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

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

Six-months Technical Report no. 4

June 1-November 30, 2003

Maria Cristina Amézquita
Project Scientific Director

Presented to The Netherlands Cooperation, channeled through The Netherlands Embassy in Bogotá, Colombia. December 15, 2003.

CONTENTS

Acknowledgements

We express our gratitude to The Netherlands Ministry of Development Cooperation in The Hague, The Netherlands Embassy in Bogotá, Colombia, and The Netherlands Embassy in San José, Costa Rica 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. 4: June 1 - November 30, 2003"*** informs on project advances during the second semester of its second year of implementation, in agreement with the project Annual Plan 2003. The most important research activities during this semester were: a) Consolidated socio-economic analysis of "improved farms" vs. "typical farms" in research areas on the three project sub-eco-systems (Andean Hillsides, Colombia, Tropical humid forest, Colombian Amazonia, and Sub-humid and humid tropical forest, Costa Rica); b) Consolidated statistical analyses of soil carbon stock data from the three sub-ecosystems; and c) Initiation of evaluation of the new small-plot experiment established at Esparza, Costa Rica.

It is our pleasure to inform that activities conducted and completed during the second semester of our second year are in full agreement with the project Annual Plan 2003.

We thank project member and consultants for their fruitful discussions and valuable contributions offered during the Fourth International Coordination Meeting held at CIAT on September 22-25, 2003. They are now published in the Project Internal Document no. 9, entitled ***"Two-year Project Achievements: December 1, 2001 – November 30, 2003"***, dated December 15, 2003.

With best wishes for success in the third year of our project.

María Cristina Amézquita
Ph. D. in Production Ecology and Resource Conservation
Project Scientific Director
Cali, Colombia, December 15, 2003.

Participant Institutions

- **CIPAV**: Centre 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. 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 representatives: Drs 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. in Production Ecology and Resource Conservation.
  Project Scientific Director.
- **Dr. Enrique Murgueítio**. CIPAV's Executive Director.
  Project Administrative and Financial Director.
- **Bertha Leonor Ramírez**. Ph.D. in Agroforestry Systems.
  Universidad de la Amazonía.
- **Dr. Edgar Amézquita**. Ph.D. in Soil Sciences. CIAT.
- **Dr. Muhammad Ibrahim**. Ph.D. in Agronomy. CATIE.
- **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.

Consultants

- **Professor Dr. Leendert 't Mannetje,** Ph. D. in Tropical Grasslands.
  Wageningen University and Research Centre.
- **Dr. Myles Fisher**, Ph. D. in Plant Physiology. Lead scientist Inter-Centres
  Working Group on Climate Change.
- **Dr. Douglas Pachico**, Ph. D. Economics. Director for Research, CIAT.

Project members

- ***Field research – Hillsides ecosystem (Colombia)***
  María Elena Gómez. Agronomist, M.Sc.- CIPAV (80% time)
  Piedad Cuellar. Participatory research, M.Sc.- CIPAV (50% time)

- ***Field research – Semi-humid Tropical Forest (Costa Rica)***
  Tangaxuhan Yanderall, PhD student
  Alexander Navas, Agronomist, CATIE
  Francisco Casasola, Agronomist – CATIE (part time).

- ***Field research – Humid Tropical Forest (Colombian Amazonia)***
  Bertha Leonor Ramírez. Agroforestry Systems. Ph.D. (full time).
  Jaime Enrique Velásquez. Agronomist. Ph.D (part time).
  Jader Muñoz, Geologist (part time).
  B.Sc. students (part time): Jaime Andrés Montilla y Juán Carlos Suárez
  Universidad de la Amazonia.

- ***Environmental Economist:***
  José Gobbi, Economist Ph.D. (35% time).

- ***Mathematical modelling***
  M.Sc. students under Dr. Bram van Putten. Wageningen University (part time).

- ***DB analyst/statistician***
  Héctor Fabio Ramírez. Statistician (half time).

- ***Soil sampling and biomass measurement***
  Hernán Giraldo. Agronomist (full time).

- ***Executive Assistant***
  Francisco Ruiz. Industrial Engineer (full time).

Research Services

- ***Laboratory analyses***
  Samples from Colombian ecosystems: contracted with CIAT.
  Samples from Costa Rica ecosystem: contracted with CATIE.

- ***GIS (cartography and 3D images)***
  To be contracted possibly with CIAT or with Wageningen University.

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

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 Amazonia, 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 year, from December 1, 2001 to November 30, 2006. Total project cost is US$ 3,698.525. Financial support approved by The Netherlands Ministry of Development Cooperation, channelled through The Netherlands Embassy in Bogotá, Colombia, is US$1,381.765 representing 37 % of the project 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 (June 1 - November 30, 2003) according to Annual Plan 2003

The activities described below have been successfully accomplished during the second six months of the second year of our project: June 1 - November 30, 2003, in accordance with Annual Plan 2003. The Chronogram of Activities 2003 is included as Annex 1 of the present report.

Technical and administrative coordination activities

1. **Fourth International Coordination Meeting, CIAT, September 22-25, 2003.** This meeting was attended by the Executive Committee and almost all project members and consultants. The program of this meeting and the summary of discussions and recommendations are included as Annex 2 of the present document.

2. **Fifth International Coordination Meeting** will be held at Punta Arenas, Costa Rica, on July 26-29, 2004.

3. **Preparation and handling of Six-months Technical and Financial Reports June 1-Nov 30, 2003.** They were handled to The Netherlands Embassy in Bogotá on 11 Dec, 2003.

4. **Participation at Carbo Europe Conference: "Mitigation Alternatives through Agriculture and Grassland Systems", Sep 3-9, 2003 Clermont-Ferrand, France.** The conference was attended by the Project Scientific Director, who presented a half-hour invited paper on the project results, and by Dr. Bram van Putten, who co-authored a recently published document on verification methods, here included as Annex 4. The Conferences was jointly organised by CarboEurope and Global Carbon Project. Sponsors (*http://www.bgc-jena.mpg.de/public/carboeur/*), (*http://www.globalcarbonproject.org*). **Conference Objectives:** (1) The conference aimed to present to a wide scientific audience the results of three years of integrated European research, on GREENGRASS project. (2) Prepare a document to the UNCCCC with methodological recommendations

regarding EU countries accounting for GHG emission reductions through grassland systems. (3) Compare and discuss approaches and findings with parallel ongoing regional and international carbon research initiatives on grassland systems, and (4) Enhance the integration of disciplines (biological, physical…) and ecosystems (land) in carbon research. **Target Audience:** Scientists and leaders of research programmes in the field of the terrestrial carbon cycle and carbon management in view of the Kyoto Protocol, consultants for certification of Kyoto projects, policy makers involved in climate change, land use, land use change and forestry.

Research Activities

It is our pleasure to inform that research activities conducted and completed during the second semester of our second year are in full agreement with the project Annual Plan 2003. The most important research activities during this semester were:

a) Consolidated socio-economic analysis of "improved farms" vs. "typical farms" in research areas on the three project sub-eco-systems (Andean Hillsides, Colombia, Tropical humid forest - Colombian Amazonia, and Sub-humid and humid tropical forest, Costa Rica). Methodology, presented by Gobbi, J and analysis and interpretation of results of farmers socio-economic survey for each sub-ecosystem, presented by Ramírez, B. *et al.*, on Humid Tropical Forest sub-ecosystem, Colombian Amazonia; Cuellar, P. *et al.* on Andean Hillsides, Colombia; and Ibrahim, M. *et al.* on Sub-humid and humid Tropical Forest, Costa Rica, are presented in the Project Internal Document no. 9 ***"Two-year Project Achievements"***, December 2003.

b) Consolidated statistical analyses of soil carbon stock data from the three sub-ecosystems. Data resulting from the evaluation of long-established systems, both soil/carbon data and biomass/botanical composition/vegetation data, were analysed by sub-ecosystem, using the same statistical methodology for all sub-ecosystems. Statistical methodology, analysis and interpretation of results from each sub-ecosystem are presented by Amézquita, M.C. *et al.* on Andean Hillsides, Colombia; Ibrahim, M. *et al.*, on Sub-humid and humid Tropical Forest, Costa Rica, and Amézquita, M.C. *et al.* on Humid Tropical Forest, Amazonia, Colombia in the Project Internal Document no. 9 ***"Two-year Project Achievements"***, December 2003.

c) Initiation of evaluation of the new small-plot experiment established at Esparza, Costa Rica. Detailed description of activities and preliminary evaluations are described by Ibrahim, M., *et al.* in the Project Internal Document no. 9 ***"Two-year Project Achievements"***, December 2003.

The Project Internal Document no. 9, entitled ***"Two-year Project Achievementss"***, December 2003, is composed of technical contributions from project members and consultants that were presented and discussed at the Fourth International Coordination Meeting, held at CIAT, September 22-25, 2003, and further edited for publication.

3. Budget

Budget tables 1-8 in Annex 4 of this report show real budget execution for years 1 and 2, and estimated budget requirements for years 3-5. These tables show project budget, global and per institution/year, discriminated by donor and matching funds.

Annexes

Annex 1: Chronogram of Activities - Annual Plan 2003
Annex 2: Program, Fourth International Coordination Meeting, CIAT, Cali, Colombia, September 22-25, 2003, and Summary Recommendations.
Annex 3: Bonn COP's , June 2003. Summary.
Annex 4: Budget tables (8).

****

Annex 1

Chronogram of Activities Annual Plan 2003

CHRONOGRAM OF ACTIVITIES - ANNUAL PLAN 2003

December 1, 2002 - November 30, 2003

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 contract for project personnel	Signed contract														CIPAV
	Preparation and agreement of Terms of Reference for Consultants	Accepted TOR's														Project Direction CIAT WU
	Preparation of ANNUAL PLAN 2003	Plan handled to The Netherland Embassy in Bogotá, Colombia (Dec 20, 2002)														Project Direction
	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	Third International Coordination Meeting	Meeting conducted														Project Direction CATIE CIAT CIAPV U.AMAZ. W U
	Preparation of Third Six-months Technical and Financial Reports.	Reports handled to The Netherlands Embassy in Bogotá, Colombia. June 30, 2003.														All Participant Institutions
	Fourth International Coordination Meeting	Meeting conducted														Project Direction CIAT WU CIPAV CATIE U.AMAZ.
	Preparation of Fourth Six-months Technical and Financial Reports.	Reports handled to The Netherlands Embassy in Bogotá, Colombia. before Dec 31, 2003.														All Participant Institutions.

CHRONOGRAM OF ACTIVITIES - ANNUAL PLAN 2003

December 1, 2001 - November 30, 2003
CONT. PAG -2

OBJECTIVE	ACTIVITY	INDICATORS	12	1	2	3	4	5	6	7	8	9	10	11	12	Participant Institutions
2. TECHNICAL AND ADMINISTRATIVE COORDINATION (Cont.).	Preparation of Proceedings 2003	Internal publication ready											■	■	■	W.U. CIPAV CATIE CIAT U.Amzonia — Project Direction
	Preparation of ANNUAL PLAN 2004.	Plan handled to The Netherlands Embassy in Bogotá, Colombia (December 31, 2003).													■	Project Direction and Participant Inst.
3. DESIGN OF SOCIO-ECONOMIC DB STRUCTURE	1.Farm characterisation. 2.Prod costs monitoring, 3.Socio-economic regional indices	Database design ready					■	■	■	■	■	■				Project Direction and CATIE Economics consultant
4.SOCIO-ECONOMIC REGIONAL CHARACTERISATION (secondary information from various sources) and FARM CHARACTERIZATION (surveys).	History of land management, regional indices and farm characterization.Three sub-ecosystems. Colombian Andean Hillsides. Colombian Amazonia, and C Rica.	Information collected and documented														U.AMAZ
																CIPAV
				■	■	■	■	■	■	■	■	■	■	■		CATIE

CHRONOGRAM OF ACTIVITIES - ANNUAL PLAN 2003
December 1, 2002 - November 30, 2003
CONT. PAG -3

OBJECTIVE	ACTIVITY	INDICATORS	12	1	2	3	4	5	6	7	8	9	10	11	12	Participant Institutions	
6. FIELD BIO-PHYSICAL RESEARCH: DETAILED CHARACTERIZATION OF LAND MANAGEMENT SYSTEMS AND FIRST C SAMPLING	Sub-ecosystem: Humid Tropical Forest- Amazonia (Colombia).	1. General characterisation of Land Management Systems to be studied: production systems, soil, climate. Information documented.		■	■	■										Project Direction U. Amazonia	
		2. Soil characterisation: pH, P, CEC, Texture, Bulk density, Total C, Oxidisable C, Total N.		■	■	■	■									Project Direction, U. Amazonia.	
		3. Vegetation characterisation: type of vegetation, density, biomass estimation		■	■	■	■									Project Direction, U.Amazonia.	
7. STATISTICAL ANALYSIS on Initial Characterisation and First C Sampling data. BIO-PHYSICAL DATABASE.	All sub-ecosystems: Andean Hillsides-Colombia, Sub-humid and humid forest-Costa Rica, and Humid forest-Colombian Amazonia (data from years 1 and 2).	Data analysed. Reports prepared.	■				■	■	■	■			■	■		All institutions	Project Direction and participant researchers
8. 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	

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 Fourth International Coordination Meeting CIAT, September 22-25, 2003 and Summary Recommendations

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-WU

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

FOURTH INTERNATIONAL COORDINATION MEETING

CIAT, Cali, Colombia, September 22-25, 2003

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

Executive Committee

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

Project Members

- ***Field research - Andean Hillsides, Colombia.***
  María Elena Gómez. Agronomist, M.Sc., CIPAV
  Piedad Cuellar, Animal Scientist, M.Sc., CIPAV
  Project office at CIAT's Science Park.
- ***Field research - Humid Tropical Forest, Colombian Amazonia***
  Dr. Jaime Enrique Velásquez, Animal Scientist, Ph.D.
  Jader Muñoz, Geologist
  Jaime A. Montilla and Juán Carlos Suárez, students.
  Universidad de la Amazonia
- ***Field research - Sub-humid and humid Tropical Forest, Costa Rica***
  Tangaxuhan Llanderal, Ph.D. student
  Alexander Navas, Agronomist
  Francisco Casasola, Agronomist
  CATIE
- ***Environmental Economist***
  Dr. José Gobbi, Environmental Economics, Ph.D., CATIE.
- ***Mathematical modelling***
  Dr. Bram van Putten students, Mathematics and Statistics Research Group.
  Wgeningen University
- ***Data base management/statistical programming***
  Héctor Fabio Ramírez, Statistician, B.Sc.
  Project office at CIAT's Science Park.
- ***Soil and vegetation sampling***
  Hernán Giraldo, Agronomist, B.Sc.
  Project office at CIAT's Science Park.
- ***Project Executive Assistant***
  Francisco Ruíz, Industrial Engineer, B. Sc.
  Project office at CIAT's Science Park.

Consultants

- *Professor Dr. Leendert 't Mannetje*, Tropical Grasslands, Ph.D, Wageningen University.
- *Dr. Douglas Pachico*, Economist, Ph.D., Research Director, CIAT.
- *Dr. Edgar Amézquita*, Soil Sciences, Ph.D., CIAT.
- *Dr. Myles Fisher*, Ecologist, Ph.D., CGIAR Climate Change Research Group.

Soil Sample Analyses: Contract with CIAT and CATIE's Soil Laboratories.

PROGRAM

Sat 20 and Sun 21 Sep, 2003.- Arrival to Cali Airport, transport to CIAT's hotel

Monday September 22.- GENERAL and Andean Hillsides sub-ecosystem
Session moderators : Prof. L. 't Mannetje (morning); E. Murgueitio (afternoon)
Participants responsible for summary preparation, please handle your reports in printed and magnetic media to Francisco Ruíz, at the end of the day or at the end of the meeting. Thanks.

8:00– 8:15 am	Presentation of participants	
8:15– 8:30 am	Welcome Address by Host Institution	Dr. Joachim Voss Director General, CIAT
8:30-8:45 am	Policy Issues on C Sequestration	Leendert 't Mannetje
8:45-9:30 am	Project Achievements in its first two years: Dec 1, 2001-Nov 30, 2003.	María Cristina Amézquita.
9:30–9:45am	Discussion and recommendations	Summary preparation: P.Buurman
9:45–10:15 am	C seq. research: Methodological issues	Peter Buurman
10:15-10:30am	Discussion and recommendations	Summary preparation.: E. Amézquita
10:30-10:45 am	Coffee Break	
10:45-11:30am	Socio-economic evaluation: Objectives, methodology and results summary.	José Gobbi
11:30-11:45 am	Discussion and recommendations	Summary preparation: E. Castro
11:45-12:30 pm	Economic Valuation of Carbon as Environmental Service.	Edmundo Castro, CRESEE (Centro Reg Estudios en Economia Ecologica), Costa Rica.
12:30–12.45pm	Discussion and recommendations	Summary preparation: J. Gobbi
12:45-2:30 pm	Lunch	
2:30-3:30 pm	**Andean Hillsides sub-ecosystem**: Statistical Analysis of Carbon data.	M.C..Amézquita, H.F.Ramírez, H. Giraldo, M.E.Gómez, E.Amézquita.
3:30-3:45 pm	Discussion and recommendations	Summary preparation: P.Buurman
3:45-4:00 pm	Coffee break	
4:00-4:45 pm	Andean Hillsides sub-ecosystem. Socio-economic data.	P. Cuellar, H.F.Ramírez, J. Gobbi and M. C .Amézquita
4:45–5:00 pm	Discussion and recommendations	Summary preparation: E. Murgueitio
5:00-6:00 pm	Summary recommendations on Andean Hillsides research	P. Buurman, E. Amézquita, E. Castro, E. Murgueitio.
6:00-8:00 pm	Cocktail	CIAT VIP Room

Tuesday September 23.- Sub-humid and humid Tropical Forest, Costa Rica

Session moderators: Dr. Myles Fisher (morning); Dr. Bertha Ramírez (afternoon)
Participants responsible for summary preparation, please handle your report in printed and magnetic media to Francisco Ruíz, at the end of the day or at the end of the meeting if you wish Thank you very much.

8:30 -9:30 am	**Humid and sub-humid tropical forest, Costa Rica**. First two years research activities. Questions and Discussion.	Muhammad Ibrahim
9:30-12:30 pm	Analysis of Carbon data, discussion and recommendations. (with a short coffee break 10:30-10:45).	M. Ibrahim, Alexander Navas and Llanderal Teangaxuhan. Summary preparation: Peter .Buurman
12:30-2:00 pm	Lunch	
2:00–3:00 pm	Socio-economic data.	José Gobbi and M. Ibrahim.
3:00-3:30 pm	Discussion and recommendations.	Summary preparation: E. Castro, E Murgueitio
3:30-3:45 pm	Coffee break	
3:45-5:00 pm	Summary recommendations on Sub-humid and humid Tropical Forest research, Costa Rica.	L. ´t Mannetje, M. Fisher, P. Buurman, E.Castro, E. Murgueitio
5:00-6:00 pm	Specific Issues to be discussed	

Wednesday September 24.- Humid Tropical Forest, Colombian Amazonia

Session Moderators: Muhammad Ibrahim (morning); Piedad Cuellar (afternoon)
Participants responsible for summary preparation, please handle your report in printed and magnetic media to Francisco Ruíz, at the end of the day or at the end of the meeting if you wish Thank you very much.

8:30-9:30 am	**Humid Tropical Forest sub-ecosystem, Colombian Amazonia**. First two years research activities. Questions / discussion	Bertha L. Ramírez
9:30-12:30 am	Analysis of Carbon data, discussion and recommendations. (with a short coffee break 10:30-10:45)	M. C .Amézquita, H.F.Ramírez, B. Ramírez, H. Giraldo, J.Muñoz and J. Velásquez. Summary prep: Edgar Amézquita
12:30-2:00 pm	Lunch	
2:00–3:00 pm	Socio-economic data.	B. Ramírez, J. Gobbi, Jaime.A. Montilla and J. Muñoz.
3:00-3:30 pm	Discussion and recommendations.	Summary prep: E. Murgueitio
3:30-3:45 pm	Coffee break	
3:45-5:00 pm	Summary recommendations on Humid Topical Forest, Colombian Amazonia	Prof. ´t Mannetje, P. Buurman, E. Amézquita, E. Murgueitio, E. Castro
5:00-6:00 pm	Summary recommendations and closing remarks	L. ´t Mannetje, P. Buurman and M. C. Amézquita

Thursday 25 September.- FIELD TRIP

8:30-4:30 pm	Field Trip	All participants are invited
	Bus leaves from CIAT at 8:30am	
8:00 pm	Bus leaves CIAT for dinner in Cali "Petite France" Restaurant.	All participants are invited

**************** END OF MEETING **************

The Netherlands Cooperation Activity CO-010402 Fourth International Coordination Meeting

Summary of discussions and recommendations 22 and 23 September, 2003

1. Soil carbon

CATIE uses dry combustion while CIAT uses a modified Walkley Black "wet combustion" procedure of dissolution in acid dichromate with external heat to determine soil C.

> ***Recommendation:*** A number of samples covering a range of soil textures and C concentrations should be exchanged to assess the differences.

Dr. Buurman presented evidence that for comparison of carbon stocks between land use systems, the most reliable way is to recalculate stocks based on a fixed soil mass. The most logical fixed mass to use for this purpose is that of the soil of the system with the lowest bulk density, typically the native forest, which are lower than in intervened systems. Taking fixed mass as a basis of calculation means that fixed depths are abandoned and data of carbon analysis are recalculated on soil mass to take account of the changes in bulk density that occurs under different patterns of land use. Dr Buurman presented a worked example of how a correction procedure might be applied (see example below).

> ***Recommendation:*** All data for soil C stocks should be recalculated using the model procedure.

Recalculation of carbon stocks using fixed mass
DOVIO

Bosque nativo	thickness	bd	C	Total weight	Total carbon
	dm	kg/dm3	%	kg/m2	kg/m2
0-10	1	0.64	6.56	64	4.20
10-20	1	0.84	5.57	84	4.68
20-40	2	0.94	4.49	188	8.44
40-100	6	0.90	1.75	540	9.45
				876	26.77
Pastura degradada	1	0.89	4.71	89	4.19
	1	1.02	3.58	102	3.65
	2	1.01	2.22	202	4.48
	5.37	0.90	1.13	483	5.46
				876	17.79
	Valor original			933	18.28
Pastura mejorada	1	0.92	4.63	92	4.2596
	1	1.15	3.27	115	3.7605
	2	1.26	2.23	252	5.6196
	3.76	1.16	1.11	417	4.6287
				876	18.27
	Valor original			1155	21.42

Dr. Ibrahim outlined methodological problems with soil sampling:

- Spatial variability in soil carbon content
- Differences in the history of plots
- Different biophysical aspects: topography, soil texture, soil fertility
- Vegetation cover, species diversity and abundance
- Differences in grazing regimes
- Risk of farmers not wishing to continue the co-operation and sale of the property

> ***Recommendation:*** For a proper interpretation of results it is essential to know the history of land use of each specific field. It would be definitely useful to have information about burning practices.

It was emphasised that findings from research on soil C from temperate agro-systems have little relevance for tropical agro-systems, e.g. in relation to the depth of soil C stocks and hence the depth of sampling. For example, in the US Conservation Reserve Program, where arable land is converted to perennial grasses or trees, C accumulation occurred in the top 10 cm, occasionally in the top 20 cm. In contrast, in tropical pasture systems, 75 to 95% of the accumulation is deeper than 20 cm. The implication is that when the temperate systems are cropped once more any accumulated C, which is in the plough layer, will be lost. In contrast in tropical systems, most of the accumulated C is below the plough layer and should remain even if they are cropped.

> ***Recommendation:*** Norms for temperate systems are irrelevant to our systems and should be ignored. Indeed we should take all opportunities that occur to emphasize in international fora the uniqueness of tropical systems. This is where we have a real win-win advantage.

2. Degraded pastures

The term *degraded pasture* as used so far, includes a large range of vegetation types and degradation stages. Some of these systems are grazed, others abandoned. The large variability of data pertaining to this system indicates that a narrower definition is called for.

> ***Recommended definition:*** Degradation reflects changes in soil quality in relation to plant production and survival leading to invasion of herbaceous and woody weeds, leading to reduced herbage production, loss of desirable species, increase in bare soil and reduced carrying capacity and animal production. There is also a difference between "actively degrading" pastures and "abandoned degraded" pastures. The latter can have substantial production of non-pasture species, for example, secondary forest.

"Degraded pasture" is a "treatment" in the project, but different areas of degraded pastures are not comparable.

> ***Recommendation:*** Proper sampling of "degraded" pastures must involve stratification of the area into classes such as trees, shrubs, herbaceous weeds, productive grasses, unproductive grasses and bare ground. The areas occupied by each class should be estimated and stratified sampling of the soil should be carried out with the number of samples for each class in accordance with the proportion of the areas covered by each class. Then a mean C content can be calculated.

3. Statistical analysis

Analysis of variance indicates that slope is a major variable influencing carbon stocks/contents. By using mean values of carbon stocks for whole fields, this variable is relegated to variance of mean values. This is a loss of information.

> ***Recommendation:*** Compare means for the three or four positions in each field, and compare it with similar positions in other land uses. This will probably reduce the variability of data and emphasize the differences between land uses.

As C stocks are very different in the various different land uses, combining all data for a particular sub region may not give good results.

> ***Recommendation:*** Evaluation of data should preferably be carried out for each data set separately.

The project is not a designed experiment with replications and the treatments at the different sites are not the same, e.g. improved pastures may consist of different grass and /or legume species; therefore, "treatments" can not be compared.

Recommendations:

- Analysis of variance is merely a tool for preliminary evaluation of the data, and rigorous data evaluation must rely on pattern analysis.
- Means of clusters cannot be compared.
- In case of the relation between C content and soil texture only sites of good drainage may be compared (do not have standing water on the soil surface at any time during the year).
- Slope and hydrology are important variables in relation to carbon dynamics and should be included in the analysis and compared pair-wise. This should reduce variability. In flat areas, where slope is not relevant, site drainage may be substituted if groundwater is an important near-surface variable.
- Hydrological properties of a sampling position should be taken into account.

The principal components analysis gives some results that defy logic. One of these is the negative correlation between clay and organic matter on one hand and CEC on the other hand. This problem may be due to the fact that the dimensions of the variables are different; carbon is quantified over depth, while CEC and texture components are expressed as percentages.

> ***Recommendation:*** Better results may be expected when all parameters are quantified over depth.

Not all variables used in the principal components analysis are independent. Texture fractions together add up to 100%, and the sum of stable and oxidizable carbon equals total carbon.

> ***Recommendation:*** To eliminate this bias, it is better to use, e.g. clay and silt (quantified over depth), oxidizable carbon, and stable carbon.

Because the number of variables is small, the number of principal components should preferably not exceed 2 or 3.

> ***Recommendation:*** PC's with Eigen values lower than 1 should not be used.

4. Causal relations

We should use all statistical analysis to extract causal relations that we can understand in terms of soil/organic matter dynamics.

> ***Recommendation:*** We should be very critical with respect to statistical relations that make no apparent sense.

5. CEC-carbon relations.

Data from Costa Rica suggest a negative relation between CEC and C.

> ***Recommendation:*** Because this is illogical, we should look for an explanation. Reasons for deviations may be: large amounts of unhumified litter, hydromorphic circumstances in some samples, etc. It would be useful to find out what causes this illogical behaviour. For these relations, percentages would be a better measure than accumulated values. Look for a joint influence of C and clay.

Recommendations of the discussion of socio-economic factors

- It is important to define the type of farmer with regard to a combination of indicators with respect to each zone of each sub-ecosystem, for example farm size and capital resources.
- The number of farms is limited and the methodology adopted partially overcomes this limitation. It is a "socio-economic case study".
- It is important to define the terms "typical farm" and "pilot farm". These terms are not appropriate in the present context nor in the future as farm dynamics change.
- Change the terms "with project" and "without project" for the financial and economic analyses because the Project does not make interventions in land use.
- Define the profit from different land uses and then try various combinations of to optimize the farms with respect to the biophysical and socioeconomic context using modelling.
- The most important primary tool is the recording system that the project will contribute to strengthen the business capacity of the farmers. The recording system should include accounting of future value of natural capital, for example, water where it is strategically important.

6. Future vision of the project

At present environmental services are not tangible goods for farmers, so that it is important to emphasize this when possible.

> ***Recommendation:*** A useful start would be to make farmers and decision makers aware of the issue and seek information of projects that address other environmental services and explore possible synergies with them.

Specific recommendations for Costa Rica

- Include notes about the history of land use in the forested zone: deforestation, subsistence agriculture (maize and beans), cattle raising. In recent years there has been less use of fire.
- Farmers' organizations are important for the future offer of environmental services.

Specific recommendations for the Andean hillsides

- Change the term "Block" (1 y 2) to "Zone"
- Check the data of land use history for some categories (fodder banks and others).

7. New experiments

As new experiments will be under a cutting regime, it is important to decide what to do with the cut material. If it is totally removed, little or no carbon will be sequestered or there may even be a reduction in soil C. If all material is left on the plots, C sequestration will be enhanced. Therefore a decision needs to made what proportion of the cut material is removed. As a guide, under grazing about 30% (maximum) of standing dry matter is consumed, so that at least 70% enters the litter and decomposes. It will also be necessary to decide how to implement this regime, that is how to harvest only 30% of the standing biomass.

Comments for C-Sequestration Project
Edmundo Castro

Title: Socioeconomic evaluation: Objectives, methodology and results summary

1. Summary Preparation

It is known that agro-silvo pastoral systems managed with agro-ecological technologies are able to accumulate organic matter not only into the tree tissues but also in the soil through roots and decomposed matter. These systems theoretically act as net carbon sinks when the level of their emissions is less than the level of carbon accumulation. That biological action given by the photosynthesis process could take place in these production systems by changing conventional to organic technologies mainly when ranchers are willing to participate. Ranchers will react adopting ecological technologies according to the economic opportunity cost of land use as well as the economic policy incentives to transform current technologies to alternative animal production systems.

To incentive land use modifications, financial analysis of the current and desired land use situation, where carbon as environmental service be recognized to the farmer in monetary terms must be carried out. Thus, the feasibility of the alternative system can be calculated and expressed en financial terms (NPV, IRR), The financial indicators will support ranchers decisions to get into the alternative productive economic model. However, the improvement in family socioeconomic indicators has to be demonstrated to support rancher decisions.

Due to the socioeconomic importance of the agro silvo pastoral systems in Latin America, and the CO2 emissions form industrialized countries, the carbon sequestration project aims to demonstrate the net income benefits to ranchers getting into the clean alternative systems and the macro social impact of the initiative. The process must be joined however with a program of payment for carbon as environmental service, so that income from industrialized countries which signed of the Kyoto protocol can participate with a positive social impact for ranchers participating in tropical countries

2. Andean Hillside Sub ecosystem

Summary recommendations.

- Instead of using Gross Income as a financial indicator to measure system productivity, it is recommended to use net income as a measure of profitability
- The financial analysis must be based in a normal cash flow plus a satellite account for natural capital stocks and flows in economical terms (valuation is required) in each accounting period. That will allow for decisions based on appreciation or depreciation of the natural capital in the production process including not only carbon but also other environmental services and natural stocks.

3. Humid and sub humid tropical forest CR

Recommendations

- To include within the farm system analysis the economic value of those environmental services with internal potential to capture and re invest in the watershed.
- In the pacific, water is an extremely important environmental service then is probable that water has more socioeconomic importance than carbon
- When a green accounting join the cash flow, it should be taking into consideration the nutrients imported into the farm such is the case of gallinasa and others.
- To be prepared for the institutional and legal requirements to pay for environmental services. It is necessary to reduce burocracia and perverse incentives as well.
- To include in further stages of the project the rancher capacity to behave in micro enterprise terms, otherwise training is required.
- Once the feasibility analysis of the agroecological system can demonstrate its benefits when compared to the current situation, the target oriented approach to improve socioeconomic and environmental indicators as optimizacion of farmer resources (natural, human, financial, managerial) can be recommended.

Discusión y Recomendaciones Septiembre 24/2003
Sub-Ecosistema Piedemonte de Amazonia

Moderador: Enrique Murgueitio

- Ubicar el uso de "suelo degradado" con características similares al muestreado pero sin presencia atípica alta de ganado como el que se trabajó.
- Los datos de C (total, oxidable y estable) de los usos de la tierra evaluados generan gran discusión porque los dos tratamientos mejores tienen una diferencia muy grande, pueden tener influencia de sitio de muestreo por la cercanía al río y su posible influencia (también el color del suelo es diferente, más oscuro, para el productor este sitio es más fértil). El contenido de carbono estable relacionado con el carbono total es difícil de explicar. Hay que buscar cómo explicar la situación y cómo presentar la información (¿se puede analizar en conjunto con los otros usos de la tierra si hay un efecto fuerte de sitio influenciado por el tipo de suelo?)
- Se recomienda evaluar otras parcelas en la misma zona cerca y lejos del río con otros usos (bosque ripario, pastos nativos, monocultivos) así como revisar la historia mejor la historia de inundación, el tiempo de deforestación (posible residuos de carbono del bosque en zona húmeda).
- Se recomienda evaluar otros parámetros químicos del suelo e hidrológicos (Dr Peter Buurman).
- Hay dudas sobre la definición de los sistemas "asociación de *B humidicola* con leguminosa nativa" porque el % es bajo y la cantidad de N es baja y no superior a otros tratamientos.
- Análisis socioeconómico: representatividad de los sistemas cercanos al río para (% de vega es mucho más bajo).
- Conseguir los 6 tratamientos en las dos zonas: vegas y onduladas. Hay que buscar vestigios de carbón vegetal de la discusión (evaluación por isótopos).
- Reconstruir de la historia del suelo de la vega (solo el 1,6% de los predios del subecosistema) y manejo especialmente la quema del bosque.

Para Todos los Sub-Ecosistemas

- Calcular la relación C / N para todos los sitios.
- Definir el procedimiento para las mediciones de biomasa para los bancos forrajes en las parcelas de investigación: periodicidad de corte para cada especie, fragmentación de material cosechado, % de material a depositar en el suelo y % a extraer, fertilización (periodicidad, tipo y cantidad).
- En el área socioeconómica la prioridad serán los registros que permitan conocer en detalle el flujo financiero de diferentes usos de la tierra que se están evaluando (pastos mejorados, pastos degradados, bancos de forrajes, silvopastoriles).
- Se deben seleccionar algunos temas de capital natural que sean posibles de registrar para involucrar en el futuro algunos parámetros de análisis económico – ambiental (ej: aforos y consumos de agua; consumo de leña).
- Se recomienda presentar la información de costos de las fincas como costos marginales por actividad.

Annex 3

Bonn COP's, June 2003 - Summary

Bonn Conference, June 2003.Summary[1]

Bram van Putten[2]

1. Introduction

The Clean Development Mechanism (CDM) has been defined in Article 12 of the Kyoto Protocol. According to the Marrakech Accords, terrestrial carbon sink projects, limited to afforestation and reforestation (AR), are allowed to be used under the CDM. Such activities could stimulate other environmental benefits through private investments in developing countries but can also have adverse effects on biodiversity, environment and local socio-economic structures. Rules for CDM sinks projects are planned to be decided at COP9 in December 2003.

This discussion paper aims to contribute to the negotiations a scientific perspective on critical issues related to decisions to be taken during SBSTA 18 and COP9 and addressing the eligibility and implementation of CDM sinks projects, but also addresses more general scientific and methodological issues related to the Kyoto process:

- Definitional and GHG accounting rules for sinks in the CDM in the First Commitment Period
- Evaluation of project plans for eligibility in the CDM
- Monitoring and Verification of carbon sinks in CDM projects
- Looking ahead: beyond the First Commitment Period
- Frequently asked questions about sink capacity in the CDM and tropical forestry.

The following summary comments directly on issues related to the SBSTA mandate: definitions, leakage, permanence, additionality, environmental and socio-economic issues.

2. Definitions of 'Forest, Afforestation, Reforestation'

The adoption within the CDM of the current forest definition agreed for Articles 3.3 and 3.4 of the Kyoto Protocol would be a transparent, feasible way to ensure consistency in sink activities. It will allow inclusion of agroforestry projects but may create disincentives to invest in dry or degraded areas with marginal forest cover (where forest cover is below the country-specific threshold of between 10 and 30%).

In order to avoid perverse rewards for recent deforestations for other reasons, sticking to the base date 31.12.89 is essential (Schulze et al., 2003). The global coverage of freely-available remotely sensed land cover images such as the 1990 LANDSAT images allows, in the absence of official national data, determination of the presence or absence of forest for any piece of land within six months around the base date (***Section 1.1, Appendix I***).

---

[1]: *a Discussion paper (48 p.) in the framework of the project Concerted Action CarboEurope-GHG, supported by the European Commission, DG Research, under the Fifth Framework Programme, Key Action Global Change and Ecosystems. Published May 2003, and presented at UNFCCC SB 18, Bonn, Germany, 4-13 June 2003, on Friday 6 June, 2003. The paper is also published at: ftp://ftp.bgc-jena.mpg.de/pub/outgoing/afreib/CDM. Bram van Putten contributed as co-author.*

[2]: *Ph.D. in Mathematics. Wageningen University and Research Centre.*

3. *Non-permanence*

The Colombian proposal of 'Temporary Emission Reduction Units' (tCERs) seems practical and transparent, easy to monitor and verify, avoids the need for long-term insurance against forest loss due to natural or human-induced events, and has minimal risk of over-crediting. tCERs would be renewed periodically following certification of carbon stock changes and greenhouse gas emissions (***Section 1.2***). Non-permanence of carbon sinks can be minimised by proper project framework and design with strong involvement of and benefits for local stakeholders.

4. *Additionality and Baselines*

Among the options for defining additionality (FCCC/SBSTA/2003/4) a definitions should be chosen that avoids that any afforestation, irregardless of its original purpose, meets the additionality criterion. A good definition is given in Ellis (2003): An afforestation or reforestation project activity is additional if the net enhancement of sinks is higher than those that would have occurred in the absence of the registered CDM project activity, if the project activity itself is not a likely baseline scenario, and the project activity is governed by the principle that its undertaking contributes to the conservation of biodiversity and sustainable use of natural resources. Additionality (**Section 1.3**) is a key criterion for project evaluation in the scheme we propose in **Section 2 (Evaluation Criteria Figure 3)**. A spatial concept for baselines is proposed in **Appendix II**.

5. *Leakage and project boundaries*

It is difficult to trace all pathways of possible leakage, particularly through market pathways. Leakage regarding carbon stock changes on land outside the project boundaries could be monitored by remote sensing and statistical surveys to determine the local and regional magnitude of shifted activities and changes in ARD rates (***Section 1.4, Appendix II***). The risk of leakage can be minimised by a proper project framework and design and is a key criterion for project evaluation in the scheme we propose in ***Section 2***.

6. *Pools and fluxes*

CDM projects are likely to lose environmental integrity if only carbon stock changes, and no other greenhouse gases are accounted for. N_2O emissions in plantations in which management includes fertilization or introduction of leguminous trees or on wet soils can easily offset the carbon sink in the growing trees (***Section 1.5***). We propose technical solutions to this problem in ***Section 3, Level 3.***

7. *Monitoring and verification of carbon stock changes and Non-CO2 GHGs*

AR projects will need to be monitored by staff of the project and verified independently by an external agency, known as the Designated Operational Entity (DOE). Costs are incurred at these stages, to be added to the establishment costs. The difficulties of measurement are not always appreciated. Standardised procedures are described in the *IPCC Good Practice Guidance* (under development). However, there is an inevitable trade-off between accuracy and costs. Efficient sampling procedures will be needed to detect changes over the five-year commitment period. Various levels of complexity for observational strategies applicable to monitoring or verification are described with their advantages, disadvantages and pitfalls in ***Section** 3*. More elaborate monitoring schemes will increase the cost but reduce the uncertainty in the carbon sink estimate. This should be reflected in the achievable carbon credits of a project.

8. Socio-economic and environmental aspects

AR projects must contribute to the conservation of biological diversity and the sustainable use of resources (COP 7, Marrakech). This has been taken by some to mean that monocultures of non-native species are disallowed in AR projects, as they are generally lower in biodiversity than native vegetation. Moreover, monocultures in tropical conditions are sometimes harmful to soil, causing erosion; and fast growing trees (whether non-native or native) usually utilise large amounts of water that can adversely affect the yield of catchments. In some cases plantations may displace local communities. On the other hand, monocultures of fast-growing trees have been studied extensively and their growth is therefore relatively predictable, making them attractive in carbon sequestration projects. Sometimes they contain significant biodiversity, especially if present as several age classes in one location. Moreover, they may provide a ready supply of timber and fuel, relieving pressure on the native forest. In ***Section 2***, we propose a decision framework for CDM project evaluation which allows a ranking of projects, including their rejection, with regard to socio-economic and environmental criteria (***Evaluation Criteria Figure 2***).

8. Crediting period

Projects that start with involvement of local people or have a significant investment in technology transfer, training and capacity building, such as agroforestry, forest restoration or low-input AR projects in marginal areas will be encouraged by long crediting periods. These project types are likely to produce the highest socio-economic and environmental benefits and involve a lower risk of trade-off regarding Non-CO_2 gases than intensive plantations. The start of the project should be defined such, that the GHG accounting encompasses any initial losses of carbon (or emissions of other GHGs) from, for example, site preparation or clearing of previous vegetation. Monitoring should be as intensive as possible in the start phase of AR projects to avoid overcrediting associated with the rapid changes in GHG sources and sinks associated with disturbances at this stage in the life cycle.