costa Rica.
- Statistical Analysis and interpretation of the complete database on Soil Carbon Stocks, from both topographies, Humid Tropical Forest Ecosystem, Amazonia, Colombia: flat topography, sampled in 2002; and mild-slope topography, sampled in 2004.
- Continuation of periodic biomass evaluation of small-plot Experiments in the three Ecosystems.
- Socio-economic Research Activities: Development and Analysis of Simulation Scenarios of farmer's investment in systems with capacity to sequester Carbon - all Ecosystems.
- Planning of Extrapolation of Project results to similar areas in Tropical America – Contract with ISRIC, The Netherlands.

3. Executed funds of present semester (June 1 – Nov 30, 2005) distributed by Activity

4. Budget Tables 2005

Annexes

Annex 1: Chronogram of Activities - Annual Plan 2005.

Annex 2: Program VI International Coordination Meeting and Training Course on Green House Gasses (GHG), held at CIAT, Cali, on August 16-19 and August 22-24, 2005, respectively.

Annex 3: *La Cooperación Holandesa para el Desarrollo, en el Mundo, en Colombia, y en el Proyecto Captura de C.* Contribution from Maurice van Beers, The Netherlands Embassy in Bogotá, to the VI International Coordination Meeting. CIAT, August 16, 2005.

Annex 4: *The Role of Grassland and Forest as Carbon Store".* Contribution from Prof. L. 't Mannetje, Wageningen University, The Netherlands, to the VI International Coordination Meeting. CIAT, August 16, 2005.

Annex 5: Activity Report, Humid and Sub-humid Tropical Forest Ecosystems, Costa Rica.

Annex 6: Activity Report, Andean Hillsides Ecosystem, Colombia.

Annex 7: Activity Report, Amazonia, Colombia.

Annex 8: Complete Statistical Analysis of Soil Carbon Stocks from both Topographies, Flat and Mild-slope (2002-2004), Humid Tropical Forest, Amazonia, Colombia.

Annex 9: Socio-economic Evaluation Report. Development and Analysis of Simulation Scenarios in all Ecosystems.

Annex 10: Contract with ISRIC for extrapolation and GIS maps work

Annex 11: Budget Tables (10) with executed budget for years 1, 2, 3 and 4, and projected budget for year 5.

Acknowledgements

We express our gratitude to The Netherlands Ministry of Development Cooperation in The Hague, and The Netherlands Embassy in Bogotá, Colombia for making real this important project.

Our project combines efforts from the national research community --represented by CIPAV and Universidad de la Amazonía, Colombia-- and the international research community --represented by CIAT, CATIE and Wageningen University and Research Centre-- to help prepare ourselves and our future generations to mitigate the effects of global warming. Our hope is to achieve relevant high quality research results that will contribute to mitigate the adverse effects of global warming in vulnerable ecosystems of the developing world, as the American Tropical Forest Ecosystem.

The present document ***"Six-months Technical Report No.8: June 1- Nov 30, 2005"*** describes project advances during the second semester of the fourth year of project's implementation, in agreement with our Annual Plan 2005. The most important research activities during this semester were: a) Development of simulation scenarios for farmers' investment, based on previous socio-economic analysis in the project ecosystems (Andean Hillsides, Colombia, Tropical humid forest, Colombian Amazonia, and Sub-humid and humid tropical forest, Costa Rica); b) Completion of field work on soil carbon sampling in Costa Rica ecosystems and in the Humid Tropical Forest, Amazonia, Colombia; c) Complete statistical analysis of Soil Carbon Stocks (SCS) from Andean Hillsides Ecosystems, Colombia; d) Continuation of periodic biomass evaluation of all small-plot experiments established on degraded land in all project ecosystems; and e) Agreement and signature of Terms of Reference with ISRIC, Wageningen for extrapolation and GIS maps work.

Project members are actively participating at scientific and policy-oriented congresses, workshops and other events on carbon sequestration and related topics, at national and international level. This fact is an important recognition of the high scientific quality of the work being done by project team and the relevance of present project's results.

We are pleased to inform that activities conducted and completed during the second semester of our fourth year are in full agreement with the project Annual Plan 2005.

We thank project member and consultants for their fruitful discussions, valuable contributions and efficient work done.

With best wishes for success in the project's fifth and final year.

María Cristina Amézquita
Ph. D. in Production Ecology and Resource Conservation
Project Scientific Director
Cali, Colombia, December 15, 2005.

Participant Institutions

CIPAV: Centre for Research on Sustainable Agricultural Production Systems, Cali, Colombia.
Legal and technical representative: Dr. Enrique Murgueitio, Executive Director.

Universidad de la Amazonia, Florencia, Colombia.
Legal representative: Dr. Oscar Villanueva Rojas, Rector.
Technical representative: Dr. Bertha Leonor Ramírez, researcher.

CIAT: International Centre for Tropical Agriculture, Cali, Colombia.
Legal representative: Dr. Joachim Voss, Director General.
Technical representative: Dr. Edgar Amézquita, Soil Scientist.

CATIE: Centro Agronómico Tropical para Capacitación y Enseñanza, Turrialba, Costa Rica.
Legal representative: Dr. Pedro Ferreira Rossi, Director General.
Technical representative: Dr. Muhammad Ibrahim, researcher.
Environmental Economist: Dr. José Gobbi, researcher.

Wageningen University and Research Centre, Wageningen, The Netherlands.
Representatives: Drs. Bram van Putten and Peter Buurman, researchers.

Project Executive Committee

- **Dr. María Cristina Amézquita.**
  Project Scientific Director.
  Ph.D., Production Ecology and Resource Conservation.

- **Dr. Enrique Murgueitio.**
  Project Administrative and Financial Director. CIPAV's Executive Director.

- **Bertha Leonor Ramírez**. Researcher, Universidad de la Amazonía.
  Ph.D., Agroforestry Systems.

- **Dr. Edgar Amézquita**. Researcher, CIAT. Ph.D., Soil Sciences.

- **Dr. Muhammad Ibrahim**. Researcher, CATIE. Ph.D., Agronomy.

- **Dr. Bram van Putten**. Ph.D. in Mathematics.
  Wageningen University and Research Centre.

- **Dr. Peter Buurman**. Ph.D. in Soil Chemistry and Dynamics.
  Wageningen University and Research Centre.

Consultant: Professor Dr. Leendert 't Mannetje.

Ph. D. in Tropical Grasslands. Wageningen University and Research Centre.

Project members

- ***Field research – Hillsides ecosystem (Colombia)***
  María Elena Gómez. Agronomist, M.Sc.- CIPAV
  Piedad Cuellar. Participatory research, M.Sc.- CIPAV

- ***Field research – Semi-humid Tropical Forest (Costa Rica)***
  Tangaxhuan Llanderal (Ph. D. cand), CATIE.
  Alexander Navas, Agronomist, CATIE.

- ***Field research – Humid Tropical Forest (Colombian Amazonia)***
  Bertha Leonor Ramírez. Agroforestry Systems. Ph.D.
  Jaime Enrique Velásquez. Agronomist. Ph.D.
  Jader Muñoz, Ph.D. (cand.)
  B.Sc. students
  Universidad de la Amazonia.

- ***Environmental Economist***:
  José Gobbi, Ph. D., Economics. CATIE.

- ***Mathematical modelling***
  M.Sc. students under Dr. Bram van Putten. Wageningen University.

- ***DB analyst/statistician***
  Héctor Fabio Ramírez. Statistician.

- ***Soil sampling and biomass measurement***
  Hernán Giraldo. Agronomist

- ***Executive Assistant***
  Francisco Ruiz. Industrial Engineer.

- ***Students***
  Octavio Mosquera, CIAT. Ph. D. student at Wageningen University.
  Laura Cabrera and Gabriel González, Ecology students U. Javeriana, Bogotá.
  Lucero Gómez, Agricultural Administration student, U. Santo Tomás. Cali.

Research Services

- ***Laboratory analyses***
  Samples from Colombian ecosystems: contracted with CIAT's Soils Laboratory.
  Samples from Costa Rica ecosystem: contracted with CATIE's Soils Laboratory.
- ***GIS (cartography and 3D images)***
  Contracted with ISRIC, Wageningen, The Netherlands.

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1. Background

1.1 PROJECT EXECUTIVE SUMMARY

The present multi-institutional research project was presented by a developing country (Colombia) to The Netherlands Ministry of Development Cooperation, through The Netherlands Embassy in Bogotá, Colombia, for financial support consideration. Its broad research topic is Climate Change: mitigation alternatives for vulnerable ecosystems in developing countries. It combines efforts from the national research community, represented by CIPAV and Universidad de la Amazonía, and the international research community, represented by CIAT, CATIE and Wageningen University and Research Centre, to help prepare ourselves and our future generations to mitigate the effects of global warming. This research project responds to the United Nations Framework Convention on Climate Change (UNFCCC, New York, May 9, 1992; last modified on 11 October 2000) Article 3 (numeral 2), Article 4 (numerals d and g), Article 5 (numerals a and b), Article 12 (numeral 4), Kyoto Protocol Article 10 (numeral d), The Bonn Agreement (COP6 - July, 2001), The Marrakesh Conference (COP7 - Nov, 2001) and The Netherlands Implementation of Clean Development Mechanism (CDM) and related research on mitigation alternatives (October 22, 2001). It consulted the 1996 IPCC Guidelines for National Greenhouse Gas Inventories, and Winrock (2000) methodology for monitoring carbon storage in agroforestry projects.

The project main goal is to contribute to sustainable development, poverty alleviation and mitigation of the undesirable effects of climate change, in particular CO_2 *emissions, in vulnerable sub-ecosystems of the American Tropical Forest ecosystem. This main goal will be attained through conduction of scientific research and systematic observations on a range of pasture, agropastoral and silvopastoral systems, in small, medium-size and large farms, in three sub-ecosystems of the American Tropical Forest ecosystem vulnerable to climate change: the eroded Andean hillsides of Colombia (densely populated), the semi-humid tropical forest of Costa Rica (densely populated), and the humid tropical forest of the Amazonian region in Colombia (zone of social conflict).*

Research aims at identifying improved and sustainable pasture, agropastoral and silvopastoral systems that provide a viable and economically attractive solution to the farmer (alleviating poverty) and offer environmental services, particularly increases in soil organic matter, carbon accumulation and act as carbon sinks. Research will be conducted in Colombia and Costa Rica. Emphasis is given to poverty alleviation; in the sense that this research aims at demonstrating that enhancing C accumulation and protecting carbon sinks is an economically attractive activity for farmers.

Project duration is 5 years (Dec1, 2001 - Nov30, 2006). Project cost is US $ 3,869.645,88, with a total contribution from The Netherlands Ministry of Development Cooperation, channelled through The Netherlands Embassy in Bogotá, Colombia, of US $ 1,552.885,88, representing 40.13 % of the project's total cost.

1.2 THE PROJECT: MAIN GOAL, OBJECTIVES, EXPECTED PRODUCTS AND RESEARCH METHODOLOGY.

MAIN GOAL

To contribute to sustainable development, poverty alleviation and mitigation of the undesirable effects of greenhouse gasses on climate change, in particular CO_2, in vulnerable sub-ecosystems of the American Tropical Forest ecosystem.

Sub-ecosystems considered within the American Tropical Forest ecosystem are:
(a) Eroded Andean hillsides of the semi-evergreen seasonal forest (H)
(b) Flat and mild-slope areas of the semi-humid tropical forest of low altitude (SHF)
(c) Flat and mild-slope areas of the humid tropical forest (HF) .

Land managements systems to be monitored and evaluated include: degraded pasture (negative control), native pasture, improved grass-alone pasture, improved grass with herbaceous legume, improved grass with woody legumes, improved grass with other trees (fruit trees, wood trees), forage banks, "barbechos"/"charrales"/"rastrojos" and natural forest (positive control). Table 1 shows the land management systems to be evaluated within each sub-ecosystem.

Table 1: Land Management Systems to be evaluated within each sub-ecosystem		H	SHF	HF
1. Degraded land and degraded pasture ⟶	- CONTROLS	✔	✔	✔
2. Native pasture			✔	✔
3. Improved grass-alone pasture		✔	✔	✔
4. Improved grass-herbaceous legume			✔	✔
5. Improved grass-woody legumes				✔
6. Grass–other trees (fruit trees, wood trees)			✔	✔
7. Forage banks for "cut and carrying"		✔	✔	✔
8. "Charrales", "barbechos", "rastrojos"			✔	✔
9. Natural Forest ⟶	+ CONTROL	✔	✔	✔

OBJECTIVES

(1) **Compare** the various land management systems within each sub-ecosystem, in order to **identify** those that are more economically attractive to the farmer (help alleviate poverty) and have higher levels of carbon accumulation and carbon sinks.
(2) **Perform an economic evaluation** of these land management systems in terms of their benefit associated with carbon accumulation and carbon sinks.
(3) **Provide recommendations** on appropriate technology and management for these land management systems in order to make them economically attractive to the farmer and beneficial to the environment as contributors to increases in carbon sequestration and carbon sinks.
(4) **Develop cost-effective methodologies for C monitoring** in these different land management systems.
(5) **Develop mathematical models to extrapolate carbon sequestration capacity** in similar areas within the American Tropical Forest Ecosystem for future decision-making in research and policy-making.

EXPECTED PRODUCTS

- **Identified** pasture, agropastoral and silvopastoral systems that are viable and economically attractive to the farmer and enhance C accumulation and sinks.
- **Estimated** carbon levels, animal productivity and farmer's economic benefit in the various land management systems studied across sub-ecosystems.
- **Estimated** economic benefit of C accumulation in these land managements systems.
- **Recommended** policy guidelines developed for paying C incentives to farmers in these land management systems in the tropics.
- **Shared new knowledge** with farmers, researchers and policy-makers invited to field days and training events.
- **Better knowledge of C accumulation levels** in these complex pasture, agropastoral and silvopastoral systems in the tropics.
- **Refined criteria, methodology and scientific information** for future research on carbon sequestration in pasture, agropastoral and silvopastoral systems in the tropics.
- **Identified land-use systems and sites for targeting CDM** within the American Tropical Forest Ecosystem.

RESEARCH METHODOLOGY

Research methodology for this 5-year project was discussed in detail and agreed by participant institutions, project members and consultants during the First International Coordination Meeting, held at CIAT, December 17-19, 2001 and improved in subsequent meetings and discussion sessions. Research methodology is common across sub-ecosystems and comprises the four following research strategies:

A. Evaluation of a range of long-established land management systems of similar age within each sub-ecosystem (11-20 years of age) to quantify and compare the level of C accumulation between them and in comparison with two extreme reference states: degraded pasture (negative control) and native forest (positive control).
B. Evaluation of new small-plot experiments established on degraded pasture sites, to quantify and compare after 4 years the level of C accumulation newly established improved systems vs. the degraded pasture.
C. Socio-economic evaluation of research areas, farms and land use systems.
D. Model building to estimate C accumulation in silvopastoral systems.

2. Activities 2nd semester year 4 (December 1– May 31, 2005) according to Annual Plan 2005

The activities described below have been successfully accomplished during the last six months of the fourth year of our project: December 1 – May 31, 2005, in accordance with Annual Plan 2005. The Chronogram of Activities 2005 is included as **Annex 1** of the present report.

Technical and administrative coordination activities

- **VI International Coordination Meeting, held at CIAT, Cali, Colombia, August 16-19, 2005.-** The planning of this meeting started already during the first semester 2005. The Program is included as **Annex 2** of the present report.

  This meeting was particularly important as, for the first time, project's results were shared with decision-makers from the Colombian Government. The meeting was also attended by Mr. Maurice van Beers, from the Netherlands Embassy in Bogotá, who presented a very interesting conference entitled ***"The Netherlands Cooperation in the World, in Colombia, and in the present Project"***, whose Spanish version is here included as **Annex 3**. The contribution from Prof L.'t Mannetje, project's consultant from Wageningen University, entitled ***"The Role of Grassland and Forest as Carbon Store"*** appears as **Annex 4**. Meeting summary and recommendations are described later in this report.

- **3-day Training Course on Green House Gasses (GHG), held at CIAT on August 22-24, 2005.-** Besides the conduction of the project's VI International Coordination Meeting, a 3-day international training course for project personnel, on Green House Gasses (GHG), offered by Dr. Pascal Boeckx, from Ghent University, Belgium, took place the week immediately following the meeting. Thanks to project efforts, Ghent University agreed to cover costs of travel and accommodation at CIAT of the lecturer, Dr. Pascal Boeckx. This course was very useful to the project as it provided basic training to project personnel in a complementary subject to Carbon sequestration: measurement and analysis at field level of the three most important GHG (CO_2, Methane, and Nitrous Oxide). Course program is also included as **Annex 2**.

- **Preparation, discussion and agreement of the project's Annual Plan 2006 .-** As agreed with The Netherlands Cooperation, through The Netherlands Embassy in Bogotá, the project's Annual Plan 2006 was prepared earlier than previous Annual Plans, and handled to the Embassy on October 31, 2005. After their study, it was approved.

- **Preparation of Eight Six-months Technical and Financial Reports.-** As stated and agreed in the document "Acuerdo de Contribución", of December 2001, the Eight Six-months Technical and Financial Report for this period, were prepared and handled to The Netherlands Embassy in Bogotá on December 15, 2005.

Research Activities

- **Completion and statistical analysis of the second Carbon sampling cycle (years 2004-2005) in two ecosystems: the Humid Tropical Forest Ecosystem, Amazonia, Colombia; and the Humid and Sub-humid Tropical Forest Ecosystems, Costa Rica.-**

  At the end of the project's fourth year, field work related to C evaluation of long-established systems was completed in all ecosystems. For Andean Hillsides Ecosystem, the database is ready and the complete statistical analysis of Soil Carbon Stocks (SCS) from both C-sampling cycles (2002-2005) was completed. For Amazonia and Costa Rica Ecosystems, laboratory results are ready and the preliminary statistical data analysis was completed during this semester.

  In the Humid Tropical Forest, Amazonia, Colombia, soil carbon and vegetation evaluations on six long-established land use systems, on mild-slope topography ('Pekin Farm") were completed during the first semester 2005, and the statistical data analysis was completed during the present semester. In Costa Rica, all long-established land use systems in Esparza and Pocora were sampled for a second time (years 2004-2005), as initially planned. Soil samples from Costa Rica ecosystems were analysed at CATIE's Soils Laboratory. A preliminary statistical analysis of data from second C-sampling was done during this 2nd semester 2005.

  Activity Reports from Costa Rica, Andean Hillsides and Amazonia are included respectively, as **Annex 5**, **Annex 6** and **Annex 7** of the present report. Complete statistical analysis results from Amazonia, both topographies --flat and mild-slope-- are included as **Annex 8** of this report

- **Socio-economic Research Activities: Development and Analysis of Simulation Scenarios for farmer's investment in systems with capacity to sequester Carbon - all Ecosystems.**

  During this semester, socio-economic results achieved from comparing improved vs. conventional farms in the project ecosystems, have been completed, analysed and interpreted. That is: the project has completed phase 1 --characterization of improved vs. conventional farms in all ecosystems. Has also completed phase 2 --estimation of economic benefit associated with the various land use systems under study, and development and analysis of simulation scenarios for farmer's investment in pasture systems with capacity for C sequestration. A progress report is included as **Annex 9** of the present report.

- **Continuation of periodic biomass evaluation of Small-plot Experiments in the three Ecosystems.**

In order to measure the effect on C sequestration of newly-established improved pasture and silvo-pastoral systems planted on degraded land, five (5) small-plot experiments were established in degraded areas. Those five experiments are: 2 in Andean Hillsides: Dagua and Dovio sites, Colombia; 2 in the Humid Tropical Forest, in flat and mild-slope topographies, Florencia, Amazonia, Colombia; and 1 experiment in Esparza, Sub-humid Tropical Forest ecosystem, Pacific coast, Costa Rica. The initial Cevaluation took place at the beginnings of the project, in the first semester 2002. The final C evaluation will take place at the end of the project.

In the interim, periodic biomass evaluations carried out every 2-3months, of each improved system studied in the five experiments, has been done to monitor biomass production of improved systems to be later associated with C sequestration.

- **Planning Phase: Extrapolation of Project results to similar areas in Tropical America – Contract with ISRIC, Wageningen, The Netherlands**

An important project objective, stated at "Acuerdo de Contribución", December 2001, is to extrapolate project results on carbon sequestration of pasture, agro-pastoral and silvo-pastoral systems estimated in the project research areas, to similar areas in Tropical America. To accomplish this goal, it is necessary to work with a geo-referenced database of Tropical America, where each point is represented by its altitude, longitude and latitude, with information on soil type, climate variables (temperature, precipitation) and land use.

ISRIC (International Institute on Soils Research), from Wageningen University, The Netherlands, has developed a geo-referenced database of Tropical America with soil type information at a scale 1:5000. Additionally, CIAT has a database on land use for Tropical America. A contract between the project and ISRIC was signed to carry-out this work, starting November 2005. Terms of Agreement of the contract with ISRIC is included as **Annex 10** of this report.

VI International Coordination Meeting

CIAT, 16–19 August 2005
Summary of
Agreements and Recommendations

Accompanying activity: The international training course on greenhouse gases was held at CIAT on 22–25 August 2005. Participants included Project members, several guests at the Meeting held the previous week, and outside participants from different research institutions. Thanks to arrangements made by the Project through its contact, CarboEurope, this course was run by Dr Pascal Boeckx from the University of Ghent, Belgium, which also totally financed it. The course's goal was a written proposal to be developed in the next year for a joint subproject with our Project on on-farm measurements of three greenhouse gases (CO_2, nitrous oxide, and methane). This project would be financed by Belgium.

1.1 Summary of the Meeting

One of the Project's objectives is to offer recommendations to policy decision makers at local, national, and international levels on measures for mitigating the adverse effects of climate change on vulnerable ecosystems in developing countries. For this reason, the Project invited to this Meeting, important representatives of the public policy sector of Colombia, and other important guests from the private and research sectors. The Project is especially pleased to mention that the Netherlands Cooperation was also present at this Meeting, represented by Mr Maurice van Beers from the Royal Embassy of The Netherlands, Bogotá.

All Project members participated in the Meeting, that is, 33 people, including researchers and students from its five partner institutions (*see* "Participants"). Other participants were The Netherlands Cooperation (Mr Maurice van Beers), and important guests from the Colombian public policy and research/education sectors (*see* "Outside Participants).

The Meeting was organized for four days:

- Day 1. The Meeting's guests were shown, in summary form, the progress made by the Project in the 3½ years since its implementation on 1 December 2001. At the end of the day a 2-hour Discussion Panel composed of policy decision-makers was held , entitled "**How can our Project's results be useful for decision-making in the Colombian National System for the Environment?** "
- Day 2. Detailed presentations of the Project's progress on biophysical and socioeconomic issues, according to ecosystem
- Day 3. A field day was held in one of the Project's study areas: El Dovio in northern Valle del Cauca, Eroded Andean Hillsides, Colombia.

Day 4. Discussions were held to analyze progress made, agree on details for activities in 2006, and discuss the possible new proposal for phase II of the Project with new members, specifically the U. Santo Tomás, CRC, CORPOGUAJIRA and, possibly, Carbones del Cerrejón

The Meeting opened with the Project's Scientific Director welcoming the participants. The Director General of the host institution, CIAT, Dr Joaquim Voss, followed with warm words of welcome. He also emphasized the importance of this highly articulated Project and expressed his great interest as CIAT itself will participate in the Project's second phase. Mr Maurice van Beers, of the Royal Embassy of The Netherlands in Colombia, offered a most interesting presentation on the activities of The Netherlands Cooperation in the world, in Colombia, and specifically its experience with the Project. The Scientific Director presented Project's achievements in its first 3½ years of work.

The morning session closed with an invited presentation from the Director of IDEAM, Dr Carlos Costa, who gave an excellent description of Colombia's activities with respect to climate change. The following presentations described the Project's specific achievements in each of the following ecosystems: Eroded Andean hillsides (Colombia), humid tropical forest (Colombian Amazon), and humid and subhumid tropical forests (Costa Rica).

The day concluded with a 2-hour panel discussion with the Project's guests on the theme *How can our Project's results be useful for decision-making in the Colombian National System for the Environment?* The resulting comments and recommendations are summarized in the next section.

1.2 Summary of Comments and Recommendations by the Panel of Guests

Theme:
How can our Project's results be useful for decision-making in the Colombian National System for the Environment?

16 August, Tuesday, 16:15–18:00
(10–15 minutes per Panelist and comments from the audience)

Panel Participants

- Dr Claudia Rincón, Director of Planning, MAVDT, Bogotá
- Dr Leonardo Muñoz, Director of Ecosystems, MAVDT, Bogotá
- Dr Carlos Costa, Director, IDEAM, Bogotá
- Captain Dr Francisco Arias, Director, INVEMAR, Santa Marta
- Dr Camilo Aldana, Director, CONIF, Bogotá
- Dr Manuel Rodríguez, International Consultant on Environmental Issues

Summary of Comments

The guests began their discussions by first thanking the Royal Embassy of The Netherlands in Colombia and the Project's Directorate for the opportunity of learning first hand about this research project, its participating institutions, members, its work and scientific methodologies, and the research results achieved during its first 3½ years of implementation.

All the Panelists congratulated the Project's executors for its quality and achievements. They highlighted the progress made in evaluation methodologies for both biophysical (carbon in soils) and socioeconomic factors. There are lessons learned that could be applied to other contexts in the programs and projects of many institutions. The importance of interinstitutional work stood out.

The Panelists sincerely congratulated the Project for its achievements and agreed on the importance of its methodology and scientific results being taken advantage of by decision makers in Colombia on environmental issues, both at national and international levels.

Guest Panelists' Comments and Suggestions

Drs Claudia Rincón and Leonardo Muñoz, MAVDT

They first described the Colombian National System for the Environment (SINA). It is made up of the Ministry for the Environment, 33 regional autonomous corporations (CARs), 6 urban authorities, and 5 research institutes (IDEAM, the von Humboldt Institute, INVEMAR, SINCHI, and the Institute of Environmental Research for the Pacific). They cited, as a principal strength of SINA, its capacity for national leadership and its high institutional coherence.

To answer the Panel's principal question, they commented that the Project's results in each of its four contrasting ecosystems—Eroded Andean Hillsides (Colombia); Humid Tropical Forest (Colombian Amazon); Subhumid Tropical Forest (Costa Rica); and Humid Tropical Forest (Costa Rica)—could be applied by the MAVDT and CARs. For example:

- The Project helps connect sustainable practices with activities related to mitigating the adverse effects of climate change and solving rural poverty.
- The MAVDT is interested in research that generates solutions for major environmental challenges when this is based on social equity. The Project supports both these components.
- The MAVDT can use the information collected by the Project to generate indicators on (a) soil management (b) poverty; and (c) the interrelationships between poverty, soil conservation, food security, and conservation and management practices.
- To implement SINA's Information System.
- It offers the CARs guidelines for implementing indicators at a regional level.

- It supports the *National Action Plan for the Struggle against Desertification and Drought*, even in ecosystems that are not dry but susceptible to desertification. Dr Leonardo Muñoz points out that 17% of the national territory is highly vulnerable. Colombia needs to halt soil loss linked with hydric regulation and plant coverage in pilot cases of extremity such as the middle basin of the Patía River.
- The Project provides methodology and scientific information on national forest regulation, taking into account that the Forest Law also includes agroforestry systems. The Project's contribution to this theme is its scientific methodology and data generated on C sequestration, sustainability, and integration between environmental and socioeconomic benefits of improved and well-managed systems of a pastoral, agropastoral, silvopastoral, or agroforestry nature.
- The MAVDT is interested in the Project's progress with agropastoral, silvopastoral, and agroforestry systems because the new Forest Law, which is currently being discussed in the Congress of the Republic opens the way for environmental services for forests and other equivalent forms of use, and is intended to increase connectivity among ecosystems.
- The Project contributes highly significant results for the "Amazonian Cooperation Treaty", "Bio-Andes", and "Pacific Agenda XXI".
- The Project provides solid scientific information that supports the idea that the benefits of environmental services reach the generators of these services. The socioeconomic approach shows that conservation can be carried out while generating income that helps alleviate poverty.
- The Project contributes to the national discussion on generating regional capacities and synergies among different regions.
- The current challenge for much of the country is to increase connectivity among protected areas, which therefore demand greater and better recommendations for land use that would be compatible with forests and natural ecosystems. The Project contributes such recommendations.
- The Project contributes methodology and connectivity on the issue of carbon sequestration for forest plantations. Moreover, it contributes valuable elements for forest conservation policy.
- A highly significant contribution from the Project is the development of a scientific methodology that evaluates, estimates, analyzes, and interprets carbon sequestration in tropical ecosystems.
- The Project's results provide valuable information for the MAVDT's *Second Communication on Climate Change*.
- At the government level, it is important to improve the synergies between the MAVDT and other national actors such as the Ministries of Finance and Agriculture. The Project contributes towards these synergies. Hence, it is important that the Project's results are also disseminated to the livestock and economic sector, including the Ministries of Agriculture and Finances.

Dr Carlos Costa, Director, IDEAM

Dr Costa organized his discussion on the question, "Where does this Project leave us?" and summarized his responses in terms of various issues. He suggested that:

Issue 1. The Project contributes documented and tested methodology for evaluating carbon sequestration in pastoral, silvopastoral, and forest systems in contrasting and heterogeneous tropical ecosystems.

Issue 2. The Project's scientific data are useful for improving the precision of national estimates of the balance of emissions, particularly CO_2.

Issue 3. Its results serve to define lines of action for the Government on the issue of its *Policy on Climate Change*, specifically actions for mitigation and adaptation.

Issue 4. Its scientific methodology can be extrapolated to other environments, for example, research on other land ecosystems or other production systems, and could be even useful for research on aquatic ecosystems such as mangroves.

Issue 5. The Project must expand its research to other ecosystems, particularly native savannas and alpine regions.

Issue 6. It must also expand its research to other land use systems such as forest plantations.

Issue 7. The methodology generated by the Project to evaluate, estimate, analyze, and interpret carbon sequestration is important for supporting the *Primer of Good Practices* described in the MAVDT's *Second Communication on Climate Change.*

Issue 8. This Project's results go beyond the issues of carbon sequestration and climate change. They also contribute solid scientific data and documented recommendations on many other issues such as soil improvement practices; improved practices of livestock production that are environmentally sustainable in ecosystems vulnerable to climate change; employment generation; social and economic benefits of improved and well-managed pastoral, agropastoral, and silvopastoral systems; and the potential of silvopastoral and pastoral systems to contribute environmental and economic services to the farmer in four contrasting ecosystems.

Issue 9. This Project opens the door to other living systems, besides forestation and reforestation—pastoral, silvopastoral, and agroforestry systems—that can mitigate the adverse effects of climate change. It accordingly contributes elements of policy on this issue.

Issue 10. Dr Costa agrees with the previous Panelists that the Project's results must be disseminated to the livestock sector and the Ministries for Agriculture and Economic Development.

Issue 11. IDEAM plays a key role in the *Second Communication of Colombia on Global Climate Change.* It must therefore improve the calibration of national information on the balance of gases and calculation of emissions. In the near future, it should generate a guide of good practices for the country. Hence, Dr Costa considers the Project to be useful for some components related to carbon.

Dr Costa also expressed the following comments:

- Because of its progress in socioeconomic issues, the Project goes much beyond the field of carbon sequestration, having useful elements for issues such as land management.

- A review should be made of other information on soils (chemical and physical variables) that was evaluated by the methodology but not presented at the Meeting.
- The methodology developed by the Project could be applied to other environments such as the native savannas of Orinoquía for which the Government has special interest in developing.
- In the future, the Project could help the country decide on issues such as extensive versus intensive livestock production. To this end, and in the context of mechanisms for clean development, in-depth economic analyses will be needed.

Captain Dr Francisco Arias, Director, INVEMAR

INVEMAR works in a very different Colombia: the marine country, which has a great complexity of aquatic ecosystems. It also has major deposits of carbon and natural systems that can very efficiently sequester carbon such as mangroves, coral reefs, and paddocks of marine phanerogams. Moreover, phytoplankton is an enormous and dynamic compartment of the carbon cycle with a positive balance of greenhouse gases.

The impact of global climate change on Colombia will have serious effects such as those that coastal plains will suffer with increases in sea levels (17% of the area of Colombia's Caribe Region) and saline infiltration of surface and underground waters.

The trend in scientific research is to develop national capacities, regional and international cooperation, which, in its turn, should improve the country's capacity to negotiate. But the question must be asked: how to facilitate this? For example, the replacement of illegal crops urgently requires the participation of scientific research to generate solutions for a social and environmental reality.

Although large differences exist between the challenges INVEMAR faces and those of this Project, some positive ideas are offered to help with their research.

As responsible for national research on marine and coastal issues, Captain Arias suggested that the Project—through its objectives, organization, methodology, scientific results, and conclusions so far—challenges researchers in climate change on issues for marine and coastal ecosystems in Colombia such as the following:

Issue 1. The complexity of terrestrial ecosystems studied by the Project (pastoral, agropastoral, silvopastoral, forestry, degraded soils) can be assimilated into the complexity of marine and coastal ecosystems—such as corals, mangroves, phanerogams, and marine grasses—with the capacity to sequester C because of their high phytoplankton content.

Issue 2. After having listened to Project presentations and their results, Captain Arias sees considerable connectivity and complementarity between Project activities and INVEMAR's research on climate change issues. The Project's results especially complement INVEMAR's work on coastal plains and the subject of saline infiltration of surface and underground waters.

Issue 3. The Project's results serve to better understand the trends of scientific research that we should address. Moreover, it invites the development of national and regional capacity, and the search for interrelationships with the international academic community.

Issue 4. The Project provides Colombia with a new capacity for management and negotiation that can influence the decisions of COP 2005 and COP 2006, specifically in the allocation of resources to the country.

Issue 5. The Project offers an alternative to communities cultivating coca and poppy through pastoral, agropastoral, and silvopastoral systems that, with appropriate management practices, offer farmers environmental services and economic benefits.

Dr Camilo Aldana, Director, CONIF

Dr Aldana remembers that for the 19 years he has been in charge of CEGA (Center for Livestock and Agricultural Studies), which is affiliated with the Banco Ganadero in Bogotá, no-one has ever discussed carbon sequestration in pastoral and silvopastoral systems. Attending this Meeting therefore represented a new learning experience for him. It opened up new challenges. He now sees many possibilities that could be applied to CONIF's research with forest systems. He commented as follows:

- At CONIF, considerable work is carried out in the area of environmental services for the forest sector (forests, forest plantations, and silvopastoral systems) because of growing awareness of these services and the belief in the justice and desirability of paying for them to prevent deforestation and encourage conservation. Those who conserve forests should be paid. Equally, incentives for environmental services should be offered to investors who establish forest plantations and agropastoral and silvopastoral systems. Environmental services are "externalities", that is, they are benefits that do not reach those who provide them. The *Certificate of Forest Incentives* is one approach to solving this problem.
- Colombia has 25 million hectares suitable for reforestation but only plants an average of 150,000 every year. Thus, investment in plantations is under represented, and incentives are needed to maintain native forests.
- Forest development, which includes agroforestry and silvopastoral systems, needs the combination of effective management with payment for environmental services and the creation of markets for these—whether through the Kyoto Protocol or equivalents. Hence, cutting-edge scientific research is needed for these issues. The Project contributes this component to the country.
- The Project's results should be made known to MAVDT's Climate Change Group; investors in forest, agroforestry, and silvopastoral systems; the national Government; and the national and international scientific community. The Project is to be congratulated for the quality and usefulness of its results.
- Dr Aldana asked the following questions: How can one enter the international carbon market? How can one enter to the group of investors who pay for carbon sequestration? There was no clear answer to these questions.

Dr Manuel Rodríguez, former Minister for the Environment, Colombia, and International Consultant on Environmental Issues

Dr Rodríguez indicated that he was very impressed by the Project's results. He considered it an unusual partnership between highly heterogeneous research centers and yet it produced results. It is a partnership between highly qualified centers with others of lesser trajectory; between national centers of regional character with international centers; and an alliance between the scientific communities of developed and developing countries. He sincerely congratulated the Project's Directorate on its excellent leadership, adding "Hopefully, phase II of this Project will be financed". He also made the following comments and suggestions:

- For Colombia, this type of research is highly significant for encouraging negotiations on the issue of climate change as it is very important that international negotiation is sustained in systematic scientific research. Dr Rodríguez proposed that analyses of the Project's results be used in Colombia's negotiations on the issue of climate change.
- Dr Rodríguez agreed with the other Panelists that this Project goes well beyond the issue of climate change. It contributes solid scientific information on many other aspects such as scientific methodology, sustainability through environmentally friendly pastoral and silvopastoral systems that are economically attractive to the farmer. It has a capacity for extrapolating research results.
- He emphasized that the Project should make an effort to define with greater precision the degree of intervention in the forest where evaluations have been made in each ecosystem to avoid imprecise interpretations on the forest's capacity to sequester C. He suggests that, for example, some forests could be regarded as "highly disturbed fragments". (To date, the Project evaluates forests as "highly disturbed", "moderately disturbed", or "in natural regeneration without intervention for more than n years", e.g., for more than 80 years, etc.). He commented on Brazilian data (no reference) that showed native Amazon forests to sequester, on a net basis, 5 t/ha of C per year.
- Dr Rodríguez asks "What is the relationship between scientific research and public policy? Scientific research and public policy form a significant relationship. In the last 15 years, environmental research in Colombia has increased and, although much is yet to be done, it is good to ask now how national science has affected policy. For example, the current government has just issued the document *Vision 2019: A Proposal for Discussion*, which projects the country's future for the next 14 years. The great surprise was that, despite the Colombian Constitution of 1991 recognizing sustainable development and carrying 50 articles on the environment, *Vision 2019* lacks the environmental theme in both its two governing principles and its four major objectives (environmental sustainability, sustainable development, social development, and economic development). A great opportunity exists for the public and private sectors to help fill this gap.
- The ex-Minister suggests that, given the Project's nature and objectives, its conclusions, recommendations, and studies of the levels and potential for carbon sequestration of different land uses should also be done holistically, as well as for individual ecosystems.

- That is, the Project should show it delivers solutions that contribute social, economic, and environmental benefits to small farmers in ecosystems that are vulnerable to climate change.

How to ensure that the Project's results support policy decisions?

To answer this question put by the Project's Directorate, Dr Rodríguez and the other Panelists suggested that the Project:

a. Seek the support of a policy maker who can translate the Project's results for policy decision makers, and who is responsible for drafting one or more policy papers that are different to but highly complements the scientific articles that the Project publishes. The profile of this professional would therefore differ from that of the Project's current members.
b. Look for connection with other projects of international cooperation and so orient its initiatives on environmental management. In this regard, The Netherlands Cooperation has an important role in integrating results generated by different projects. The Panel suggested that one or more follow-up meetings must be held with the Netherlands Cooperation and the participants of this Meeting.
c. Contribute valuable elements to the *National Action Plan for the Struggle against Desertification and Drought.*
d. Expand its evaluations to two important ecosystems for Colombia: the native savannas of Orinoquía and alpine regions.
e. Present results with caution, seeking to benefit policy on forest conservation and adequate land management. To prevent discrepancies arising between sectors, recommendations should avoid emphasizing certain research data that appear to give an alleged advantage of improved pastures over forests or native vegetation.
f. Analyze information on soils derived from the Project's methodology that would help improve initiatives on better land management by small farmers.
g. Make its conclusions and final recommendations holistically, seeking to favor strategies that aim to help overcome poverty without degrading the environment.
h. For phase II, seek articulation with SINA and encourage CARs to be co-financiers.

1.3 Summary of Internal Comments and Agreements on Project activities during 2006

1. ISRIC contract for production of digital maps and extrapolation region of Project results in Tropical America

The Project signed a contract on April 28, 2005 with the International Soil Reference and Information Centre (ISRIC) to produce: (1) three digital maps and corresponding paper copies (one per ecosystem: Tropical Andean Hillsides, Sub-humid and Humid Tropical Forest of Central America, and Amazonian Tropical Humid Forest) indicating the regions for extrapolation of the Project's research results in each ecosystem; (2) a database accompanying the maps; (3) a report explaining the methods and results.

The later wich will be presented by Dr. Vincent van Engelen, ISRIC, at the Project's VII International Coordination Meeting, Costa Rica, June 2006.

The regions for extrapolation of the project results include:

(a) Tropical Andean Hillsides in Colombia, extending into similar environments in the neighbouring countries of Ecuador, Peru and Bolivia
(b) Sub-humid and humid tropical forest at the Atlantic and Pacific coasts of Costa Rica, extending into similar environments in the neighboring countries of Panama, Nicaragua, Honduras, El Salvador and Guatemala
(c) Humid Tropical Forest, Amazonia in Colombia, extending into similar environments in the neighbouring Amazonian countries (Peru, Brazil, Bolivia and Ecuador) -

Total cost of the contract is 20,204 Euros to be paid as follows: 10,000 Euros on November 2005 and the rest at the end of the contract once final results are approved by the Project Direction. Text of the full contract appears as **Annex 10** in the present Technical Report.

2. Preparation of a Scientific Book with Project results

The group agreed to publish the results of the project in a scientific book using the format of a recognized publisher. The book will be composed of various chapters to be prepared by project members according to the leadership of the Project Scientific Director. It was agreed that an Editorial Committee be created, composed by Drs. María Cristina Amézquita, Peter Buurman, Muhammad Ibrahim, Bertha Ramírez and Enrique Murgueitio, to read and perform technical edition of the chapters. It was agreed that the first draft of the various chapters be ready by May 31, 2006, to be presented and discussed at the VII International Coordination Meeting to be held in Costa Rica on the last week of June 2006. The first draft can be written either in English or Spanish. Once each chapter is revised by the Editorial Committee, all chapters will be translated into English and Spanish. It was agreed that Professor Leendert 't Mannetje will perform the final edition of the English version, and Dr. María Cristina Amézquita will perform the final edition of the Spanish version.

3. Project Meetings in 2006

Two meetings will be held in 2006 for the completion of the project: one in Costa Rica and other in Colombia. The "VII International Coordination Meeting", a 4- day meeting, will be held in Costa Rica on the last week of June 2006. Muhammad Ibrahim kindly agreed to be responsible for the meeting organization. The last project meeting will be a 2-day "Decision-makers Meeting" to be held in Cartagena, Colombia during the first week of October 2006.

4. Project Training courses in 2006

Funds will be made available by the project for 3 short courses: 2 in Costa Rica, and 1 in Colombia. The courses are: (1) "Methodologies for Carbon Sequestration", a 3-day course to be held at CATIE, Turrialba, Costa Rica, in April 2006; (2) "Organic Matter", a 3-day course to be held at CATIE immediately after the first course, April 2006; and (3) Methodologies for the Statistical Analysis of Carbon Sequestration data, to be held at Universidad de la Amazonia, Florencia, Colombia, either at the end of 2005 or beginnings of 2006 (exact date to be agreed). These courses will be attended by Project members, using project funds, but will also be offered to researchers and policy-makers from different interested institutions, who will need to pay for their participation.

5. Technical comments

Amazonia research results.-

- It is important to make a clear definition of Amazonian Piedmont area in Colombia, both mild-slope and flat topographies, where the project is conducting carbon sequestration evaluations, as these ecosystems are different from the large Amazon region in Colombia and other Latin American countries.
- It is necessary to clearly define the type of "Native Forest" areas where carbon evaluations are been made. It was suggested that forest characterization be made in terms of type and years of human intervention. The project has to be aware of the differences between these forests and native untouched Amazonian forests for extrapolation purposes. Dr. Manuel Rodriguez mentioned studies conducted on carbon sequestration on the Amazonian jungle by Brazil and TROPENBOS Institute (without references).
- In the analysis of Soil Carbon Stocks from long-established systems in Amazonia mild-slope topography, the system "Brachiaria humidicola + legumes" can be included in the statistical analysis without problem.
- Why is biomass production in sloping areas higher than in flat lands? Is there a drainage effect? why do legumes reduce stable carbon?

Costa Rica research results:

The Costa Rica soil C data need checking, recalculation of carbon stocks on fixed-weight basis and renewed statistical analysis. The complete and final database of Soil Carbon Stocks from Costa Rica's long-established systems needs to be made available to the project. It was suggested that there may be possible error in results from the soils laboratory analyses.

Andean hillsides research results.-

- Some trials, especially the forage banks of Dovio and Dagua give unexpected results, possibly due to large differences in soil characteristics. It is necessary to find the reasons of these deviations. The group recommended that a soil's specialist, Dr. E. Amézquita, should help clarify this issue.
- Data on CEC of soils should be transformed to meq/ha as recommended by Peter
- Data presented for Andean hillsides showed significant differences in soil characteristics between sites (example 22 vs 66% sand in degraded and forest sites) and therefore in the analysis of variance to compare these sites, some systems might not be included.

General Comments for all Ecosystems

- It is necessary to evaluate consistency of soil data in order to 1) judge homogeneity of trial fields and 2) eliminate dubious results. This applies to data from all ecosystems.
- Correction of Soil C Stocks data from long-established systems from Andean Hillsides and Amazonia SCS databases was done together with Drs. Peter Buurman, Prof L. 't Mannetje, Bram van Putten and María Cristina Amézquita in WU in May 2005 for this purpose. Peter reported that errors detected in the databases, based on the ratio oxidisable C/total C, were not related to field sampling but laboratory analysis and we need to ascertain where the laboratory errors are.
- A meeting should be convened with each institution to share the procedures of data evaluation. Soils data should be explained to all participants.
- A special workshop should be carried-out with project members from participant institutions in order to explain the procedure for data checking, data cleaning, data processing and statistical analysis of SCS.
- **Socio-economy:** In investment models presented, it is important to state real costs of establishment and maintenance of the different land uses, in particular, improved pasture systems (grass-monoculture, grass-legume-tree associations) and forage banks.
- **Socio-economy:** Be aware that income data during the first year of establishment for some land use systems can be misleading as some land uses increase their income during posterior years.
- For further studies on carbon, it is recommended that the several sites are selected based on a pre-sampling conducted to select sites that are very homogeneous in terms of the soil characters and management histories

Spatial Statistical Analysis.-

The group agreed that the concepts on spatial statistical analysis presented by Dr. Bram van Putten can be useful for analyzing the data on soil carbon stocks and agreed that Dr Putten take the responsibility to do the analysis with the Amazon data on SCS, from flat topography, which show less variation. Once the project is convinced with the analysis, it can be applied to the other ecosystems.

Further research question.-

After listening to the presentation made by Dr. Ramón Gualdrón, Coordinator of Land Rehabilitation Program, Carbones del Cerrejón, Guajira, Colombia, a question was made: If recuperation of soil physical structure in mine reclamation occurs within 9 years, does this also apply to degraded grasslands / degraded soil?

6. Methodology for measuring and estimating above-ground C

Muhammd Ibrahim agreed to make available to the group the methodology used by CATIE to estimate above-groud C in pasture and pasture-tree systems

7. Methodology for estimating GHG

As a product of the GHG Course offered by Dr. Pascal Boeckx from Ghent University, Belgium, on August 22-24 at CIAT, the methodology to estimate the three GHG content on field plots (methane, nitrous oxide and CO_2) was stated. Dr. Boeckx explained three methods:

(1) The least expensive and practical, which he recommends.- Manual cages, of 10 cm diameter x 30cm depth, placed inside the soil, 6 per plot, on which the three GHG are evaluated in a 3-hour period, evaluations conducted every day for one month on the two contrasting seasons (dry and wet season),GHG collected after each measurement period and then transported to the laboratory for analyses (in Ghent University);

(2) Electronic boxes of similar size as the manual ones, connected to a computer that reads the GHG content in periodic times. Cost US$ 35,000/cage.
(3) Tower.- like Edi Covariance towers. Cost US $ 150,000. They require a very homogeneous landscape, flat, with the same wind direction day and night, not practical under our conditions and land use systems.

1.4 Summary of Comments from possible future Partners on Project's Proposal for its Second Phase (2007 onwards)

- Discussion Session, Friday 19 August 3-6 pm -

Future: Project Proposal for a Second Phase of the present project

A Project Proposal Profile o concept note has been prepared for a second phase of the project. It was agreed that collaborating institutions will provide feedback. Possible new partners include the five partner institutions of the ongoing project, plus four additional partners from the Colombian public and private sectors: Universidad Santo Tomás, Bogotá; CORPOGUAJIRA, Riohacha; CRC, Popayán; and possibly Carbones del Cerrejón, La Guajira. This Project Profile was also discussed on wednesday 17 August with members of the Colombian Ministry of the Environment and SINA (National Colombian Environmental System) to have their feedback and suggestions to make it useful to government needs and policies.

3. Executed Funds during this period (December 1, 2004 – May 31, 2005) distributed by Activity.

In order to show how executed funds were invested in the various activities conducted during the present reporting period (June 1 – Novemebr 30, 2005) the next table (table 1, included below) was prepared, using "Activities" as rows, "Budget Categories" as columns, and % allocated to each activity from the various budget categories as cells.

4. Budget Tables 2005

Budget tables 1-10 are included as **Annex 11** of this report. They show real budget execution for years 1, 2, 3 and 4, and estimated budget requirements for year 5. The tables show project budget --global and per institution-- per year and for the total 5-year of project duration, discriminated by donor funds and matching funds.

Annexes

Annex 1: Chronogram of Activities - Annual Plan 2005.

Annex 2: Program VI International Coordination Meeting and Training Course on Green House Gasses (GHG), held at CIAT, Cali, on August 16-19 and August 22-24, 2005, respectively.

Annex 3: *La Cooperación Holandesa para el Desarrollo, en el Mundo, en Colombia, y en el Proyecto Captura de C.* Contribution from Maurice van Beers, The Netherlands Embassy in Bogotá, to the VI International Coordination Meeting. CIAT, August 16, 2005.

Annex 4: *The Role of Grassland and Forest as Carbon Store.* Contribution from Prof. L. 't Mannetje, Wageningen University, The Netherlands, to the VI International Coordination Meeting. CIAT, August 16, 2005.

Annex 5: Activity Report, Humid and Sub-humid Tropical Forest, Costa Rica.

Annex 6: Activity Report, Andean Hillsides Ecosystem, Colombia.

Annex 7: Activity Report, Amazonia, Colombia.

Annex 8: Complete Statistical Analysis of Soil Carbon Stocks from flat and mild-slope Topographies (2002-2004), Humid Tropical Forest, Amazonia, Colombia.

Annex 9: Socio-economic Evaluation Report. Development and Analysis of Simulation Scenarios in all Ecosystems.

Annex 10: Contract with ISRIC for extrapolation and GIS maps work

Annex 11: Budget Tables (10) with executed budget for years 1, 2, 3 and 4, and projected budget for year 5.

Annex 1

Chronogram of Activities
Annual Plan 2005

CHRONOGRAM OF ACTIVITIES - ANNUAL PLAN 2005

December 1, 2004 - December 31, 2005

OBJECTIVE	ACTIVITY	INDICATORS	12	1	2	3	4	5	6	7	8	9	10	11	12	Participant Institutions
1. PROJECT ORGANISATION ACTIVITIES.	Preparation and agreement of annual contracts for project personnel	Signed contract														CIPAV
	Preparation and agreement of Terms of Reference for Consultants	Accepted TOR´s														Project Direction CIAT WU
	Renewal of contract with farmers for the three sub-ecosystems: Andean Hillsides, Amazonia and Costa Rica farms.	Contracts accepted. Farms ready to work.														U.A.-CIPAV CATIE
2. TECHNICAL AND ADMINISTRATIVE COORDINATION	Preparation of ANNUAL PLAN 2005.	Plan handled to The Netherland Embassy in Bogotá, Colombia (before December 31, 2004)														Project Direction
	VI International Coordination Meeting, CIAT,Cali, Colombia, Aug 29 - Sep 2, 2005	Meeting conducted														Project Direction CATIE CIAT CIAPV U.AMAZ. W.U
	Preparation of Seventh Six-months Technical and Financial Reports.	Reports handled to The Netherlands Embassy in Bogotá, Colombia. June 15, 2005.														All Participant Institutions
	Preparation of Eight Six-months Technical and Financial Reports.	Reports handled to The Netherlands Embassy In Bogotá, Colombia, Dec 15, 2005.														Project Direction CATIE CIAT CIPAV U.AMAZ. W.U
	Preparation of ANNUAL PLAN 2006.	Plan handled to The Netherlands Embassy in Bogotá, Colombia before December 31, 2005.														Project Direction and Participant Inst.
3. SOCIO-ECONOMIC SIMULATION	Design and analysis of simulation scenarios. Three Sub-ecosystems	Tool ready. Simulation scenarios analyzed														Project Direction and CATIE Economics consultant

CHRONOGRAM OF ACTIVITIES - ANNUAL PLAN 2005
December 1, 2004- December 31, 2005
CONT. PAG -2

OBJECTIVE	ACTIVITY	INDICATORS	12	1	2	3	4	5	6	7	8	9	10	11	12	Participant Institutions
4. Continuation of SECOND CARBON SAMPLING in AMAZONIA, COLOMBIA and COSTA RICA SUB-ECOSYSTEMS	1. Soil carbon and vegetation evaluations - six new treatments, Amazonia Colombia (cont. from past semester)	Data organised according to agreed formats														Project Direction U. Amazonia
	2. Soil carbon and vegetation evaluations - second spacial replication, costa Rica (cont. from past semester)	Data organised according to agreed formats														Project Direction CIATIE
5. STATISTICAL ANALYSIS OF Soil Carbon Stocks	1. Complete Statistical analysis on Soil Carbon Stocks from Andean Hillsides Ecosystems															
Both C-samplings: Andean Hillsides and Costa Rica sub-ecosystems	2. Complete Statistical analysis of Soil Carbon Stocks from Costa Rica Ecosystems															
First C-sampling: Amazonia	3. Statistical analysis of Soil Carbon Stocks from First C-sampling, Amazonia															
6. EVALUATION OF SMALL-PLOT EXPERIMENTS - BIOMASS PRODUCTION	Andean Hillsides-Colombia.	Two experiments evaluated every 2 months.														CIPAV CIPAV
	Humid Tropical Forest - Colombian Amazonia	Two experiments evaluated every two months														Univ. Amazonia
	Semi humid and humid Tropical Forest - C. Rica	One experiment evaluated every two months.														CATIE
7. EXTRAPOLATION	1. Agreement and Signature of TOR with ISRIC, Wageningen, The Netherlands 2. Starting of work	Contract with ISRIC signed														Wageningen University, ISRIC and Project Direction

CONVENTIONS:

- EXECUTED BY PROJECT DIRECTORS
- HUMID TROPICAL FOREST, COLOMBIA - U. AMAZONIA
- ANDEAN HILLSIDES, COLOMBIA - CIPAV
- SEMI-HUMID TROPICAL FOREST, COSTA RICA -CATIE
- WAGENINGEN UNIVERSITY PARTICIPATION
- CIAT PARTICIPATION

Annex 2

Program VI International Coordination Meeting and Training Course on Green House Gasses (GHG)

CIAT, August 16-19 and 22-24, 2005

The Netherlands Cooperation
Activity CO-010402

Research Network for the Evaluation of Carbon Sequestration Capacity of Pasture, Agropastoral and Silvopastoral Systems in the American Tropical Forest Ecosystem

CIPAV- U. Amazonia -CIAT-CATIE-W. University

Project duration: 5 years
December 1, 2001 – November 30, 2006

VI INTERNATIONAL COORDINATION MEETING
and
Green House Gasses Course

CIAT, Cali, Colombia
August 16-19 and 22-24, 2005

Conference Room: "Nariño", CIAT

CIPAV: Center for Research on Sustainable Agricultural Production Systems, Cali, Colombia.
Universidad de la Amazonia, Florencia, Colombia.
CIAT: International Center for Tropical Agriculture, Cali, Colombia.
CATIE: Centro Agronómico Tropical para Capacitación y Enseñanza, Turrialba, Costa Rica.
Wageningen University and Research Center, Wageningen, The Netherlands.

PROGRAM

Saturday 14, Sunday 15 and Monday 15 August:
Arrival to Cali Airport and transport to CIAT's hotel.

Tuesday 16 August
Moderators: Prof. L. 't Mannetje (am session) and Mr. E. Murgueitio (pm session).

8:00 – 8:30 am	Welcome and Introduction of participants	Dr. Ma. Cristina Amézquita Project's Scientific Director
8:30-8:45am	Welcome Address from Host Institution	CIAT's Director General Dr. Joachim Voss
8:45-9:00am	The Netherlands Cooperation: the world, Colombia, this Project	Mr. Maurice van Beers
9:00-9:10am	Questions	
Project Overview		
9:10 – 9:30am	C-Seq Project: Its Relevance to Grasslands Science and Kyoto Protocol Policy	Prof. Dr. L. 't Mannetje Wageningen University
9:30 – 9:40am	Questions	
9:40 – 10:25am	Project Achievements Dec 2001-Aug 2005. Key issues for discussion during this meeting	Dr. M. C. Amézquita
10:25-10:35am	Questions	
10:35–10:45am	Coffee	
10:45-11:15am	Project Progress in Socio-economic Research (2001- 2005). Model on Financial Viability.	Dr. J. Gobbi, Environmental Economist, CATIE
11:15-11:30am	Questions	
Presentation from the Colombian Ministry of the Environment – IDEAM		
11:30-12:15m	Colombia and Climate Change: Strategy	Dr. Carlos Costa Director IDEAM, Bogotá
12:15-12:30m	Questions	
12:30m-2:00pm	Lunch	
Project Achievements by Ecosystem (2001-2005)		
2:00-2:30pm	Humid Tropical Forest Ecosystem, Amazonia, Colombia	Dr. Bertha L. Ramírez U. Amazonia, Colombia
2:30-2:40pm	Questions	
2:40–3:10pm	Humid and Sub-humid Tropical Forest Ecosystems, Costa Rica	Dr. Muhammad Ibrahim, CATIE, Costa Rica
3:10-3:20pm	Questions	
3:20-3:50pm	Eroded Andean Hillsides Ecosystem, Colombia	Mr. Enrique Murgueitio, CIPAV, Colombia
3:50-4:00pm	Questions	
4:00-4:15pm	Coffee	
4:15-5:30pm	Discussion Panel: How our Project can be useful in the decision-making process. Comments and Recommendations from External Guests. 10 min each. Questions.	Drs. Claudia Rincón, Leonardo Muñoz, Carlos Costa, Manuel Rodríguez, Camilo Aldana, Cap F. Arias
7:00 – 10:00pm	Cocktail – CIAT's VIP Room	

Wednesday August 17

Moderators: Dr. P.Buurman (bio-physical discussions) - am and pm sessions
Ms P. Cuellar (socio-economic discussions)- am and pm sessions

C Sequestration and Socio-economic Results by Ecosystem		
9:00-9:30am 9:30-9:45am	Soil data evaluation for the C Sequestration Project Questions	Dr. Peter Buurman Wageningen U.
Humid and sub-humid Tropical Forest Ecosystems, Costa Rica		
9:45 – 10:30am	Soil C Stocks and aboveground C in long-established pasture and silvopastoral systems compared to native forest and degraded land (data 2002-2005). Statistical Analysis. Use of CO2FIX models	Dr. M. Ibrahim and T. Llanderal
10:30- 10:45am	Questions and Recommendations	
10:45-11:00am	Coffee	
11:00-11:20am	Biomass evaluations - small-plot experiment Esparza	Dr. M. Ibrahim
11:20-11:30am	Questions and recommendations	
11:30-12:00am	Model on Financial viability scenarios: General Concept for all ecosystems. Socio-economic results Costa Rica.	Dr. J.Gobbi
12:00-12:30pm	Questions and General Recommendations	
12:30m-2:00pm	Lunch	
Humid Tropical Forest Ecosystem, Amazonia, Colombia		
2:00–2:45pm	Soil C Stocks in long-established pasture systems compared to native forest (data 2002-2005). Flat and mild-slope topographies. Statistical Analysis	M.C.Amézquita, H.F. Ramírez, H. Giraldo.
2:45-3:00pm	Questions and Recommendations	
3:00-3:15pm	Roots biomass and Soil Carbon Stocks in pasture systems	Dr. Bertha Ramírez
3:15-3:30pm	Biomass evaluations - small-plot experiments	Dr. J. Velázquez
3:30-3:45pm	Protein Banks, Amazonia Experiments	Mr. J. C. Suárez
3:45-4:00pm	Questions and Recommendations	
4:00-4:15pm	Coffee	
4:15-4:35pm	Socio-economic research Results and Model on Financial Viability Scenarios.	Mr. J. Muñoz Dr. J. Gobbi
4:35-4:45pm	Questions and Recommendations	
4:45-5:30pm	Discussion Panel: "What have we learnt from this Project"?	Moderator: Dr. M. Ibrahim

- Moderators of discussion sessions are asked to prepare a summary report in magnetic media to be presented at the Closing Session and handled to F. Ruiz.

Thursday August 18: Field Day (Dovio, north of Valle del Cauca)

Bus departs from CIAT's Hotel Reception at 6am and returns to CIAT at around 5pm

Friday August 19

Moderators: M. Ibrahim (morning session) and B. Ramírez (pm session)

C Sequestration and Socio-economic Results by Ecosystem (cont.) **Andean Hillsides, Colombia**		
9:00–9:30am	Soil C Stocks in long-established systems, compared to native forest and degraded land. Statistical Analysis 2002-2005	Dr. M.C.Amézquita, H.Giraldo, M.E.Gómez
9:30-9:45am	Questions	
9:45:10:00am	Root biomass vs. Soil C Stocks in pasture systems	Engs. H. Giraldo and M.E.Gómez
10:00-10:20am	Botanical composition of a natural regeneration of a degraded pasture, Dagua	Mr. G. A. González
10:20-10:30am	Questions	
10:30-10:45am	Coffee	
10:45-11:00am	Biomass evaluations of small-plot experiments	Engs. M.E. Gómez and H. Giraldo
11:00-11:15am	Questions and Recommendations	
11:15-11:35am	Socio-economic research results	MSc. P. Cuéllar and Dr. J. Gobbi
11:35-11:45am	Questions and Recommendations	
Project Activities 2006 – Annual Plan 2006. News		
11:45-12:15pm	Spatial Statistical Analysis of Soil C Stock data: Concepts	Dr. Bram van Putten Wageningen University
12:15-12:30pm	Questions and Recommendations	
12:30-2:00pm	Lunch	
2:00 – 2:30pm	Annual Plan 2006: News	Dr. M.C.Amézquita
2:30-3:30pm	General Discussion: Future work 2006. – Extrapolation; Project's Scientific Book; Newsletter; VII Int. Coordination Meeting (date and place); other Project meetings 2006. Future?	
3:30–3:45pm	Coffee	
Recommendations from Session Moderators. Closing Session		
3:45-4:45pm	Presentation of a unified recommendations list from Session Moderators	All session moderators
4:45- 5:00pm	Closing Session.	
7:00pm – 1:00am	Social event (bus leaves from CIAT's hotel Reception at 7pm to go to Cali)	

- Moderators of discussion sessions are asked to prepare a summary report in magnetic media to be presented at the Closing Session and handled to F. Ruiz.

End of Meeting. Thanks for your participation

Participants

Partner Institutions

- **CIPAV**: Center for Research on Sustainable Agricultural Production Systems, Cali, Colombia.
  Legal and technical representative: Dr. Enrique Murgueítio, Executive Director.
- **Universidad de la Amazonia**, Florencia, Colombia.
  Legal representative: Dr. Luis Eduardo Torres García, Rector.
  Technical representative: Dr. Bertha Leonor Ramírez, researcher.
- **CIAT**: International Centre for Tropical Agriculture, Cali, Colombia.
  Legal representative: Dr. Joachim Voss, Director General.
  Technical representative: Dr. Edgar Amézquita, Soil Scientist.
- **CATIE**: Centro Agronómico Tropical para Capacitación y Enseñanza, Turrialba, Costa Rica.
  Legal representative: Dr. Pedro Ferreira Rossi, Director General.
  Technical representative: Dr. Muhammad Ibrahim, researcher.
- **Wageningen University and Research Centre**, Wageningen, The Netherlands.
  Representatives: Drs. Bram van Putten and Peter Buurman, researchers.

Project Executive Committee

- **Dr. María Cristina Amézquita.**
  Ph.D., Production Ecology and Resource Conservation.
  Project Scientific Director.
- **Mr. Enrique Murgueitio**. CIPAV's Executive Director.
  Project Administrative and Financial Director.
- **Dr. Bertha Leonor Ramírez**. Ph.D., Agroforestry Systems.
  Universidad de la Amazonía.
- **Dr. Edgar Amézquita**. Ph.D., Soil Sciences. CIAT.
- **Dr. Muhammad Ibrahim**. Ph.D., Agronomy. CATIE.
- **Dr. Bram van Putten**. Ph.D., Mathematics.
  Wageningen University and Research Centre.
- **Dr. Peter Buurman**. Ph.D., Soil Chemistry and Dynamics.
  Wageningen University and Research Centre.

Consultant: **Professor Dr. Leendert 't Mannetje**, Ph. D. in Tropical Grasslands.
Wageningen University and Research Centre.

Project members

- ***Field research – Hillsides ecosystem (Colombia)***
  María Elena Gómez. Agronomist, M.Sc.- CIPAV
  Piedad Cuellar. Participatory research, M.Sc.- CIPAV
- ***Field research – Semi-humid Tropical Forest (Costa Rica)***
  Tangaxuhan Llanderal, PhD student
  Alexander Navas, Agronomist, CATIE
  Francisco Casasola, Agronomist – CATIE
- ***Field research – Humid Tropical Forest (Colombian Amazonia)***
  Bertha Leonor Ramírez. Agroforestry Systems. Ph.D.
  Jaime Enrique Velásquez. Agronomist. Ph.D
  Jader Muñoz, Geologist
  Studs: J.A Montilla, J.C. Suárez, E.R. Castañeda, Wilmar Y. Bahamon
  Universidad de la Amazonia.

- ***Environmental Economist:***
  José Gobbi, Economist Ph.D.
- ***DB analyst/statistician***
  Héctor Fabio Ramírez. Statistician.
- ***Soil sampling and biomass evaluations***
  Hernán Giraldo. Agronomist.
- ***Executive Assistant***
  Francisco Ruiz. Industrial Engineer.
- ***Students in practice:***
  Lucero Gómez, Universidad Santo Tomás, Cali
  Laura Cabrera and Gabriel A. González, Universidad Javeriana, Bogotá
  María Camila Rebolledo, Montpellier University, France

Research Services

- ***Laboratory analyses***
  Soil samples from Colombian ecosystems: contracted with CIAT's Soils Lab.
  Ing. Octavio Mosquera, Head Soils Laboratory, CIAT.
  Samples from Costa Rica ecosystems: contracted with CATIE's Soils Lab.
- ***GIS (cartography and extrapolation)***
  Contracted with ISRIC (Int. Soil's Research Institute), Wageningen University.

External Participants

Dr. Manuel Rodríguez, International Advisor on Environmental Issues, Bogotá.

Colombian Ministry of the Environment, Bogotá

- Dr. Claudia Rincón, Planning Director
- Dr. Leonardo Muñoz, Director of Ecosystems

Colombian National Environmental Research Institutes

- Dr. Carlos Costa, Director General, IDEAM (National Institute for Environmental Research), Bogotá.
- Captain Dr. Francisco Arias, Director General, INVEMAR (Colombian National Research Institute on Marine and Coastal Zones), Santa Marta.
- Dr. Camilo Aldana, Director General, CONIF (National Corporation of Forestry Research), Bogotá.
- Dr. Dollors Armenteras, Principal Researcher, Von Humboldt Institute, Bogotá.

CRC (Environmental Corporation for Cauca Dept), Popayán, Colombia

- Dr. Jesús Elmer Alvarez, Director Environmental Management

CORPOGUAJIRA (Env. Corporation for Guajira Dept), Riohacha, Colombia

- Dr. Juán Carlos Serrato Reyes, Researcher, Environmental Planning

CIAT (International Center for Tropical Agriculture), Cali, Colombia

- Dr. Idupulapati Rao, Leader Soils Research Project

FEDEGAN (Colombian Federation of Cattle Producers), Bogotá

- Dr. José Félix Lafaurie, Executive President

Universidad Santo Tomás, Bogotá

- Dra. Luz M. Marciales, Regional Centres Coordinator / Participatory Research
- Ing. Eduardo Plata, Environmental Researcher

UNITROPICO (Universidad del Trópico Americano), Yopal, Colombia

- Dr. Pablo Avila, Rector

Green House Gasses (GHG) Course
CIAT, August 22-24, 2005
By Dr. Pascal Boeckx, Ghent University, Belgium

Monday August 22
Moderators: Drs. P. Buurman (morning session) and B. van Putten (pm session)

Morning Session		
9:00 – 9:30am 9:30 – 11:30am 11:30-11:45am 11:45 – 12:00m 12:00-2:00pm	Welcome Address and presentation of participants Part 1: Agriculture and Environment Coffee Questions Lunch	M.C.Amézquita P. Boeckx
Afternoon Session		
2:00pm – 4:00pm 4:00-4:15pm 4:15-4:45pm 7:00-10:00pm	Part 2: Environmental impact of Climate Change Coffee Questions Social event. Bus leaves from CIAT's Reception at 7pm and returns to CIAT at around 11pm	P. Boeckx

Tuesday August 23
Moderators: Drs. P. Buurman (morning session) and Bram van Putten (pm session)

Morning Session		
9:00 – 11:00m 11:00 – 11:15am 11:15- 12:00m 12:00-2:00pm	Part 3: Greenhouse gas emission and sequestration in terrestrial ecosystems Coffee Questions Lunch	P. Boeckx
Afternoon Session		
2:00pm – 4:00pm 4:00-4:15pm 4:15-5:00pm	Part 4: Measurement of GHG emission from terrestrial ecosystems Coffee Questions	P. Boeckx

Wednesday August 24: Field day. Bus leaves from CIAT's Reception at 7am and returns to CIAT at around 5pm

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- Moderators of discussion sessions are asked to prepare a summary report in magnetic media to be presented at the Closing Session and handled to F. Ruiz.

End of Course. Thanks very much to Pascal and all participants

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Annex 3

"La Cooperación Holandesa para el Desarrollo, en el Mundo en Colombia, y en el Proyecto Captura de C".

Contribution from Maurice van Beers, The Netherlands Embassy, Bogotá. VI International Coordination Meeting. CIAT, August 16, 2005.

La Cooperación Holandesa para el Desarrollo en el Mundo, en Colombia y el Proyecto "Evaluación de Secuestro de C de Sistemas de Pasturas, Agro-pastoriles y Silvo-pastoriles en el Ecosistema Tropical Selvática Americano"

Maurice van Beers

1. En el Mundo

Los cambios climáticos son un problema mundial lo cual requiere medidas a nivel mundial. Esto es igual de cierto tanto para las causas de los cambios como por las consecuencias. El grupo de países en transición no contribuye sustancialmente a las causas del cambio climático, mas cuando se enfoca en las emisiones per cápita.

Países en transición son relativamente vulnerables por las consecuencias de los cambios climáticos mientras no posean los medios para neutralizar los efectos del calentamiento global, tomando en cuenta que además grandes grupos de sus poblaciones, como en Colombia un grupo alrededor del 50% están viviendo en la pobreza. Además, son los pobres mas que todo quienes sufren los efectos de los cambios climáticos como inundaciones, cosechas fracasadas y climas extremos.

Por lo tanto, los países industrializados se han comprometido a apoyarles en la adaptación a las consecuencias de los cambios climáticos y a tomar la iniciativa en la reducción de emisiones, así también apoyarán a los países en transición en le desarrollo de sus políticas de clima.

En el marco de las políticas internacionales de clima nos hemos obligado a reducir la emisión de gases del efecto invernadero en el período entre 2008-2012 con 6% comparado con el año 1990, dentro de las directrices generales de la Unión Europea en el marco del protocolo de Kyoto. Lo anterior quiere decir que Holanda debe lograr una reducción de 50 metric toneladas de CO2 equivalentes. De éstas, los Países Bajos realizarán la mitad en el propio país, la otra mitad, 25 metric toneladas, se realizará en otros países por medio de mecanismos flexibles definidos en el protocolo de Kyoto como la Implementación Conjunta, Negocio Internacional de Créditos de Carbonos y el Mecanismo de Desarrollo Limpio.

Dentro de las políticas holandesas de cooperación internacional existen varias posibilidades de financiar actividades dentro del marco de convenios del calentamiento global, tales como:

- Hacer accesible la energía y servicios energéticos a grupos marginalizados a través de la aplicación de tecnologías de reducción de emisión (mitigación).
- La adaptación a las consecuencias negativas del calentamiento global.
- La construcción y el desarrollo de capacidades necesarias en las organizaciones e instituciones para la formulación e implementación de políticas nacionales de cambios climáticos y para participar en el mecanismo de desarrollo limpio (MDL).

Al comienzo del período de 2002 a 2005 el énfasis de las políticas de la Cooperación para el Desarrollo estaba mas en mitigación y fortalecimiento de capacidad institucional que en adaptación. Ahora este balance ya está cambiando justo porque los objetivos de adaptación, clima y reducción de la pobreza, se dejan combinar muy bien con los objetivos de la Cooperación Holandesa.

La Cooperación Holandesa usa tres canales: bilateral multilateral y el canal particular.

Bilateral

A parte de las actividades del gobierno holandés las cuales son coordinadas por las embajadas hay otros programadas y proyectos que son adelantados directamente bajo la responsabilidad del Ministerio de Cooperación. Los mas importantes son:

Netherlands Climate Change Assistance Programme (NCCSAP).

La primera fase del programa tenía como énfasis el soporte al desarrollo de las Comunicaciones Nacionales a través de fortalecer la capacidad de investigación y monitoreo relacionado con el Cambio Climático. En Colombia se ha enfocado en estudios de la Costa Caribeña, realizados por el INVEMAR como organización central con acompañamiento del Instituto para cuestiones Medio Ambientales de Holanda (IVM). La segunda fase, que ha comenzado en Colombia en el 2004 es acompañada desde Holanda por el ETC de Leusden. El énfasis de la segunda fase es mas dirigido a acompañamiento en la creación y formulación de políticas en el tema de Cambio Climático.

Cooperative Programme on Water and Climate (CPWC)

El programa de cooperación CPWC (2004-2008) era iniciado para estimular la cooperación entre las disciplinas de Cambio Climático, gerencia hídrica, ayuda de emergencia en caso de catástrofes. Es un programa bien amplio que recibe cofinanciación por parte del gobierno holandés para actividades como investigación, asistencia técnica, entrenamiento y educación. El IHE (Institute for Water Education – UNESCO) en Holanda está encargado con el secretariado de ese programa.

Capacity Development by SouthSouthNorth

Este programa para el fortalecimiento de capacidades de los mecanismos para el desarrollo limpio (MDL) contribuye a la reducción de pobreza a través de instalación de capacidades en el sector público y privado. Uno de los objetivos es el desarrollo de portafolio de proyectos de MDL en el cual los mas pobres de los países participantes pueden aprovechar.

Probablemente Colombia participará en una siguiente fase para el apoyo de la Oficina de Mitigación de Efectos Climáticos la cual se fundó desde hace tres años con financiamiento del Banco Mundial.

Además los Países Bajos han firmado un Memorando de Entendimiento con varios países, incluido Colombia, para que entre los dos países se pueda intercambiar los niveles de compromiso relacionados con la emisión de gases de efecto invernadero.

Para lograr este propósito, los Países Bajos tiene la posibilidad de comprar reducciones de emisión de gases de efecto invernadero a través del mecanismo "Mecanismo de Desarrollo Limpio" (MDL), en países en desarrollo que emitan estos gases a niveles inferiores a sus obligaciones internacionales. La "compra"de estas reducciones de emisión no solamente beneficia a los Países Bajos para cumplir con su meta, sino que también estimula la inversión en proyectos "limpios" lo cual ayuda a un desarrollo sostenible en otros países como Colombia. Con la "venta" de los "carboncredits"se obtiene un mayor rendimiento sobre la inversión.

Red cross Preparedness for Disasters related to Climate Change.

Los elementos mas importantes de este programa son promover una mayor conciencia en las oficinas locales de la cruz roja sobre los cambios climáticos y las consecuencias de éstos. El objetivo principal del programa, que mayormente se está adelantando en Vietnam y Nicaragua, es un mayor conocimiento sobre el análisis de riesgos en relación con la vulnerabilidad de comunidades locales.

Global Change System for Analysis Research and Training (START).

El proyecto START tiene como objetivo la estimulación de investigación sobre los efectos de los cambios climáticos para brindar a los tomadores de decisiones locales y regionales información científica sobre el tema.

Kyoto: think Global, Act Local.

Este proyecto, de cinco años de investigación construcción de capacidad, está coordinado por la Universidad Tecnológica de Twente en Holanda. El objetivo del programa es hacer mas accesible la Convención Marco de las Naciones Unidas sobre Cambio Climático-CMNUCC y los protocolos de Kyoto para proyectos forestales coordinados por comunidades locales en países en vía de desarrollo. Tales programas solo son accesibles para reforestación debido a que la capacidad de secuestro de $CO2$ es mas medible allí.

Multilateral

En el período de 2002 – 2005 el Ministerio para la cooperación por el desarrollo ha reservado igual cantidad de medios financieros como capacidad para mesas y grupos de trabajo del CMNUCC para las problemáticas de adaptación en los países menos desarrollados.

Además, Holanda sigue siendo, como los años anteriores, un donante importante del "Global Environment Facility"(GEF). En el período 2001 – 2004 se han donado alrededor de 75 millones de euros al GEF para la financiación de proyectos dentro de los marcos de los convenios medio ambientales, como el convenio de Biodiversidad, el convenio de desiertos, y Kyoto. Alrededor del 40% de este monto está reservado para proyectos relacionados con clima. Colombia es, como es conocido, uno de los GEF beneficiarios, como por ejemplo el proyecto de biodiversidad Andes ejecutado por el instituto Von Humboldt y el de apoyo a un mejor manejo a las áreas protegidas coordinado por la Unidad de Parques Nacionales.

Particular

Por medio del canal particular se ha contribuido sustancialmente a instituciones, organizaciones y ONG tanto en Holanda como en países en transición. Un instrumento importante en relación con políticas de clima es el programa para estimulación de mercados en surgimiento (PSOM) de donde se están cofinanciando muchos proyectos de mitigación. El carácter principal de éstos proyectos es transferencia de tecnología y conocimiento en cooperación con el sector privado local. El PSOM programa tiene un presupuesto de 48 millones de euros para 36 países y del cual Colombia es uno. El PPP (public private partnership) es un instrumento que incentiva la formación de asociaciones público-privadas para financiar proyectos con énfasis en reducción de la pobreza y desarrollo sostenible. El programa con el Sector Privado por medio del canal particular ha resultado en donaciones del orden de unos 4 millones de euros en 2004.

2. En Colombia

En el 2004, Colombia y los Países Bajos celebraron 100 años de relaciones diplomáticas. Durante los últimos 40 años, la cooperación bilateral para el desarrollo forma una parte importante para la presencia holandesa en Colombia. Para Colombia, el presupuesto para el año 2004, destinado a los programas de Medio Ambiente y Derechos Humanos / Buen Gobierno y Paz, llegó a los 12 millones de euros.

Una parte importante de la cooperación a Colombia se ha reservado para programas de medio ambiente de los cuales los programas y proyecto mas importantes son el fortalecimiento del Sistema Nacional Ambiental (SINA), fortalecimiento institucional de Parques Nacionales y el proyecto del uso sostenible de la biodiversidad de los Andes colombianos a través del Instituto de investigación no Von Humboldt. Además tenemos un programa importante a través de Ecofondo. Atención especial reciben el Chocó biográfico y la Orinoquía / Amazonía, en donde la embajada está adelantando dos proyecto grandes enfocados en la producción sostenible, fortalecimiento de gobierno y ordenamiento territorial con énfasis para la autonomía comunitaria de las comunidades negras e indígenas. A través de la UNICEF la cooperación adelanta un programa de capacitación a mas de 200 municipios en mas de 17 departamentos de tamaño medio para desarrollar su PGIR y así obtener un mejor manejo de sus residuos sólidos.

El proyecto *"Research Network for the Evaluation of Carbon Sequestration Capacity of Pasture, Agro-Pastoral and Silvo-pastoral Systems in the American Tropical Forest Ecosystems"*, se ha comenzado en el 2001 y va hasta el 2006. Un proyecto que para nosotros es un ejemplo de rigor científica con un valor aplicado alto que ya puede demostrarnos algunos resultados interesantes sobre como lograr mayores niveles de rentabilidad con un buen manejo de pasturas en comparación con otros paisajes.

A partir de este año, la Cooperación Holandesa comenzará con algunas contrapartes, como el Ministerios de Medio Ambiente, Vivienda y Desarrollo Territorial, la Unidad de Parques Nacionales y el Instituto Von Humboldt, una fase de cooperación transitoria que dura hacía el 31 de diciembre de 2006. Este tiempo se usará para el análisis interno en la embajada y con nuestro socios aquí en Colombia, sobre como podemos llegar a una cooperación más sectorial, para obtener un mayor impacto y menos resultados aislados (como en los proyecto muchas veces es el caso). La búsqueda de trabajar de una forma mas sectorial, está motivada por la escasez de fuentes económicas por el cual se busca actividades que contribuyan a mas que un objetivo. Como por ejemplo, la estimulación de redes ecológicas al borde de los ríos las cuales contribuyen a la conservación de la biodiversidad, reducción de la erosión y a la captura de los gases del efecto invernadero.

Actividades que apuntan a solo un objetivo son cada vez menos atractivas para la financiación. Esta forma sectorial de trabajar debería comenzar a partir del 2007.

¿Cómo se pueden usar los resultados que nos van a mostrar durante el día de hoy para hacer políticas medio ambientales?. Por ejemplo: para políticas que promuevan el desarrollo de incentivos para un mejor aprovechamiento sostenible y económicamente interesantes para el campesino y ganadero de los ecosistemas de pasturas. Y usar los resultados para el desarrollo de proyectos de MDL y aplicable para el mercado de carbo-créditos.

Pero lo mas importante, como se puede desarrollar, y mas que todo ejecutar, políticas que integran estos mecanismos a otras políticas como la conservación de biodiversidad, reducción de la pobreza, reactivación del campo, etc. La Cooperación Holandesa a través de proyecto no será sostenible. Se buscará financiar políticas y actividades que son mas integradas, mas sectoriales con una pretensión para un impacto mas grande.

Les invitamos a pensar con nosotros sobre cómo lograr este mayor impacto para aplicarlo a partir del 2007.

Muchas gracias.

Annex 4

"The Role of Grassland and Forest as Carbon Store"

Contribution from Prof. L. 't Mannetje, Wageningen University, The Netherlands.
VI Int. Coordination Meeting. CIAT, August 16, 2005.

The Role of Grassland and Forest as Carbon Store

L. 't Mannetje

Introduction

Global warming is a hot issue and much R and D funding goes to forestry development with the object to increase CO_2 storage. However, many people, including donor agencies don't realize that grasslands, including sown pastures and rangelands, are equally as important for the storage of CO_2 as forests.

Rangelands, (mostly natural grasslands) cover about 50 % of the earth's land surface. They are found on all continents and in all climates: in the tropics in Australia, Africa, South America and Asia; in temperate regions in Australia, South and North America, Europe and Eurasia. They also occur in the arctic regions as tundra and taiga.

Rangelands are not only natural vegetation types, occurring in climates that are too dry or too cold for dense tree growth. They also originated as a result of grazing and burning of abandoned croplands and after forest clearing in humid and sub-humid regions, in which case they form a sub-climax vegetation, maintained by grazing, cutting or burning ('t Mannetje 2002).

Rain forests and rangelands are the last remaining land resources of the world and they are both in danger of degradation and disappearance through inadequate use, over-exploitation and destruction and both rangelands and forests are equally as deserving of the attention of politicians, administrators, scientists and the general public. Rangelands in semi-arid densely populated regions, e.g. in Africa are in even greater danger than rain forests, because of regular droughts and because they are subject to intense cropping and overgrazing, leading to degradation and desertification. However rangelands in subhumid and humid regions have greater resilience and are generally not overused, except in densely populated regions. Nevertheless, they are also subject to degradation due to inadequate or no fertility management.

Grassland and Carbon Sequestration

Grassland ecosystems have both economic and environmental functions, the most important environmental one being that of a vegetation cover that protects the soil and ensures production of feed for animals (wild and domesticated), firewood, timber and other indirect benefits to the inhabitants of rangelands. In addition rangelands contain medicinal plants, germplasm for new and wild relatives of existing crop and pasture plants and their soils are large stores of C on about an equal footing as forests.

Grassland systems play a beneficial role in the storage of C, but a negative role because of the emission of CH_4, mainly by grazing ruminants, whilst the role of extensively used rangelands in relation to the release of N_2O is negligible, because of the low levels of N in the rangeland ecosystems. However, N_2O and NH_3 emissions from intensively managed pastures in Western Europe can reach significant levels.

Grasslands also release CO_2 to the atmosphere as a result of respiration, decomposition of litter, burning and the fermentation of feed in the rumen. Although burning of grassland is a common practice in the seasonally dry tropics, the total amount of CO_2 released by burning is of the order of 4-7 Gt/yr, which is previously stored C and compensated for by photosynthesis of the regrowth (Goudriaan, 1990; Minami *et al.*, 1993). Furthermore, if the material would not be destroyed by fire, most of it would decompose within a year, releasing the same amount of CO_2 to the atmosphere (Hall and Scurlock, 1991). In a study covering the whole continent of Australia over a period of 18 years Graetz (2002) concluded that for a full year, the CO_2 emissions from grassland and clearing fires are dwarfed by the uptake as a result of regrowth. Over a whole year, the grassland fire CO_2 emission is just 5% of the continental uptake flux of 5.97 Gt CO_2 , which is recovered by regrowth in less than 1 year. Repeated burning of savannas increases the C content of the soil because every year a fraction of the burned wood is turned into the very stable charcoal (Minami *et al.*, 1993).

Carbon sequestration by an ecosystem occurs when the amount of CO_2 absorbed by growing plants is greater than the amount of CO_2 released by respiration, soil organic carbon and litter decomposition. The amount of C accumulation in the soil depends on the Net Primary Production (dry matter growth minus respiration) of the vegetation. C_4 grasses have a greater Net Primary Production than C_3 grasses and legumes. Therefore, net C sequestration by grassland will be higher in tropical than in temperate zones. Long and Jones (1992) estimated that tropical grasslands alone store 26 % of the total terrestrial C, tropical forest 19 %.

The introduction of improved grasses and legumes to rangelands will improve production and also increase the C sequestration potential compared to the native savannas. In the llanos of Colombia, Fisher *et al.* (1994) measured C storage of 237 t/ha under a 6-year-old *Andropogon gayanus-Stylosanthes capitata* pasture, with about half of it in the 40-100 cm deep soil layer, compared with 186 t/ha under unimproved savanna. At another site, the soil under unimproved savanna held 197 t/ha C, that under *Brachiaria humidicola* alone 223 t/ha and under *B. humidicola-Arachis pintoi* 268 t/ha. Comparable levels of C sequestration have been measured by Ayarza *et al.* (1987), Tarré *et al.* (2001) and Boddey *et al.* (2002). The deposition of C at depth can be explained by the massive root systems and deep-rootedness of tropical grasses, that often extends to more than 1 m (Ayarza *et al,* 1993; Fisher *et al.*, 1994).

Effects of Grassland Management on Soil C sequestration

Follett *et al.* (2003) measured soil organic ^{14}C activity to determine how long soil C had been sequestered in the soil of historic prairie lands in the United States by radiocarbon dating. Nearly one-half of the total weight of soil organic C was in the top 20 cm and up to one-third in the top 10 cm of the soil. The remaining one-half was located from 20 to 200 cm below the surface. The mass of soil organic C was between 85-150 t ha^{-1} in the top 2 m of soil. Soil organic C that is sequestered below 20 cm has mean residence times greater than 1000 to 2000 years. Soil C at depths of about 2 m has mean residence times of 9000 to 13000 years, but accounts for only about five percent of the total. Thus, once sequestered, immense amounts of soil organic C have remained in soil profiles for a very long time.

Follett and Schuman (2005) reviewed climatic and management factors on rate of C accumulation and long-term C sequestration in The United States. They found that fertilization, grassland improvement and proper grazing could result in the sequestration of 10.5 to 34.3 million metric tons of C per year. About half these amounts could be obtained from rangeland management improvement. Soil C sequestration is generally greater under grazing than under cutting.

Conservation practices that conserve soil and increase vegetation also increase C storage (Gavenda et al.2000). They listed the following measures:

1. Installing permanent vegetation buffers, such as windbreaks, contour hedgerows, and riparian buffers
2. Converting marginal agricultural land to perennial grassland or forest
3. Using conservation or no-till cultivation systems
4. Increasing fertilizer and water use efficiency
5. Increasing cropping intensity
6. Managing woodlands to conserve soils and increase biomass
7. Incorporating trees into agricultural operations through agroforestry
8. Using cover crops

Soil erosion is a major cause of soil organic C loss and increasing greenhouse gas emissions. This takes place by:
(1) Exposing C locked within soil aggregates,
(2) Mineralizing C by oxidation and microbial processes, and
(3) Decreasing the soil's ability to support vegetation by lowering soil fertility, losing water as runoff, decreasing plant-available soil water, burying or flooding crops, and other erosion related effects.

However, soil organic C under pasture is also subject to changes, depending on the age, nutritional status and condition of the vegetation. Asner *et al.* (2003) concluded that
(1) aboveground and soil C stocks decreased with pasture age on both clayey and sandy soils,

(2) declines in plant biomass were well correlated with declines in soil C and with available phosphorus (P) and calcium (Ca), and
(3) despite low initial values for total and available soil P, ecosystem P stocks declined further with pasture age, as did a number of other nutrients.

Carbon Dynamics of Forests

There is much misunderstanding about the CO_2 economy of forests. Many people are of the (uninformed) opinion that forest preservation and planting of new forests are the best answer to CO_2 accumulation in terrestrial ecosystems. A growing forest accumulates CO_2 mostly in tree roots, trunks, leaves and litter and less in the soil. However, once the trees are mature and have little or no growth, they will only assimilate as much CO_2 as they lose in respiration. Hoch *et al.* (2003) postulated that mature trees in temperate forests might not offset global warming by mopping up excess CO_2. They tested the assumption that current atmospheric CO_2 levels limit photosynthesis and growth and thus don't add to CO_2 storage. During spring, when trees develop new leaves, deciduous trees rely heavily on C reservoirs of sugars, starches and fats, because atmospheric CO_2 is insufficient. Furthermore, limited supplies of other nutrients, particularly N and P, may limit assimilation and growth.

CO_2 emissions to the atmosphere in a forest system, particularly in the humid tropics, can be considerable in the form of decaying litter and decomposing soil organic carbon. Rivers in humid forested ecosystem, like Amazonia, are CO_2 saturated and add to atmospheric CO_2. (Richey *et al.*, 2002). Detailed studies by Mayorga (2005) agreed with this. They found that this CO_2 was derived from present vegetation, not from ancient deposits. They concluded that Amazonia was at best in equilibrium with the atmosphere regarding CO_2, or even added to it.

Deforestation is carried out for arable cropping and for grassland establishment. Arable land stores little C in the soil in contrast to grasslands (Detwiler, 1986). Ibrahim (1994) measured 47 t/ha C in the top 10 cm of soil under grazed *B. brizantha – A. pintoi* pastures, which had been established 3 years previously, in the Atlantic Zone of Costa Rica. This amount of soil C was comparable with that found under the original rainforest. Therefore, deforestation, although deplorable for many reasons, does not necessarily lead to total C storage loss when the land is sown to grassland. The permanent destruction of rangelands by cultivation and desertification, however, is usually irreversible and therefore a significant addition to C releases from terrestrial sources.

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Annex 5

Activity Report, Humid and Sub-humid Tropical Forest Ecosystems, Costa Rica

Evaluation of Carbon Storage in Pastoral and Silvopastoral Systems

M. Ibrahim, T. Llanderal, M. Chacón and F. Casasola

I. Background

In Costa Rica the study on C- stocks in existing pasture, silvopastoral and forest systems is carried out in Esparza which corresponds to a sub-humid region in the Pacific where cattle production is being carried out and in Pocora which is representative of the humid tropics of Costa Rica (Table 1). During 2005, soil sampling was carried out on existing plots to measure the C-stocks at different depths along with measurements on DM availability of the pastures. Land use systems are shown in table 2. It should be noted that samples were taken on pastures with degraded soil as another treatment. In the existing experiments monthly biomass was measured on pastures and fodder banks and sampling of soil will be done in December 2005. The data of C-stocks on existing experiments was used to develop parameterize the CO_2Fix model. Data from other studies on root biomass, litter production and quality was used to model C-stocks in the CO_2Fix model. With respect to training and outreach, the project contributed to training experts of national institutions on basic concepts and methods of quantification of C in pasture and silvopastoral systems.

Table 1. Climatic conditions in the sites of the study area, Costa Rica.

	Site	
Climatic variable	**Esparza**	**Guapiles**
Temperature (°C)	27	29
Annual rainfall (mm)	2500	4500
Length of rainy season	5-6 months	9 or more months

The land use systems studied in both regions are shown in Table 2.

Table 2. Land use systems under study in Costa Rica.

Site	
Esparza	**Pocora**
Weedy pasture (*Hyparrhenia rufa*)	Forest
Productive pasture (*H. rufa*)	*I. ciliare*
Fodder bank	Degraded pasture
Secondary forest	*B. brizantha+A. pintoi*
Forest	*A. mangium+A. pintoi*
B. decumbens	*B. brizantha*
B. brizantha+C. Alliodora+G. Ulmifolia	

II. Results

2.1. Carbon storage in soil by system in Esparza

2.1.1. Soil profile 0-100 cm depth

The results in Esparza showed that total C was highest in the weedy pastures and lowest in *B. decumbens* pastures that were slightly degraded. High C in the weedy pastures may be associated with turn over of organic matter. Soil C was somewhat low in the secondary forest and similar trends were observed with mean oxidisable C. There were no differences between treatments in mean total stable C (Table 3).

Table 3. Carbon storage (mean ± standard error) by land use system at 1 m in Esparza, 2005.

Depth (cm)	Land use system	Mean total C (ton/ha)	Mean oxidisable C (ton/ha)	Mean stable C (ton/ha)
0-100	Native forest	149.24 ± 23.25 ab	141.11 ± 22.01 ab	9.39 a
	H. rufa pasture	127.53 ± 10.01 abc	119.56 ± 9.51 abc	8.75 ± 1.28 a
	B. decumbens pasture	84.30 ± 9.35 c	75.10 ± 8.48 c	10.11 ± 1.25 a
	Fodder bank	132.29 ± 13.62 abc	125.94 ± 13.21 abc	7.42 ± 1.66 a
	Silvopastoral system	108.42 ± 7.63 bc	99.57 ± 6.57 bc	9.81 ± 1.92 a
	Weedy pasture	179.04 ± 32.72 c	171.61 ± 31.94 a	8.79 ± 1.86 a
	Secondary forest	103.50 ± 10.5 bc	98.36 ± 9.87 bc	6.51± 0.94 a
Mean		129.76	122.18	8.66
CV(%)		41.69	42.57	57.29

2.1.2. Soil profile 0- 40 cm depth

Lowest total C in this profile was observed with secondary forest and *B. decumbens* pastures and highest values for weedy and *H. rufa* pastures and native forest. Stable C was highest for *B. decumbens* pasture and lowest for secondary forest (Table 4).

Table 4. Carbon storage (mean ± standard error) by land use system at 0-40 cm in Esparza, 2005.

Depth (cm)	Land use system	Mean total C (ton/ha)	Mean oxidisable C (ton/ha)	Mean stable C (ton/ha)
0-40	Native forest	114.16 ± 5.04 a	108.24 ± 14.63 a	5.92 ± 0.6 abc
	H. rufa pasture	104.92 ± 8.33 a	97.96 ± 7.96 ab	6.96 ± 1.04 ab
	B. decumbens pasture	67.42 ± b	59.27 ± 6.49 c	8.16 ± 1.22 a
	Fodder bank	94.06 ± 4.83 ab	89.29 ± 5.08 abc	4.76 ± 1.3 abc
	Silvopastoral system	82.51 ± 5.62 ab	74.85 ± 4.91 bc	7.66 ± 1.34 ab
	Weedy pasture	113.42 ± 17.03 a	109.03 ± 17.27 a	4.39 ± 0.88 bc
	Secondary forest	65.70 ± 2.81 b	62.44 ± 2.46 c	3.26 ± 0.42 c
Mean		94.88	97.34	5.89
CV(%)		32.59	24.55	56.78

2.1.3 Soil profile 40 – 100 cm depth

At this soil depth weedy , secondary forest and fodder bank had the highest amount of C and lowest value was observed with the *B. decumbens* pasture. Mean stable C was not different between treatments (Table 5).

Table 5. Carbon storage (mean ± standard error) by land use system at 40-100 cm in Esparza, 2005.

Depth(cm) 40-100	**Land use system**	**Mean total C (ton/ha)**	**Mean oxidisable C(ton/ha)**	**Mean stable C(ton/ha)**
	Native forest	35.08 ± 8.74 b	32.87 ± 7.84 b	3.47 ± 1.39 a
	H. rufa pasture	22.61 ± 2.64 b	21.60 ± 2.52 b	1.79 ± 0.42 a
	B. decumbens pasture	16.87 ± 3.29 b	15.83 ± 2.87 b	1.95 ± 0.92 a
	Fodder bank	38.24 ± 9.38 ab	36.65 ± 8.93 ab	2.66 ± 0.98 a
	Silvopastoral system	25.91 ± 2.11 b	24.72 ± 1.81 b	2.14 ± 0.65 a
	Weedy pasture	65.62 ± 18.16 a	62.58 ± 17.27 a	4.40 ± 1.52 a
	Secondary forest	37.80 ± 9.48 ab	35.93 ± 9.15 ab	3.24 ± 0.63 a
Mean		34.88	33.19	2.77
CV(%)		81.37	80.79	110.27

Above and below ground carbon stocks in land uses, Esparza

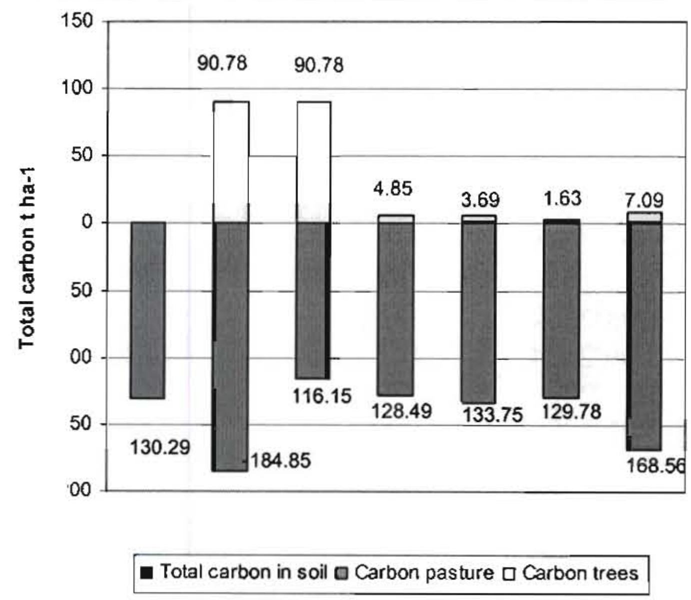


Figure 1. Above and below ground carbon stocks in land uses, Esparza, Costa Rica, 2004

2.1.4. Biomass by system in Esparza

Biomass availability was determined for the established land-use systems in Esparza and Pocora as well as for the new experiments in Esparza. The established systems evaluated in Esparza were two improved pastures (*Brachiaria brizantha* and *B. decumbens*) and two native pastures (both consisting of *Hyparrhenia rufa*; one weedy and one well managed, Table 6). Production was higher in the H. rufa pastures and lowest in weedy pasture.

Table 6. Mean DM production/cycle in different land use systems in Esparza

Land use	DM Production/ha/cycle
Weedy pasture	1298±55.5
H. rufa	1997 ± 80.79
B. decumbens	1599± 56.5
B, rizantha	1683± 55.43

Biomass availability- new experiments

Biomass availability measured in different months and different treatments is shown in table 7. Mean DM availability for *H. rufa*, *B. brizantha* and *B. brizantha* + *A. pintoi* pastures were 1790, 68, 2054.7 and 1790.68 kg DM/ha/cycle respectively. Low biomass availability was observed between the months of December and April.

Table 7. Biomass availability/ha in the new experiments established in Esparza.

Date	H. RUFA	B. brizantha	B. briz – A. pintoi
28/07/2003	1740	1135	1770
04/11/2003	1775	1895	1920
08/12/2003	1830	1955	1870
13/01/2004	885	1620	1004
25/03/2004	1502	1180	1310
08/06/2004	1855	1700	1895
11/08/2004	3316	3347	3234
28/09/2004	1426	1267	1711
11/11/2004	1752	1473	1464
26/01/2005	1166	2248	2366
06/04/2005	1968	2795	2792
10/05/2005	1116	1198	1221
Mean ± Standard deviation	**1790.68 ± 854.66**	**2054.70 ± 933.54**	**1790.68 ± 854.66**

Association between soil and carbon variables

Three principal components account for 60 to 72% of the total variability of the data in Esparza (Table 8-10). Explanation of the principal components varies for the three depth intervals considered for this analysis. However, it can be said that the principal component 1 is explained by total N and CEC. For the rest of the variability Oxidasable C and Stable C are also important, and an inverse relationship was observed between sand and clay. Presence of clay is associated to high contents of stable and oxidasable carbon in the 0-40 cm depth interval.

Table 8. Association between soil and carbon variables at 0-40 cm depth in Esparza, Costa Rica: Principal Component Analysis.

Variable	PC1(24.4%)	PC2 (18.9%)	PC3(16.14%)
pH	**-.478586**	-.432387	-.088492
Sand (ton/ha)	-.037989	0.431057	**-.548280**
Clay (ton/ha)	-.212304	0.270472	**0.631255**
CEC (ton/ha)	**0.598701**	0.002002	0.056629
p (ton/ha)	0.019428	**0.649561**	-.133053
Oxidasabe C (ton/ha)	0.115116	0.197580	**0.368916**
Stable C (ton/ha)	-.171133	0.184555	**0.354611**
Total N (ton/ha)	0.568401	**-.242990**	**0.101577**

PC1: CEC, Total N and low pH

PC2: P

PC3: Oxidasable C and Stable C with predominance of clay over sand

Table 9. Association between soil and carbon variables at 40-100 cm depth in Esparza, Costa Rica: Principal Component Analysis.

Variable	PC1 (29.4%)	PC2 (25.3%)	PC3 (17.2%)
pH	-.402433	0.275046	-.000735
Sand (ton/ha)	0.098814	**0.641667**	-.215118
Clay (ton/ha)	-.035280	**-.643531**	0.133478
CEC (ton/ha)	**0.482843**	-.113931	-.391399
p (ton/ha)	-.153181	-.177757	0.130064
Oxidasabe C (ton/ha)	**0.477425**	0.109839	**0.463773**
Stable C (ton/ha)	0.388578	0.152860	**0.569592**
Total N (ton/ha)	**0.437619**	-.135914	**-.475687**

PC1: Oxidasable C , Total N and CEC

PC2: Predominance of sand over clay

PC3: Oxidasable C, Stable C and low Total N

Table 10. Association between soil and carbon variables at 0-100 cm in Esparza, Costa Rica: Principal Component Analysis.

Variable	PC1 (26.4%)	PC2 (23.5%)	PC3 (17.8%)
pH	**-.492378**	-.106808	0.012980
Sand (ton/ha)	-.268231	**0.624648**	0.132378
Clay (ton/ha)	0.239630	**-.651760**	-.120913
CEC (ton/ha)	**0.503349**	0.301405	-.187581
p (ton/ha)	-.061820	-.128332	-.124590
Oxidasabe C (ton/ha)	**0.345546**	0.020018	**0.588248**
Stable C (ton/ha)	0.181987	-.063935	**0.665954**
Total N (ton/ha)	**0.467430**	0.248623	-.356999

PC1: Oxidasable C, Total N, CEC and low pH

PC2: Predominance of sand over clay

PC3: Oxidasable C and Stable C

2.2 Carbon storage in soil by system in Pocora

2.2.1 Soil profile: 0-100 cm

The statistical analysis showed that there were significant differences between treatments with respect to the amount of C stored in the 0- 100 cm soil depth. Mean total C was lowest for the degraded pasture and highest value was observed for the silvopastoral system with *B. brizantha* + *A. pintoi* though the values of C was not different from that of *I. Ciliare* and *A. mangium* pastures. It is important to note that total C measured in the forest was lower than that of *B. brizantha* and *A. pintoi* pasture. Mean oxidisable C was also highest for *B. brizantha* and *A. pintoi* pasture and lowest values was observed for degraded pasture. Values of improved pasture and silvopastoral system had a similar pattern to that of total C. (Table 11). On the other hand mean stable C was higher for *B. brizantha* pastures and lowest values were observed for *I. ciliare* pasture.

2.2.2 Soil profile 0-40cm

The amount of total C in the 0-40 cm soil depth was highest for *I. Cilare* and *B. brizantha* + *A. pintoi* pastures and lowest for forest and degraded pasture. There was no difference between *A. mangium* + *A. pintoi* pasture with that of *I. cilare* and *B. brizantha* + *A. pintoi* pasture and similar trends was observed for mean oxidisable C stocks.. Mean stable C was lowest for *I. cilare* pasture and highest for *B. brizantha* pasture indicating that pastures were enhancing stable carbon stocks (Table 12).

Table 11. Carbon storage (mean ± standard error) by land use system at 1 m in Pocora, 2005.

Depth (cm) 0-100	Land use system	Mean total C (ton/ha)	Mean oxidisable C (ton/ha)	Mean stable C (ton/ha)
	I. ciliare pasture	170.37 ± 15.8 ab	166.97 ± 15.84 a	3.73 ± 1.23 d
	B. brizantha+A. pintoi	181.60 ± 5.32 a	175.10 ± 5.8 a	7.63 ± 0.81 c
	A. mangium+A. pintoi	165.01 ± 14.68 ab	156.13 ± 14.32 ab	11.11 ± 0.89 b
	B. brizantha	138.32 ± 6.06 b	123.99 ± 6.02 b	16.24 ± 1.53a
	Forest	134.76 ± 7.98b	127.32 ± 7.06 b	8.67 ± 1.51 bc
	Degraded pasture	95.11 ± 4.09c	89.32 ± 4.46 c	6.33 ± 0.85 cd
Mean		149.97	142.40	8.20
CV(%)		23.71	24.65	41.31

Table 12. Carbon storage (mean ± standard error) by land use system at 0-40 cm in Pocora, 2005.

Depth (cm)	Land use system	Mean total C (ton/ha)	Mean oxidisable C (ton/ha)	Mean stable C (ton/ha)
0-40	*I. ciliare* pasture	117.41 ± 5.3 a	114.84 ± 5.29 a	2.57 ± 0.63 a
	B. brizantha+A. pintoi	116.76 ± 3.75a	112.57 ± 4.03 a	4.19 ± 0.46 bc
	A. mangium+A. pintoi	99.88 ± 8.6 ab	94.82 ± 8.56 b	5.06 ± .35 b
	B. brizantha	92.13 ± 4.83b	81.47 ± 4.6 b	10.66 ± 1.4 c
	Forest	84.41 ± 6.41 b	79.44 ± 5.72 b	4.97 ± 0.85 b
	Degraded pasture	82.99 ± 4.33 b	77.93 ± 3.98 b	5.06 ± 0.48 b
Mean		101.08	96.15	4.94
CV(%)		18.28	18.95	39.76

2.2.3 Soil profile 40- 100 cm soil depth

The highest total C- stocks at this soil profile was observed with *I. cilare* though it was not different from that of *B. brizantha+A. pintoi* and *A. mangium +A. pintoi*. Lowest value was observed with degraded pasture which had C-stocks below 25 t C/ha and similar trend was observed with mean oxidisable C. The plots of *B. brizantha* and *A. mangium + A. pintoi* had significantly higher stable C stocks than that of degraded and *I. ciliare* pasture. In summary *B. brizantha* and *A. maginum* pastures could be important systems for improving stable C stocks of soils (Table 13).

Table 13. Carbon storage (mean ± standard error) by land use system at 40-100 cm in Pocora, 2005.

Depth (cm) 40-100	Land use system	Mean total C (ton/ha)	Mean oxidisable C (ton/ha)	Mean stable C (ton/ha)
	I. ciliare pasture	79.45 ± 6.36 a	78.19 ± 6.66 a	1.74 ± 1.08 b
	B. brizantha+A. pintoi	64.84 ± 3.23 ab	62.53 ± 3.19 b	3.43 ± 0.58 ab
	A. mangium+A. pintoi	65.13 ±2.35 ab	61.31 ± 6.01 b	6.05 ± 0.73 a
	B. brizantha	46.19 ± 3.01 c	42.51 ± 2.74 c	5.58 ± 0.55 a
	Forest	50.34 ± 4.58 bc	47.87 ± 3.83 bc	3.70 ± 1.26 ab
	Degraded pasture	24.23 ± 3.6d	22.77 ± 2.9 d	2.54 ± 1.5 b
Mean		58.26	55.70	3.93
CV(%)		25.33	25.56	66.36

2.2.4 Carbon storage in biomass by system in Pocora

The data showed that available DM of *A. pintoi* in the silvopastoral system with *A. mangium* had lower yields than that of *B. brizantha* and *I. ciliare* pastures which had higher DM yields and this may be associated to excessive shading of the associated tree species. Nevertheless it should be noted that this tree is a fast growing species and large quantities of leaf litter fall from *A. mangium* may have contributed to C- stocks in this treatment. The degraded pasture was characterized with the invasion of unpalatable weeds and this may explain relatively high DM yields observed in this treatment. Available DM tended to decline between the months of December and April which correspond to the dry season (Table 14).

Table 14. Biomass availability (mean ± standard deviation) in the established land-use systems in Pocora.

Date	*A. pintoi*	*B. brizantha*	*I. ciliare*	*I. ciliare* degraded
26/07/2004	562.4 ± 325.7	1709.2 ±310.8	1439.6 ± 600.7	1855.8 ± 539.4
27/08/2004	564 ± 163.9	1920±210.8	1295 ± 390.4	2211.4 ± 514.4
15/10/2004	755 ± 186.3	2221.2 ± 437.4	1878 ± 558.4	1607.2 ± 322.2
22/11/2004	646.6 ± 193.8	1610.8 ± 459.7	1363.4 ± 357.3	2715.8 ± 845.5
21/12/2004	251.6 ± 136.1	548.4 ± 258.1	1421 ± 474.5	837.6 ± 786.6
21/01/2005	475.6 ± 169.2	1895.2 ± 379.0	2077.2 ± 416.1	810.4 ± 324.6
21/02/2005	528.4 ± 213.8	1828.4 ± 492.1	2108.4 ± 398.5	944.6 ± 317.3
18/03/2005	527.2 ± 690.6	1458.4 ± 544.8	1727.4 ± 804.8	1692.4 ± 662.6
Mean ± Standard error	538.8 ± 26.34	1610.23 ± 77.63	1663.75 ± 46.95	1584.40 ± 67.65

Biomass growth in A. mangium trees in silvopastoral systems

The results in Figure 2 showed that the amount of C stored in biomass of Acacia mangnum increased linearly in time with a total of 12.8 t/ha (tree density 180 trees/ha) and fixation of 2.5 tons/ha above ground C.

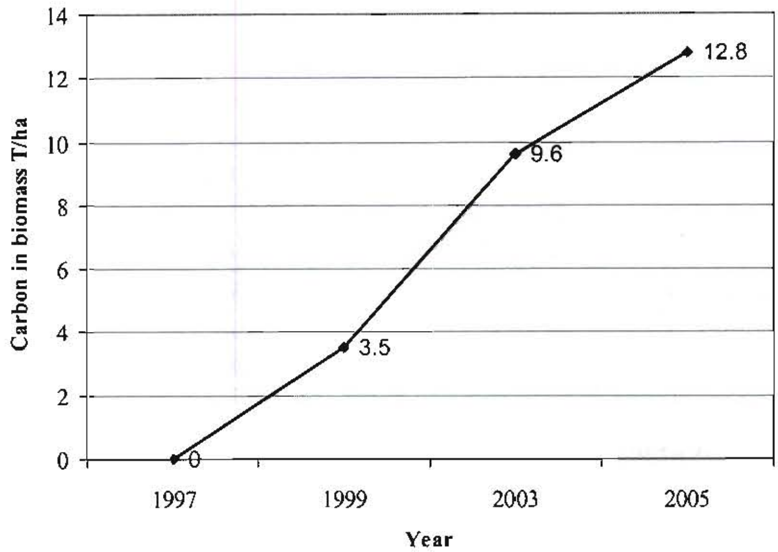


Figure 2. Accumulation curve of Acacia manguim, Pocora, Costa Rica, 2005. Andrade 1999 and Network Project.

Association between soil and carbon variables

The results in tables 15, 16 and 17 show the main variables that explain carbon at different depths. In general, 76-81% of data variation was explained by three principal components in the three depth intervals considered for this report. In comparison to the results for Esparza, the relationship between sand and clay is not obvious in Pocora. The content of clay is associated to the stable carbon content of the soil. Contrary to the observed in Esparza, nitrogen is associated to the carbon variables.

Table 15. Association between soil and carbon variables at 0-40 cm depth in Pocora Costa Rica: Principal Component Analysis.

Variable	PC1(46.2%)	PC2 (19.9%)	PC3(13.24%)
pH	0.386203	-.337948	0.148315
Sand (ton/ha)	0.326620	-.221873	-.134647
Clay (ton/ha)	**-.401168**	0.047213	0.186239
CEC (ton/ha)	**-.478800**	0.187162	0.049598
p (ton/ha)	-.099952	**0.526960**	**-.569010**
Oxidasabe C (ton/ha)	0.311463	**0.550693**	0.330440
Stable C (ton/ha)	-.329248	-.061504	**0.611496**
Total N (ton/ha)	**0.372261**	0.463219	**0.340350**

PC1: Low CEC and low clay
PC2: Oxidasable C, Total N and P
PC3: Stable C and low P

Table 16. Association between soil and carbon variables at 40-100 cm depth in Pocora, Costa Rica: Principal Component Analysis.

Variable	PC1 (33.9%)	PC2 (27.5%)	PC3 (15.2%)
pH	**-.440467**	-.322558	-.010938
Sand (ton/ha)	0.141777	0.001258	**0.769162**
Clay (ton/ha)	**0.548829**	0.033940	-.060524
CEC (ton/ha)	**0.527010**	0.005018	0.282570
p (ton/ha)	-.218362	0.239985	0.349960
Oxidasabe C (ton/ha)	-.216351	**0.581548**	0.146259
Stable C (ton/ha)	0.308643	0.315965	**-.420578**
Total N (ton/ha)	-.131096	**0.631785**	-.063334

PC1: Clay, CEC and low pH

PC2: Total N and Oxidasable C

PC3: Sand and low Stable C

Table 17. Association between soil and carbon variables at 0-100 cm in Pocora, Costa Rica: Principal Component Analysis.

Variable	PC1 (41%)	PC2 (28%)	PC3 (12%)
pH	**-.453774**	0.092886	0.368898
Sand (ton/ha)	0.252985	0.042977	**0.790565**
Clay (ton/ha)	**0.463504**	-.231327	0.053164
CEC (ton/ha)	0.384082	-.395868	-.105933
p (ton/ha)	0.260987	0.317307	**-.437370**
Oxidasabe C (ton/ha)	0.256411	**0.565077**	0.079225
Stable C (ton/ha)	**0.402096**	-.217071	0.156242
Total N (ton/ha)	0.268681	**0.558736**	0.053780

PC1: Clay and Stable C with low pH

PC2: Total N and Oxidasable C

PC3: Sand and low P

2.4 Modelling of C- stocks- CO_2Fix model

The CO_2Fix model is being used to model carbon stocks in pasture and silvopastoral systems. This model was developed for forest systems and is being adapted for pasture and silvopastoral systems and therefore preliminary data is being presented on advances of this model. In figure 1 is shown the model for secondary forest. In 20 years the model show an accumulation of 185 tons/ha and estimated C fixation is 3.04 t/ha/ yr which is in accordance with what has been reported in other studies for secondary forest (Figure 3). For the teak forest plantations accumulated C was 237 t/ha/yr and estimated rate of fixation is 2.4 t/ha (Figure 4). The degraded pasture accumulated 73 tC/ha and had annual rate of 1.2 t/ha/ yr (Figure 5) whereas the native pasture with trees accumulated in 20 yrs 204 t C/ha and had an estimated fixation of 2.65 t/ha/yr (Figure 6). Over the next months the project will work to revise the parameters for improved pastures and to model C stocks with different tree densities and pasture types. It will also develop a model for balance of greenhouse gases.

2.5 Training and outreach

During 2005 the project organised several workshops with national institutions and NGOs to train experts on methodologies for quantification and monitoring of C- stocks in pasture and silvopastoral systems. A cooperative agreement was signed between CATIE and CEDECO an NGO funded by HIVOS-Holland, to provide technical assistance to this institution in the field of estimation of green house gases and design of good farming practices to enhance C-sequestration and reduction of emissions of greenhouse gases. A total of 50 experts were trained during this year. The results of the project was presented in strategic international courses on 1) climate change – MDL; and 2) forest plantations.

Table 16. Parameters used for modelling C stocks with CO2Fix land use models.

Land use	Biomass in pasture	Biomass in tree	C in roots	Organic carbon in soil
Secondary forest Figure 1	- 2 T/ha at the beginning of the model was based on field data with presence of natural pastures. By Ramos Veintimilla, R.A. 2003	- Description of forest: # species 99, # individuals /ha: 667.6 - Biomass estimated using allometric equations Ferreira, C.M. 2001. - Growth data develop for this study with field data of GEF project. - Comparison according to Soudre 2004, INISEFOR 2002.	- 1.53 MgC/ha. - Fine roots Ramos Veintimilla, R.A. 2003.	- 116.1 t/ha, According to field data of GEF project.
Teca plantation Figure 2	- 2 T/ha at the beginning of the model based on collect data on natural pastures Ramos Veintimilla, R.A. 2003.	- # individuals /ha: 601.7 - Growth data based on study of Pérez Cordero, L.D.; Ugalde Arias, L.; Kanninen, M. 2000. - Volume data: Pérez Cordero, Luis Diego; Kanninen, Markku. 2003. - Biomass calculated based on allometric equation develop Pérez y Kanninen 2003. Field data coming to GEF project.	Base on CO2Fix model develop By Kanninen y Álvaro Vallejo, CAFTA Project.	- 105 t/ha according to field data GEF project. Influenced for the C level on soil Thinning of stands 3, 10, 20, 30 y 40 years
Degraded pasture Figure 3	6 T/ha/año based on data field and literature Jaragua (Hyparrhenia rufa Stapf.),	Adult trees* 27.23 individuos/ha, C inicial 1.88 t/ha . Small trees** 42.93 individuals/ha, C initial 2.96 t/ha Calculation of content of biomass according to Ruiz, A. 2002. Compared data with results of López et al 1999. Growth data process according to data field developed with SYLVIA program Assumptions of wood yield of 20% of the total individuals of each 20 yrs	1.53 MgC/ha. Fine roots, data By Ramos Veintimilla, R.A. 2003.	21.46 t/ha Field data according to GEF project.
Native pasture Figure 3	6 T/ha based on data collect by Ramos Veintimilla, R.A. 2003, Boddey et al 2002.	Adult trees * 56 individuos/ha, Inicial C 2.75 t/ha . Young trees** 87.3 individuos/ha, C inicial 4.33 t/ha	1.53 MgC/ha. Fine roots according to Ramos	143 t/ha Field data according to GEF project

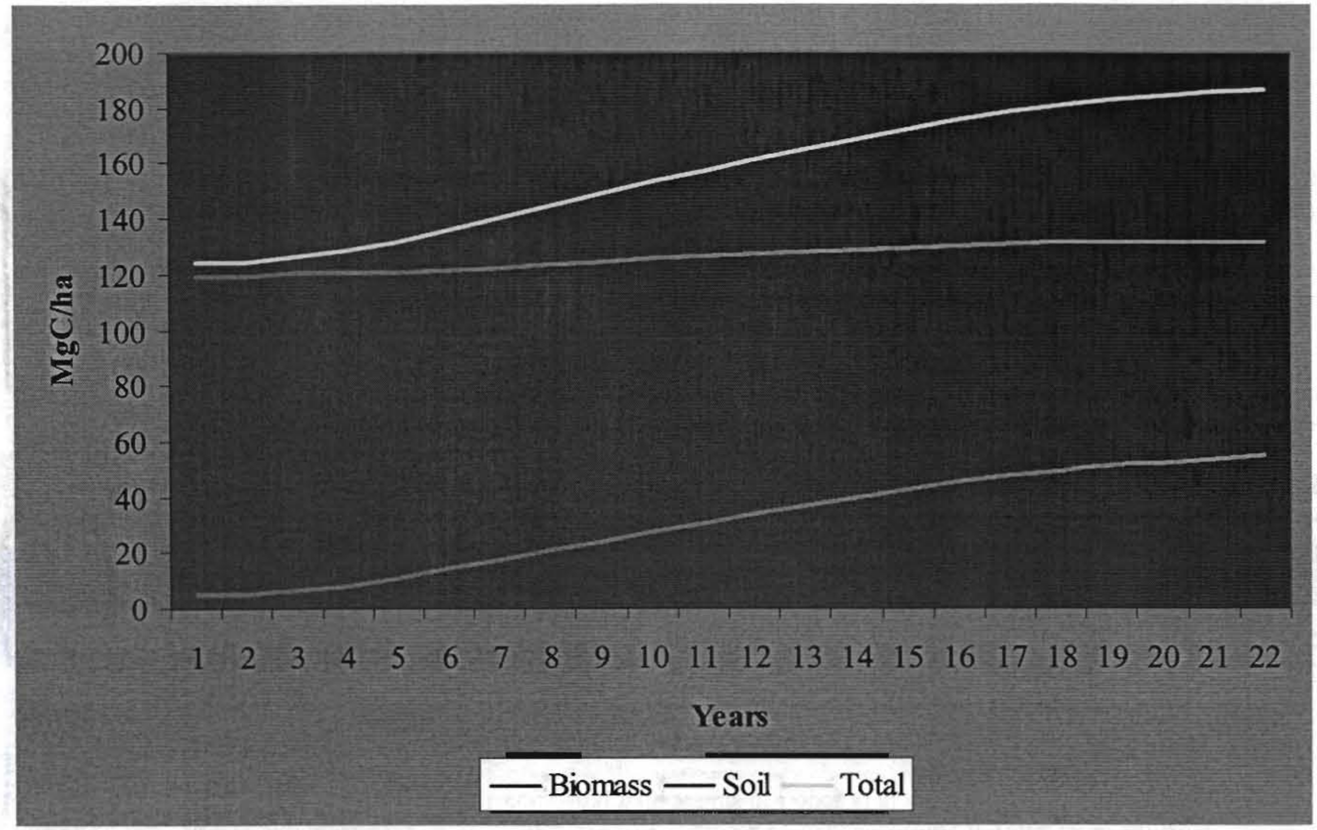
	Bouman et al 1998.	Calculation of contents of biomass according to Ruiz, A. 2002. Compared data with results of López et al 1999. Growth data process according to field data and develop with SYLVIA program. Assumptions of wood yield of 20% of the total individuals each 20 years.	Veintimilla, R.A. 2003,	
Improved pastures Figure 5	8 T/ha based on data: Ramos Veintimilla, R.A. 2003, Boddey et al 2002. Bouman et al 1998.	Big trees* 10.43 individuos/ha, C inicial 0.41 t/ha . Small trees** 19 individuos/ha, C inicial 1.23 t/ha Calculation of biomasa content according to Ruiz, A. 2002. Data compared with results of López et al 1999. Growth data process according to field data and develop with SYLVIA program. Assumptions of wood yield of 20% of the total of individuals of each 20 years.	3.2 MgC/ha. Fine roots according to data collect by Ramos Veintimilla, R.A. 2003, Veldkamp 1993.	139.48 t/ha Field data according to GEF project

* Is related to species of low growth and oldest, with wide canopy, maximum high of 30 meters, can reach diameters of > 1 m, are commons to find as isolated trees in pastures, e.g *Guazuma ulmifolia* (Guácimo), *Pithecelobium cyclocarpum* (Guanacaste), *Samanea saman* (Cenizaro), etc.
** Is related to species with fast and médium growth, fuste recto, small canopy, high between 15 and 25 m, with 60 cm of dap max. Natives of pastures eg *Cordia alliodora* (laurel), *Tabebuia rosea* (roble), etc.
*** SILVIA, its a program for simulations of growth of forest species that with some observed field data of the interes specie develop an allometric equation for simulation of diameter and high growth, of this sense its possible to obtain the volume and biomass growth of the trees on pastures.
Equation for young trees High (30*EXP(-2,2*EXP(-0,049*$A7)), dbh (100*EXP(-2,5*EXP(-0,05*$A7))

- Equation for adult trees High altura (30*EXP(-2,2*EXP(-0,049*$A7)), dap (100*EXP(-2,5*EXP(-0,05*$A7))

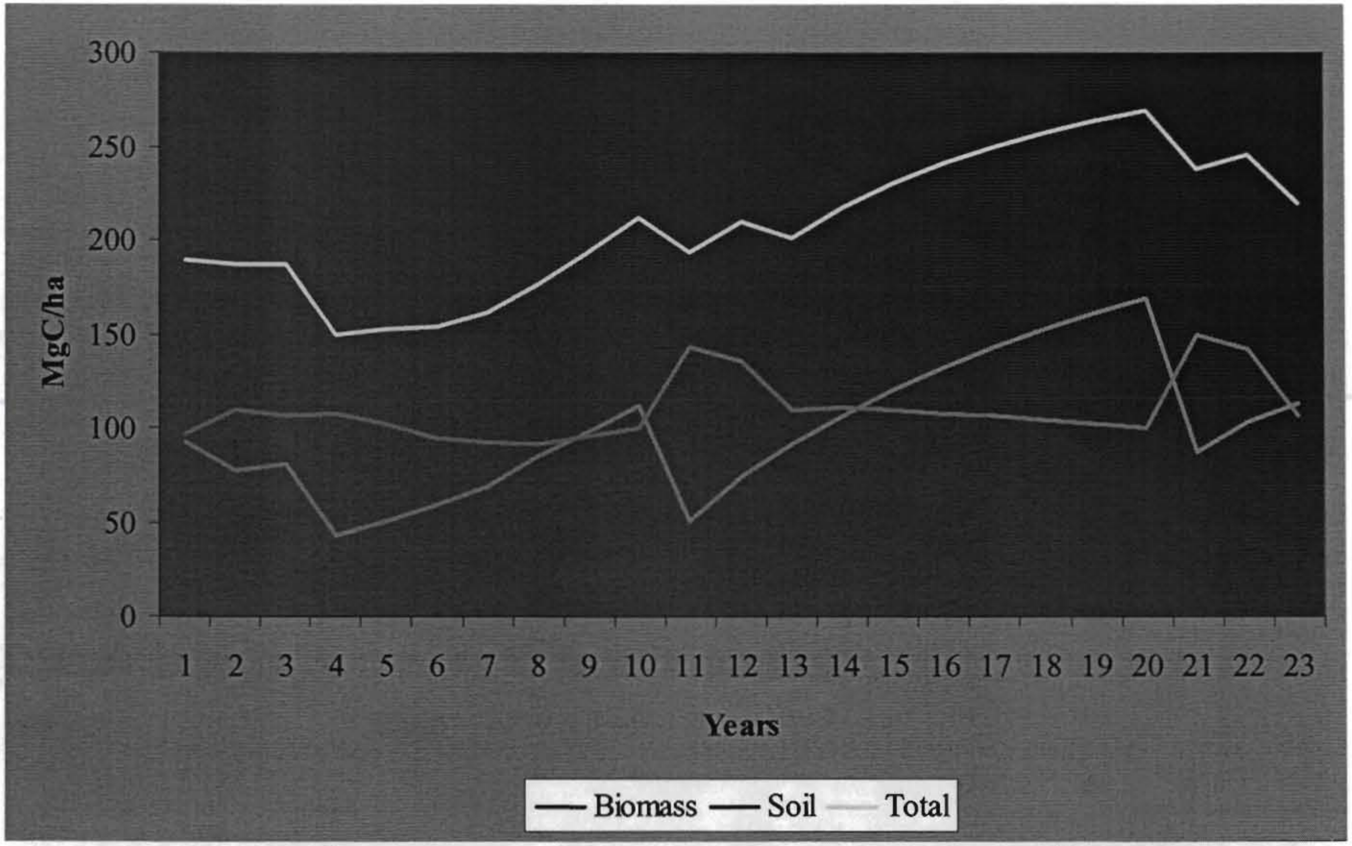
SILVIA es un programa para simular el crecimiento de especies forestales que con algunos datos observados en campo de la especie de interés desarrolla una ecuación alométrica para simular el crecimiento en diámetro y altura, de esta manera se pudo obtener el crecimiento en volumen y biomasa de los árboles en pasturas.

- Ecuación para árboles pequeños: altura (30*EXP(-2,2*EXP(-0,049*$A7)), dap (100*EXP(-2,5*EXP(-0,05*$A7))
- Ecuación para árboles grandes: altura (30*EXP(-2,2*EXP(-0,049*$A7)), dap (100*EXP(-2,5*EXP(-0,05*$A7))



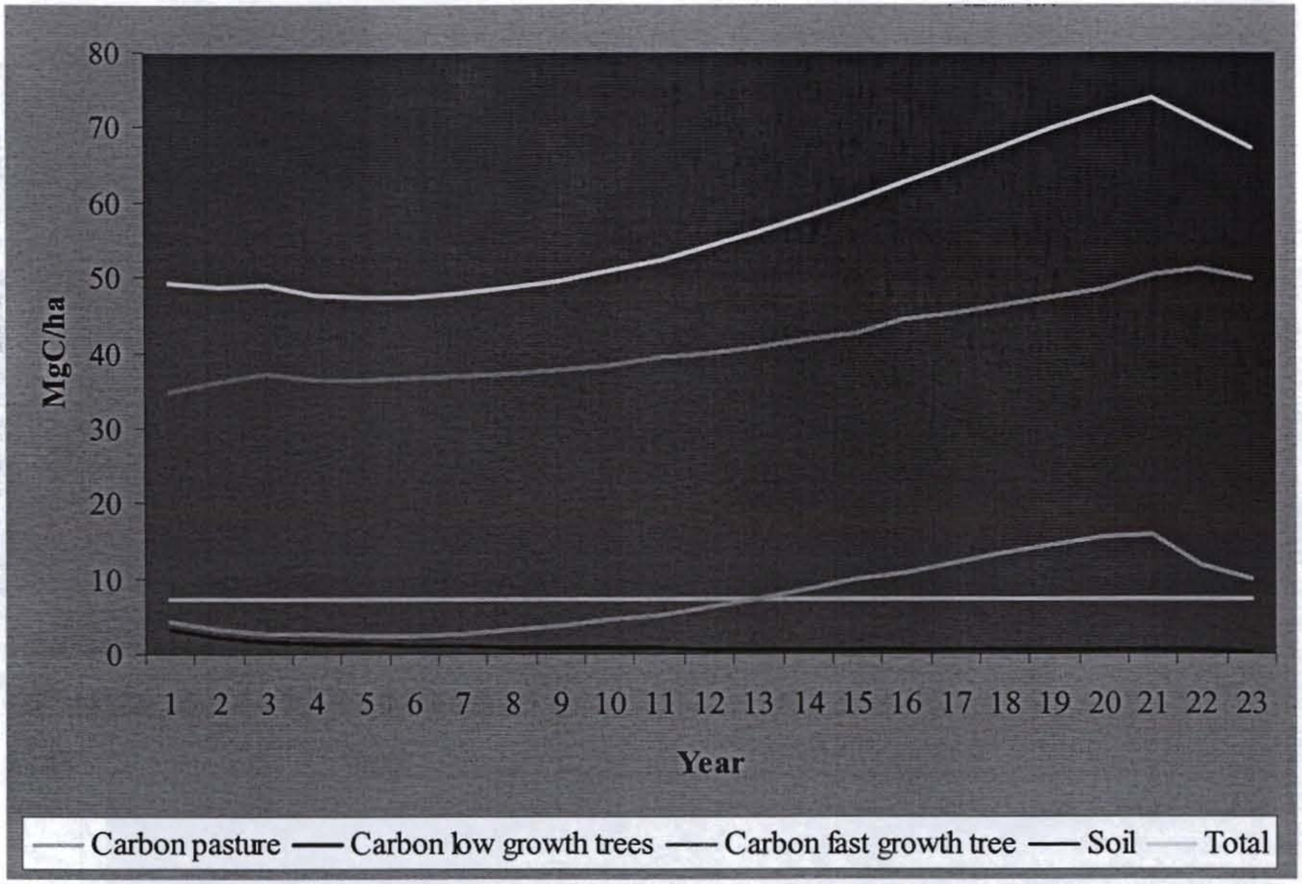
year	Biomass	Soil	Total
0	**5.2**	**119.24**	**124.45**
1	5.09	119.31	124.4
2	6.2	120.33	126.53
3	8.21	120.3	128.5
4	10.9	120.62	131.52
5	**14.17**	**121.32**	**135.49**
6	17.61	122.3	139.91
7	20.89	123.4	144.29
8	24.13	124.43	148.57
9	27.38	125.37	152.75
10	**30.68**	**126.26**	**156.94**
11	33.8	127.14	160.95
12	36.84	127.97	164.81
13	39.81	128.73	168.55
14	42.57	129.45	172.02
15	**45.17**	**130.11**	**175.28**
16	47.4	130.67	178.08
17	49.3	131.12	180.42
18	50.93	131.41	182.34
19	52.34	131.57	183.91
20	**53.57**	**131.65**	**185.22**

Figure 3. Model of carbon sequestration for secondary forest in Esparza, Costa Rica. 2005



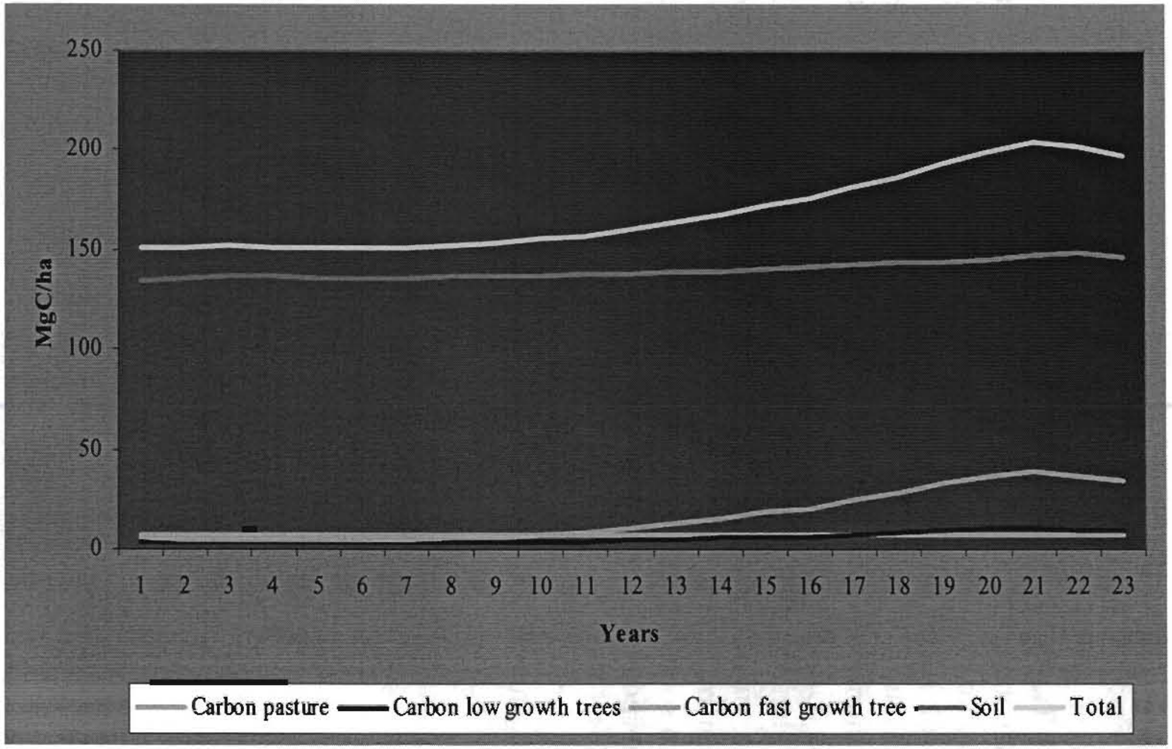
Year	Biomass	Soil	Total
0	**92.42**	**96.79**	**189.21**
1	77.47	109.14	186.61
2	80.59	106.13	186.72
3	42.59	107.03	149.61
4	50.41	102.56	152.96
5	**58.7**	**94.75**	**153.46**
6	68.55	92.21	160.76
7	85.42	91.17	176.6
8	98.32	95.4	193.73
9	111.81	100.03	211.84
10	**50.24**	**143.1**	**193.34**
11	74.42	135.16	209.58
12	91.49	109.21	200.7
13	106.31	110.37	216.68
14	120.21	109.66	229.87
15	**132.75**	**107.75**	**240.5**
16	143.48	106.02	249.5
17	152.94	104.09	257.03
18	161.22	102.09	263.31
19	168.42	100.24	268.66
20	**87.31**	**149.92**	**237.22**

Figure 4. Model of carbon sequestration for *Tectona grandis* plantation in Esparza, Costa Rica. 2005



year	Carbon pasture	Carbon low growth trees	Carbon fast growth tree	Soil	Total
0	**7.2**	**3.08**	**4.16**	**34.84**	**49.28**
1	7.19	2.18	3.26	36.04	48.67
2	7.19	1.72	2.79	37.14	48.84
3	7.19	1.46	2.58	36.5	47.73
4	7.19	1.28	2.54	36.32	47.32
5	**7.19**	**1.09**	**2.51**	**36.66**	**47.45**
6	7.19	0.98	2.79	36.96	47.93
7	7.19	0.9	3.21	37.32	48.61
8	7.19	0.82	3.78	37.78	49.57
9	7.19	0.76	4.5	38.34	50.79
10	**7.19**	**0.67**	**5.1**	**39.28**	**52.24**
11	7.19	0.63	6.17	39.97	53.96
12	7.19	0.6	7.33	40.69	55.81
13	7.19	0.58	8.57	41.62	57.96
14	7.19	0.56	9.86	42.66	60.27
15	**7.19**	**0.52**	**10.61**	**44.34**	**62.67**
16	7.19	0.53	12.07	45.35	65.14
17	7.19	0.53	13.38	46.25	67.35
18	7.19	0.54	14.56	47.4	69.7
19	7.19	0.56	15.64	48.52	71.91
20	**7.19**	**0.55**	**15.77**	**50.42**	**73.94**

Figure 5. Model of carbon sequestration for degraded pasture with trees Esparza, Costa Rica. 2005.



year	Carbon pasture	Carbon low growth trees	Carbon fast growth tree	Soil	Total
0	**7.2**	**3.95**	**5.53**	**134.58**	**151.26**
1	7.19	3.38	4.91	135.89	151.37
2	7.19	3.11	4.6	136.97	151.87
3	7.19	3.02	4.49	136.25	150.95
4	7.19	3.04	4.52	135.87	150.62
5	**7.19**	**2.97**	**4.46**	**136.02**	**150.65**
6	7.19	3.11	4.84	136.13	151.26
7	7.19	3.28	5.41	136.3	152.18
8	7.19	3.51	6.25	136.59	153.53
9	7.19	3.76	7.39	136.96	155.3
10	**7.19**	**3.89**	**8.44**	**137.79**	**157.32**
11	7.19	4.3	10.36	138.3	160.15
12	7.19	4.77	12.64	138.81	163.42
13	7.19	5.32	15.31	139.52	167.34
14	7.19	5.95	18.33	140.31	171.78
15	**7.19**	**6.33**	**20.6**	**141.98**	**176.09**
16	7.19	7.15	24.33	142.74	181.41
17	7.19	8.05	28.31	143.28	186.82
18	7.19	9.03	32.47	144.13	192.83
19	7.19	10.1	36.76	145.05	199.1
20	**7.19**	**10.7**	**39.05**	**147.46**	**204.39**

Figure 6. Model of carbon sequestration for native pasture with trees Esparza, Costa Rica. 2005.

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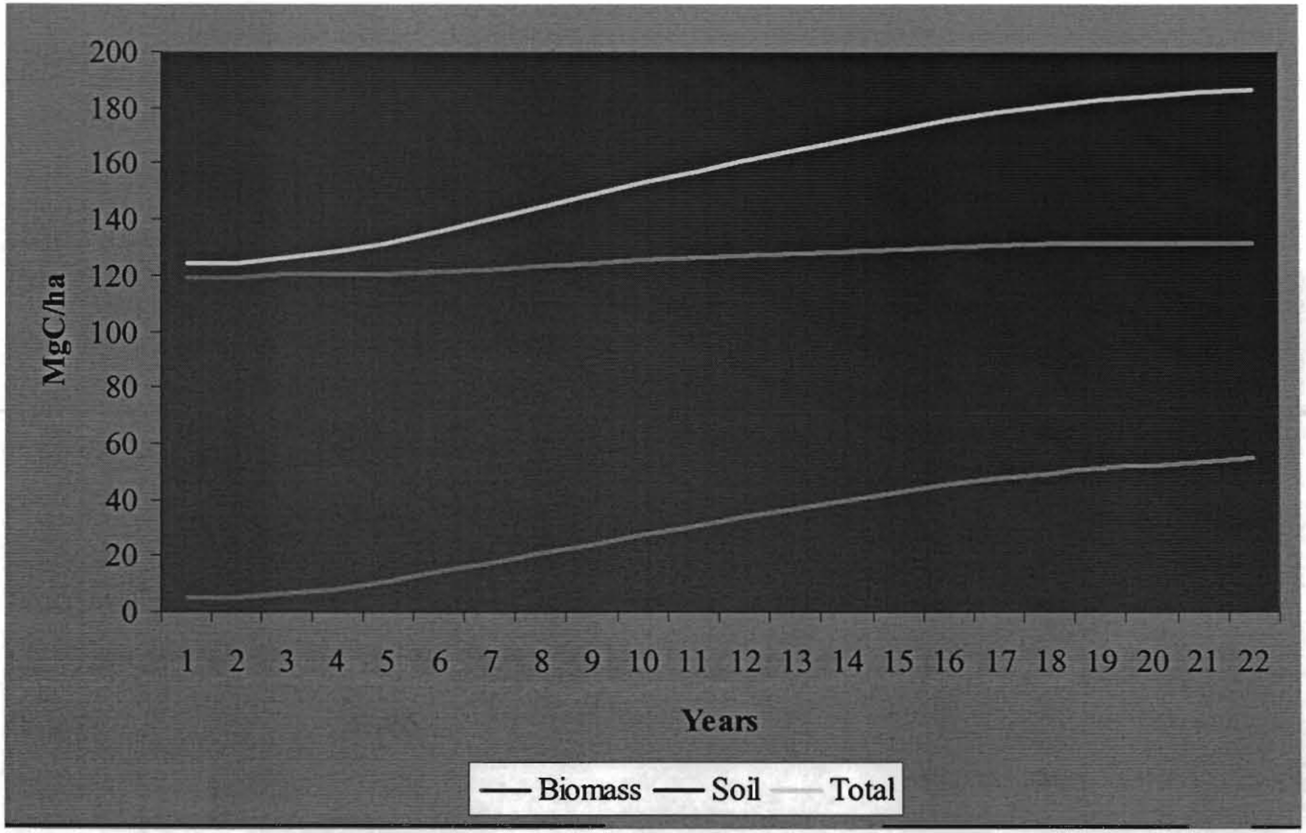
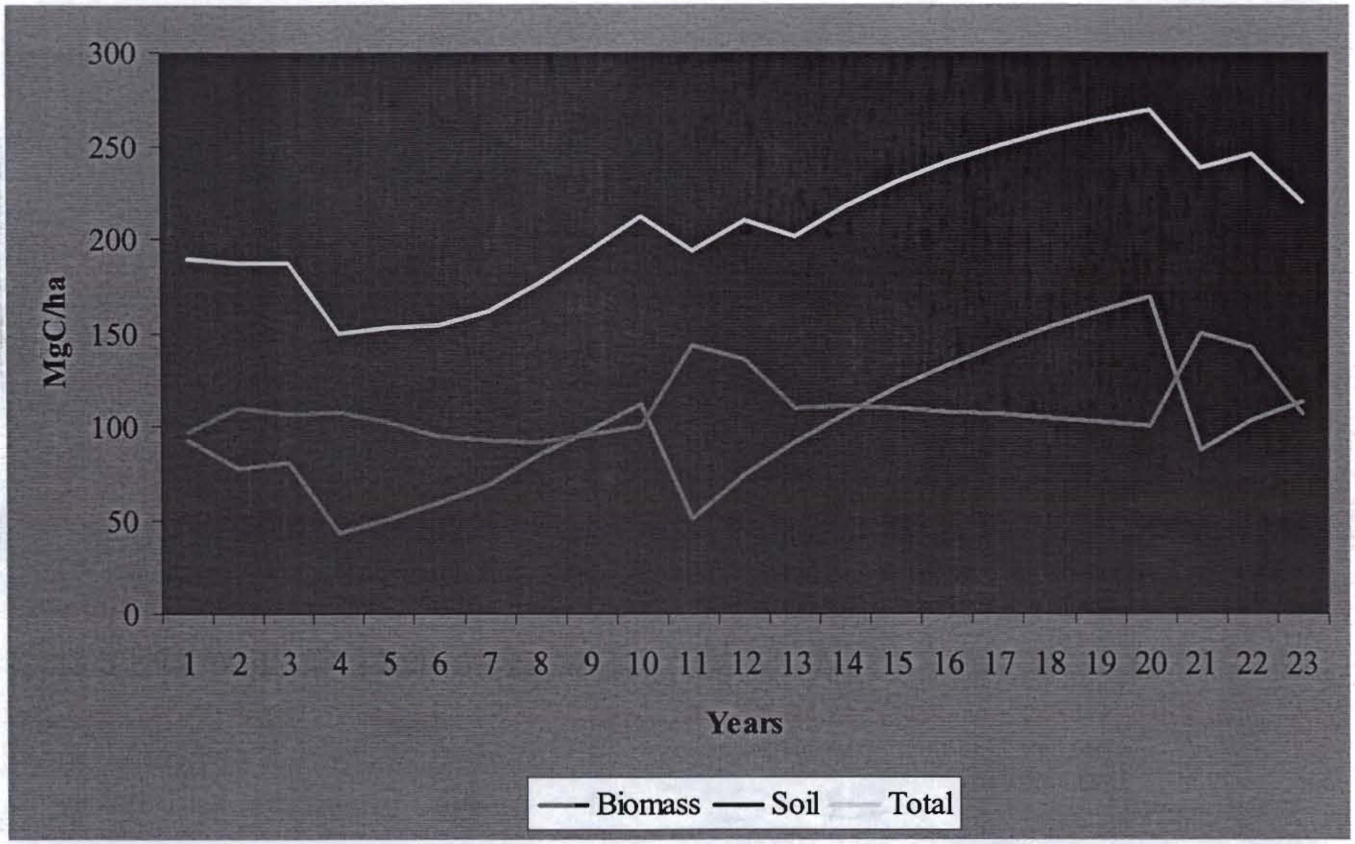


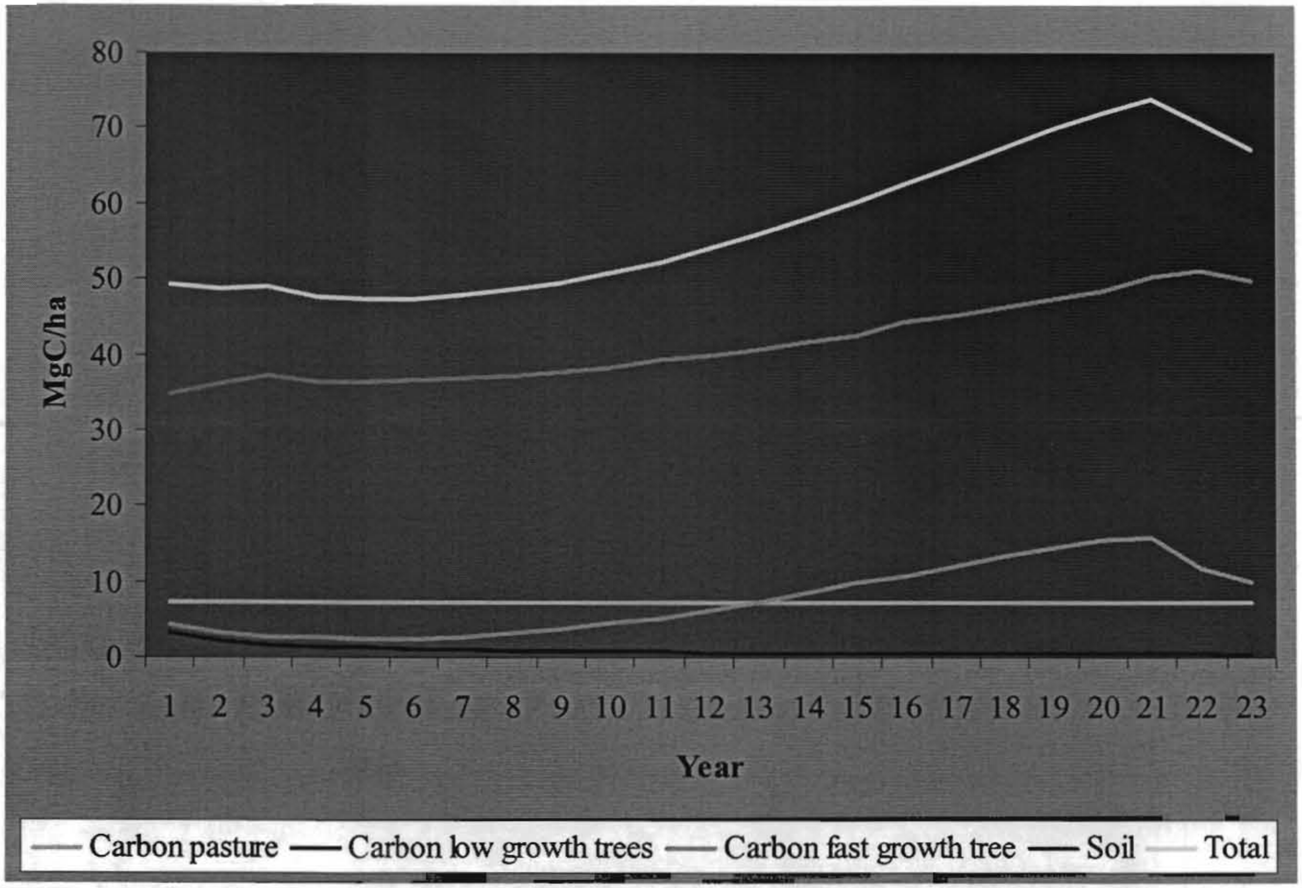
year	Biomass	Soil	Total
0	**5.2**	**119.24**	**124.45**
1	5.09	119.31	124.4
2	6.2	120.33	126.53
3	8.21	120.3	128.5
4	10.9	120.62	131.52
5	**14.17**	**121.32**	**135.49**
6	17.61	122.3	139.91
7	20.89	123.4	144.29
8	24.13	124.43	148.57
9	27.38	125.37	152.75
10	**30.68**	**126.26**	**156.94**
11	33.8	127.14	160.95
12	36.84	127.97	164.81
13	39.81	128.73	168.55
14	42.57	129.45	172.02
15	**45.17**	**130.11**	**175.28**
16	47.4	130.67	178.08
17	49.3	131.12	180.42
18	50.93	131.41	182.34
19	52.34	131.57	183.91
20	**53.57**	**131.65**	**185.22**

Figure 3. Model of carbon sequestration for secondary forest in Esparza, Costa Rica. 2005



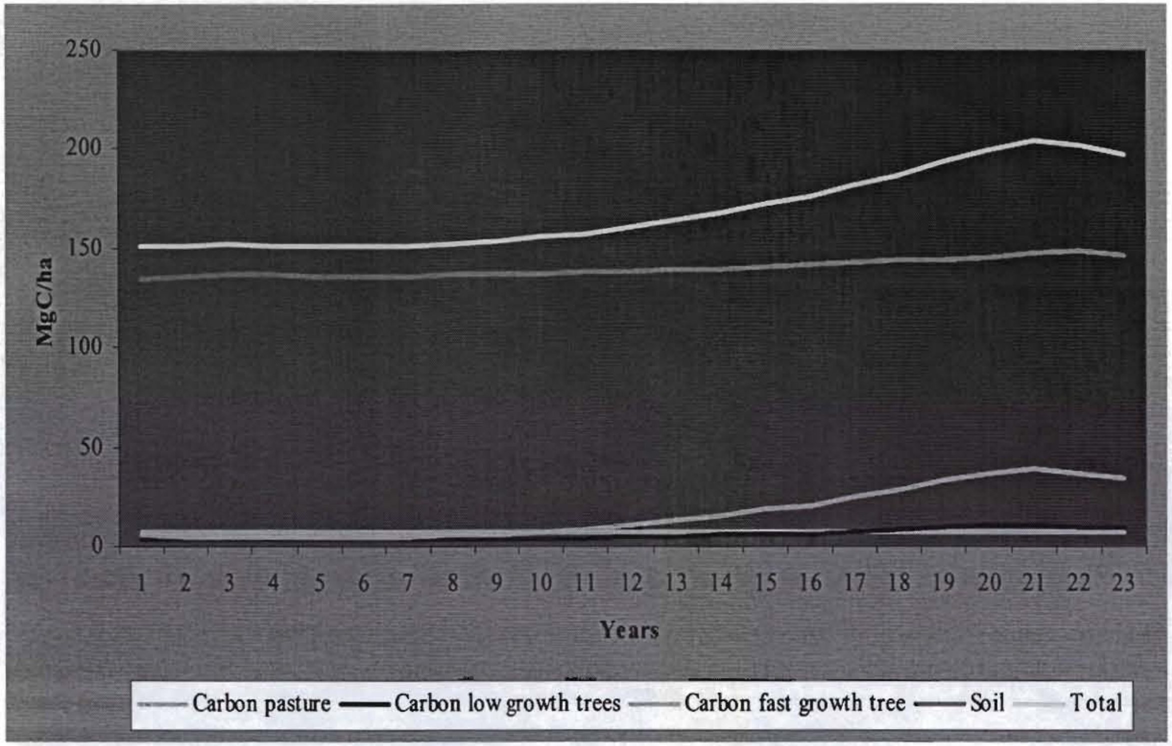
Year	Biomass	Soil	Total
0	**92.42**	**96.79**	**189.21**
1	77.47	109.14	186.61
2	80.59	106.13	186.72
3	42.59	107.03	149.61
4	50.41	102.56	152.96
5	**58.7**	**94.75**	**153.46**
6	68.55	92.21	160.76
7	85.42	91.17	176.6
8	98.32	95.4	193.73
9	111.81	100.03	211.84
10	**50.24**	**143.1**	**193.34**
11	74.42	135.16	209.58
12	91.49	109.21	200.7
13	106.31	110.37	216.68
14	120.21	109.66	229.87
15	**132.75**	**107.75**	**240.5**
16	143.48	106.02	249.5
17	152.94	104.09	257.03
18	161.22	102.09	263.31
19	168.42	100.24	268.66
20	**87.31**	**149.92**	**237.22**

Figure 4. Model of carbon sequestration for *Tectona grandis* plantation in Esparza, Costa Rica. 2005



year	Carbon pasture	Carbon low growth trees	Carbon fast growth tree	Soil	Total
0	**7.2**	**3.08**	**4.16**	**34.84**	**49.28**
1	7.19	2.18	3.26	36.04	48.67
2	7.19	1.72	2.79	37.14	48.84
3	7.19	1.46	2.58	36.5	47.73
4	7.19	1.28	2.54	36.32	47.32
5	**7.19**	**1.09**	**2.51**	**36.66**	**47.45**
6	7.19	0.98	2.79	36.96	47.93
7	7.19	0.9	3.21	37.32	48.61
8	7.19	0.82	3.78	37.78	49.57
9	7.19	0.76	4.5	38.34	50.79
10	**7.19**	**0.67**	**5.1**	**39.28**	**52.24**
11	7.19	0.63	6.17	39.97	53.96
12	7.19	0.6	7.33	40.69	55.81
13	7.19	0.58	8.57	41.62	57.96
14	7.19	0.56	9.86	42.66	60.27
15	**7.19**	**0.52**	**10.61**	**44.34**	**62.67**
16	7.19	0.53	12.07	45.35	65.14
17	7.19	0.53	13.38	46.25	67.35
18	7.19	0.54	14.56	47.4	69.7
19	7.19	0.56	15.64	48.52	71.91
20	**7.19**	**0.55**	**15.77**	**50.42**	**73.94**

Figure 5. Model of carbon sequestration for degraded pasture with trees Esparza, Costa Rica. 2005.



year	Carbon pasture	Carbon low growth trees	Carbon fast growth tree	Soil	Total
0	**7.2**	**3.95**	**5.53**	**134.58**	**151.26**
1	7.19	3.38	4.91	135.89	151.37
2	7.19	3.11	4.6	136.97	151.87
3	7.19	3.02	4.49	136.25	150.95
4	7.19	3.04	4.52	135.87	150.62
5	**7.19**	**2.97**	**4.46**	**136.02**	**150.65**
6	7.19	3.11	4.84	136.13	151.26
7	7.19	3.28	5.41	136.3	152.18
8	7.19	3.51	6.25	136.59	153.53
9	7.19	3.76	7.39	136.96	155.3
10	**7.19**	**3.89**	**8.44**	**137.79**	**157.32**
11	7.19	4.3	10.36	138.3	160.15
12	7.19	4.77	12.64	138.81	163.42
13	7.19	5.32	15.31	139.52	167.34
14	7.19	5.95	18.33	140.31	171.78
15	**7.19**	**6.33**	**20.6**	**141.98**	**176.09**
16	7.19	7.15	24.33	142.74	181.41
17	7.19	8.05	28.31	143.28	186.82
18	7.19	9.03	32.47	144.13	192.83
19	7.19	10.1	36.76	145.05	199.1
20	**7.19**	**10.7**	**39.05**	**147.46**	**204.39**

Figure 6. Model of carbon sequestration for native pasture with trees Esparza, Costa Rica. 2005.

Annex 6

Activity Report, Andean Hillsides, Colombia

Evaluación de Producción de Biomasa en las Experimentos Establecidos En Áreas Degradadas de Laderas Andina

María Elena Gómez Z
Hernán Giraldo G

RESUMEN

Se establecieron experimentos con diferentes sistemas de uso: pastura y silvopastoril partiendo de una pastura de degradada en dos localidades en el municipio de El Dovio y Dagua, donde se lleva a cabo el monitoreo de carbono en sistemas con 10 años de establecidos en pasturas degradadas, pasturas mejoradas, bancos mixtos de forraje y bosques nativos.

El objetivo del establecimiento de este experimento es comparar en un período de cuatro años la acumulación de carbono y el potencial de producción de biomasa en diferentes sistemas de uso del suelo. Los sistemas que se evaluaron fueron: pastura en monocultivo de ***Brachiaria*** H. Mulato Ciat 36061 , pastura mixta de ***B. decumbens*** H. mulato Ciat 36061con ***Arachis pintoi***, bancos mixtos de forraje con ***Tithonia diversifolia***, ***Trichanthera gigantea*** y ***Erytrhina poeppigiana*** bajo dos sistemas de manejo mejorado con fertilización orgánica con lombricompuesto, fertilizantes de síntesis química y ***Arachis pintoi*** como cobertura y manejo local utilizando fertilización orgánica con lombricompuesto y la regeneración natural de la pastura degradada.

Durante el periodo evaluado 2004-2005 se obtuvo la siguiente producción de biomasa acumulada: En El Dovio la pastura en monocultivo 10.990 Kg/ha y 14.205 Kg/ha en asociación, en los bancos mixtos, manejo mejorado 15.277 kg/ha y manejo local 15.456 kg/ha. En Dagua la pastura en monocultivo 14.516 kg/ha y 11.946 Kg/ha en asociación y en los bancos mixtos, manejo mejorado 8.975 kg/ha y manejo local 8.127 kg/ha.

Localización: Los experimentos están localizados en la zona de ladera sobre la cordillera Occidental en los municipios de El Dovio y Dagua en el departamento del Valle del Cauca

Lugar	Coordenadas	Datos Climáticos *
El Dovio	N 4° 31' 85" W 76° 10' 33"	Asnm: 1.881 Precipitación: 1043 mm/año Temperatura: 18.5 °C Humedad Relativa: 86.4
Dagua	N 3° 36' 0.092" W 76° 37' 44	Asnm: 1.513 Precipitación: 1099 mm/año Temperatura: 21.5 °C Humedad Relativa: 58.4

*Promedios tomados en la zona correspondientes al año 2002

Diseño Experimental

Las parcelas se establecieron en un diseño de cuadrado latino con cuatro tratamientos: pastura en monocultivo de ***Brachiaria*** H. Mulato Ciat 36061 , pastura mixta de ***B. decumbens*** H. mulato Ciat 36061con ***Arachis pintoi***, bancos mixtos de forraje manejo mejorado con ***Tithonia diversifolia***, ***Trichanthera gigantea*** y ***Erytrhina poeppigiana*** con fertilización orgánica con lombricompuesto, fertilizantes de síntesis química y ***Arachis pintoi*** como cobertura y regeneración natural de una pastura degradada. Adicionalmente se estableció un tratamiento de bancos mixtos de forraje con manejo local, que es el manejo que tradicionalmente hacen los agricultores de la zona utilizando fertilización orgánica con lombricumpuesto que se produce en la finca.

Distribución de los tratamientos en el campo

R. Natural	Pastura en Monocultivo	Pastura en Asociación	Banco Mixto M. Mejorado	Rep. 1	Banco Mixto M. Local
Pastura en Monocultivo	R. Natural	Banco Mixto M. Mejorado	Pastura en Asociación	Rep. 2	Banco Mixto M. Local
Pastura en Asociación	Banco Mixto M. Mejorado	Pastura en Monocultivo	R. Natural	Rep. 3	Banco Mixto M. Local
Pastura en Monocultivo	R. Natural	Banco Mixto M. Mejorado	Pastura en Asociación	Rep. 4	Banco Mixto M. Local

Los tratamientos con pastura fueron sembrados en surcos separados 50 cm entre ellos, en la asociación se alternó la siembra con ***Arachis pintoi***. En los bancos de forraje se utilizó un arreglo espacial mixto con surcos dobles en los extremos (50 cm x 50 cm x 100 cm) con ***T. Diversifolia*** , seguido por un surco mixto de ***E Poeppigiana*** (150 cm) y ***T. gigantea*** (100 cm) y en el centro 3 surcos sencillos de T gigantea (100 cm x 100 cm).

Composición de la parcela útil para el muestreo de árboles

Especie	Número de plantas	Composición por especie (%)	Área m^2	Composición por área en (%)
T. Diversifolia	62	61	28	39
T.gigantea	31	31	34	47
E. Poeppigiana	8	8	10	14
Total	101	100	72	100

Por el arreglo utilizado que tuvo en cuenta el tipo de crecimiento arbustivo de *T. diversifolia* ocupó el 39% del área con una mayor densidad de 2 plantas/m^2.

RESULTADOS

Para hacer la caracterización inicial se partió de los resultados obtenidos en los muestreos de suelo en los sistemas establecidos, partiendo de la pastura degradada, que conformó la línea de base este experimento.

Tabla 1. Caracterización General del Suelo

Sitio	Profundidad cm	Densidad Aparente g/cc	pH	C. Total g/kg	P g/kg	N g/kg
	0-10	0.9	5.8	47	3.8	4.309
El Dovio	10-20	1.0	5.9	36	2.3	3.354
	20-40	1.0	5.9	22	1.5	2.012
	40-100	0.9	6.0	11	0.9	1.093
	0-10	0.8	5.3	49	0.4	3.743
Dagua	10-20	1.0	5.3	34	0.3	2.550
	20-40	1.1	5.4	20	0.2	1.185
	40-100	1.1	5.2	8	0.3	499

Producción de Forraje

La siembra en las parcelas en el diseño inicial se realizó entre los meses de octubre y noviembre del 2003 y la de las parcelas de banco mixto de manejo mejorado seis meses más tarde.

Una vez sembradas las parcelas se realizaron varios cortes de uniformización hasta lograr un establecimiento parejo de las pasturas y un mejor desarrollo de los árboles.

La cuantificación de la producción se inició en febrero del 2004 las pasturas y en los árboles en marzo 2004.

Los cortes en las pasturas se hicieron a un intervalo de 63 días, en los bancos los intervalos fueron diferenciales de acuerdo al desarrollo de la planta: para la ***T. diversifolia*** los intervalos fueron de 90 y 60 días en el 2004 y 90 en el 2005, para las especies arbóreas que han tenido un desarrollo más lento 180 días para ***T. gigantea*** y ***E. Poepppigiana*** dos cortes durante todo el periodo que corresponde a una poda de formación ya que esta especie conformará un estrato de mayor altura. El ***Arachis pintoi*** que corresponde a un estrato cobertura se cosechó por primera vez a los 20 meses de establecido.

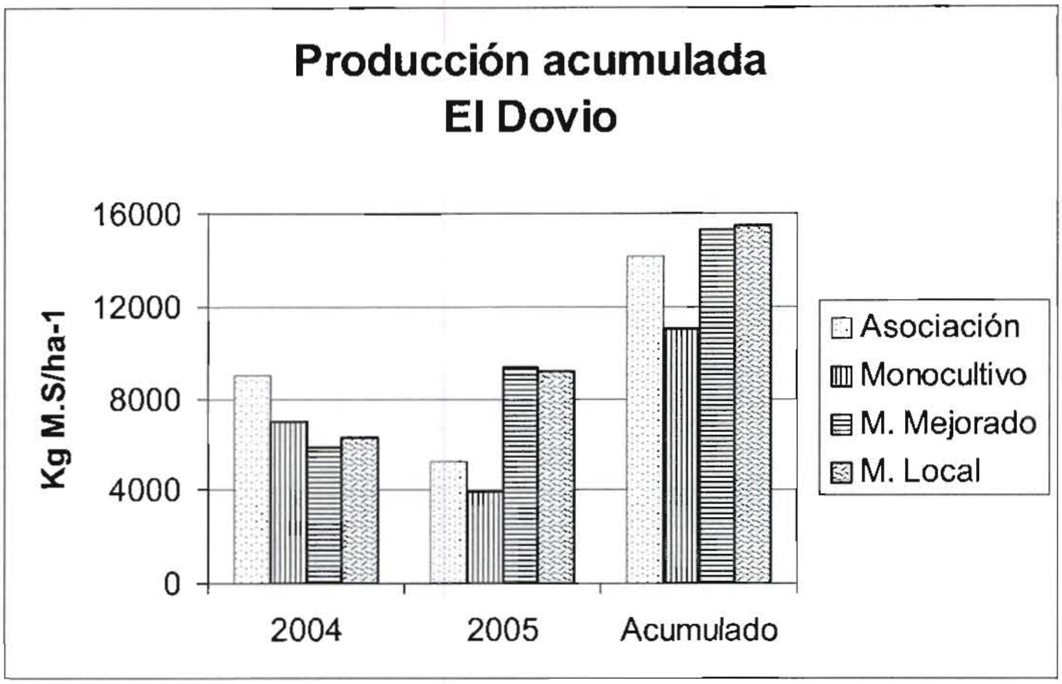
Tabla 2. Producción de Forraje Kg M.S /ha^{-1} / por Corte de Febrero 2004 - Julio 2005

		Tratamientos			
Sitio	**Corte**	**Asociación**	**Monocultivo**	**Banco Mixto M. Mejorado**	**B. Mixto M. Local**
El Dovio	1	2.485	1.686	1.951	2.030
	2	1.406	926	642	832
	3	1.263	931	2.817	2.888
	4	1.535	1.314	474	580
	5	1.231	1.259	2.097	4.740
	6	1.055	904	1.489	1.642
	7	1.440	1.013	5.807	2.815
	8	1.117	806		
	9	1.083	864		
	10	1.590	1.287		
Dagua	1	1.871	2.235	340	418
	2	579	812	255	261
	3	666	1.178	1.596	1.648
	4	1.849	1.671	623	633
	5	1.450	2.769	1.194	1.631
	6	880	1.251	664	1.056
	7	1.343	1.203	2.119	2.480
	8	880	627	2.189	
	9	1.265	1.495		
	10	1.163	1.275		

Tabla 3. Producción Acumulada de Forraje Kg M.S /ha^{-1} en el año 2004* – 2005

		Tratamientos			
Sitio	**Año**	**Asociación**	**Monocultivo**	**Banco Mixto M. Mejorado**	**B. Mixto M. Local**
El Dovio	2004	8.975	7.020	5.884	6.330
	2005	5.230	3.970	9.393	9.196
Dagua	2004	7.295	9.916	2.814	2.960
	2005	4.651	4.600	6.165	5.167

* Al año 2004 le corresponden 4 cortes y 3 para el 2005



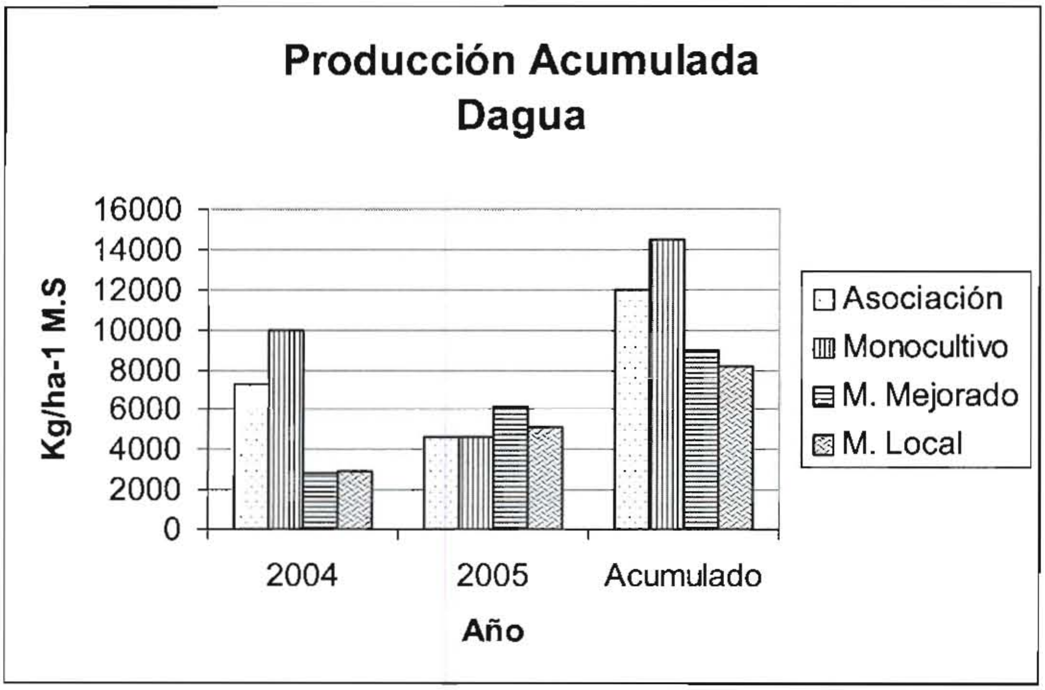
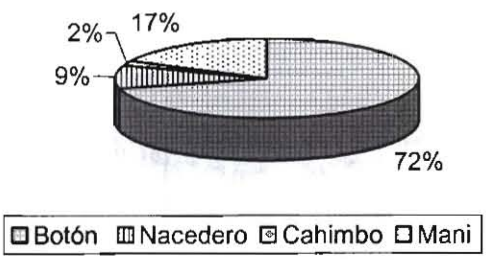
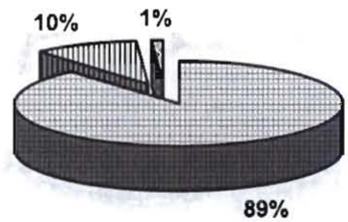


Tabla 4. Producción Acumulada de Forraje Kg M.S /ha^{-1} 2004 – 2005 por Especie en los Bancos Mixtos

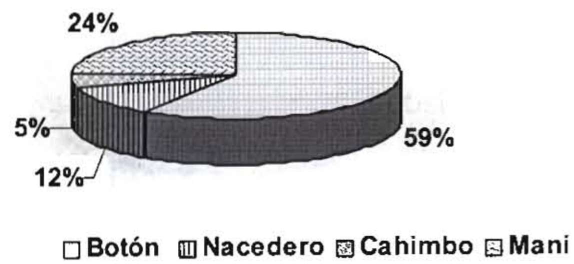
	Bancos Mixtos						
	Manejo Mejorado				Manejo Local		
	Tithonia Diversifolia	Trichantera. gigantea	Erythrina poeppigiana	Arachis Pintoi	Tithonia Diversifolia	Trichantera gigantea	Erytrhina Poeppigiana
El Dovio	10.880	1.432	303	2.664	1.3750	1.596	176
Dagua	5.312	1.034	442	2.189	6.283	1.172	672

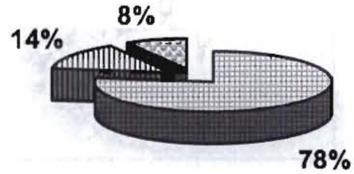
Aporte en la biomasa total acumulada 2004-2005 por especie en porcentaje El Dovio





Dagua





En el mayor aporte fue hecho por la ***T diversifolia*** en los dos sistemas de manejo de los bancos, el ***A pintoi*** en el manejo mejorado ocupó el segundo lugar, es importante resaltar que esta especie esta ocupando un estrato de cobertura que normalmente es ocupado por malezas.

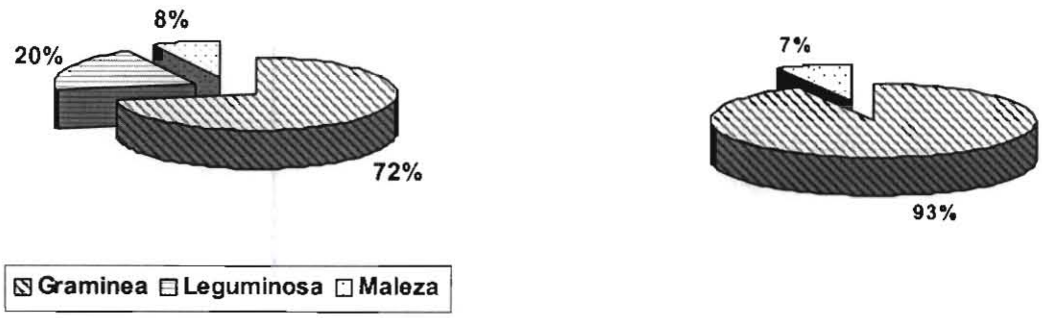
Tabla 5. Producción Acumulada de Forraje Kg M.S /ha^{-1} 2004 – 2005 por Especie en las Pasturas

	Asociación			Monocultivo	
	Gramínea	Leguminosa	Maleza	Gramínea	Maleza
El Dovio	9.333	3.903	967	10.245	745
Dagua	8.562	2.446	938	13.110	1.046

Aporte en la biomasa total acumulada 2004-2005 por especie en porcentaje

La proporción ocupada por la pastura se mantuvo constante en los dos sistemas, la leguminosa entró con una proporción del 20% y el 27% en el sistema de pastura asociada.

El Dovio



Dagua

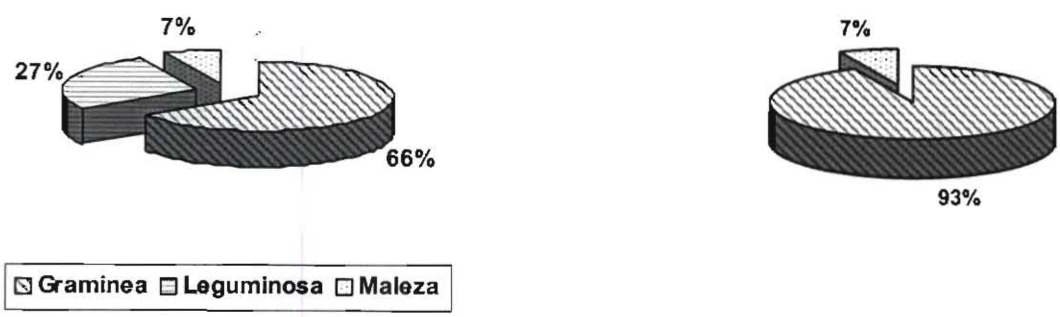


Tabla 6: Biomasa de Raíces Finas en Sistemas de Uso del Suelo Dagua: Laderas Andinas

Profundidad (cm)	Uso del Suelo (Ton/ha)					
	Suelo Degradado		Regeneración Natural *(Pastura Degradada)*		Pastura Mejorada (*Brachiaria decumbens*)	
	Por Profundidad	Acumulado	Por Profundidad	Acumulado	Por Profundidad	Acumulado
0 - 10	2.2	2.2	4.94	4.94	11.2	11.2
10-20	0.51	2.71	1.17	6.11	3.72	14.94
20 - 40	0.18	2.89	0.33	6.44	1.4	16.32
40 - 100	0.12	3.01	0.11	6.55	0.32	16.64

Tabla 7: Biomasa de Raíces Finas *vs.* C. Total en Sistemas de Uso del Suelo Dagua: Laderas Andinas

Uso del Suelo (Ton/ha)

Profundidad (cm)	Suelo Degradado		Regeneración Natural *(Pastura Degradada)*		Pastura Mejorada *(Brachiaria decumbens)*	
	Raíces	C. Total	Raíces	C. Total	Raíces	C. Total
0 - 100	3.01	125	6.55	171	16.64	165
0 - 40	2.89	75	6.44	119	16.32	109
40 - 100	0.12	50	0.11	52	0.32	56

Gráfico 1: Porcentaje de Raíces Según 3 Usos del Suelo a 1m Profundidad

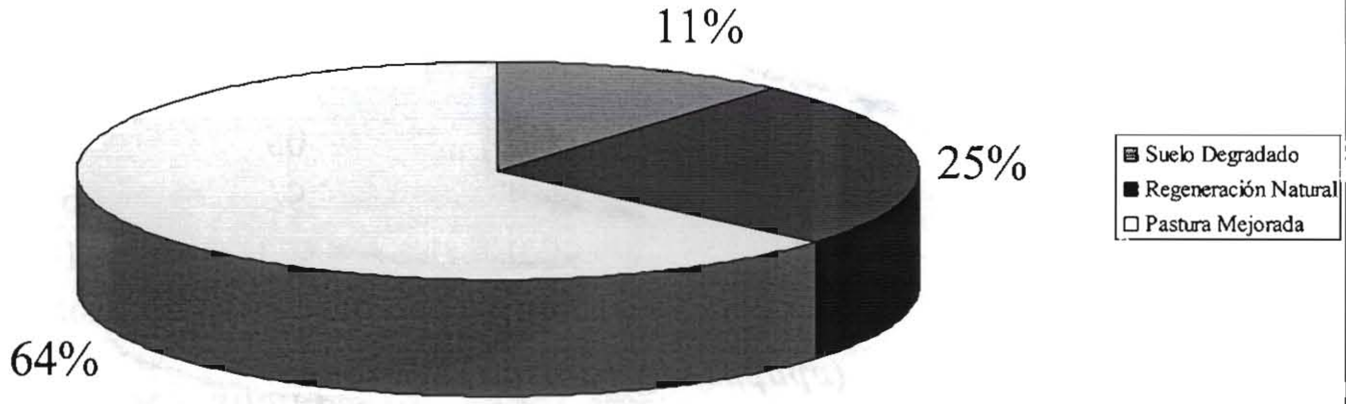


Tabla 8: Resumen Actividades de ladera Andinas

Actividades 2005 Laderas Andinas	Mes
Evaluación del Experimento nuevo	
Producción de forraje	
Bancos mixtos - pasturas	Enero
Pasturas	Marzo
Bancos mixtos	Abril
Pasturas	Mayo
Pasturas	Julio
Bancos Mixtos	Agosto
Bancos mixtos -Pasturas	Septiembre
Bancos mixtos -Pasturas	Octubre
Regeneración natural -Composición botánica por especie	
Realizado por Gabriel Arturo González (Dagua)	Octubre
Muestreos de Suelos	
Calicatas	Septiembre - Octubre
Coordinación y apoyo Estudiantes	
U. Javeriana (Laura Cabrera y Gabriel González)	Junio -Julio
U. Montpellier (María Camila Rebolledo)	Mayo
Capacitación	
- Modelos de rentabilidad financiera de usos de tierra con capacidad para la captura de carbono (José Gobbi)	Mayo
- Green House Gasses	Agosto
Reuniones	
Internas todo equipo proyecto	
CIAT	Marzo,Mayo, julio
Internacionales	
VI International Coordination Meeting	Agosto

Informe de Actividades Socioeconómicas A Octubre 31 de 2005

Piedad Cuéllar

Las actividades llevadas a cabo durante el año 2005 correspondientes a los aspectos socio económicos de la Red de Laderas Andinas son las siguientes:

Abril de 2005: Recolección de datos económicos de los productores de Bellavista y de La Virgen (fincas piloto y fincas convencionales), correspondientes a Enero – Marzo de 2005.

Mayo de 2005: Reunión con el Dr José Gobbi, para análisis de los datos Económicos por Finca correspondientes al año 2004, y el desarrollo del Modelo de Evaluación Financiera por cambios en el Uso del Suelo.

Julio de 2005: Recolección de datos económicos correspondientes a Abril – Junio de 2005.

Junio – Julio de 2005: Talleres socio – económicos enfocados en los temas "Servicios Ambientales" y "Género", llevados a cabo por la pasante Laura Cabrera de la Universidad Javeriana de Bogotá, en las comunidades de Bellavista y La Virgen.

Los talleres se desarrollaron dos (2) en Bellavista, con visitas previas a cada familia invitada de la comunidad, y uno (1) en La Virgen.

Agosto de 2005: Presentación de resultados socio-económicos y un Modelo Preliminar de viabilidad Financiera, IV Encuentro Internacional llevado a cabo en las instalaciones del CIAT.

Septiembre de 2005: Taller con productores de las fincas Piloto y las Convencionales (La Virgen y Bellavista) sobre resultados socio-económicos correspondientes al análisis de registros 2004 y primer semestre 2005.

Actividades a realizar: Noviembre de 2005, recolección datos económicos correspondientes a Julio – Octubre de 2005, con los productores en La Virgen y Bellavista.

Resultados Socio Económicos y Modelo de Viabilidad Financiera

Tipo de Finca	Ingreso Bruto Ha-1 año^{-1} en US $	Margen Bruto Ha^{-1} año^{-1} en US $	Ingreso Neto Ha^{-1} año^{-1} en US $
Mejoradas			
Consolidadas	1855	482	419
En Transición	790	261	240
Convencionales			
	217	184	182

Modelo Financiero

El cambio de Uso de Suelo propuesto para la evaluación financiera preliminar fue pasar de pasturas nativas a pasturas mejoradas (*Brachiaria sp.* + *Cynodon sp.*, y *Arachis pintoi*) con árboles (50 árboles de *Trichanthera sp.*, por Ha) y un Banco Forrajero Mixto (80% árboles y arbustos : 20% Caña de Azúcar). Se propuso definir un sistema de finca con la siguiente distribución en el uso del Suelo, Bosque 43%, Banco Forrajero Mixto 15%, Pasturas Mejoradas con árboles 25% (el área restante queda para distribuirse entre área para cultivos de seguridad alimentaría e instalaciones).

Los siguientes indicadores se utilizaron en el modelo:

Indicador	Promedio
Leche por ha^{-1} año^{-1}, litros	1400
Leche destinada para venta, %	96
Leche para autoconsumo, %	4
Peso del ternero al destete, kilos	160
Edad al destete en meses	8 – 9
Peso de la vaca al descarte, kilos	420

Precios de Venta de lo producido por la Ganadería Bovina en US $

Litro de leche	0.36
Libra de queso	1.0
Ternero al destete, US $ por kilo de peso vivo	0.84
Vaca de descarte, kilo de peso vivo	0.75

Costos de Establecimiento por Ha, US $

1. Banco Forrajero Mixto + Caña de Azúcar

Árboles y arbustos + fertilización	433
Mano de obra	623
Total	**1056**

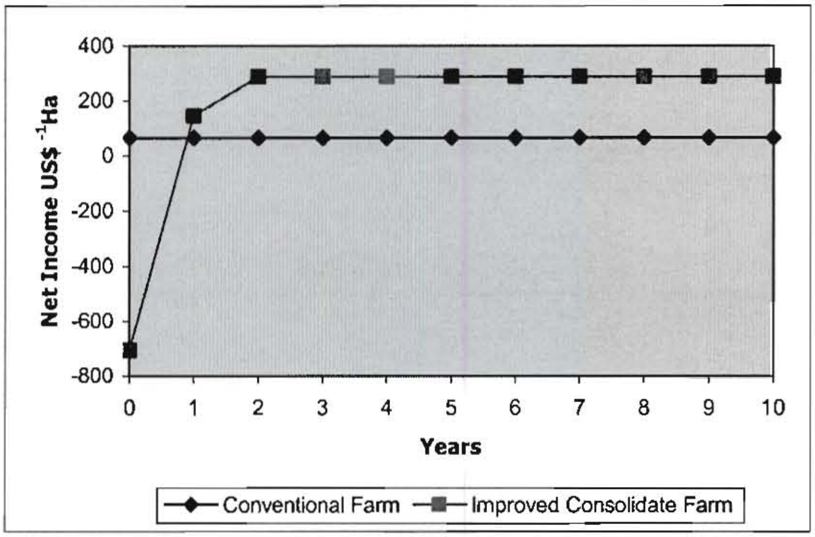
2. Pasturas Mejoradas + Maní forrajero y árboles (50 árboles por Ha)

Establecimiento de pasturas + leguminosa	1007.6
Siembra de árboles	42.9
Cercas vivas (*Trichanthera sp.*)	96.3
Alambre para cercas (200 m)	100.4
Total	**1247.2**

Fuente de los Datos: Registros de los Productores
Precios: Constantes en dólares.
Tasa de cambio utilizada: 1 dólar (US $): 2390 pesos colombianos
Tasa de descuento: 12%

Asunciones del Modelo:
Carga animal ha^{-1}: 0.8 para pastura nativa
2.4 para un Sistema de Manejo Integrado (Bancos Forrajeros Mixtos + Pasturas Mejoradas con árboles y leguminosas
Horizonte de la inversión: 10 años

Gráfico del cambio de Uso de Suelo en Laderas Andinas



VPN: US $ 324.6
TIR: 21.6%

Los resultados del Modelo preliminar indican que el cambio de Uso del Suelo sería positivo, sin embargo, los ingresos del primer año son negativos, adicionando el efecto de pago por Captura de Carbono, la situación puede cambiar.

Nota: Son los resultados presentados durante el Seminario de Agosto 2005; algunos factores deben cambiarse, como sugerencia de los participantes. (Complementar el sistema con un área para seguridad alimentaría, reducir el área propuesta para Bosques o de pastura nativa a regeneración natural.

Annex 7

Activity Report, Humid Tropical Forest Ecosystem, Amazonia, Colombia.

Ecosistema Bosque Tropical Amazónico
Informe de Actividades y Resultados año 2005

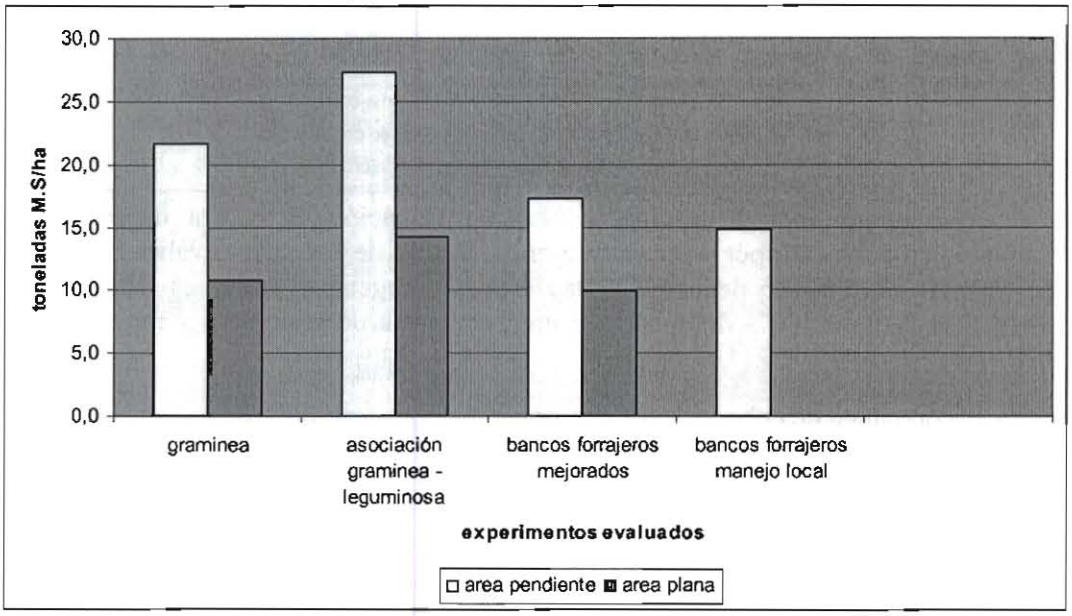
1. Evaluación Periódica de Biomasa de los Nuevos Experimentos.

Durante este periodo se han realizado evaluaciones periódicas de la producción de biomasa, cada 90 días se realiza un corte de las especies evaluadas y los resultados son expresados en toneladas de materia seca por hectárea, los experimentos evaluados son:

- Gramínea híbrido 4624 sembrada en monocultivo.
- Gramínea híbrido 4624 sembrada en asociación con *Arachis pintoi.*
- Bancos forrajeros mejorados
- Bancos forrajeros con manejo local
- Regeneración natural

Los resultados de la biomasa total acumulada, mostrados en la figura 1, revelan que la producción de los experimentos ubicados en el terreno pendiente ha tenido mejor desarrollo que aquellos ubicados en terreno plano; situación causada principalmente por un menor desarrollo de las plantas en los experimentos establecidos en terreno plano, debido a limitaciones tanto física como químicas del terreno plano, como son, alta compactación y limitaciones de nutrientes, consecuencia de un mayor uso agropecuario de estos suelos.

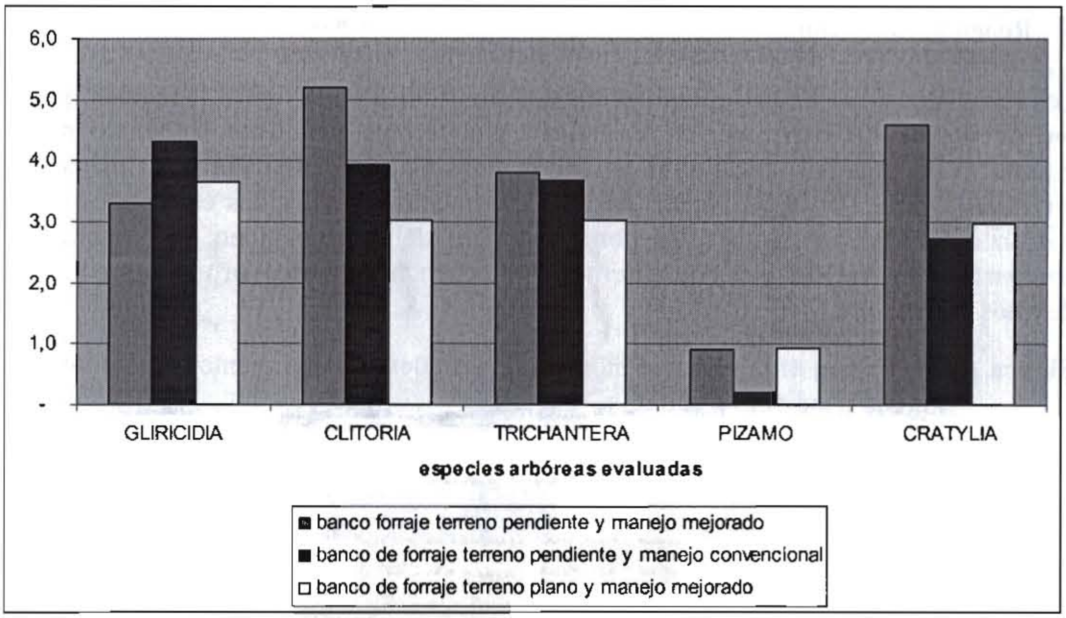
Figura 1. Producción acumulada de biomasa de los nuevos experimentos evaluados en terreno pendiente y plano.



Las mayores producciones de biomasa de las gramíneas en monocultivo y de la asociación gramínea – leguminosa sobre las obtenidas de los bancos de forraje, evaluados en los dos tipos de terreno, tienen su explicación en el desarrollo fisiológico de cada especie. Las arbóreas de los bancos necesitan de un mayor periodo vegetativo para alcanzar su madurez fisiológica y la evaluación en el tiempo actual no permite diferenciar esto.

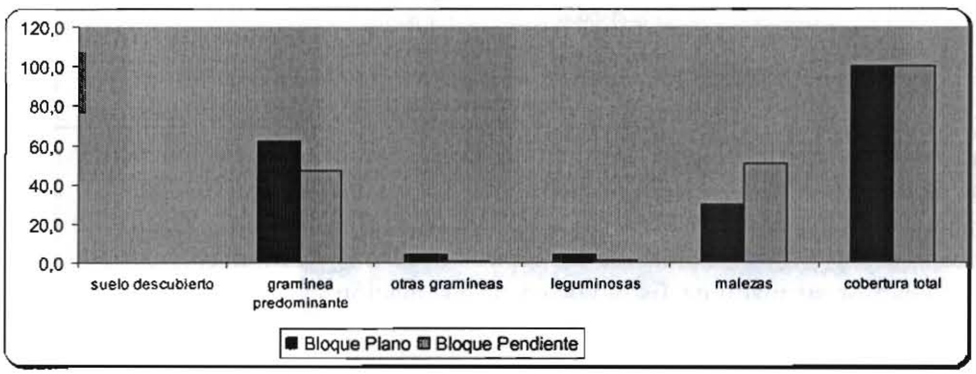
Con referencia a la producción total de biomasa por especie arbórea, de los bancos de forraje con manejo mejorado (aplicación de fertilizante inorgánico y orgánico después de cada corte) y convencional (aplicación de abono orgánico después de cada corte), durante un periodo de 540 días de evaluación (6 cortes), ver figura 2, las especies ***Clitoria farchildiana*** y ***Cratilia argentea***, presentaron la mayor producción en el experimento ubicado en terreno pendiente bajo condiciones de manejo mejorado, ***Trichantera gigantea*** tuvo un desarrollo homogéneo en los dos tipos de manejo, ***Gliricidia sepium*** presentó mayor producción bajo el manejo convencional en terreno pendiente y ***Erythrina fusca*** debido al desarrollo como especie de estrato alto, a partir del tercer corte se determinó no cortarla, por esta razón su producción se muestra disminuida en la grafica.

Figura 2. Producción acumulada de biomasa de bancos de forraje evaluados en terreno pendiente y plano.



En el experimento de regeneración natural la evaluación se realiza midiendo los porcentajes de cobertura por componente en cada uno de los sitios evaluados. Como conclusión parcial puede decirse que las especies vegetales presentes han logrado realizar cobertura en 100% del área, con predominancia de gramíneas y malezas. Ver figura 3.

Figura 3. Porcentaje de cobertura por componente del experimento de regeneración natural evaluados en terreno pendiente y plano.



2. Muestreos de Suelo para determinación de Carbono en Nuevos Experimentos.

Pasados tres años desde el establecimiento a partir de pasturas degradadas de los nuevos experimentos, en suelos de pendientes (bloque pendiente – Granja Balcanes) y planos (bloque plano- Granja Santo Domingo) en el ecosistema amazónico, tiempo durante el cual se han adelantado periódicamente evaluaciones de producción de biomasa ($M.S.ha^{-1}$) y de acuerdo con el objetivo propuesto del proyecto de captura de carbono, durante el año 2005 se evaluará el carbono almacenado en el suelo por los sistemas de uso del suelo estudiados:

Tratamiento 1 (T1): Brachiaria híbrido 4624 establecido en monocultivo
Tratamiento 2 (T2): Brachiaria híbrido 4624 y la leguminosa herbácea ***Arachis pintoi***.
Tratamiento 3 (T3): Bancos forrajeros mixtos de corte y acarreo, de cinco especies arbustivas

- Matarratón – ***Gliricidia sepium***
- Bohío- ***Clitroria farchildiana***
- Nacedero- ***Trichantera gigantea***
- Cratylia veranera - ***Cratylia argentea***
- Pizamo- ***Erithryna fusca***.

Tratamiento 4 (T4); Regeneración natural.

Se tomarán 432 muestras de suelo a 4 profundidades 0-10, 10-20, 20-40 y 40-100 centímetros, en 5 sistemas de uso del suelo en dos tipos de terreno plano y pendiente. La evaluación de la información resultante se realizará aplicando un diseño experimental de cuadrado latino. Esta información se complementará con los resultados del monitoreo de biomasa; con el propósito de determinar, cual de los sistemas de uso del suelo estudiados son mas eficientes en captura de carbono y ayudarán en el alivio de la pobreza de los campesinos, aportando forraje para alimento de sus animales.

Los resultados esperados de captura de carbono por estos sistemas de uso del suelo deben analizarse teniendo en cuenta los contenidos de nutrientes originales del suelo, mostrados en la tabla 1. Estos análisis fueron tomados antes del establecimiento de los nuevos experimentos y de manera general permiten deducir que son suelos ácidos con toxicidad en aluminio y pobres en la mayoría de los elementos necesarios para el crecimiento y desarrollo de las plantas. Sin embargo, es importante hacer énfasis que los resultados correspondientes al terreno plano presentan mayores deficiencias en elementos esenciales como P, K, Ca, Mg, Cu, Fe y Mn

Tabla 1. Resultados de los análisis iniciales de suelos de los bloques pendiente y plano.

Descripción	Bloque Pendiente (Granja Balcanes)	*Bloque Plano (Granja Santo Domingo)*
pH	4.66	*4.65*
Materia orgánica %	2.96	*3.1*
P-Bray (ppm)	1.74	*1.1*
K (meq)	0.26	*0.18*
Ca (meq)	0.64	*0.13*
Mg (meq)	0.22	*0.06*
Al (meq)	8.53	*3.12*
Cu (ppm)	0.78	*0.33*
Fe (ppm)	244.8	*72.2*
Mn (ppm)	19.8	*2.61*
Zn (ppm)	0.61	*0.55*
B (ppm)	0.40	*0.36*

3. Ultimo Muestreo de C en Sistemas ya Establecidos en el Ecosistema Amazónico.

La evaluación de carbono del Ecosistema Amazónico se realizó en Colombia, en suelos del piedemonte amazónico del Departamento del Caquetá, ubicado al sur occidente del país. El paisaje de piedemonte se caracteriza por un área montañosa, completada por un relieve de colinas o lomas suaves de aspecto ondulado y predominando finalmente un valle extenso; el cual, según la clasificación de Holdridge (1978), corresponde a bosque húmedo tropical (Bht). Con respecto al tipo de intervención, el piedemonte es un área de intensa actividad humana y ha servido como antesala para la colonización de la selva.

El ICA (1987), realizó una descripción detallada de las características fisiográficas de la región encontrando que el 74.2 % del territorio se encuentra bajo selva, comprendiendo alturas entre 100 y 400 m.s.n.m., el 20.2% del territorio se encuentra ubicado en el piedemonte que incluye áreas de cordillera, serranía, piedemonte llanero y piedemonte amazónico en alturas entre 400 - 1000 m.s.n.m. y solamente el 5.6% corresponde a territorio de sabana (especialmente los denominados llanos del yari), comprendidos entre 200 y 400 m.s.n.m.

El proyecto INPA, realizado por el IGAC (1993), identificó los paisajes geomorfológicos de montaña (cordillera), piedemonte, valles y lomerío. Refiriéndose al paisaje de mesón o lomerío a suelos con alta variabilidad en relieve, ubicados entre los 200 a 400 m.s.n.m, desde ondulado con pendientes de 12 a 25%, hasta fuertemente quebrados con pendientes de 40%; suelos de valle o vega, originados por la actividad sedimentaria de los ríos, ubicados entre 0 y 200 m.s.n.m., en un relieve que va de plano a ligeramente ondulado, con pendientes menores de 12%, predominando los planos de 0 – 3%; el paisaje de piedemonte comprende parte del lomerío ubicándose en alturas superiores a los 400 m.s.n.m. y pendientes mayores del 40%. Por último el paisaje de cordillera ubicado por encima de los 2000 m.s.n.m.

Bajo estas características de paisaje se tomaron 608 muestras de suelo en 6 sistemas de uso del suelo con más de 10 años de establecidos en la finca Pekín, ubicada en el municipio de la Montañita- Caquetá sobre paisaje de lomerío. La finca Pekín esta ubicada a una altura de 258 m.s.n.m, localizada al occidente del Departamento del Caquetá y a 30 kilómetros al norte de la ciudad de Florencia, capital del departamento. Se sitúa geográficamente a 1° 24' de Latitud norte y 75° 27' de Longitud al Oeste del meridiano de Greenwich. (IGAC, 1993. Situada sobre un paisaje de piedemonte de la Cordillera Oriental de Colombia, su superficie de 1400 hectáreas.

Sistemas de uso del suelo evaluados:

	Tamaño (ha)	Años de establecimiento
T-1: Brachiaria humidícola monocultivo	10	10
T-2: Brachiaria decumbens monocultivo	20	10
T-3: Brachiaria decumbens + desmodiun ovalifolium	10	15
T-4: Brachiaria humidícola + arachis pintoi	15	15
T-5: Boque nativo intervenido	5	100

4. Evaluación Socio-económica.

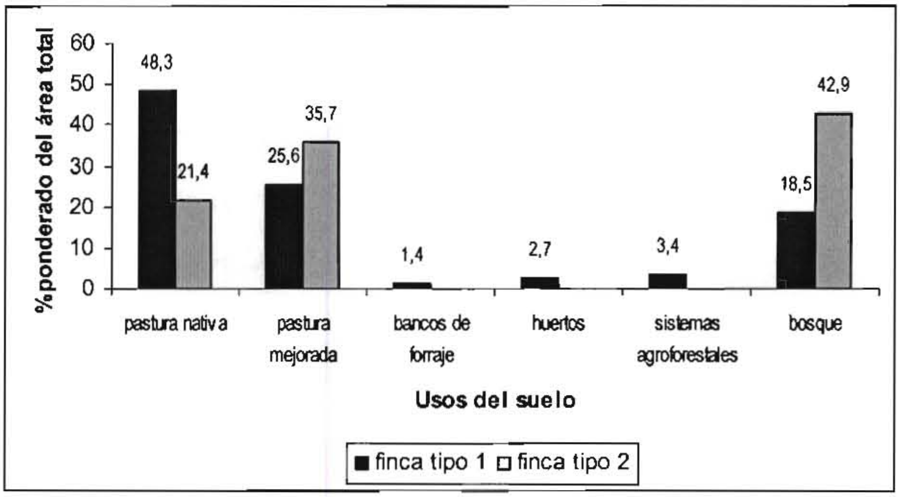
Para alcanzar una de las metas del proyecto captura carbono es necesario establecer una línea base socioeconómica y de uso del suelo que permita modelar todo este conjunto y relacionarlo con la capacidad de acumulación de carbono de cada actividad productiva.

De acuerdo con lo anterior, uno de los objetivos específicos del proyecto es la cuantificación de los índices productivos de las fincas y los beneficios económicos de los finqueros. Por esta razón, se escogieron fincas ubicadas al interior del ecosistema bosque tropical húmedo Amazonía colombiana para hacer una evaluación financiera de las mismas, a través del registro sistemático de las actividades desarrolladas y sus ingresos y egresos, en formatos diseñados para que sean diligenciados directamente por los finqueros.

De acuerdo con el tamaño y las principales actividades desarrolladas, se monitorean fincas típicas de la región amazónica. Las fincas tipo 1, corresponden a fincas pequeñas con actividades de producción diversificadas (ganadería, caucho, huertos de frutales, pollos, cerdos, bancos de forraje, etc.). Las fincas tipo 2, son empresas comerciales que solamente se dedican a la ganadería. Ver figura 4.

El monitoreo financiero y de actividades de las fincas se ha realizado durante 12 meses, (julio de 2004 a junio de 2005). Cada mes se realiza un taller de colección y chequeo de datos, los cuales se almacenan en una base electrónica y finalmente se corren en el programa Risk Analysis, para determinar los modelos financieros.

Figura 4. Porcentaje del área de la finca dedicada a las diferentes actividades productivas, ponderadas por el área total.



En la tabla 2 se presenta un resumen de los indicadores financieros encontrados para cada uno de los tipos de fincas, en la misma, puede observarse que debido al mayor tamaño de la finca tipo 2, la producción, el margen bruto y la ganancia neta total son superiores a los reportados para las fincas del tipo 1.

Sin embrago, cuando el análisis se realiza por hectárea la diferencia no es tan notoria; situación que puede explicarse por las características de diversificación de las pequeñas fincas, donde, el consumo de frutos del huerto, cerdos, aves, huevos y peces producidos en la misma finca (autoconsumo) disminuye los gastos en efectivo de las familias y un aumento en la producción bruta de las fincas, hecho que se manifiesta en los resultados obtenidos en el margen bruto y la utilidad neta de las mismas.

Tabla 2. Resumen de los indicadores financieros encontrados para los dos tipos de fincas. (Valores expresado en US$)

Indicador	**Finca Tipo 1**	**Finca Tipo 2**
Producción Total Bruta	8.771,61	107.644,44
Margen Bruto Total	6.671,32	74.190,18
Margen Bruto Total. ha-1	71,07	92,74
Ganancia Neta Total	6.467,40	88.481,84
Ganancia Neta Total. ha-1	77,45	110,60

De manera general puede decirse que en las fincas tipo 1 la venta de ganado representa el 54% de los ingresos, equivalentes a $US 3.512 y la venta de leche equivale a 46% US$ 2.980, mientras que los mismos rubros en las fincas tipo 2 estor porcentajes varían a 67% US$ 72.089 y 33% US$ 35.556 respectivamente.

Annex 8

Statistical Analysis of Soil Carbon Stocks Flat and Mild-slope Topographies, Amazonia, Colombia (2002-2005)

Soil Carbon Stocks in Long-established Systems: Research Results 2002-2005

Humid Tropical Forest, Amazonia, COLOMBIA

M. C. Amézquita, H. F. Ramírez, B. L. Ramírez, and H. Giraldo

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Adjusted according to suggestions from the "*VI International Coordination Meeting*"
CIAT, August 16-19, 2005.

Experimental Farms

4 Farms near Florencia, Colombia
800 m.a.s.l., 1.8°N, 75.5°W
4000 mm/yr
poor, acid soils (pH < 5.0)

Flat Topography:

- "La Guajira" commercial farm (260 ha): beef and dual-purpose cattle under improved grass and grass+legume pastures.
- "Santo Domingo" experimental farm, Universidad Amazonia (45 ha).

Mild-slope Topography:

- "Pekín" commercial farm (1400 ha): beef and dual-purpose cattle under improved grass and grass+legume pastures.
- "Balcanes" experimental farm, Universidad Amazonia (65 ha).

SAMPLING DESIGN
Flat Topography

- **6 Land Use Systems**
- **3 Spatial Reps per System**
- **9 Sampling Points per System/Rep**
- **4 Soil Depths**

0-10 cm
10-20 cm
20-40 cm
40-100 cm

- **TOTAL SAMPLES: 672**

- **Soil parameters analysed per sample: 7**

Texture, Bulk Density, pH, P, CEC, Total C, Oxidisable C, Total N.

SAMPLING DESIGN
Mild-slope Topography

- **6 Land Use Systems**
- **3 Spatial Reps per System**
- **3 Slope Positions**
- **3 Sampling Points per Slope Position/System/Rep**
- **4 Soil Depths**

  0-10 cm
  10-20 cm
  20-40 cm
  40-100 cm

- **TOTAL SAMPLES: 672**

- **Soil parameters analysed per sample: 7**

Texture, Bulk Density, pH, P, CEC, Total C, Oxidisable C, Total N.

Humid Tropical Forest
Amazonia, Colombia

Flat Topography

Table 1: Systems' Characterisation.

System	Age (yr)	bd (gr/cm^3)	PH (Um)	P (mg/kg)	N (mg/kg)	CEC (cmol/kg)	Sand (%)	Clay (%)
1. Degraded Pasture (*Paspalum notatum*)	40	1.06	4.5	1.6	2195	10.8	35.1	43.5
2. *B. decumbens*	10	1.21	4.5	3.3	2001	8.6	36.1	41.3
3. *B. humidicola*	10	1.02	4.4	2.9	2344	12.2	35.9	43.7
4. *B. decumbens+leg*	10	1.14	4.6	15.0	2712	9.4	45.2	32.8
5. *B. humidicola+leg*	10	1.08	4.8	8.7	2542	9.6	45.4	35.6
6. Forest: nat regen.	>50	1.16	4.3	3.4	1692	7.6	40.4	36.0

Each soil parameter estimate in this table is the mean of 27 laboratory determinations (3 space replications x 9 soil samples/replication) taken at 0-10cm depth, except bd (taken at 0-20cm) during June- August 2003. Soil samples were analysed at CIAT´s Soils Laboratory, February 2004.

Table 2: Land Use History of each System - Information given by the farm owner (last 50 years) -				
SYSTEM	**Farm**	**Up to 1950**	**1960-1992**	**1993-2005**
1. Degr. Pasture	Santo Domingo (Reps 1,2)	Forest	*Paspalum notatum* under grazing (Degraded)	
2. B. decumbens	Santo Domingo (Reps 1-3)	Forest	*H. rufa+P.notatum* under grazing	*B. decumbens* under grazing
3. B. humidicola	La Guajira (Reps 1-3)	Forest	*P. notatun* under grazing	*B. humidicola* under grazing
4. B. decumbens+leg	La Guajira (Reps 1-3)	Forest	*B. decumbens* under grazing	*B. decumbens* + leg under grazing
5. *B. humidicola+leg*	La Guajira (Reps 1-3)	Forest	*B. humidicola* under grazing	*B. humidicola* + leg under grazing
6. Forest (natural regeneration)	La Guajira (Reps 1-3)	Forest	Forest with minor intervention (animals looking for shade)	

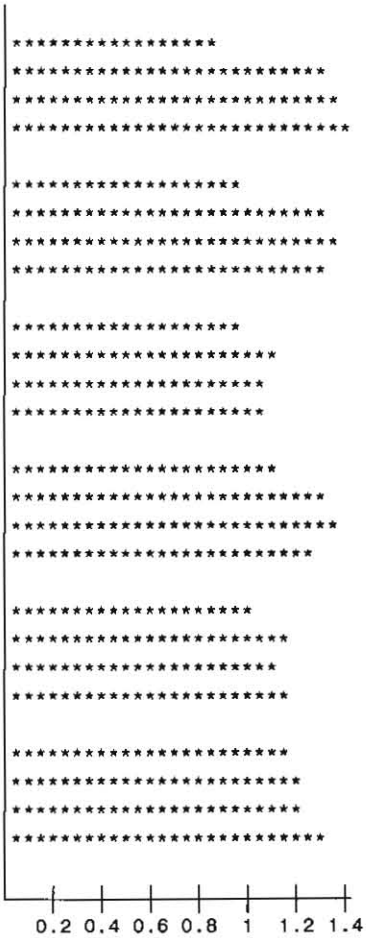
Table 3: Botanical Composition of Degraded vs. Improved Pastures during the C evaluation period. Aug 2003 (minimum rainfall period). Flat Topography

SYSTEM	N	Bare soil (%)	Total DM (kg/ha)	Botanical Composition (% in Total DM)			
				Weeds	Main grass	Other grass	Leg
1. *B.humidicola+leg*	36	12	7192	5	79	4	12
2. B. decumbens	36	9	6344	10	69	20	1
3. B. humidicola	36	14	5856	1	97	2	0
4. B. decumbens+leg	36	13	4098	3	70	11	16
5.*Degraded Pasture*	52	13	1792	32	19	48	1

Table 4: Soil and C Determinations. Analytical methods CIAT´s Soils Laboratory. Nov-Dec, 2002.

Determination	Analytical Method
Soil physics	
1. Bulk density (gr/cm3)	Dry weight of soil (gr) over volume of cylinder (cm^3)
2. Soil texture	Bouyoucos method (% sand, clay, silt)
Soil chemistry	
3. P (mg/kg)	Colorimetrically using autoanalyzer through "Azul de Molibdeno" method, Bray II (ppm or mg/kg).
2. CEC (cmol/kg)	Amonium acetate method (meq/100g).
3. pH (Um)	Potenciometrically in a soil/water ratio 1:1.
4. Total N (mg/kg)	Spectrophotometrically via autoanalyzer after a digestion with Sulphuric acid + Salicilic acid (Temminghoff, E.J.M. ed., 2000) (ppm or mg/kg).
5. Oxidisable C (gr/kg)	Walkey and Black method modified by Kurmies Temminghof, E.J.M. ed. 2000. Methodology for chemical Soil and Plant Analysis. Wageningen University. Environmental Sciences.
6. Total C (gr/kg)	Idem to total C plus heat at 120 degrees Celsius.

Fig 1: Humid Tropical Forest, Amazonia, Colombia
Flat Topography
Bulk density per depth in land use system (treatments)



Bulk density (gr/cm3)

trat	Profundidad	N	Densidad Mean	Std	CV (%)
Brac_h+leg nativ	0-10	27	0.85	0.10	12.27
	10-20	27	1.30	0.20	15.43
	20-40	27	1.31	0.25	18.36
	40-100	27	1.36	0.26	18.70
Brac_d+leg nativ	0-10	27	0.95	0.10	10.39
	10-20	27	1.32	0.05	3.85
	20-40	27	1.37	0.18	13.42
	40-100	27	1.30	0.08	6.07
Brac_h en Mon	0-10	27	0.93	0.12	13.19
	10-20	27	1.10	0.05	4.46
	20-40	27	1.06	0.04	3.42
	40-100	27	1.07	0.04	3.26
Brac_d en Mon	0-10	27	1.10	0.11	9.73
	10-20	27	1.32	0.09	7.12
	20-40	27	1.33	0.09	6.44
	40-100	27	1.24	0.05	4.38
Past Degradada	0-10	21	0.99	0.08	8.35
	10-20	21	1.13	0.08	7.43
	20-40	21	1.09	0.08	7.17
	40-100	21	1.16	0.08	7.22
Bosque Nativo	0-10	27	1.15	0.15	13.25
	10-20	27	1.18	0.14	11.58
	20-40	27	1.21	0.16	13.51
	40-100	27	1.29	0.19	14.56

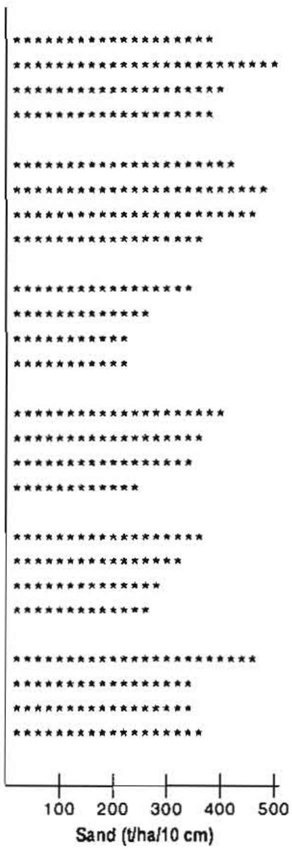
Fig 2 : Total N, Sand and Clay (expressed as t/ha/10 cm Layers)

Total N (t/ha/10 cm)

trat	Profundidad	N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	27	2.1	0.42	19.61
	10-20	27	2.0	0.48	23.49
	20-40	27	1.4	0.35	23.54
	40-100	27	1.2	0.29	23.98
Brac_d+leg nativ	0-10	27	2.5	0.50	19.48
	10-20	27	1.9	0.37	18.75
	20-40	27	1.3	0.27	19.41
	40-100	27	1.0	0.17	16.58
Brac_h en Mon	0-10	27	2.1	0.40	18.31
	10-20	27	1.5	0.17	10.99
	20-40	27	1.2	0.17	13.31
	40-100	27	0.9	0.12	11.80
Brac_d en Mon	0-10	27	2.2	0.40	17.94
	10-20	27	1.7	0.33	19.26
	20-40	27	1.2	0.14	11.47
	40-100	27	1.0	0.14	13.41
Past Degradada	0-10	21	2.1	0.35	15.83
	10-20	21	1.8	0.34	18.95
	20-40	21	1.4	0.28	19.61
	40-100	21	1.1	0.22	19.27
Bosque Nativo	0-10	27	1.9	0.35	18.01
	10-20	27	1.3	0.26	18.76
	20-40	27	1.1	0.19	16.98
	40-100	27	0.9	0.24	24.21

Sand (t/ha/10 cm)

trat	Profundidad	N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	9	387.9	65.0	16.76
	10-20	9	508.7	113.7	26.29
	20-40	9	404.3	86.5	21.40
	40-100	9	387.1	114.7	29.64
Brac_d+leg nativ	0-10	9	428.3	60.3	14.08
	10-20	9	488.1	91.0	18.65
	20-40	9	466.4	84.1	18.03
	40-100	9	363.1	63.5	17.48
Brac_h en Mon	0-10	9	336.7	70.7	20.99
	10-20	9	256.2	41.1	16.04
	20-40	9	227.7	46.0	20.22
	40-100	9	213.6	55.7	26.10
Brac_d en Mon	0-10	9	398.8	72.6	18.22
	10-20	9	367.8	74.3	20.22
	20-40	9	335.1	88.7	26.48
	40-100	9	246.7	82.4	33.43
Past Degradada	0-10	7	350.9	56.4	16.09
	10-20	7	312.2	18.9	6.05
	20-40	7	272.4	37.5	13.79
	40-100	7	258.2	34.5	13.39
Bosque Nativo	0-10	9	464.3	118.5	25.52
	10-20	9	332.2	71.1	21.41
	20-40	9	335.0	64.4	19.23
	40-100	9	354.2	54.4	15.36



trat	Profundidad		Clay (t/ha/10 cm)			
			N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	******	9	302.0	27.3	9.05
	10-20	***********	9	568.5	76.4	13.45
	20-40	**************	9	706.8	50.3	7.13
	40-100	****************	9	803.2	56.1	6.99
Brac_d+leg nativ	0-10	******	9	312.5	45.8	14.68
	10-20	***********	9	565.5	66.6	11.78
	20-40	*************	9	670.6	57.6	8.59
	40-100	****************	9	785.5	34.9	4.45
Brac_h en Mon	0-10	********	9	406.3	47.3	11.64
	10-20	*************	9	636.0	25.9	4.08
	20-40	*************	9	664.0	40.0	6.03
	40-100	**************	9	717.3	48.9	6.82
Brac_d en Mon	0-10	*********	9	456.6	67.0	14.68
	10-20	*************	9	645.0	19.4	7.67
	20-40	***************	9	746.6	52.5	7.04
	40-100	****************	9	821.6	50.4	6.14
Past Degradada	0-10	*********	7	432.5	29.5	6.83
	10-20	************	7	588.4	58.0	9.86
	20-40	*************	7	655.3	49.7	7.60
	40-100	***************	7	765.6	60.4	7.89
Bosque Nativo	0-10	********	9	411.5	90.9	22.10
	10-20	**********	9	510.0	84.5	16.58
	20-40	***********	9	540.4	47.5	8.81
	40-100	************	9	621.6	49.7	7.99

200 400 600 800

Clay (t/ha/10 cm)

Fig 3: Mean carbon accumulation (Total, Oxidisable and Stable C), per depth (expressed as t/ha/10 cm layers), in 6 land use systems. Flat topography, Amazonia, Colombia.

trat	Profundidad		Total C (ton/ha/10 cm) N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	*************	27	25.81	4.00	15.48
	10-20	************	27	23.21	4.55	19.60
	20-40	*********	27	17.79	2.65	14.91
	40-100	*******	27	14.09	1.83	12.96
Brac_d+leg nativ	0-10	**************	27	28.21	4.79	16.99
	10-20	***********	27	21.84	3.28	15.03
	20-40	********	27	15.64	1.77	11.29
	40-100	******	27	11.81	0.93	7.85
Brac_h en Mon	0-10	**************	27	28.20	4.30	15.25
	10-20	**********	27	19.67	2.01	10.23
	20-40	********	27	15.37	1.54	10.01
	40-100	******	27	11.86	1.31	11.01
Brac_d en Mon	0-10	**************	27	27.45	4.32	15.73
	10-20	**********	27	19.43	2.13	10.98
	20-40	*******	27	14.98	2.04	13.64
	40-100	******	27	11.63	1.70	14.60
Past Degradada	0-10	************	21	24.36	2.46	10.11
	10-20	**********	21	19.24	2.61	13.55
	20-40	********	21	15.01	2.39	15.94
	40-100	******	21	11.26	1.60	14.16
Bosque Nativo	0-10	************	27	23.95	4.28	17.86
	10-20	********	27	15.57	2.26	14.51
	20-40	*******	27	13.01	1.56	12.00
	40-100	*****	27	10.41	2.22	21.28

10 20

Total C (t/ha/ 10 cm)

trat	Profundidad		Oxidable C (t/ha/10 cm) N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	********************	27	20.33	3.59	17.66
	10-20	***************	27	15.18	3.17	20.86
	20-40	**********	27	9.85	2.09	21.26
	40-100	******	27	6.35	1.20	18.86
Brac_d+leg nativ	0-10	**********************	27	21.52	4.29	19.92
	10-20	*************	27	12.69	2.22	17.49
	20-40	********	27	7.68	1.35	17.58
	40-100	****	27	4.34	0.67	15.31
Brac_h en Mon	0-10	*********************	27	20.60	4.34	21.07
	10-20	************	27	11.60	2.04	17.57
	20-40	********	27	8.02	1.25	15.55
	40-100	*****	27	5.11	0.97	19.04
Brac_d en Mon	0-10	********************	27	20.14	3.28	16.29
	10-20	***********	27	11.36	1.56	13.71
	20-40	******	27	5.64	1.24	21.97
	40-100	****	27	3.58	1.38	38.65
Past Degradada	0-10	******************	21	18.07	2.22	12.29
	10-20	************	21	12.45	2.39	19.20
	20-40	**********	21	10.42	2.61	25.02
	40-100	********	21	7.75	2.68	34.62
Bosque Nativo	0-10	*****************	27	17.33	3.95	22.76
	10-20	*********	27	9.03	1.89	20.94
	20-40	******	27	6.49	1.05	16.11
	40-100	****	27	4.17	1.64	39.38

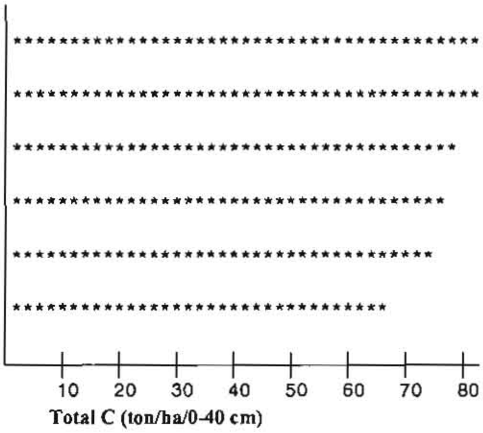
5 10 15 20

Oxidable C (t/ha/10 cm)

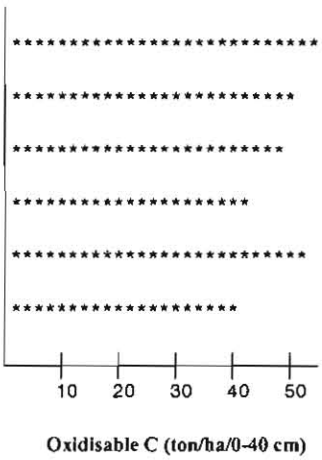
trat	Profundidad		Stable C (t/ha/10 cm) N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	***********	27	5.48	1.67	30.46
	10-20	****************	27	8.02	2.00	24.98
	20-40	****************	27	7.93	1.13	14.26
	40-100	***************	27	7.74	1.01	13.05
Brac_d+leg nativ	0-10	*************	27	6.70	1.49	22.25
	10-20	******************	27	9.16	2.64	28.80
	20-40	****************	27	7.96	0.92	11.62
	40-100	***************	27	7.47	0.54	7.29
Brac_h en Mon	0-10	***************	27	7.61	2.03	26.69
	10-20	****************	27	8.07	0.97	12.04
	20-40	***************	27	7.35	0.88	11.96
	40-100	*************	27	6.75	0.78	11.50
Brac_d en Mon	0-10	***************	27	7.32	1.54	21.05
	10-20	****************	27	8.07	1.26	15.60
	20-40	*******************	27	9.33	2.11	22.59
	40-100	****************	27	8.05	1.71	21.22
Past Degradada	0-10	*************	21	6.29	1.89	30.13
	10-20	**************	21	6.79	2.24	33.06
	20-40	*********	21	4.59	2.34	50.91
	40-100	*******	21	3.52	2.00	56.94
Bosque Nativo	0-10	*************	27	6.61	1.37	20.65
	10-20	*************	27	6.54	1.30	19.89
	20-40	*************	27	6.52	1.30	19.89
	40-100	************	27	6.24	1.19	19.84
		2 4 6 8				

Stable C (t/ha/10 cm)

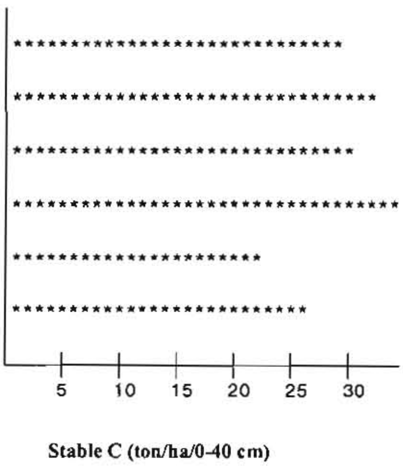
Fig 4: Mean carbon accumulation (Total, Oxidisable & Stable C, t/ha/fixed soil depth), at 0-40cm, in 6 land use systems. Flat Topography, Amazonia, Colombia.



Trat	N	Mean	Std	CV (%)
	Total C (ton/ha/0-40 cm)			
Brac_h+leg nativ	27	83.0	9.55	11.50
Brac_d+leg nativ	27	82.0	7.86	9.58
Brac_h en Mon	27	78.6	7.43	9.45
Brac_d en Mon	27	76.8	7.16	9.31
Past Degradada	21	73.6	8.09	10.99
Bosque Nativo	27	65.5	7.24	11.05



Trat	N	Mean	Std	CV (%)
	Oxidisable C (ton/ha/0-40 cm)			
Brac_h+leg nativ	27	54.3	7.51	13.82
Brac_d+leg nativ	27	49.9	7.32	14.66
Brac_h en Mon	27	48.2	7.43	15.40
Brac_d en Mon	27	42.7	5.19	12.14
Past Degradada	21	51.3	7.64	14.85
Bosque Nativo	27	39.3	6.82	17.33

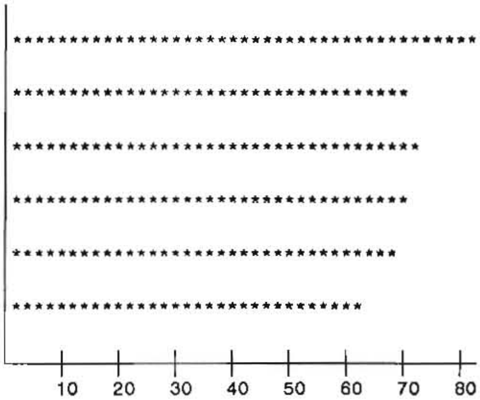


Trat	N	Mean	Std	CV (%)
	Stable C (ton/ha/0-40 cm)			
Brac_h+leg nativ	27	28.6	3.67	12.75
Brac_d+leg nativ	27	32.1	3.97	12.37
Brac_h en Mon	27	30.3	3.65	12.01
Brac_d en Mon	27	34.0	5.15	15.11
Past Degradada	21	22.2	6.58	29.56
Bosque Nativo	27	26.2	4.26	16.27

Fig 5: Mean carbon accumulation (Total, Oxidisable & Stable C, t/ha/fixed soil depth), at 40-100cm, in 6 land use systems. Flat Topography, Amazonia, Colombia.

Total C (ton/ha/40-100 cm)

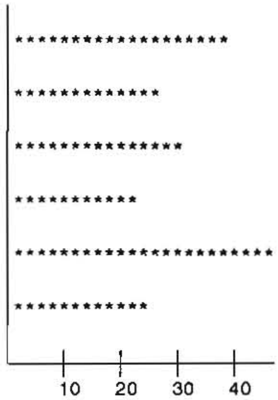
Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	82.7	8.31	10.04
Brac_d+leg nativ	27	70.8	5.56	7.85
Brac_h en Mon	27	71.1	7.84	11.01
Brac_d en Mon	27	69.7	10.18	14.60
Past Degradada	21	67.5	9.57	14.16
Bosque Nativo	27	62.4	13.29	21.28



Total C (ton/ha/40-100 cm)

Oxidisable C (ton/ha/40-100 cm)

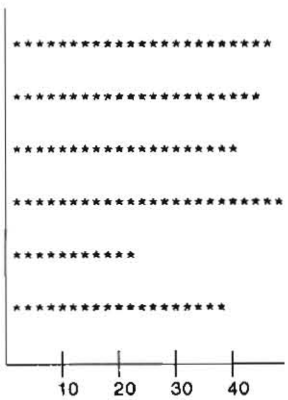
Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	37.2	5.82	15.61
Brac_d+leg nativ	27	26.0	3.99	15.31
Brac_h en Mon	27	30.6	5.84	19.04
Brac_d en Mon	27	21.4	8.30	38.65
Past Degradada	21	46.4	16.09	34.62
Bosque Nativo	27	25.0	9.84	39.38



Oxidisable C (ton/ha/40-100 cm)

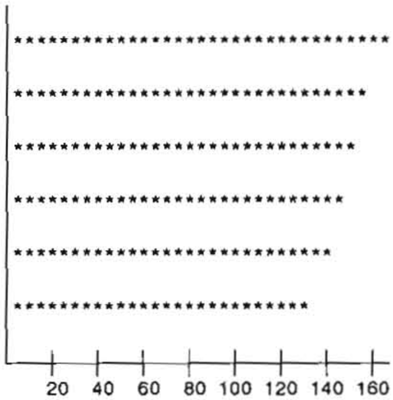
Stable C (ton/ha/40-100 cm)

Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	45.5	5.26	11.56
Brac_d+leg nativ	27	44.8	3.27	7.29
Brac_h en Mon	27	40.4	4.66	11.50
Brac_d en Mon	27	48.3	10.25	21.22
Past Degradada	21	21.0	12.01	56.94
Bosque Nativo	27	37.4	7.13	19.04

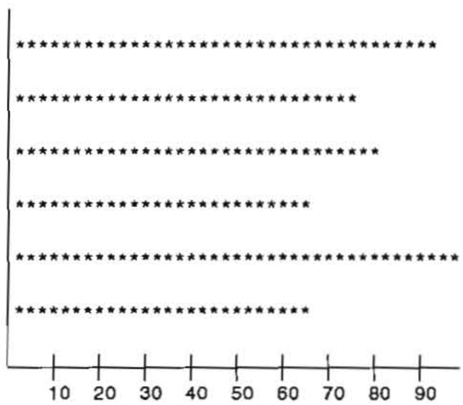


Stable C (ton/ha/40-100 cm)

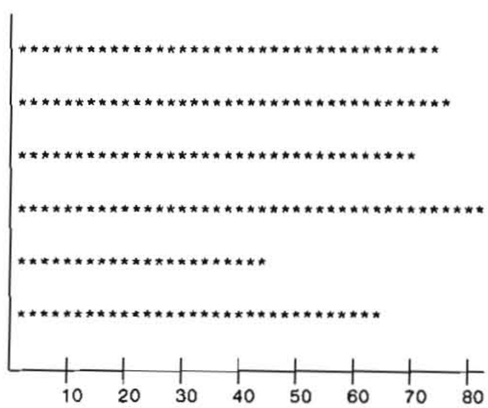
Fig 6: Mean carbon accumulation (Total, Oxidisable & Stable C, t/ha/fixed soil depth) at 1m in 6 land use systems. Flat Topography, Amazonia, Colombia.



Trat	N	Total C (ton/ha/1m) Mean	Std	CV (%)
Brac_h+leg nativ	27	165.7	15.63	9.43
Brac_d+leg nativ	27	152.9	8.70	5.69
Brac_h en Mon	27	149.7	11.46	7.65
Brac_d en Mon	27	146.6	13.47	9.19
Past Degradada	21	141.1	15.48	10.96
Bosque Nativo	27	128.0	18.77	14.66



Trat	N	Oxidisable C (ton/ha/1m) Mean	Std	CV (%)
Brac_h+leg nativ	27	91.5	10.79	11.78
Brac_d+leg nativ	27	75.9	8.68	11.43
Brac_h en Mon	27	78.9	10.57	13.39
Brac_d en Mon	27	64.2	9.70	15.10
Past Degradada	21	97.8	22.03	22.51
Bosque Nativo	27	64.3	14.28	22.20

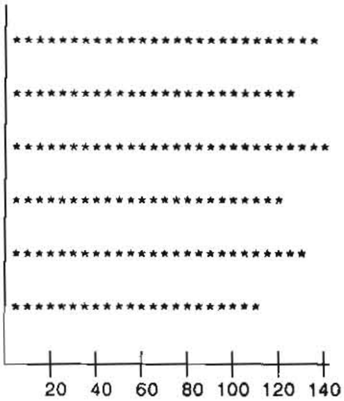


Trat	N	Stable C (ton/ha/1m) Mean	Std	CV (%)
Brac_h+leg nativ	27	74.1	7.94	10.71
Brac_d+leg nativ	27	76.9	5.21	6.76
Brac_h en Mon	27	70.8	7.25	10.23
Brac_d en Mon	27	82.3	12.80	15.54
Past Degradada	21	43.3	14.69	33.89
Bosque Nativo	27	63.6	10.81	16.98

Fig 7: Mean carbon accumulation (Total, Oxidisable & Stable C, t/ha/fixed soil mass) at 1m-equiv. in 6 land use systems. Flat Topography, Amazonia, Colombia.

Total C (ton/ha/1m - equiv)

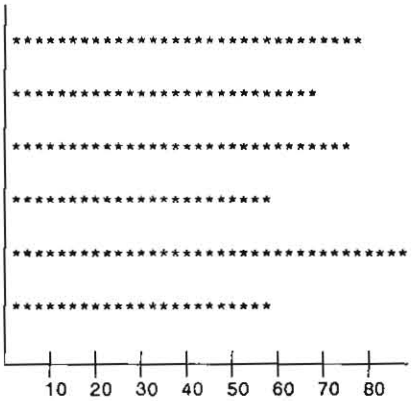
Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	135.1	12.65	9.36
Brac_d+leg nativ	27	126.3	9.13	7.22
Brac_h en Mon	27	141.8	10.37	7.31
Brac_d en Mon	27	121.8	9.86	8.10
Past Degradada	21	127.7	10.34	8.09
Bosque Nativo	27	107.5	13.24	12.31



Total C (ton/ha/1m)

Oxidisable C (ton/ha/1m)

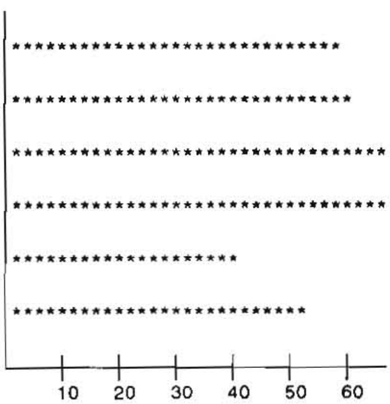
Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	77.8	9.45	12.14
Brac_d+leg nativ	27	66.2	8.59	12.96
Brac_h en Mon	27	75.5	10.37	13.73
Brac_d en Mon	27	56.7	7.65	13.49
Past Degradada	21	87.9	16.84	19.14
Bosque Nativo	27	56.4	11.27	19.96



Oxidisable C (ton/ha/1m)

Stable C (ton/ha/1m)

Trat	N	Mean	Std	CV (%)
Brac_h+leg nativ	27	57.2	5.35	9.33
Brac_d+leg nativ	27	60.1	3.78	6.29
Brac_h en Mon	27	66.3	5.88	8.87
Brac_d en Mon	27	65.1	8.67	13.32
Past Degradada	21	39.7	13.37	33.63
Bosque Nativo	27	51.1	6.84	13.37



Stable C (ton/ha/1m)

ANOVA MODEL
Flat Topography

SCS at fixed soil mass, at 0-40, 40-100 and 0-100 cm-equiv.

Source of Variation	df
Land Use System	5
Spatial Rep (Land Use System)	11
Residue = Sampling Point (System x Rep)	139
TOTAL	**155**

Table 5: Soil Carbon Stocks (t/ha/fixed soil depth), Humid Tropical Forest, Amazonia, Colombia. Flat Topography

Soil Depth	System	Total C (ton/ha)		Stable C (ton/ha)	
0-100	*B. humidicola + leg*	169	a	76	b
	B.decumbens + leg	152	b	77	b
	B.humidicola	150	b	71	b
	B.decumbens	147	b	82	a
	Degraded pasture	141	c	43	d
	Forest	128	d	64	c
Mean, CV (%) and LSD $_{.15}$		**148, 10, 5**		**70, 12, 3**	
0-40	*B. humidicola + leg*	85	a	29	a
	B.decumbens + leg	81	b	32	a
	B.humidicola	79	b	30	a
	B.decumbens	77	b	34	a
	Degraded pasture	74	c	22	b
	Forest	66	d	26	b
Mean, CV (%) and LSD $_{.15}$		**77, 10, 3**		**29, 13, 1.8**	
40-100	*B. humidicola + leg*	85	a	46	a
	B.decumbens + leg	71	b	45	a
	B.humidicola	71	b	40	b
	B.decumbens	70	b	48	a
	Degraded pasture	68	b	21	d
	Forest	62	c	37	c
Mean, CV (%) and LSD $_{.15}$		**71, 12, 3**		**40, 15, 2**	

Table 6: Soil Carbon Stocks (t/ha/fixed soil mass), Humid Tropical Forest, Amazonia, Colombia. Flat Topography

Soil Depth	System	Total C (ton/ha)		Stable C (ton/ha)	
0-100	*B.humidicola*	144	a	67	a
	B. humidicola + leg	138	b	59	b
	Degraded pasture	134	c	42	d
	B.decumbens + leg	128	c	61	b
	B.decumbens	124	d	67	a
	Forest	107	e	51	c
Mean, CV (%) and LSD .15		**129, 10, 4**		**58, 12, 3**	
0-40	*B. humidicola + leg*	85	a	29	d
	B.decumbens + leg	81	a	32	b
	B.humidicola	79	b	30	c
	B.decumbens	77	b	34	a
	Degraded pasture	74	c	22	f
	Forest	66	d	26	e
Mean, CV (%) and LSD .15		**77, 10, 3**		**29, 14, 1.8**	
40-100	*B.humidicola*	65	a	37	a
	Degraded pasture	60	b	20	e
	B. humidicola + leg	53	b	29	c
	B.decumbens + leg	47	c	30	c
	B.decumbens	47	c	33	b
	Forest	42	d	25	d
Mean, CV (%) and LSD .15		**52, 12, 2**		**29, 15, 2**	

Table 7: Factors affecting SCS (t/ha/1m-equiv) Amazonia, Flat Topography

Source	df	Total C			Stable C		
		F	p	SS(%)	F	p	SS(%)
Land Use System	5	20	***	51	51	***	57
Spatial Rep (Land Use System)	11	1.6	ns	4	4	*	10
Residual (non-explained var.)	139			46			34
Total	155						
Mean		129			58		
$\sqrt{\sigma^2}$		11			7		
CV (%) adjusted		9.8			12.3		
R^2		55%			67%		

*** $p < 0.01$; ** $0.01 \leq p \leq 0.05$; * $0.05 \leq p \leq 0.10$; ns $p \geq 0.10$; SS(%) = (Source SS/Total SS) x 100

Table 8a: Association between Soil and C Variables at fixed soil mass (1m-equiv.) - Flat Topography Principal Component Analysis Variance explained: 70 %

Variable	PC_1 (47 %)	PC_2 (23 %)
Stable C (ton/ha/1m-equiv)	-0.05	0.66*
Total N (ton/ha/1m-equiv)	0.47*	-0.20
Oxidable C (ton/ha/1m-equiv)	0.49*	-0.33
Sand (ton/ha/1m-equiv)	0.02	-0.43*
Clay (ton/ha/1m-equiv)	0.48*	0.45
CEC (meq/ha/1m-equiv)	0.55	0.18

PC1: Oxidisable C and Total N with high Clay content

PC2: Stable C with high Clay and very low Sand content.

Table 8b: Grouping of sampling points according to first 2 Principal Components at 1m-equiv. Flat Topography

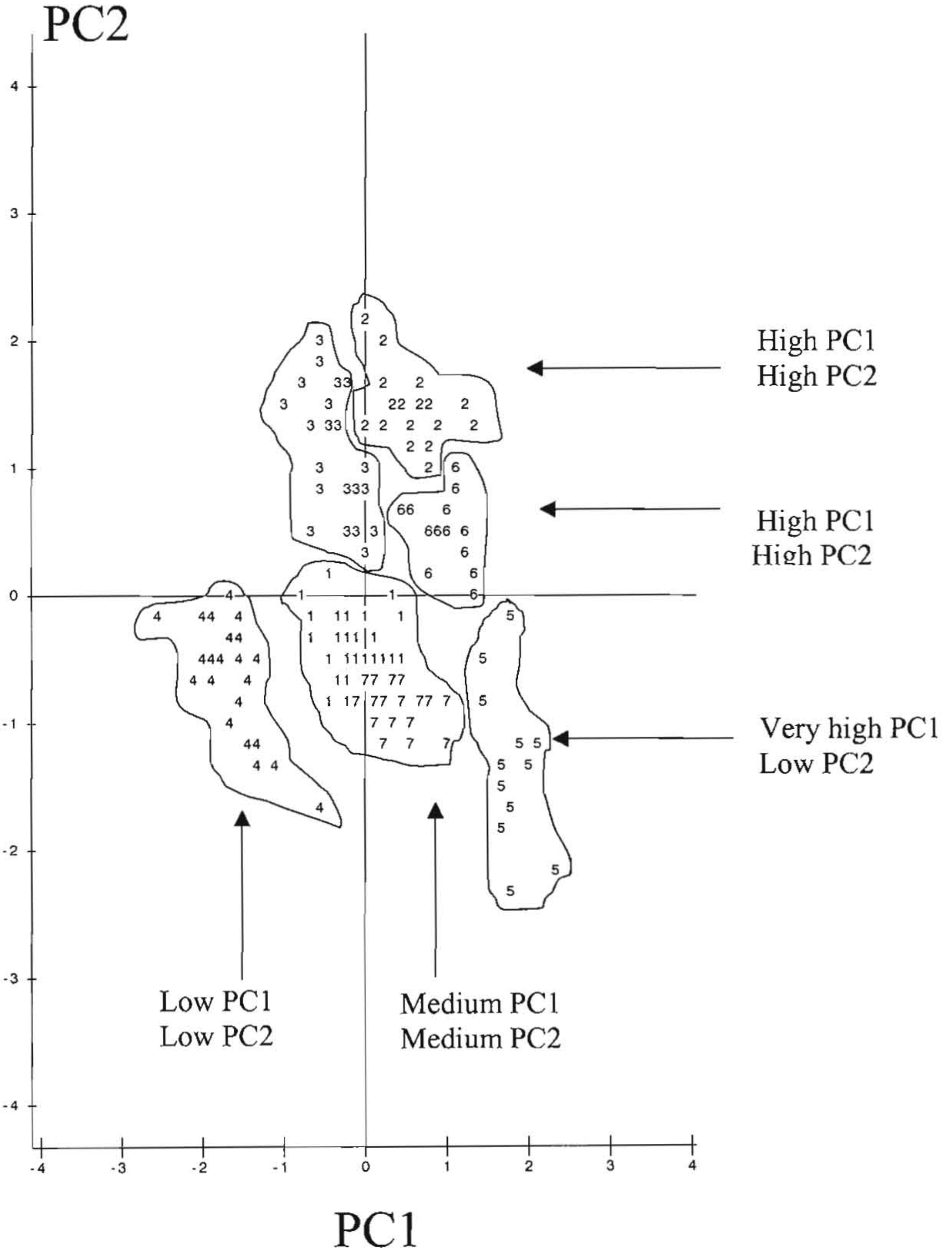
N=156 sampling points, Cluster R^2 = 88 %

Classification Criteria	Cluster Number						
	1 N=35	2 N=21	3 N=26	4 N=27	5 N=13	6 N=15	7 N=19
Principal Components	**Cluster Means**						
PC1	-0.02	0.57	-0.35	-1.62	1.79	0.97	0.38
PC2	-0.40	1.46	1.07	-0.66	-1.34	0.52	-0.89
Original Soil parameters	**Cluster Means**						
Oxidable C (ton/ha/1m-equiv)	71	72	57	56	103	79	78
Stable C (ton/ha/1m-equiv))	60	70	67	51	33	58	59
Total N (ton/ha/1m-equiv))	11	11	10	9	14	12	13
Sand (ton/ha/1m-equiv))	3433	1865	2340	2173	2532	2255	3610
Clay (ton/ha/1m-equiv))	5071	6386	5847	3535	6330	6338	4998
CEC (meq/ha/1m-equiv)	77	88	74	53	97	93	78

Table 8c: Soil C Stocks per Cluster and Cluster members
Flat Topography
N=156, Clusters = , R^2 = 88%

Cluster (N)	Cluster Description	Oxidisable C		Stable C		Cluster Members
		Min-Max	Mean	Min-Max	Mean	
2 (N= 21)	High PC1 High PC2	57 – 92	72	62 – 81	70	*B. humidícola* mono (N=21)
6(N= 15)	High PC1 Medium PC2	61 – 95	79	51 – 68	58	*B. humidícola* mono (N=7), Degraded Pasture (N=8)
3 (N= 26)	Medium-low PC1 Medium PC2	42 – 67	57	55 – 84	67	*B. decumbens* mono (N=26)
5 (N= 13)	Very high PC1 Low PC1	91 – 106	103	13 – 58	33	Degraded Pasture (N=13)
1 and 7 (N= 54)	Medium PC1 Low PC2	50 – 103	73	45 – 71	60	*B. humidícola* + leg (N=20) *B. decumbens* + leg (N=15)
4 (N= 27)	Low PC1 Low PC2	31 – 90	56	40 – 63	51	Native Forest (interveened) (N=27)

Cluster Groups Flat Topography



Humid Tropical Forest
Amazonia, Colombia

Mild-slope Topography

(slope < 10%)

Table 1: Systems Characterisation

System	Age (yr)	bd (gr/cm^3)	pH (Um)	P (mg/kg)	N (mg/kg)	CEC (cmol/kg)	Sand (%)	Clay (%)
1. Degraded Pasture *(Paspalum notatum)*	40	1.17	4.6	1.9	2166	13.6	50.0	44.0
2. *B. decumbens*	15	1.11	5.0	2.4	2649	11.3	53.3	31.0
3. *B. humidicola*	15	1.20	4.5	2.9	2451	10.2	56.1	31.0
4. *B. decumbens+leg*	15	1.15	4.5	3.4	2011	9.0	46.1	39.9
5. *B. humidicola+leg*	15	1.12	4.9	2.7	2928	11.5	50.1	30.8
6. Forest: nat regen.	>80	1.11	4.0	3.9	1860	8.7	60.7	36.3

Each soil parameter estimate in this table is the mean of 27 laboratory determinations (3 space replications x 9 soil samples/replication) taken at 0-10cm depth (except bd, taken at 0-10 cm), during June-August 2003. Soil samples were analysed at CIAT's Soils Laboratory, February 2004.

Fig 1: Humid Tropical Forest, Amazonia, Colombia
Mild-slope Topography
Bulk density per depth in 6 land use system (treatments)

Trat	Profundidad		Bulk density (gr/cm3)			
			N	Mean	Std	CV (%)
Brac_h+leg nativ	0-10	*********	27	0.91	0.24	26.25
	10-20	*************	27	1.30	0.20	15.42
	20-40	**************	27	1.41	0.12	8.78
	40-100	*************	27	1.34	0.12	1.12
Brac_d+leg nativ	0-10	**********	27	0.97	0.07	7.14
	10-20	*************	27	1.32	0.12	8.94
	20-40	*************	27	1.28	0.12	9.38
	40-100	*************	27	1.26	0.09	7.33
Brac_h en Mon	0-10	***********	27	1.06	0.11	10.29
	10-20	*************	27	1.33	0.07	5.39
	20-40	*************	27	1.30	0.13	9.69
	40-100	***********	27	1.11	0.48	42.92
Brac_d en Mon	0-10	********	27	0.84	0.05	6.04
	10-20	**************	27	1.37	0.09	6.62
	20-40	**************	27	1.44	0.08	5.23
	40-100	**************	27	1.42	0.13	9.05
Past Degradada	0-10	***********	12	1.05	0.09	8.15
	10-20	*************	12	1.28	0.05	3.56
	20-40	*************	12	1.31	0.05	4.04
	40-100	*************	12	1.28	0.04	2.82
Bosque Nativo	0-10	**********	27	0.96	0.13	13.42
	10-20	*************	27	1.25	0.11	9.00
	20-40	************	27	1.18	0.08	7.08
	40-100	***********	27	1.11	0.41	36.69

1

Bulk density (gr/cm3)

Fig 2 : Total N, Sand and Clay (expressed as t/ha/10 cm layers)

Trat	Profundidad	N	Mean	Std	CV (%)
		Total N (t/ha/10 cm)			
Bosque Nativo	0-10	27	1.8	0.53	29.29
Bosque Nativo	10-20	27	1.7	0.53	31.00
Bosque Nativo	20-40	27	1.1	0.34	29.32
Bosque Nativo	40-100	27	0.7	0.23	28.37
Brac_h+leg nativ	0-10	27	2.6	0.64	24.02
Brac_h+leg nativ	10-20	27	2.1	0.49	22.74
Brac_h+leg nativ	20-40	27	1.3	0.33	24.97
Brac_h+leg nativ	40-100	27	0.7	0.25	32.58
Brac_d+leg nativ	0-10	27	1.9	0.37	18.98
Brac_d+leg nativ	10-20	27	1.7	0.23	12.88
Brac_d+leg nativ	20-40	27	1.4	0.20	14.35
Brac_d+leg nativ	40-100	27	1.0	0.17	16.24
Brac_h en Mon	0-10	27	2.5	0.35	13.34
Brac_h en Mon	10-20	27	1.9	0.30	15.06
Brac_h en Mon	20-40	27	1.4	0.20	13.44
Brac_h en Mon	40-100	27	0.9	0.21	18.52
Brac_d en Mon	0-10	27	2.2	0.28	12.44
Brac_d en Mon	10-20	27	2.0	0.28	13.69
Brac_d en Mon	20-40	27	1.4	0.24	16.99
Brac_d en Mon	40-100	27	0.9	0.20	20.88
Past Degradada	0-10	12	2.2	0.39	17.13
Past Degradada	10-20	12	1.8	0.32	17.80
Past Degradada	20-40	12	1.5	0.24	15.62
Past Degradada	40-100	12	1.1	0.20	16.79

Total N (t/ha/10 cm)

trat	Profundidad	N	Mean	Std	CV (%)
		Sand (t/ha/10 cm)			
Bosque Nativo	0-10	9	587.7	74.9	12.75
Bosque Nativo	10-20	9	643.7	48.4	7.52
Bosque Nativo	20-40	9	543.5	38.7	7.13
Bosque Nativo	40-100	9	529.8	46.0	7.85
Brac_h+leg nativ	0-10	9	458.8	105.1	22.93
Brac_h+leg nativ	10-20	9	565.4	63.6	11.26
Brac_h+leg nativ	20-40	9	604.4	115.9	19.19
Brac_h+leg nativ	40-100	9	543.9	155.2	28.54
Brac_d+leg nativ	0-10	9	449.1	79.2	17.65
Brac_d+leg nativ	10-20	9	474.7	114.0	24.02
Brac_d+leg nativ	20-40	9	366.3	63.4	17.33
Brac_d+leg nativ	40-100	9	311.2	49.3	15.85
Brac_h en Mon	0-10	9	597.1	43.0	7.20
Brac_h en Mon	10-20	9	488.8	92.8	18.99
Brac_h en Mon	20-40	9	406.4	78.5	19.33
Brac_h en Mon	40-100	9	304.1	49.5	13.64
Brac_d en Mon	0-10	9	449.1	33.0	7.36
Brac_d en Mon	10-20	9	697.6	59.6	8.56
Brac_d en Mon	20-40	9	639.3	55.3	8.65
Brac_d en Mon	40-100	9	574.2	163.5	28.49
Past Degradada	0-10	4	51.5	32.0	62.20
Past Degradada	10-20	4	10.5	9.3	88.59
Past Degradada	20-40	4	15.2	16.1	105.53
Past Degradada	40-100	4	8.7	8.9	102.54

Sand (t/ha/10 cm)

Trat	Profundidad	Clay (t/ha/10 cm)	N	Mean	Std	CV (%)
Bosque Nativo	0-10	********	9	351.6	41.5	11.82
	10-20	************	9	549.5	77.4	14.10
	20-40	*************	9	585.8	54.6	9.33
	40-100	************	9	554.9	40.6	6.54
Brac_h+leg nativ	0-10	*******	9	279.2	47.7	17.10
	10-20	**********	9	460.3	79.7	17.33
	20-40	************	9	542.3	38.3	7.07
	40-100	************	9	540.6	70.1	12.98
Brac_d+leg nativ	0-10	*********	9	388.6	40.0	10.31
	10-20	***************	9	712.8	74.0	10.39
	20-40	*****************	9	810.2	56.0	6.92
	40-100	*******************	9	882.8	44.9	5.09
Brac_h en Mon	0-10	********	9	330.4	42.0	12.72
	10-20	***************	9	688.1	57.5	8.36
	20-40	*****************	9	781.9	35.8	4.58
	40-100	****************	9	743.1	42.7	4.85
Brac_d en Mon	0-10	******	9	258.8	19.6	7.61
	10-20	**********	9	425.1	25.5	6.00
	20-40	************	9	542.7	20.4	3.77
	40-100	*************	9	578.8	79.8	13.79
Past Degradada	0-10	**********	4	464.5	53.0	11.43
	10-20	***************	4	676.5	47.3	7.00
	20-40	****************	4	746.3	29.2	3.92
	40-100	*****************	4	814.6	27.0	3.32

200 400 600 800

Clay (t/ha/10 cm)

Fig 3: Mean carbon accumulation (Total, Oxidisable and Stable C), per depth (expressed as t/ha/10 cm layers), in 6 land use systems. Mild-slope Topography, Amazonia, Colombia.

Trat	Profundidad	Total C (ton/ha/10 cm	N	Mean	Std	CV (%)
Bosque Nativo	0-10	**************	27	28.9	7.40	25.58
	10-20	**************	27	28.0	6.05	21.57
	20-40	**********	27	20.2	3.22	15.89
	40-100	*******	27	13.3	4.21	31.61
Brac_h+leg nativ	0-10	*************	27	26.5	5.72	21.50
	10-20	**********	27	19.7	3.94	20.01
	20-40	******	27	12.2	2.11	17.27
	40-100	****	27	7.4	1.67	22.49
Brac_d+leg nativ	0-10	**************	27	27.4	2.81	10.24
	10-20	*************	27	26.3	2.86	10.89
	20-40	**********	27	20.5	2.17	10.53
	40-100	*******	27	14.8	1.98	13.36
Brac_h en Mon	0-10	****************	27	31.7	2.78	8.76
	10-20	************	27	23.8	3.00	12.57
	20-40	*********	27	18.2	2.25	12.31
	40-100	******	27	11.5	4.72	40.75
Brac_d en Mon	0-10	************	27	24.4	2.80	11.43
	10-20	**********	27	20.2	3.09	15.28
	20-40	*******	27	13.1	2.03	15.40
	40-100	****	27	8.5	1.68	19.60
Past Degradada	0-10	*************	12	26.0	4.64	17.80
	10-20	**********	12	19.4	2.86	14.75
	20-40	*******	12	14.8	4.13	27.74
	40-100	*****	12	10.4	2.91	27.77
		10 20 30				

Total C (ton/ha/10 cm)

trat	Profundidad	Oxidable C (ton/ha/10 cm)	N	Mean	Std	CV (%)
Bosque Nativo	0-10	*********************	27	20.8	5.23	25.15
	10-20	********************	27	19.8	5.42	27.26
	20-40	************	27	12.3	2.02	16.35
	40-100	*****	27	5.3	1.28	24.05
Brac_h+leg nativ	0-10	**********************	27	21.9	4.86	22.19
	10-20	**************	27	14.3	3.81	26.53
	20-40	*******	27	6.7	1.53	22.87
	40-100	***	27	3.2	1.01	31.23
Brac_d+leg nativ	0-10	********************	27	20.4	3.23	15.78
	10-20	*****************	27	16.6	2.60	15.61
	20-40	***********	27	11.0	1.82	16.50
	40-100	******	27	6.2	1.00	16.02
Brac_h en Mon	0-10	**************************	27	26.0	3.21	12.32
	10-20	*****************	27	16.6	2.97	17.87
	20-40	**********	27	9.9	1.21	12.14
	40-100	******	27	5.6	2.21	39.31
Brac_d en Mon	0-10	*****************	27	17.2	3.45	20.04
	10-20	*************	27	12.9	2.14	16.46
	20-40	********	27	8.2	1.60	19.36
	40-100	*****	27	4.6	1.71	37.07
Past Degradada	0-10	********************	12	19.5	5.91	30.13
	10-20	*************	12	12.8	5.00	38.83
	20-40	************	12	11.9	2.31	19.35
	40-100	************	12	11.7	2.11	17.90
		5 10 15 20 25				

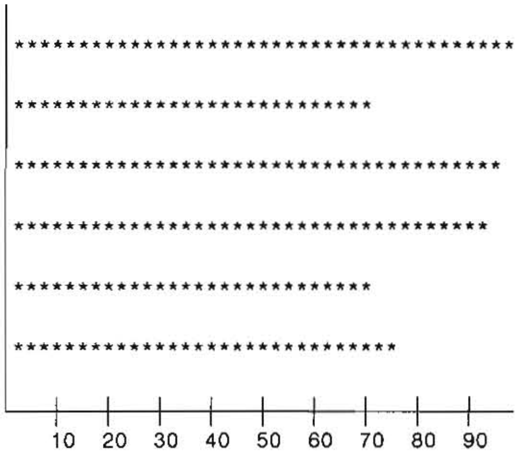
Oxidable C (ton/ha/10 cm)

Trat	Profundidad		Stable C (ton/ha/10 cm) N	Mean	Std	CV (%)
Bosque Nativo	0-10	****************	27	8.1	4.21	51.68
	10-20	****************	27	8.1	1.96	23.92
	20-40	****************	27	7.9	3.48	43.94
	40-100	****************	27	7.9	3.67	45.94
Brac_h+leg nativ	0-10	*********	27	4.6	1.71	36.42
	10-20	***********	27	5.3	1.56	29.06
	20-40	***********	27	5.5	2.34	42.31
	40-100	********	27	4.2	1.30	30.86
Brac_d+leg nativ	0-10	**************	27	7.0	1.23	17.49
	10-20	*******************	27	9.6	1.46	15.09
	20-40	*******************	27	9.5	2.33	24.42
	40-100	*****************	27	8.6	2.08	24.06
Brac_h en Mon	0-10	***********	27	5.6	1.61	28.41
	10-20	***************	27	7.2	1.47	20.17
	20-40	*****************	27	8.3	2.22	26.78
	40-100	************	27	5.9	2.77	46.42
Brac_d en Mon	0-10	**************	27	7.2	3.40	47.07
	10-20	**************	27	7.2	2.58	35.79
	20-40	**********	27	4.8	2.04	41.93
	40-100	********	27	3.9	1.36	34.56
Past Degradada	0-10	*************	12	6.4	2.68	41.23
	10-20	*************	12	6.5	3.51	53.54
	20-40	******	12	3.1	3.66	114.67
	40-100	*	12	0.3	0.63	197.20
		2 4 6 8				

Stable C (ton/ha/10 cm)

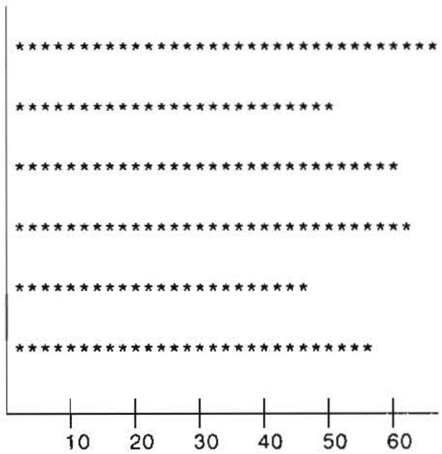
Fig 4: Mean carbon accumulation (Total, Oxidisable and Stable C, t/ha/fixed soil depth), at 0-40cm, in 6 land use systems. Mild-slope Topography Amazonia, Colombia.

Trat	Total C (ton/ha/0-40 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	97.5	16.00	16.39
Brac_h+leg nativ	27	70.7	10.66	15.07
Brac_d+leg nativ	27	94.9	8.0	8.22
Brac_h en Mon	27	92.1	8.0	8.39
Brac_d en Mon	27	70.9	8.0	11.36
Past Degradada	12	75.2	10.0	13.34



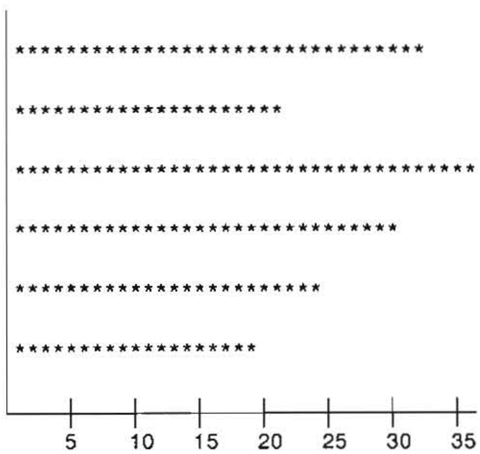
Total C (ton/ha/0-40 cm)

Trat	Oxidisable C (ton/ha/0-40 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	65.3	12.00	18.25
Brac_h+leg nativ	27	49.6	6.81	13.71
Brac_d+leg nativ	27	59.1	6.66	11.25
Brac_h en Mon	27	62.6	6.37	10.16
Brac_d en Mon	27	46.7	7.06	15.08
Past Degradada	12	56.3	10.49	18.61



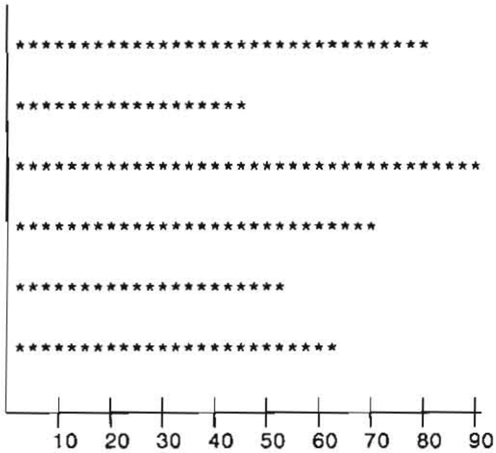
Oxidisable C (ton/ha/0-40 cm)

Trat	Stable C (ton/ha/0-40 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	32.1	9.38	29.17
Brac_h+leg nativ	27	21.1	5.85	27.70
Brac_d+leg nativ	27	35.7	5.82	16.28
Brac_h en Mon	27	29.5	5.92	20.04
Brac_d en Mon	27	24.1	7.08	29.27
Past Degradada	12	19.4	7.09	36.52



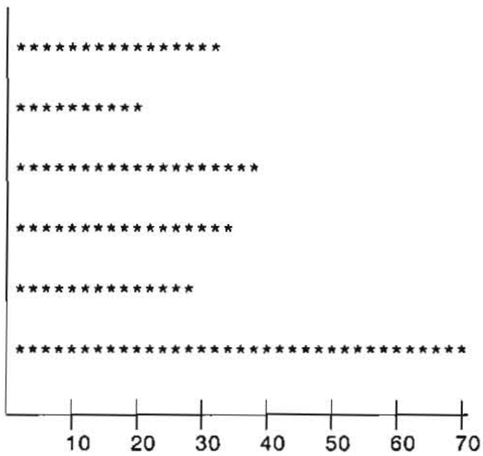
Stable C (ton/ha/0-40 cm)

Fig 5: Mean carbon accumulation (Total, Oxidisable and Stable C, t/ha/fixed soil depth), at 40-100cm depth, in 6 land use systems Mild-slope Topography Amazonia, Colombia.



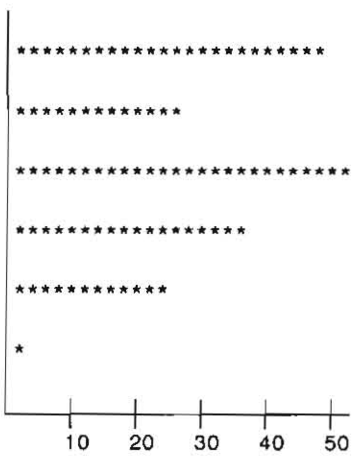
Total C (ton/ha/40-100 cm)

Trat	Total C (ton/ha/40-100 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	90.4	16.55	18.32
Brac_h+leg nativ	27	44.5	10.02	22.49
Brac_d+leg nativ	27	89.1	11.90	13.36
Brac_h en Mon	27	82.1	9.44	11.49
Brac_d en Mon	27	51.2	10.05	19.60
Past Degradada	12	62.9	17.48	27.77



Oxidisable C (ton/ha/40-100 cm)

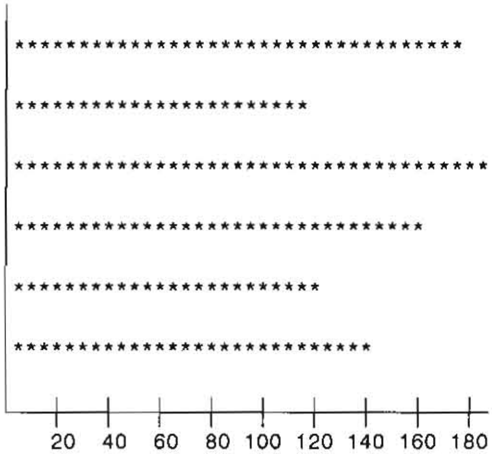
Trat	Oxidisable C (ton/ha/40-100 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	37.2	7.64	20.50
Brac_h+leg nativ	27	19.3	6.03	31.23
Brac_d+leg nativ	27	37.3	4.42	12.78
Brac_h en Mon	27	40.0	3.23	8.09
Brac_d en Mon	27	27.6	10.26	37.07
Past Degradada	12	70.6	12.64	17.90



Stable C (ton/ha/40-100 cm)

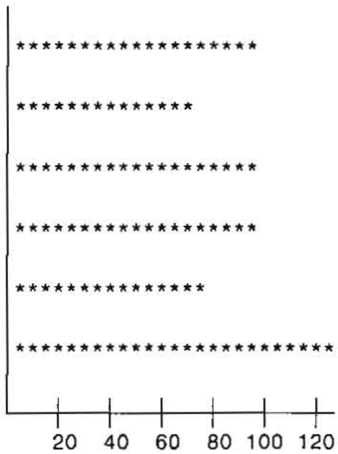
Trat	Stable C (ton/ha/40-100 cm) N	Mean	Std	CV (%)
Bosque Nativo	27	53.1	17.81	33.56
Brac_h+leg nativ	27	25.2	7.79	30.86
Brac_d+leg nativ	27	51.7	12.45	24.06
Brac_h en Mon	27	42.2	9.70	22.97
Brac_d en Mon	27	23.6	8.17	34.56
Past Degradada	12	1.9	3.77	197.20

Fig 6: Mean carbon accumulation (Total, Oxidisable and Stable C, t/ha/fixed soil depth), at 1m in 6 land use systems Mild-slope Topography Amazonia, Colombia.



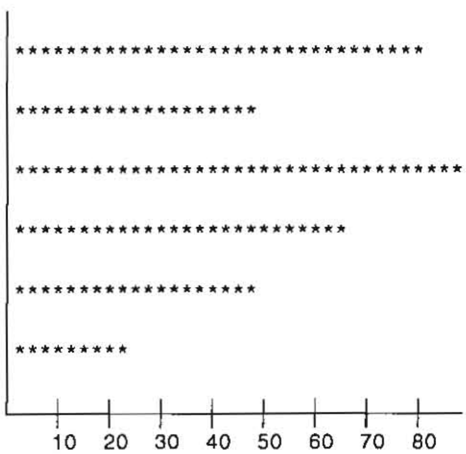
Total C (ton/ha/1m)

Trat	N	Mean	Std	CV (%)
Bosque Nativo	27	188.0	26.37	14.04
Brac_h+leg nativ	27	115.2	18.77	16.28
Brac_d+leg nativ	27	184.0	18.33	9.96
Brac_h en Mon	27	174.3	15.30	8.78
Brac_d en Mon	27	122.2	15.87	12.98
Past Degradada	12	138.2	22.74	16.46



Oxidisable C (ton/ha/1m)

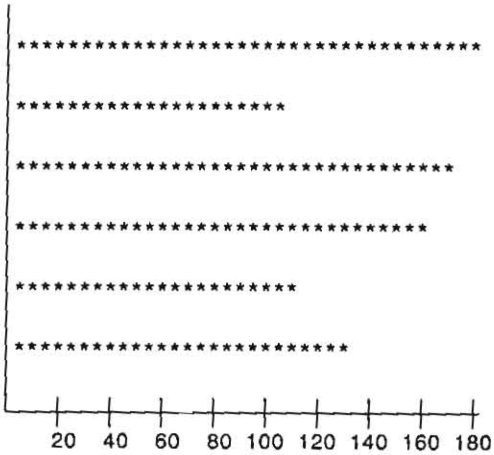
Trat	N	Mean	Std	CV (%)
Bosque Nativo	27	102.7	16.11	15.69
Brac_h+leg nativ	27	68.9	10.62	15.40
Brac_d+leg nativ	27	96.5	11.10	11.49
Brac_h en Mon	27	102.5	8.80	8.58
Brac_d en Mon	27	74.4	14.02	18.83
Past Degradada	12	126.9	12.73	10.02



Stable C (ton/ha/1m)

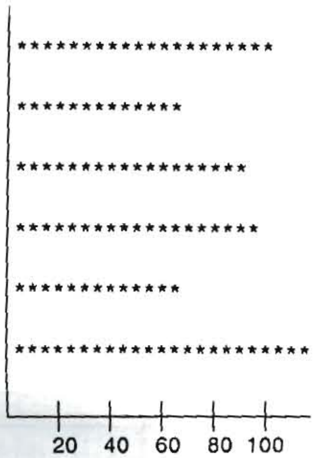
Trat	N	Mean	Std	CV (%)
Bosque Nativo	27	85.2	23.73	27.84
Brac_h+leg nativ	27	46.3	12.48	26.93
Brac_d+leg nativ	27	87.4	17.52	20.03
Brac_h en Mon	27	71.7	14.42	20.09
Brac_d en Mon	27	47.8	8.58	17.95
Past Degradada	12	21.3	9.42	44.15

Fig 7: Mean carbon accumulation (Total, Oxidisable and Stable C, t/ha/fixed soil mass), at 1m-equiv. in 6 land use systems Mild-slope Topography Amazonia, Colombia.



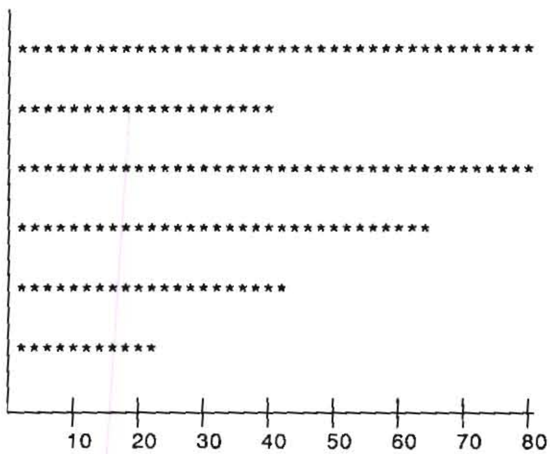
Total C (ton/ha/1m)

Trat	Total C (ton/ha/1m) N	Mean	Std	CV (%)
Bosque Nativo	27	178.0	25.74	14.47
Brac_h+leg nativ	27	105.0	15.47	14.73
Brac_d+leg nativ	27	170.0	15.20	8.95
Brac_h en Mon	27	157.0	13.78	8.80
Brac_d en Mon	27	108.0	13.25	12.30
Past Degradada	12	125.5	20.54	16.24



Oxidisable C (ton/ha/1m)

Trat	Oxidisable C (ton/ha/1m) N	Mean	Std	CV (%)
Bosque Nativo	27	98.8	16.70	16.90
Brac_h+leg nativ	27	64.4	8.95	13.88
Brac_d+leg nativ	27	90.6	9.89	10.91
Brac_h en Mon	27	94.0	8.83	9.39
Brac_d en Mon	27	65.5	11.70	17.58
Past Degradada	12	113.6	11.51	10.13



Stable C (ton/ha/1m)

Trat	Stable C (ton/ha/1m) N	Mean	Std	CV (%)
Bosque Nativo	27	79.2	21.25	26.85
Brac_h+leg nativ	27	40.6	10.28	25.32
Brac_d+leg nativ	27	79.2	14.29	18.04
Brac_h en Mon	27	62.5	12.24	19.56
Brac_d en Mon	27	41.2	7.11	17.25
Past Degradada	12	21.0	9.00	42.78

ANOVA MODEL
Mild-slope Topography

SCS at fixed soil mass, at 0-40, 40-100 and 0-100 cm-equiv.

Source of Variation	df
Land Use System	5
Spatial Rep (Land Use System)	10
Slope Position (Land Use x Spatial Rep)	33
Residue = Sampling Point (Land Use x Spatial Rep x Slope position)	98
TOTAL	**146**

Table 2: Soil Carbon Stocks (t/ha/fixed soil depth), Humid Tropical Forest, Amazonia, Colombia. Mild-slope Topography

Soil Depth	System	Total C (ton/ha)		Stable C (ton/ha)	
0-100	*B.decumbens + leg*	184	a	87	a
	Forest	177	a	80	a
	B.humidicola	162	b	65	b
	Degraded pasture	138	c	21	d
	B.decumbens	122	d	48	c
Mean, CV (%) and LSD $_{.15}$		**151, 11, 8**		**62, 21, 8**	
0-40	*Forest*	98	a	32	b
	B.decumbens + leg	95	a	36	a
	B.humidicola	92	a	30	b
	Degraded pasture	75	b	19	d
	B.decumbens	71	b	24	c
Mean, CV (%) and LSD $_{.15}$		**84, 11, 4**		**28, 20, 3**	
40-100	*B.decumbens + leg*	89	a	52	a
	Forest	80	b	48	a
	B.humidicola	69	c	36	b
	Degraded pasture	63	c	2	d
	B.decumbens	51	d	24	c
Mean, CV (%) and LSD $_{.15}$		**67, 18, 5**		**34, 30, 5**	

Table 3: Soil Carbon Stocks (t/ha/fixed soil mass), Humid Tropical Forest, Amazonia, Colombia. Mil-slope Topography

Soil Depth	System	Total C (ton/ha)		Stable C (ton/ha)	
0-100	*Forest*	181	a	81	a
	B. decumbens + leg	172	b	81	a
	B. humidicola	159	c	64	b
	Degraded pasture	129	d	21	d
	B. decumbens	109	e	42	c
	B. humidicola + leg	105	e	41	c
Mean, CV (%) and LSD $_{.15}$		**144, 11, 7**		**58, 21, 5**	
0-40	*Forest*	98	a	32	b
	B.decumbens + leg	95	ba	36	a
	B.humidicola	92	b	30	b
	Degraded pasture	75	c	19	e
	B.decumbens	71	c	24	c
	B. humidicola + leg	71	c	21	e
Mean, CV (%) and LSD $_{.15}$		**84, 11, 5**		**28, 20, 3**	
40-100	*Forest*	83	a	49	a
	B.decumbens + leg	77	b	45	a
	B.humidicola	67	c	34	b
	Degraded pasture	54	d	2	d
	B.decumbens	38	e	18	c
	B. humidicola + leg	34	f	20	c
Mean, CV (%) and LSD $_{.15}$		**60, 19, 4**		**31, 34, 4**	

Table 4 : Factors affecting SCS (t/ha/1m-equiv)
Mild-slope Topography

Source	df	Total C			Stable C		
		F	p	SS(%)	F	p	SS(%)
Land Use System	5	121	***	74	82	***	68
Repetition(Land Use System)	10	5.33	***	7	3.93	***	6
Position(Rep x Use System)	33	1.78	ns	7	1.78	ns	10
Error	98			12			16
Total	146						
Mean		144			58		
$\sqrt{\sigma^2}$		15			12		
CV (%) adjusted		11			21		
R^2		88 %			83 %		

*** $p < 0.01$; ** $0.01 \leq p \leq 0.05$; * $0.05 \leq p \leq 0.10$; ns $p \geq 0.10$;
SS(%) = (Source SS/Total SS) x 100

Table 5a: Association between Soil and C variables at fixed soil mass (1m-equiv.) - Mild-slope Topography. Principal Component Analysis. Variance explained: 77 %

Variable	PC_1 (46%)	PC_2 (31 %)
Stable C (ton/ha/1m-equiv)	-0.13	0.67*
Total N (ton/ha/1m-equiv)	0.37*	0.12
Oxid. C (ton/ha/1m-equiv)	0.40*	0.40
Sand (ton/ha/1m-equiv)	-0.52*	0.24
Clay (ton/ha/1m-equiv)	0.40	0.45*
CEC (meq/ha/1m-equiv)	0.50*	-0.35

PC1: Oxidisable C and Total N with low Sand content.
PC2: Stable C with high Clay content.

Principal Components at 1m-equiv.

Mild-slope Topography

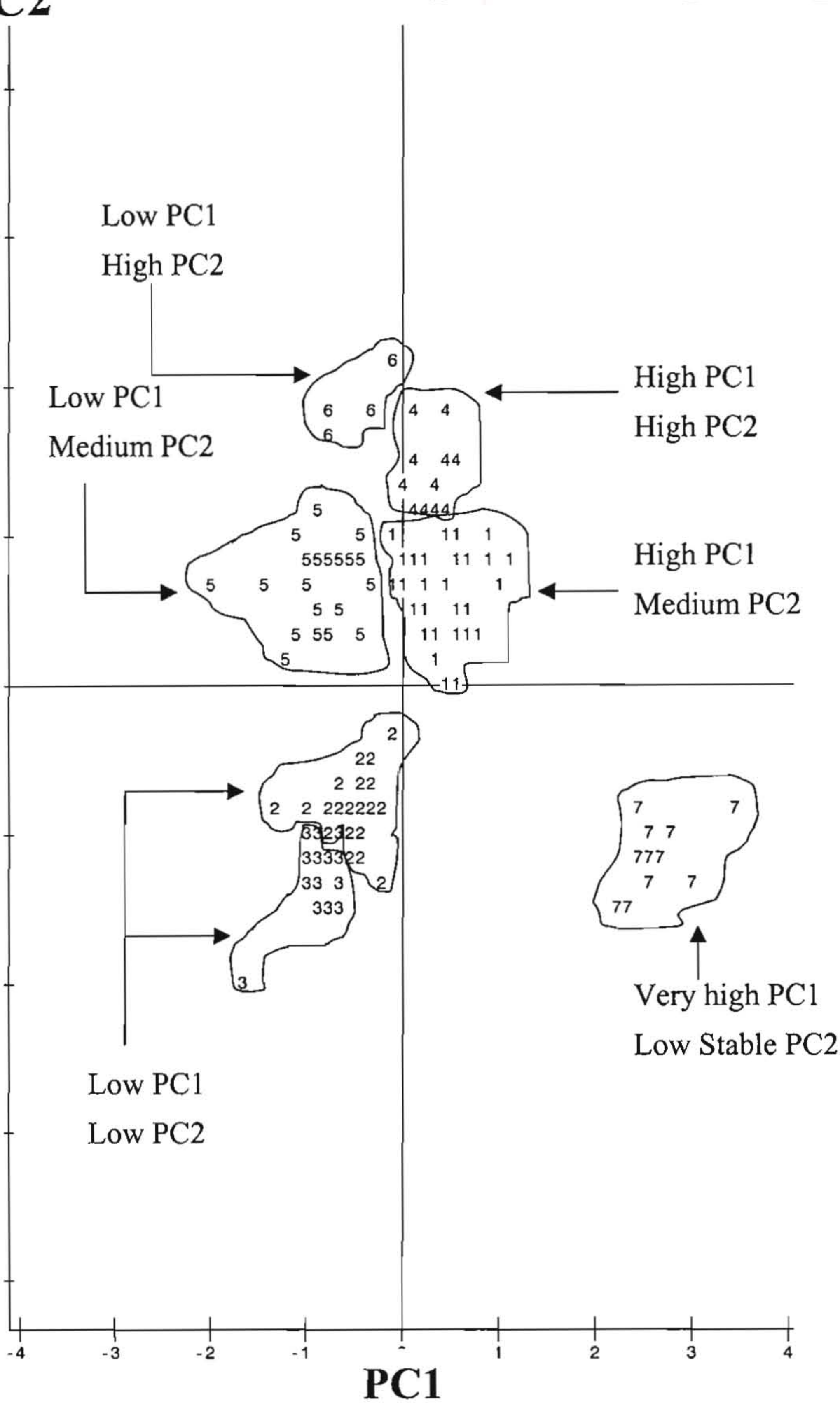
N=147 sampling points, Cluster R^2 = 93%

Classification Criteria	Cluster Number						
	1 N=43	2 N=34	3 N=20	4 N=12	5 N=21	6 N=5	7 N=12
Principal Components	Cluster Means						
PC1	0.48	-0.50	-0.86	0.28	-0.88	-0.54	2.63
PC2	0.61	-0.81	-1.27	1.38	0.71	1.85	-1.17
Original Soil parameters	Cluster Means						
Oxidable C (ton/ha/1m-equiv)	94	71	57	107	92	101	117
Stable C (ton/ha/1m-equiv)	67	43	37	100	74	118	21
Total N (ton/ha/1m-equiv)	13	12	10	13	9	12	13
Sand (ton/ha/1m-equiv)	3983	4342	4334	4084	4859	4930	211
Clay (ton/ha/1m-equiv)	6772	4745	4674	6439	5831	5758	6647
CEC (meq/ha/1m-equiv)	97	92	94	83	70	71	145

Table 5c: SCS per Cluster and Cluster members. Amazonia, Colombia. N=147, Clusters = , R2 = 93%, Mild-slope Topography.

Cluster (N)	Cluster Description	Oxidisable C		Stable C		Cluster Members
		Min-Max	Mean	Min-Max	Mean	
4 (N= 12)	High PC1 High PC2	83 – 148	106	51 – 113	91	*B. decumbens* + leg (N=9) Native Forest (N=3)
1 (N= 43)	High PC1 Medium PC2	80 – 117	94	30 – 96	67	*B. decumbens* + leg (N=16) *B. humidícola* mono (N=27)
6 (N= 5)	Low PC1 High PC2	90 – 121	101	108 – 123	118	Native Forest (N=5)
5 (N= 21)	Low PC1 Medium PC2	71 – 110	92	51 – 99	74	Native Forest (N=21)
7 (N= 12)	Very high PC1 Low PC2	96 – 137	117	8 – 37	21	Degraded Pasture (N=12)
2 and 3 (N= 54)	Low PC1 Low PC2	47 – 87	66	18 – 59	41	*B. humidícola* + leg (N=27) *B. decumbens* mono (N=27)

Cluster Groups Mild-slope Topography



Annex 9

Socio-economic Evaluation Report: Development and Analysis of Simulation Scenarios

Modelos Preliminares de la Viabilidad Financiera de Invertir en Sistemas Pastoriles, Agropastoriles y Silvopastoriles con Capacidad para el Secuestro de C en el Pacífico Central, Costa Rica

José Gobbi

1. Introducción

Los sistemas de producción ganadera pueden actuar como emisores o sumideros de carbono. Actúan como emisores de carbono cuando las prácticas de manejo ganaderas resultan en la pérdida de la materia orgánica del suelo (erosión del suelo) o en emisiones directas derivadas de técnicas tradicionales, tales como en las quemas de la cobertura vegetal para promover la regeneración de pastos. Actúan como sumideros cuando se adoptan prácticas de manejo que aumentan la materia orgánica acumulada en el suelo y en la biomasa aérea, tales como la incorporación de árboles en los potreros. Dado el proceso de calentamiento global que está sufriendo el planeta y la importancia social y económica de la ganadería en Latinoamérica (donde las tierras dedicadas a la ganadería cubren más del 60% del terreno agrícola), es necesario identificar sistemas de producción ganadera asociados con sistemas de uso del suelo, que contribuyan a la captura de carbono y que sean económicamente atractivos para los finqueros.

El Proyecto de la "Red de Investigación para la Evaluación de la Capacidad de Almacenamiento de Carbono de Sistemas Pastoriles, Agropastoriles y Silvopastoriles en el Ecosistema del Bosque Tropical Americano" tiene como metas principales el contribuir al desarrollo sustentable, reducir la pobreza y mitigar los efectos indeseables del cambio climático— particularmente las emisiones de CO_2 —en los sub-ecosistemas forestales vulnerables de la América Tropical. Las metas se alcanzan por medio de la investigación en fincas de pequeño y mediano tamaño que presentan un rango de sistemas de pasturas, agro y silvopastoriles localizadas en tres sub-ecosistemas forestales de la América Tropical vulnerables al cambio climático. Estos sub-ecosistemas son: (i) Región de Laderas Andinas de Colombia, (ii) Región de la Amazonía de Colombia y (iii) Región del Bosque Tropical Semi-Húmedo de Costa Rica.

La investigación que se lleva a cabo en las fincas del proyecto está dirigida a identificar sistemas de pasturas, agro y silvopastoriles (SPASP), con capacidad para el secuestro de carbono, que sean financieramente viables para los finqueros de la América Tropical. A tal fin, el componente socio-económico del Proyecto se orienta a evaluar el atractivo económico-financiero de los SPASP con capacidad para el secuestro de carbono, frente a los sistemas ganaderos convencionales de pasturas degradadas. En este contexto, la pregunta a contestar es si la inversión en sistemas con capacidad para el secuestro de carbono es financieramente rentable.

En este reporte se presentan un resultados preliminares de modelos de inversión de tres tipos de usos de la tierra con capacidad para el secuestro de carbono en la Región del Bosque Tropical Semi-Húmedo de Costa Rica. La estructura del reporte es la siguiente.

Primero, se presentan los objetivos específicos de la modelación. Segundo, se detalla la metodología para la elaboración de los modelos de beneficio-costo de inversión financiera. Tercero, se presentan resultados preliminares de los modelos de inversión. Por último, se presentan algunas conclusiones preliminares.

2. Objetivos de los Modelos de Inversión

Explorar la viabilidad financiera de invertir en:

(a) la incorporación de pasturas mejoradas con 30 árboles/ha a partir de pasturas degradadas sin árboles,

(b) la incorporación de pasturas mejoradas con 30 árboles/ha a partir de pasturas naturales sin árboles pobremente manejadas, y

(c) la incorporación de 1 ha de banco forrajero para reemplazar suplementación de animales con gallinaza

3. Metodología para Elaborar los Modelos

La metodología desarrollada para la formulación de los modelos sigue los lineamientos propuestos por Brown (1979) y Gittinger (1982) para la evaluación de proyectos de inversión en el sector agrícola-ganadero.

3.1. Pasos en la Formulación de los Modelos de Análisis Financieros de Inversión

a. Para cada una de los tipos de usos de la tierra con capacidad para el secuestro de carbono se estiman sus costos de establecimiento, parámetros de producción, y gastos de operación y ventas (ingresos) asociados con los misma (la situación "con" el proyecto), y para la situación inicial (la situación "sin" el proyecto, la cual representa el costo de oportunidad del cambio). Para efectuar este paso, se consultan los datos provenientes del monitoreo de fincas y a informantes claves (chapeadores, por ejemplo). Estos estimados de productividad por tipo de uso de la tierra (tales como unidades animales/ha de pastura degradada) se obtienen inicialmente de los registros de finca y se ajustan por medio de consultas con especialistas en cada uno de los países.

b. Se estiman las toneladas de carbono capturadas por cada tipo de uso del suelo y se modela su riesgo de permanencia. Se estima un precio de mercado de la ton de carbono y se lo incorpora como ingreso adicional a la situación "con" el proyecto.

c. Se crean flujos de caja para las situaciones "con" el proyecto (usos del suelo con capacidad para el secuestro de carbono) y para la situación actual de "sin" el proyecto.

d. Se computan los flujos netos incrementales correspondientes a la situación "con" el proyecto versus la situación corriente ("sin" el proyecto, la cual representa en costo de oportunidad del cambio). En base a los flujos netos incrementales se calcula la TIR de la inversión, y se estima el flujo de caja de cada situación.

e. Se conducen análisis de riesgo con el programa @RiskAnalysis (Palisade) para evaluar la robustez de la inversión (adopción) de usos de la tierra con capacidad para la captura de carbono ante cambios en las variables: producción y precio.

3.2 Formulación del Flujo de Caja

a. Para normalizar los resultados, los modelos se elaboran a escala de una hectárea.
b.El período del flujo de caja es de 10 años, correspondiente al tiempo de vida útil de las mayoría de los usos de la tierra evaluados.
c. En la construcción del flujo de caja descontado se sigue la convención que todas las transacciones caen al final del período contable. Por lo tanto, las inversiones en los usos del suelo con capacidad para el secuestro de carbono se efectúan al año 0 del proyecto.
d. Los precios de venta de los productos ganaderos y los precios de los insumos se expresan como precios de finca.
e. El flujo de caja se expresa en dólares estadounidenses, con una tasas] de cambio de 450 colones = 1 US$
f. Los gastos e ingresos fueron expresados en términos constantes con base en el 2005.

3.3. Supuestos

a. La producción ganadera se considera constante en la situación "sin" el proyecto.
b. No se asumen mejoras en los parámetros reproductivos en la situación con el proyecto en los modelos para cambios asociados con pasturas.
d. Se asume que una ha de pastura degradada puede soportar 0,2 unidades animales (UA), una ha de pastura natural 0,5 UA y una ha de pastura mejorada 1 UA.
e. Se asume que el finquero debe cercar 200 metros lineales de ha en la que se cambia el uso de la tierra.

4. Resultados Preliminares de los Modelos de Análisis Financiero

El proyecto ha planteado la hipótesis que existen ciertos tipos de usos del suelo pasturas mejoradas y bancos forrajeros) que capturan mayor cantidad de carbono que las pasturas degradas. En caso que esa hipótesis sea correcta, la condición necesaria para que los finqueros los adopten, es que los mismos sean financieramente rentable. En esta sección se describen los resultados preliminares (sin incorporar ingresos estimados por carbono) de los modelos de inversión financiera de pasturas mejoradas y bancos forrajeros correspondientes a los tres sub-ecosistemas. Los datos correspondientes a costos de establecimiento y operación de cada uno de los usos de la tierra analizados se encuentran descrito en detalle en el reporte de avance de mayo del 2005.

4.1. Modelo 1: Incorporación de pasturas mejoradas con 30 árboles/ha a partir de pasturas degradadas sin árboles

La Figura 1 muestra el flujo de caja de la incorporación de 1 ha de mejoradas con 30 árboles/ha a partir de pasturas degradadas sin árboles. La tasa interna de retorno (TIR)[1] de la inversión es del 25.3% y el valor presente neto (VPN) es de US$ 682.2. La inversión tiene un 100% de posibilidades de obtener retornos positivos (Figura 2).

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[1] En los análisis financieros, la tasa de descuento (TD) es el costo marginal del dinero, el cual está representado por la tasa de interés del crédito a la que el finquero puede obtener dinero (Gittinger 1982). Las tasas reales de descuento para el 2004 en cada uno de los países son las siguientes: Colombia 10-12% y Costa Rica 9-11%.

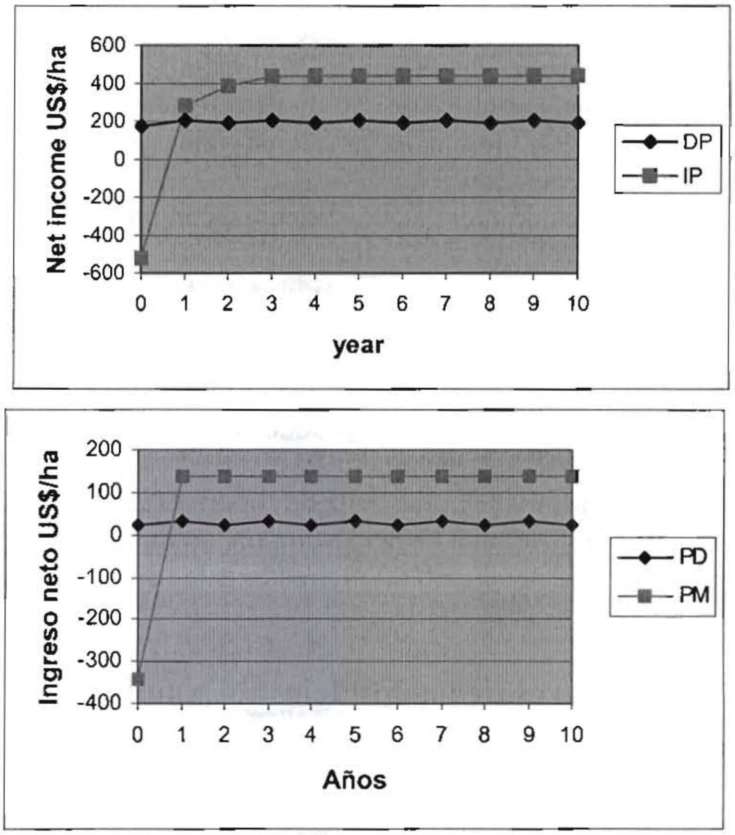

Figura 1. Flujo de caja de la inversión en 1 ha de pasturas mejoradas (PM) a partir de pasturas degradadas (PD). Bosque Sub-húmedo Tropical, Costa Rica. 2004.

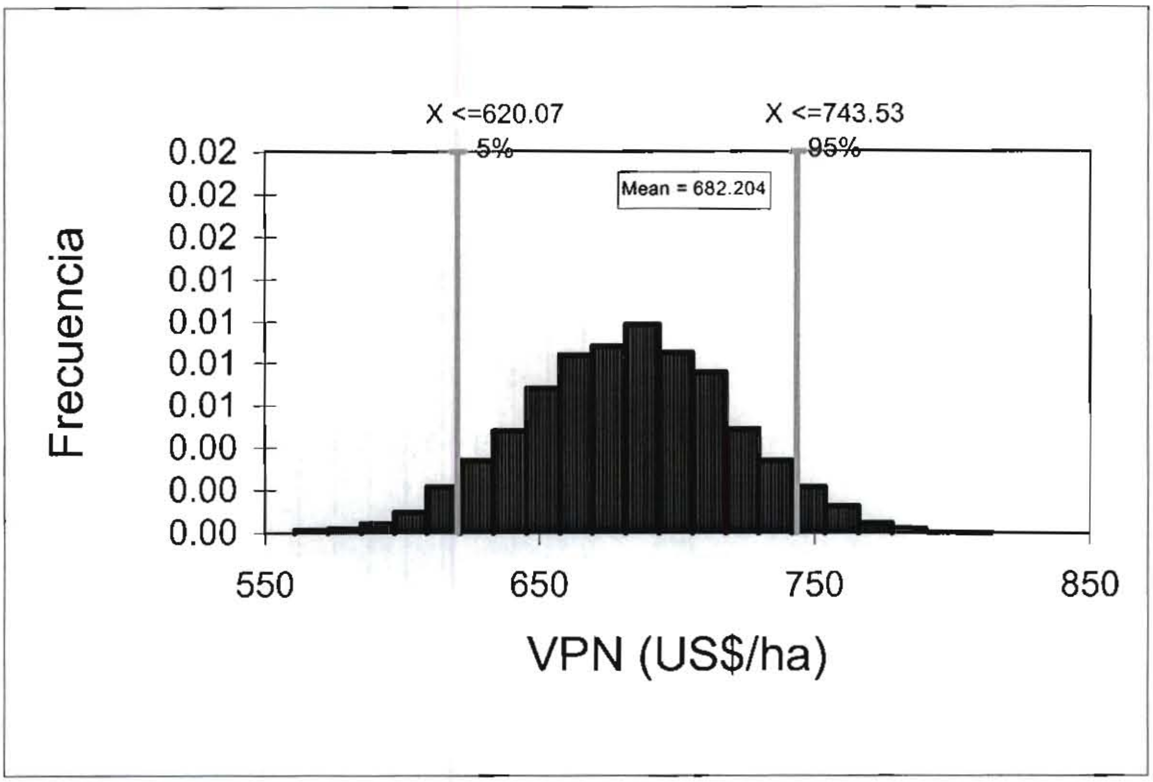

Figura 2. Análisis de riesgo de la inversión en 1 ha de pasturas mejoradas (PM) a partir de pasturas naturales (PN). Bosque Sub-húmedo Tropical, Costa Rica. 2005.

4.2. Modelo 2: Incorporación de pasturas mejoradas con 30 árboles/ha a partir de pasturas naturales sin árboles pobremente manejadas

La Figura 3 muestra el flujo de caja de la incorporación de 1 ha de mejoradas con 30 árboles/ha a partir de pasturas naturales sin árboles pobremente manejadas. La tasa interna de retorno de la inversión es del 17.9% y el VPN es de US$ 397,0. La inversión tiene un 100% de posibilidades de obtener retornos positivos (Figura 4).

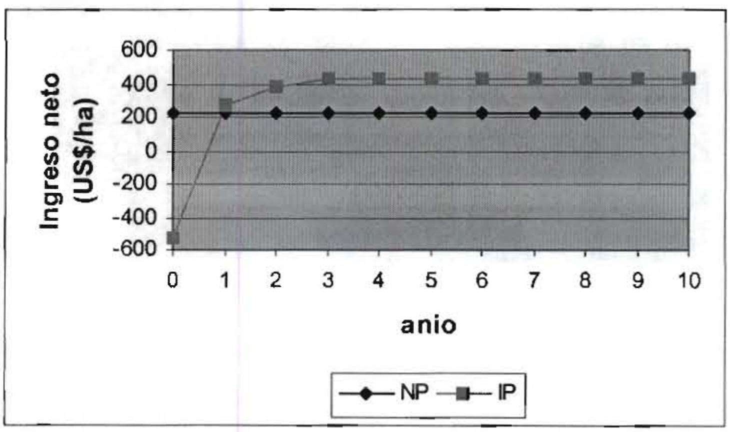

Figura 3. Flujo de caja de la inversión en 1 ha de pasturas mejoradas (PM) con 30 árboles a partir de pasturas naturales (PN) pobremente manejadas sin árboles. Bosque Sub-húmedo Tropical, Costa Rica. 2005.

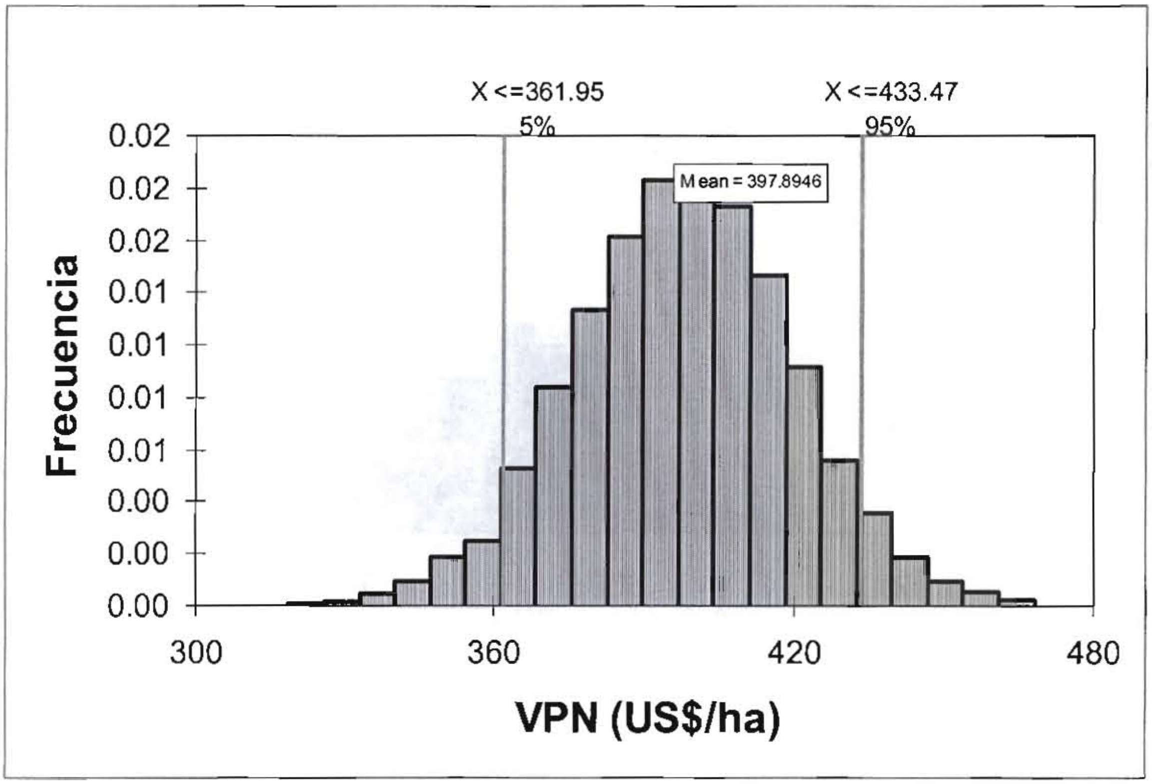

Figura 4. Análisis de riesgo de la inversión en 1 ha de pasturas mejoradas (PM) con 30 árboles a partir de pasturas naturales (PN) pobremente manejadas sin árboles. Bosque Sub-húmedo Tropical, Costa Rica. 2005.

4.3. Modelo 3: Incorporación de 1 ha de banco forrajero para reemplazar suplementación con gallinaza

La Figura 5 muestra el flujo de caja de la incorporación de 1 ha de banco forrajero para reemplazar suplementación con gallinaza. El VPN del ahorro neto a lo largo de la vida útil de banco es de US$ 779,2, con ahorros netos anuales estimados en US$ 324,9. La TIR de la inversión es del 20.5%.

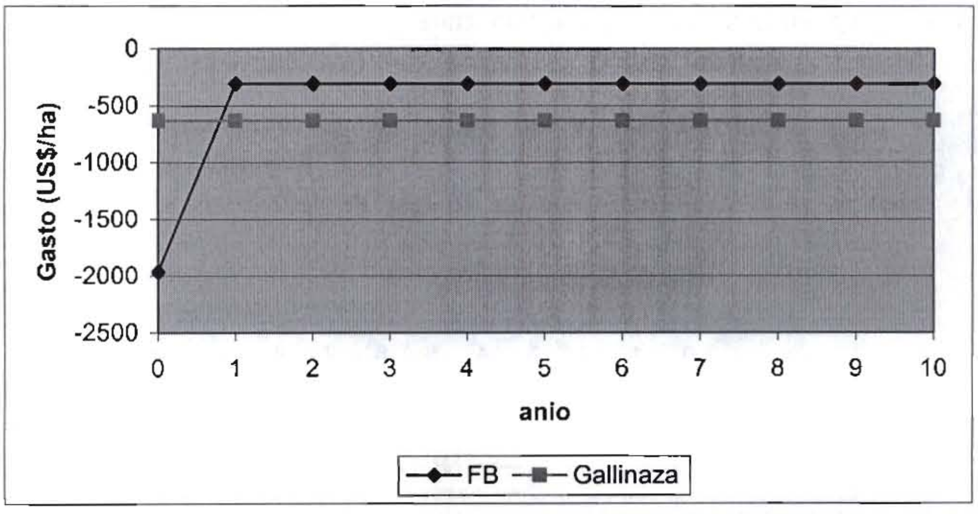

Figura 5. Flujo de caja del ahorro neto asociado a la inversión en 1 ha de banco forrajero, comparado con la alternativa de suplementación con gallinza. Bosque Sub-húmedo Tropical, Costa Rica. 2005.

5. Conclusiones Preliminares

Los modelos arrojan las siguientes conclusiones preliminares:

- Invertir en pasturas mejoradas con árboles es financieramente viable con 100% de posibilidades de obtener VPN positivos
- El reemplazo de la suplementación de gallinaza por bancos forrajeros es financieramente rentable, con ahorros netos de hasta US$ 259/año
- Los costos de establecimiento de los usos analizados son elevados y, a su vez, los flujos de caja son negativos durante los primeros años. Pagos eventuales por C podrían ayudar a aliviar esta situación

Annex 10

Terms of Agreement with ISRIC (International Institute for Soils Research), Wageningen University, The Netherlands

TERMS OF AGREEMENT

1. Introduction

The Carbon Sequestration Project, The Netherlands Cooperation CO-010402 (hereinafter referred to as CSEQ) will make available to the International Soil Reference and Information Centre (hereinafter referred to as ISRIC) a financial contribution in the amount of € 20,204 in support of producing: (1) three digital maps and corresponding paper copies (one per ecosystem: Tropical Andean Hillsides, Sub-humid and Humid Tropical Forest of Central America, and Amazonian Tropical Humid Forest) indicating the regions for extrapolation of the CSEQ's research results in each ecosystem; (2) a database accompanying the maps; (3) a report explaining the methods and results; and (4) presenting the results during the 2006 annual project meeting.

2. Purpose

The funds provided by CSEQ under this Agreement will be used:

(i) To prepare, for the three ecosystems within tropical America that occur in the CSEQ research sites –

(a) *Tropical Andean Hillsides* in Colombia, extending into similar environments in the neighbouring countries of Ecuador, Peru and Bolivia
(b) *Sub-humid and humid tropical forest* at the Atlantic and Pacific coasts of Costa Rica, extending into similar environments in the neighbouring countries of Panama, Nicaragua, Honduras, El Salvador and Guatemala
(c) *Humid Tropical Forest, Amazonia* in Colombia, extending into similar environments in the neighbouring Amazonian countries (Peru, Brazil, Bolivia and Ecuador) -

three digital maps with the corresponding paper copies at scale 1:5 M (one per ecosystem) and accompanying databases. Format of the digital maps will Arc-Info. These will indicate, for each of the ecosystems mentioned sub (i) a, b and c, similar conditions (AEZ, altitude, slope and soil conditions) as in the research sites of CSEQ in these zones. The maps will be based on an analysis of the Soil and Terrain Database for Latin America and the Caribbean (FAO-ISRIC 1998), the SRTM90 digital elevation model (USGS 2003) and the Global Agro-Ecological Zones (FAO-IIASA 2000) for the sub-ecosystems a and b. The extrapolation as mentioned under (c), will be based on the analysis of AEZ and SOTER only, but a subdivision on slopes (2%) will be made to distinguish foothills from the flat areas.

The coordinates of the research sites, the land cover of the research sites, climatic variables and the characterization of their soils in terms of the FAO-Unesco revised legend will be made available to ISRIC.

The resulting maps showing degrees of similarity to the research sites will be overlaid with the Global Land Cover 2000 map (JRC 2000) to calculate land cover per similarity unit.

(ii) To prepare a brief report explaining the methodology and the findings.

(iii) To present the results during the annual project meeting in 2006 at Cali, Colombia

3. Duration and Timing

The total duration of the project is 4 months starting at in November 2005.

4. Products

(1). Digital map and paper copy at scale 1:5 M. of extrapolation region of Tropical Andean Hillsides research results, indicating in different colours those areas under each land cover type.
(2). Accompanying databases
(3). Digital map and paper copy at scale 1:5 M. with extrapolation region of Amazonian Tropical Humid Forest research results, indicating in different colours those areas under each land cover type
(4). Accompanying databases
(5). Digital map and paper copy at scale 1:5 M. with extrapolation region of Sub-humid and Humid Tropical Forest, Costa Rica research results, indicating in different colours those areas covered by each land cover type
(6). Accompanying databases
(7). Final report explaining the methodology and the findings

5. Budget and Payment

The total budget consists of:

GIS work: 25 days @ € 504	= € 12,600.
Query of soil database: 5 days @ € 656	= € 3,280
Reporting: 4 days @ € 656	= € 2,624
Travel and per diem project meeting 2006	= € 1,700
Total	€ 20,204

CSEQ will pay ISRIC € 10,000 in November 2005. The remaining part will be paid at the end of the project, March 2006, after the products have been accepted by CSEQ.

6. Signatures

Date: 28 April 2005	Date:28 April 2005
Cali, Colombia,	Wageningen, The Netherlands
Dr. María Cristina Amézquita	Sjef Kauffman
Scientific Director	Deputy Director
Carbon Sequestration Project	ISRIC – World Soil Information

6 Banking instructions

Account holder	ISRIC World Soil Information
Bank name	ABN Amro Bank
Address	Stadsbrink 43, 6707 AA Wageningen
Postbox	POBox 8, 6700 AA Wageningen
Country	The Netherlands
Account number	41.31.03.196
BIC	ABNANL2A
IBAN	NL32ABNA0413103196