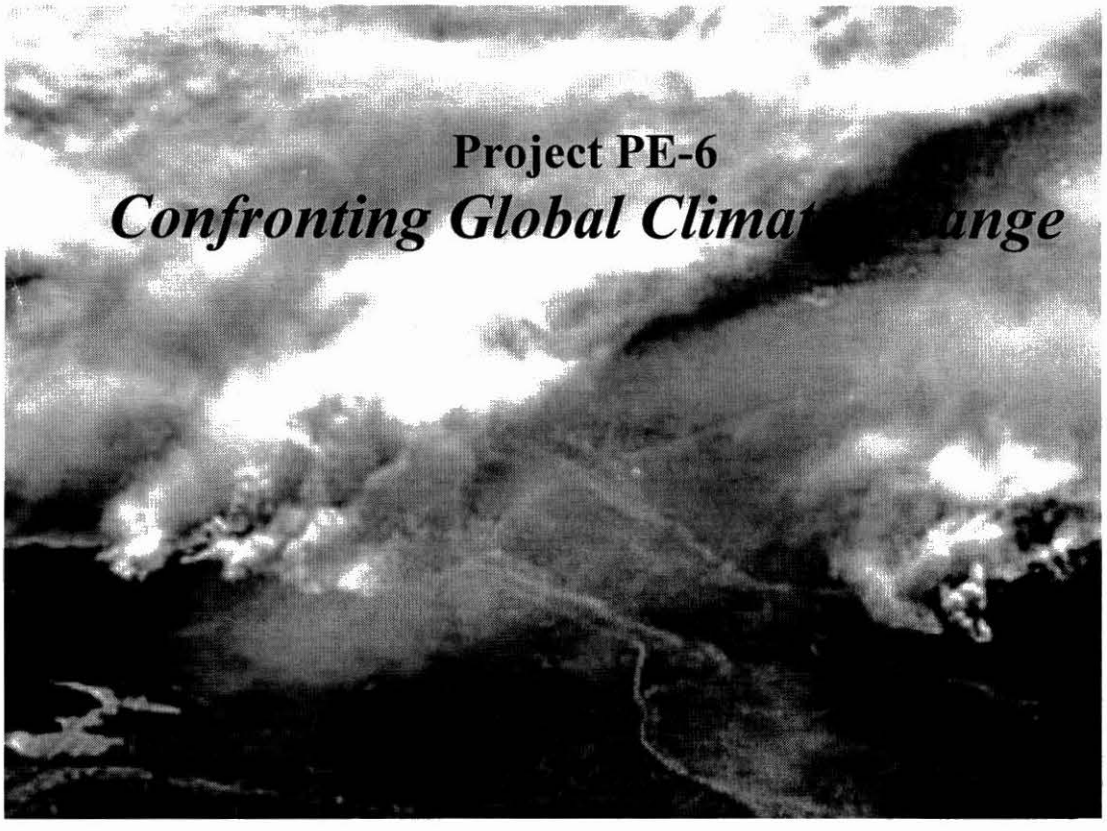
SUMMARY

ANNUAL REPORT 2003

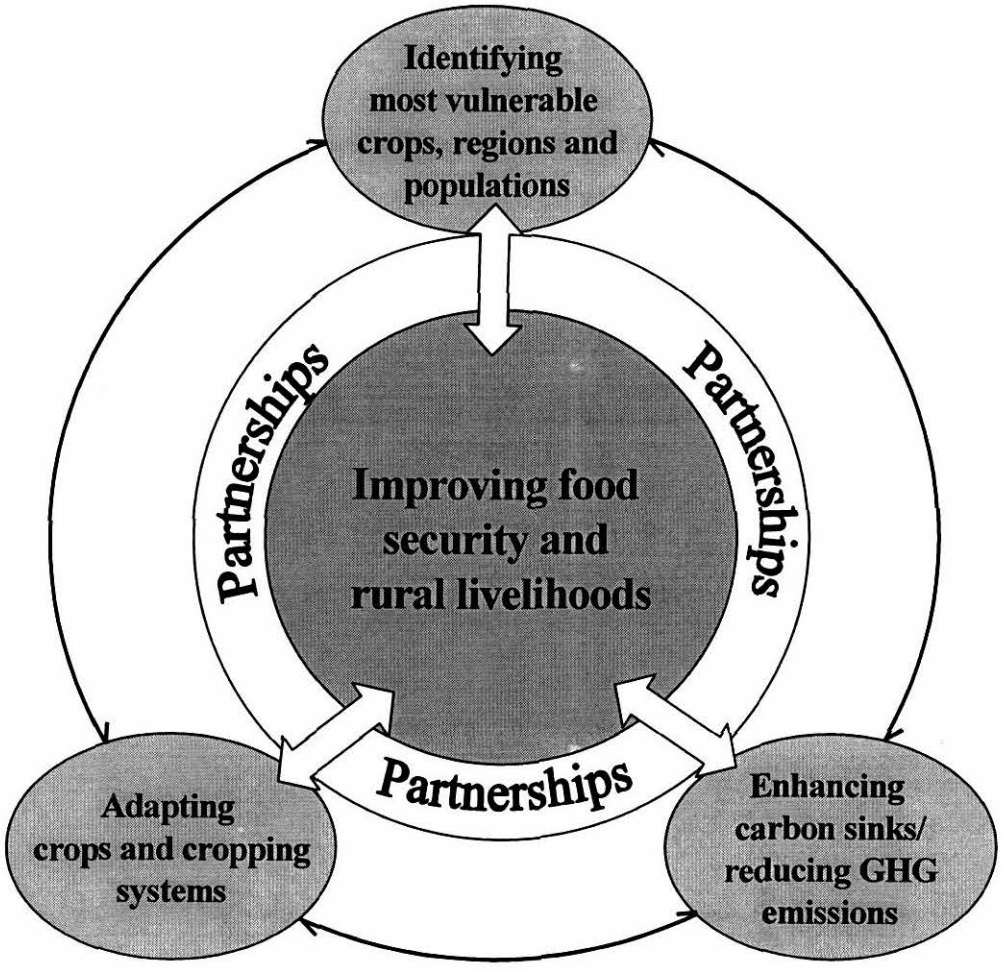


CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

SUMMARY
ANNUAL REPORT 2003

PROJECT PE-6

Confronting Climate Change



Project PE-6: Confronting Global Climate Change

Project Description

Objective: To overcome expected reductions in productivity of some major food crops and forages as a consequence of climate change (CC) in ecoregions within the scope of CIAT's mandate, while reducing the environmental impact from agriculture.

Outputs:

1. Vulnerability and opportunity assessments of responses made by ecoregions, populations, crops, and crop wild relatives at risks from changing climates.
2. Germplasm and management systems adapted to changing climatic conditions and exacerbated incidence of pests and diseases.
3. Crop, forage, water, and soil management strategies developed to minimize sources and/or increase sinks of greenhouse gases (GHGs).
4. Impact of implemented strategies for adaptation to and mitigation of CC assessed, and institutional capacity enhanced.

Gains: *Plant breeders* and *agronomists* have access to realistic and detailed definitions of the climates encountered in response to CC. *Farmers* and *consumers* of CGIAR-mandated and other food crops have varieties adapted to marked changes in temperature and drought conditions. *Farmers* benefit from informed decision capacity and sustainable systems that minimize GHG emissions (CO_2, CH_4, and N_2O) and maximize carbon sequestration for international carbon trading. *Policy makers* have information of the effects of CC on the performance of CGIAR-mandated and other food crops and possible changes required to confront CC and prevent widespread land degradation. *National governments* have more accurate information on sources of GHG emissions and their removal by sinks for incorporation in their annual inventories under Article 7 of the Kyoto Protocol.

Milestones:

2003 Advanced versions of *FloraMap* and *MarkSim*. Preliminary assessment of bean yields for Central America and Africa. Definition of areas in urgent need to preserve wild relatives of beans. Advanced lines of drought-tolerant beans available to NARS for CA. Tropical grasses ranked by their nitrification inhibition potential (greenhouse studies). Incubation protocol developed and tested to rapidly screening Nitrification inhibitory activity from plant/root extracts and exudates affecting fluxes of N2O from soils.

2004 Definition of priority areas for conserving wild relatives of cassava, and release of drought-tolerant *Brachiaria* hybrids Case study assessment of net reductions in N_2O emissions due to *B. humidicola* in CA and Colombian savannas. Develop a pilot project to trade C from agroforestry systems (AFS) in Colombia. Preliminary estimate of GWP for the Quesungual reference site (Honduras).

2005 Key crops and forages ranked according to their Nitrification inhibition capability. Field studies completed to assess effects of contrasting forages on inhibiting Nitrification activity and reducing nitrate leaching and N_2O emissions from soils. Implementation phase initiated for a pilot project to trade C from AFS in Colombia. Environmental characterization of intensive, high-input, cattle-production systems: case studies in Colombia and CA.

2006 Field studies completed to assess effects of contrasting crops on inhibiting Nitrification activity and reducing nitrate leaching and N_2O emissions from soils. Monitoring of the pilot project to trade C. Baseline assessment of GHG net fluxes in a pilot watershed in the Andes.

Users: Immediate beneficiaries are farmers growing CGIAR-mandated crops and consumers, especially poor farmers in developing regions. Policy makers will use information on predicted changes in climate to plan land use and to include environmental services as part of the development agenda for selected regions.

Collaborators: NARS and national research centers: Brazil (EMBRAPA, INPA, INPE); Colombia (CENICAFE, CENICAÑA, CIPAV, CONDESAN, CONIF, CORPOICA, IDEAM, Instituto von Homboldt, MinAgricultura, MinAmbiente, SINCHI, Universidad de Córdoba, Universidad de Pereira, Universidad del Amazonas, Universidad Nacional); Central America (Costa Rica: CATIE; Honduras: ESNACIFOR, FAO, Ministerio del Ambiente, Universidad de Honduras; CGIAR centers: ICRAF, ILRI, IPGRI; Advanced Research Institutions and Universities: GTZ (Germany), JIRCAS (Japan), ETH-Zurich (Switzerland) – Quebec (Canada); Bayreuth (Germany); Wageningen (Netherlands), Cornell and Florida (USA); Climate Change Modelers – Hadley Climate Center (UK), NCAR (USA); International and Local NGCs, farmer and community organizations.

CGIAR system linkages: Enhancement & Breeding (17.5%); Crop Production Systems (20%); Livestock (20%); Protecting the Environment (35%); Training (2.5%); Information (2.5%); Networks (2.5%). Participation in the ICWG—CC.

CIAT project linkages: IP-1, IP-3, PE-1, PE-2, PE4, PE-5, SN-2, SN-3.

CIAT: PE-6 Project Log Frame (2003-2005)

Project: Confronting Global Climate Change
Project Manager: Marco Rondón

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal To contribute to long-term increases in agricultural productivity, poverty reduction, and conservation of the global environment.	Agricultural production increased. Farmers' income increased. Agriculture-related emissions of greenhouse gases (GHG) reduced. Water production levels maintained or increased.	National statistics of agricultural production and rural income. National and international inventories of GHG. National and regional inventories of water resources.	
Purpose To overcome expected reductions in productivity of some major food crops and forages as a consequence of global climate change, while reducing the environmental impact from agriculture in ecoregions within the scope of CIAT's mandate.	Net increase in agricultural productivity resulting from adoption of climate change (CC)-adapted crops. Net reduction in the global warming potential (GWP) of key ecoregions: tropical lowlands, hillsides, and Andes.	National and regional statistics of food and forage production. Regional and national inventories of GHG compared over time.	NARS partners show interest in collaborative research. Adequate funds from global challenge programs (climate change, water) allocated. Favorable policies for the release and adoption of new crop and forage varieties. Timely implementation of policy and trading incentives to favor adoption of environmentally safe management practices.
Outputs 1. Vulnerability and opportunity assessments of responses of ecoregions, populations, crops, and wild relatives of crops in crisis from changing climates. 2. Germplasm and management systems adapted to changing climatic conditions and exacerbated incidence of pests and diseases. 3. Crop, forage, water, and soil management strategies developed to minimize sources and/or increase sinks of GHGs. 4. Impact of implemented strategies for adaptation to and mitigation of GCC assessed, and institutional capacity enhanced.	Maps of risk of yield decline (maize, beans, cassava) for Africa and Latin America. Maps of risks of loss of habitat for wild relatives of crops. Adoption of drought-adapted crop and forage varieties as key components of production systems that minimize crop failures. Pilot testing of developed methodologies in at least three benchmark ecoregions: tropical lowlands, hillsides, and Andes. Implementation of a pilot project for trading C sequestered in soils and/or biomass. Studies to assess economic benefits of adopting drought-tolerant beans and pastures in LA. Study prepared on scenarios for potential C trading in improved pastures and no-tillage cropping systems. One BSc and two MSc theses submitted.	Maps available. Information transferred to policy makers. Field verification. Project reports. National average of yields in dry seasons. National GHG inventories. Pilot contract for C trading. Studies transferred to policy makers.	Active participation of germplasm development projects. Access to benchmark sites continued. Continued commitment of local partners to project activities. Successful involvement NARS partners for release of new varieties. Approval of the CDM Successful involvement of suitable partners experienced in C trading.

Summary Annual Report 2003

Project PE6: Confronting Global Climate Change

3.1 Researchers:

Marco Rondón, Biogeochemist, Project Manager, HQ (80%-PE6, 20%-Amazon Initiative)
Juan A. Ramírez, Research Assistant (100% PE6)
Myles Fisher, Ecophysiologyst, Consultant (5% PE6)

3.2 Partners:

Main collaborators in CIAT
Peter Jones, Climate Modeler, HQ (PE6, PE4)
Andrew Jarvis, Geographer, HQ (PE4, IPGRI)
Steve Beebe, Breeder, Geneticist HQ (IP1, SB2
Idupulapati Rao, Plant Nutritionist HQ (PE2, IP1, IP5)
Carlos Lascano, Animal Nutritionist HQ (IP5)
Edgar Amézquita, Soil Physicist (PE2)
Edmundo Barrios, Soil Ecologist, PE2
Cesar Martínez, Rice Breeder (IP4)
Rubén D. Estrada, Economist (CONDESAN)
Sam Fujisaka, Anthopologist, Consultant (PE4)

Main collaborators Outside CIAT.

National Programs:
CATIE-Costa Rica: Lucio Pedroni, Muhammed Ibrahim
CIPAV-Colombia: Eduardo Murgueitio, Maria Cristina Amézquita
CONDESAN-Colombia: Rubén Darío Estrada
Cornell University-USA: Johannes Lehmann, Erick CM. Fernandes, Carol M. Schwendener
CORPOICA-Colombia: Tito Diaz, Socorro Cajas, Salvador Rojas, Fernando García, Carlos Escobar
EMBRAPA-Brazil: Tatiana Sa, Adilson Serrao, Robert Boddey, Segundo Urquiaga, Elisa Wandelli
ESNACIFOR-Honduras: Samuel Rivera, Oscar Iván Ferreira
ETH-Zurich: Dieter Hess, Michael Kreuzer, A. Machmüller, R. Beuret, M. Lötscher
FAO-Honduras: Luis Welches
GTZ-Germany: Alonso Moreno
IPGRI-Colombia: Ramón Lastra
ILRI-Kenya: Philip Thornton
INPA-Manaus, Brazil: Flavio J. Luizão
JIRCAS-Japan: Osamu Ito, Gunthur Subbarao, Kensuke Okada, T. Ishikawa, K. Nakahara
Ministry of the Environment-Colombia: Juan Pablo Bonilla, Martha Castillo
UNA-Honduras: José Trinidad Reyes
Universidad de Córdoba-Colombia:
Universidad de Pereira-Colombia: L.M. Monsalve
Universidad del Amazonas-Colombia: Bertha Ramírez
Universidad Nacional de Colombia: Juan Carulla, Alvaro García, F.L. Valencia
University of Quebec-Canada: Marc Luccotte
USDA-USA: Christienne N. Pereira
Wageningen University-Netherlands: Peter Buurman

3.3 Financial resources 2003:

Project PE6: Confronting Global Climate Change

Source	Amount US$	Proportion (%)
Unrestricted Core	171,500	100%
Restricted Core	0	0%
Carry over from 2001	0	0%
Sub-total	**171,500**	**100%**
Special project	-	0%
Total Project	**171,500**	**100%**

3.4 Research Highlights

Output 1. Vulnerability and opportunity assessments of responses of eco-regions, populations, crops, and wild relatives of crops at risk from changing climates.

A paper published this year showing with a study of the potential scenarios for the effects of climate change on maize yields in Latin America and Africa received great attention in the international media. (ttp://www.nature.com/nsu/030512/030512-6.html)

1.1 Anticipated decrease in maize yields in Colombia: Peter G. Jones (PE-4) (CIAT)

This year, attempts were made to estimate yields of maize for Colombia under scenarios of expected climates as predicted by the MarkSim daily weather simulator. Ceres model was coupled to climate data. Results indicate that several zones in Colombia where today maize is grown will experience net decline in expected yields. Though some areas particularly in the mountains could become suitable for this crop, the fact that most of these areas are located in step slopes and relatively far from populated areas, will make them not practical use for this crop. Some areas were identified that will lose the appropriate climate for maize growing. Inter-Andean Valleys and the highland plateaus fall within this range. Overall, net yield losses are anticipated. Attempts were made to warn policy makers at the Ministry of Agriculture on possible consequences of this scenario.

1.2 Bean production at risk in Central America. Peter G. Jones (PE4), Steve Beebe (IP1)

Preliminary runs of the MarkSim for Central America show that more intense droughts could be expected (mainly Honduras and Nicaragua). This will likely result in net declines in expected production of this crop in Central America where it constitutes the basic staple food for at least 10 million people. Research has being initiated to be completed next year, to couple daily weather forecast with bean models to predict the expected performance of the bean production in CA.

Output 2. Germplasm and management systems adapted to changing climatic conditions and exacerbated incidence of pests and diseases.

2.1 Developing bean germplasm tolerant to drought.

Bean is one of the most important staple food and frequently the main source of proteins for millions of people in poor countries particularly in Central and South America, and Africa. Under anticipated scenarios of higher intensity and frequency of droughts, breeding for drought tolerance is an urgent need. In most regions where drought is a problem in the Americas, Bean Golden Yellow Mosaic Virus (BGYMV) is also a serious limitation. For the Central American region, small

red and small black seeded grain type is required. In Africa a more diverse range of grain types are acceptable, although BGYMV is not yet a problem. However, recessive resistance to BCMV is highly desirable.

2.1.1 Development and testing of lines and segregating populations combining drought tolerance and disease resistance in small red and small black grain types. S. Beebe, I.M. Rao, H. Terán, C.Cajiao, Miguel Grajales (IP-1); C. Quintero, J. Tohme, (SB-2)

Last year we reported on positive results with $F_{3:5}$ families that represented our first experience with combining drought tolerance with other traits. In the course of the past year we have advanced these populations through three more generations, to $F_{6:8}$ families that were again yield tested under drought conditions. Based upon results with F_2 populations in CIAT-Palmira in 2001, superior parental materials were identified and additional crosses were created with these parents. These were evaluated in F_2 for drought, in F_3 for anthracnose, and then as F_4 families in Santander de Quilichao under moderate fertility stress and ALS pressure. In 2003 they were returned to Palmira for a second drought evaluation. Additionally, crosses for carioca grain type were evaluated in F_4 generation for drought tolerance.

New populations were created to combine high mineral content with drought tolerance, low fertility tolerance, and disease resistance. F_2 populations were evaluated for the first time in the 2003 summer planting season.

Progress in drought tolerance was confirmed in F_8 families, under intermittent drought. The fact that these materials resist both terminal and intermittent drought gives us more confidence in the tolerance of these lines, and their potential performance over environments.

2.1.2 Screening drought tolerant bean lines in Eastern Africa. P. Kimani and S. Beebe (IP-1)

Drought is one of the most important constraints to bean production in East, Central and Southern Africa. Over 396,000 t of grain are lost annually in Africa due to drought which may occur early in the season, mid-season or late in the cropping season. As bean production in the region is predominantly rain fed. Crop failures are frequent. Growing drought tolerant bean cultivars is probably the most cost-effective strategy for smallholder, resource-poor farmers in drought prone environments. However, few drought tolerant cultivars are available in sub-Saharan Africa. CIAT has been screening bean cultivars for drought since 1983 as part of integrated genetic improvement of the common bean. Recently, an international drought nursery was constituted which included the most promising drought tolerant lines.

Thirty-six drought tolerant bean lines including two susceptible checks were evaluated at Thika, Kenya in 2001, 2002 and 2003. New drought tolerant lines show up to 42% yield improvement over local commercial cultivars under both stress and non-stress conditions in Eastern Africa.

2.1.3 Identification of traits associated with drought resistance. I.M. Rao, S. Beebe, J. Ricaurte, H. Terán and R. García (IP-1)

Last year we evaluated 36 promising bred lines for their adaptation to drought stress under field conditions. The results indicated that two accessions of *P. acutifolius* (G 40068 and G 40159) and one bred line (RAB 650) were outstanding in their adaptation to water stress conditions. The superior performance of these three genotypes under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N and P more efficiently for grain production. This year, using two separate field trials, we evaluated drought adaptation of 16 elite parents of RILs and 95 RILs of the cross BAT 881 × G 21212. Two field trials were conducted

at Palmira in 2002 (June to September) to determine differences in tolerance to water stress conditions. Field evaluation of 16 elite lines showed that a bred line (SEA 15) was outstanding in its adaptation to drought stress conditions. The superior performance of this bred line under drought stress in comparison with 15 other elite parents of recombinant inbred lines (RILs) was associated with lower seed ash (mineral) content indicating efficient utilization of acquired nutrients for grain production.

Among the 95 advanced lines of the cross BAT 881 × G 21212, three lines (BH 21134-9-1-1-M-M-M-M; BH 21134-154-1-1-M-M-M-M-M; BH 21134-97-1-1-M-M-M-M-M) were superior in their adaptation to drought stress conditions. The superior performance of these three lines was related to lower levels of seed ash (mineral) and seed P indicating the usefulness of these traits for selection for drought adaptation in common bean.

2.2 Identify genotypes of grasses and legumes with dry season tolerance

A major limitation to livestock productivity in subhumid regions of tropical America is quantity and quality of dry season feed. This limitation is exacerbating as a result of longer and more severe droughts worldwide.

2.2.1 Determination of the genotypic variation in dry season tolerance in *Brachiaria* accessions and genetic recombinants in the Llanos of Colombia. I.M. Rao, J.W. Miles, C. Plazas, J. Ricaurte and R. García (IP-5)

A field study is completed this year at Matazul Farm in the Llanos of Colombia. The main objective was to evaluate genotypic differences in dry season tolerance of most promising genetic recombinants of *Brachiaria*. Results from this field study for the past 2 years indicated that the superior performance of the germplasm accession CIAT 26110 and the *Brachiaria* hybrid, FM9503-S046-024, which maintained greater proportion of green leaves during moderate dry season in the llanos of Colombia, was associated with greater acquisition of nutrients under water deficit conditions. This year, we report results from the dry season performance into fourth year after establishment. The trial comprises 12 entries, including six natural accessions (four parents) and six genetic recombinants of *Brachiaria*.

Results from this field study indicated that the superior performance of one germplasm accession (CIAT 26110) and one genetic recombinant (FM9503-S046-024) which maintained greater proportion of green leaves during dry season in the Llanos of Colombia, was associated with greater acquisition of nutrients under water deficit conditions.

2.2.2 Dry season tolerance of most promising hybrids of *Brachiaria* in the Llanos of Colombia. I.M. Rao, J. Miles, C. Plazas, J. Ricaurte and R. García (IP-5)

Previous research on evaluation for dry season tolerance in *Brachiaria* grasses indicated that the superior performance of the *Brachiaria* hybrid, FM9503-S046-024, was associated with lower levels of K and N content in green leaves. The main objective of this field study was to evaluate dry season tolerance of the more recent hybrids of *Brachiaria* in comparison with their parents when grown with low nutrient supply in soil at Matazul farm of the Altillanura.

A field trial was established at Matazul farm including 4 *Brachiaria* hybrids (BR98NO/1251; BR99NO/4015; BR99NO/4132; FM9503-S046-024) along with 2 parents (*B. decumbens* CIAT 606 and *B. brizantha* CIAT 6294). The trial was managed with strong and frequent mob grazing at 2 months interval.

The highest value of forage yield was observed with the hybrid 4624. The parent CIAT 6294 was superior to other genotypes in terms of shoot biomass production with both low and high initial fertilizer application. The hybrid 4015 produced lower amounts of dead biomass and a greater proportion of aboveground biomass was in green leaves. Another hybrid, 4132 had markedly lower stem biomass compared with green leaf biomass.

The hybrid 4132 was also outstanding in its ability to acquire nutrients, particularly from low application of fertilizer. Results on nutrient uptake also showed that two other hybrids 1251 and 4624 were also superior in their ability to acquire nutrients. The dry season performance of the 4 hybrids will be monitored for the next 2 years in comparison with the two parents in terms of forage yield and nutrient acquisition.

Output 3. Crop, forage, water, and soil management strategies developed to minimize sources and/or increase sinks of greenhouse gases.

3.1 The biological phenomenon of nitrification inhibition in *Brachiaria humidicola* and other tropical grasses. Joint project with JIRCAS, Japan.

Last year, we showed the feasibility of using a bioassay with recombinant *Nitrosomonas europaea,* that detects nitrification inhibitory (NI) activity in plant root exudates. Using this bioassay we have shown that root exudates from *B. humidicola* inhibit nitrification. The inhibitory activity of the root exudates increased with the plant age mostly because of the increase in root mass. NI activity in root exudates declined as the plants reach the maturity stage.

This year we report research on methodology development, and comparative evaluation of other tropical grasses for the ability to inhibit nitrification. Other ongoing activities to be reported next year include: isolation of the active compound responsible for NI activity in *B. humidicola*, mechanisms underlying the inhibition of nitrification in root exudates, and factors that regulate the expression of NI activity.

3.1.1 Bioassay – Improvements and Refinements in the methodology. G.V. Subbarao, K. Nakahara, T. Ishikawa, K. Okada and O. Ito (JIRCAS, Japan)

This methodology has gone through improvements to get reliable and stable measurements in detecting inhibitory effect on nitrification from root exudates, tissue extracts and soil-water extracts. The *Nitrosomonas* culture age of 6 to 7 days is found to be the optimum stage for the bioassay measurements. The bioassay appears to be at its best in detecting the inhibitory activity at 15^{O}C.

3.1.2 Root exudates – Development of Sample processing and preparation protocols for the determination of NI activity using bioassay. G.V. Subbarao, K. Nakahara, T. Ishikawa, K. Okada and O. Ito (JIRCAS, Japan)

Before root exudates can be used for the determination of NI activity, they need to be concentrated about 50 to 100 fold. Contamination of chloride from the water used for collecting root exudates or soil-water extracts, interferes with the inhibitory activity measurements. To avoid chloride contamination, the sample is evaporated to dryness and then extracted with methanol (chloride is insoluble in methanol); the methanol extract is further evaporated to dryness and then re-dissolved in dimethyl sulfoxide. The NI activity from the root exudates or plant tissue extracts from *B. humidicola* can be completely recovered into the methanol extract. This sample preparation protocol is now a standard procedure.

3.1.3 Comparative evaluation of six species of tropical grasses for the ability to inhibit nitrification from acid soil. M. Rondón, I.M. Rao and C.E. Lascano (CIAT); G.V. Subbarao, K. Nakahara, T. Ishikawa, K. Okada and O. Ito (JIRCAS, Japan)

It has being previously shown that *B. humidicola* CIAT 679 inhibits nitrification of ammonium and reduces the emission of nitrous oxide into the atmosphere. There is a need to determine the extent of genetic variation among tropical grasses in their ability to inhibit nitrification. This information will be useful to develop screening methods to select genetic recombinants of *Brachiaria* grasses that not only are resistant to major biotic and abiotic constraints but also can protect the environment. A Study was conducted under greenhouse conditions, where grasses were grown on an Oxisol from Colombian savannas during seven months, and then harvested to collect root exudates. Results indicate that substantial levels of NI (Nitrification inhibitory) activity is present in the root exudates of other *Brachiaria* grasses (*dictyoneura*, *decumbens*, Mulato hybrid), in addition to *B. humidicola*. However, among *Brachiaria* grasses tested in this study, NI activity is substantially lower in *B. brizantha* cv. Marandú. It is interesting to note that a complete absence (below the detectable limit of the bioassay) of NI activity was found from the root exudates of *P. maximum*. This grass could be used as a negative control in subsequent studies. Addition of ammonium to the pots, clearly increases both total NI activity and specific NI activity per unit of root length or root biomass.

3.1.4 Development of an incubation protocol to assess nitrification inhibition by addition of root exudates to soils. M. Rondón, I.M. Rao and C. E. Lascano (CIAT); G.V. Subbarao, K. Nakahara, T. Ishikawa, K. Okada and O. Ito (JIRCAS, Japan)

Once the NI activity of root exudates has being confirmed by the bioassay, the next step is to assess the effect of application of root exudates directly to soil. Small amounts of root exudates and soil need to be used, given the difficulties and costs involved in generating and concentrating root exudates.

As an outcome of a recent scientific internship of M. Rondón at JIRCAS laboratories, a simple incubation methodology was developed and tested to quantify the effect of application of root exudates to soils on nitrate and ammonium levels and on fluxes of nitrous oxide. Plastic syringes are used both as incubation vials and as gas collection chambers. Ten grams of air dried soil are used. The method facilitates the maintenance of stable soil moisture content at levels of 50-60% of water filled pore space (WFPS), which is considered optimum for nitrification in most soils. Temperature is kept constant in an incubation chamber. Additional syringes are used for sequential measurements of inorganic nitrogen in the soil. The method provides good reproducibility and low standard errors, which is particularly important for gas flux measurements which inherently are highly variable.

3.1.5 Effect of application of root exudates on inorganic nitrogen and fluxes of nitrous oxides from incubated soils. M. Rondón, I.M. Rao and C. E. Lascano (CIAT); G.V. Subbarao, K. Nakahara, T. Ishikawa, K. Okada and O. Ito (JIRCAS, Japan)

The incubation protocol was used to study the effect of application of root exudates from soybean (no NI activity with the bioassay) and *B. humidicola* at two concentration doses (low and high) on fluxes of N_2O and inorganic nitrogen from incubated soils. Root exudates were obtained from intact plants grown in solution media. A fertile Andisol from Japan was used.

Data from accumulated net fluxes of nitrous oxide for a period of 24 days indicate that the addition of exudates from soybean result in significantly higher net fluxes during the incubation period. Whether these fluxes are resulting from enhanced nitrification or denitrification needs to be clarified in further studies. No appreciable reduction in fluxes of N_2O appear to occur as a

consequence of the addition of root exudates from *B. humidicola* at low concentration, suggesting that the added dose of the active compound was probably not high enough to interact with all the population of nitrifying bacteria in the soil. In contrast to this, the addition of exudates of *B. humidicola* at high concentration resulted in a net decrease of around 45% of total emissions of N_2O relative to the control treatment.

Research is in progress to assess the effect of application of various root exudates into soils of contrasting chemical and physical characteristics including Oxisols from Colombian savannas and Inceptisols from Andean hillsides.

3.2 Silvopastoral multistrata systems to improve cattle productivity and reduce GHG emissions. Socorro Cajas (CORPOICA), Marco Rondón, Juan Andrés Ramírez, CIAT (PE-6). Edgar Amézquita, Mariela Rivera, CIAT (PE-2).

The savannas in the Caribbean region of Northern Colombia have been traditionally used for cattle ranching, being the second cattle producing area in the country. Productivity in these savannas is limited by lack of forage during the three months of severe dry season. As an attempt to improve availability of forage during the dry season, a 30 hectares multistrata silvopastoral experimental system, with varying proportion of tree components, was established by CORPOICA in Macagual, Cordoba in mid-1998. The systems have been continuously evaluated and resulted in net increases in the carrying capacity of the land from 2 to 4 heads of cattle per hectare. Economic analysis indicate that the cost of establishing and maintaining the systems could be recovered in three years. This year we started research to establish the baseline of carbon stocks and emissions of GHG for some of the plots in the multistrata systems. Carbon stocks were measured in soils and standing biomass and fluxes of methane and nitrous oxide were monitored biweekly using static vented gas chambers.

Biomass carbon in the control, grass only pasture (*Dichanthium aristatum*) accounts for 5 ton C/ha. As the number of trees increase in the system, total stocks of Carbon in the biomass pool increase accordingly. The most complex system including *Dichanthium aristatum* in association with grazed forage shrubs (*Leucaena leucocephala, Gliricidia sepium, Crescentia cujete, 469* planted at srhubs/ha), arboreal species (*Albizia saman, Guazuma ulmifolia, Cassia grandis,* at 169 trees/ha*)* and timber species (*Pachira quinata, Swietenia, macrophylla, Tabebuia rosea,* at 39 trees/ha*)* accumulate 25 ton C/ha in a four year period. Carbon stocks in these heavy textured soils is naturally high. In the top 60 cm the control pasture stocks 146 ton C/ha. Net carbon accrual in soils under silvopastoral systems is much smaller than in the biomass, accounting for around 1 ton c/ha-y.

The presence of shrubs/trees clearly influences net balances of GHG in the plots. At the peak of the dry season, all soils are net sinks for methane, but with the onset of the rainfall, due to low surface hydraulic conductivity, the soils easily become anaerobic turning the soils as modest net methane sources. The grass-shrub system consistently showed higher emissions of methane equivalent to 2 kg CH4/ha-y. Fluxes of nitrous oxide are relatively high as compared to other tropical systems. The grass-shrub system emitted 25 kg N_2O/ha-y compared to 15 kg N_2O/ha-y for the control.

Integrated Global Warming Potential indicate that overall, due to high carbon accumulation in biomass, the most complex silvopastoral system results in a net annual sink for GHG, while the control and shrub-based systems are net small sources. Research is in progress to extend current seven months of data into a complete annual data set.

3.3 The use of charcoal in soils: Agronomic and environmental implications

Charcoal is an ubiquitous material that has being used in agriculture by almost every culture in the planet. Increasing evidence indicates that in very low fertility soils like in savannas from South America and the Amazon, additions of charcoal could increase plant yield and improve several soil quality indicators. Charcoal is a very stable material in soils, with residence times in the order of thousands of years contrasting with mean residence times of decades to centuries for most SOM pools. This provides the possibility to use charcoal as a suitable option for long-term storage of C in soils.

3.3.1 Effect of charcoal application on crop/forage yields and on fluxes of greenhouse gases under glasshouse conditions. M. Rondón, J.A. Ramírez CIAT (PE-6)

A glasshouse pot experiment was conducted to assess the effect of increasing doses of charcoal addition to soils as reflected on plant yield, soil nutrients and fluxes of methane and nitrous oxide. A low fertility Oxisol from Matazul in Colombia was used. *B. humidicola* and soybean were grown for 45 days. Biomass production of *B. humidicola* was not affected by additions of charcoal, but dry biomass and grain yields of soybean were positively affected by the additions of charcoal reaching maximum values (net increase of 15% in dry biomass and on 20% increase in grain yield compared to the zero charcoal control), at doses of 20 g of charcoal/kg soil. Beyond this level, no additional yield increases were observed.

Influence of charcoal was also noted in the levels of various soil nutrients after harvest: Available phosphorous increased 50% in the high dose application (30 g charcoal/kg soil) relative to the non charcoal control, while for both available K and available Ca, a linear increase with increasing doses of charcoal was observed, reaching a five fold increase with the high charcoal dose. Increases in available Mg were also found but to a lesser degree. Most of these changes are attributable to increases in soil pH found with even modest additions of charcoal to acid soils.

Fluxes of methane and nitrous oxide were significantly reduced by increased additions of charcoal. Reductions were more accentuated in the pots with *B. humidicola*. Qualitative observations at harvesting time indicate that the number of nodules on the roots of soybean were increased by additions of charcoal. Another experiment is in progress using ^{15}N methodology, to specifically address the effect of charcoal additions on biological nitrogen fixation by common beans.

3.3.2 Charcoal as amendment for high fertility trenches. M. Rondón, J.A. Ramírez CIAT (PE-6) and E. Amézquita CIAT (PE-2); J. Lehmann, Cornell University.

Soil fertility is perhaps the most prevalent constraint preventing small-scale farmers to improve their agricultural productivity and livelihoods. Worldwide, farmers try to improve pockets of soils to grow their most profitable cash crops: vegetables, fruits medicinal plants, etc. Improving all the land of a farm is often inaccessible to farmers and requires long-term commitments. There is however a possibility of progressively improve patches of the land which could be expanded as more resources could be invested. One alternative is to create high fertility trenches where the soil fertility could be improved in belts of the minimum width and depth to allow good development of the crops of interest to the farmer, typically vegetable crops. Charcoal additions could be used as an additional mechanism to improve some soil quality characteristics (reduce bulk density, enhance porosity, water retention and improve soil drainage) in such high fertility trenches.

A field experiment was initiated this year to establish high fertility trenches on a steep slope farm on a low fertility Andisol in Cauca Colombia. The effects of charcoal additions on plant yield (vegetable crops) and soil quality are being studied. Additionally, the effects of charcoal on C

dynamics and fluxes of GHG are being evaluated. Preliminary results indicate that sinks of methane are reduced approximately 30% by the addition of doses of 1.5 kg charcoal/m trench during the first two months of evaluation. Nitrous oxide fluxes are relatively high in the trenches as a result of the high levels of fertilization applied. The trenches that additionally received charcoal show net decreases of around 50% in accumulated fluxes of Nitrous oxide. These results indicate that charcoal modifies the nutrient dynamics in soils. Studies are still in progress for this experiment.

3.4 Soil mineral N dynamics beneath mixtures of leaves from legume and fruit trees in Central Amazonian multi-strata agroforests. Carol M. Schwendener, Johannes Lehmann (Cornell University), Marco Rondón (CIAT), Elisa V. Wandelli (Embrapa), and Erick C.M. Fernandes (Cornell University).

Long-term applications of leguminous green mulch could increase mineralizable nitrogen (N) beneath cupuaçu trees produced on the infertile acidic Ultisols and Oxisols of the Amazon Basin. However, low quality standing cupuaçu litter could interfere with green mulch N release and soil N mineralization. This study compared mineral N, total N, and microbial biomass N beneath cupuaçu trees grown in two different agroforestry systems, north of Manaus, Brazil, following seven years of different green mulch application rates. To test for net interactions between green mulch and cupuaçu litter, dried gliricidia and inga leaves were mixed with senescent cupuaçu leaves, surface applied to an Oxisol soil, and incubated in a greenhouse for 162 days. Leaf decomposition, N release and soil N mineralization were periodically measured in the mixed species litter treatments and compared to single species applications. The effect of legume biomass and cupuaçu litter on soil mineral N was additive implying that recommendations for green mulch applications to cupuaçu trees can be based on N dynamics of individual green mulch species. Results demonstrated that residue quality, not quantity, was the dominant factor affecting the rate of N release from leaves and soil N mineralization in a controlled environment. In the field, complex N cycling and other factors, including soil fauna, roots, and microclimatic effects, had a stronger influence on available soil N than residue quality.

3.5 Agroforestry trees increase phosphorous availability in an oxisol of the Brazilian humid tropics. Christienne N. Pereira (US Department of Agriculture), Erick C.M. Fernandes and Johannes Lehmann (Cornell University), Marco Rondon (CIAT), Flavio J. Luizão (INPA).

We investigated the effect of land-use, i.e., agroforestry systems (AGR), pasture (PAS), and secondary forest (SEC), and specific agroforestry tree species, i.e., áraça-boi (*Eugenia stipitata*), Brazil nut (*Bertholletia excelsa*), cupuaçu (*Theobroma grandiflorum*), and pupunha (*Bactris gasipaes*), on P availability of acid upland soils of the central Amazon basin.

The land-use systems were established in 1991 and underwent different management regimes, with low-input fertilization in AGR and PAS, and no fertilization in SEC. A modified sequential P extraction was used to determine P availability, and total N and other nutrients were also measured. Pupunha increased resin P and Brazil nut increased bicarbonate organic P. Fertilization increased the hydroxide organic P. Áraça-boi increased hydroxide organic P. Pupunha and Brazil nut increased soil available P (sum of available Hedley fractions – AP) and fertilization increased moderately available P (sum of moderately available Hedley fractions – MAP). This suggests the use of pupunha and Brazil nut in agroforestry systems with moderate fertilization better maintain AP and MAP in soils of the central Brazilian Amazon than other tree species and land-use systems studied.

3.6 Assessment of the potential of tannins in legumes and saponins in tropical fruits to reduce methane in ruminants

It has been shown that net methane emissions by ruminants could be effectively reduced by improving the quality of the diet. Considerable progress was made at CIAT in studying the potential of saponin-rich fruits to reduce methane emission from rumen fermentation and enhance N utilization by sheep. This year it was confirmed that the inclusion of tannin-rich legumes such as *Calliandra calothyrsus* and *Flemingia macrophylla* in forage-based diets significantly reduces methane release and also inhibits nutrient degradation and N turnover.

3.6.1 In vivo evaluation of *Sapindus saponaria* and legumes as supplement on rumen fermentation and N utilization by sheep fed a low quality grass. H.D. Hess, M. Kreuzer, A. Machmüller, R. Beuret, M. Lötscher (U of Zurich); C.E. Lascano (CIAT)

Previous *in vitro* experiments showed that the inclusion of fruits of *Sapindus saponaria* into tropical diets may suppress methane release by over 10% and that supplementation with leaves from the shrub legume *Cratylia argentea* increased methane release by 300%. A respiratory chamber experiment was conducted to obtain missing information on the effect of these tropical forage resources on methane release *in vivo*. Three basal diets with contrasting forage quality were included. Results indicate that the dietary proportion of *S. saponaria* tested in this experiment did not affect the health status of sheep. Daily methane release per kg of body weight was reduced by 9% on average by *S. saponaria* supplementation and was not affected by dietary legume proportion. Legume supplementation represents an environmentally friendly way to increase animal performance of tropical livestock, since it was shown to improve N retention and to reduce methane release relative to body protein retention.

3.6.2 Effect of legumes with contrasting tannin content and their mixtures on *in vitro* rumen fermentation parameters and methane emision. F.L. Valencia (National University of Palmira), L.M. Monsalve (University of Pereira), H.D. Hess (ETH Zurich), C.E. Lascano (CIAT), M. Kreuzer (ETH Zurich)

A previous in vitro experiment (annual report 2002) had shown that the supplementation of a low-quality grass diet (*Brachiaria dictyoneura*) with *Cratylia argentea* drastically increased organic matter degradation, N turnover and methane release per unit of organic matter degraded, whereas the partial replacement of *B. dictyoneura* by *Calliandra calothyrsus* significantly reduced organic matter degradation, N turnover and methane release. Thus it was hypothesised that, to take advantage of the methane suppressing effect of *C. calothyrsus* without affecting nutrient degradation and N turnover, it was necessary to combine tannin-rich legumes with legumes free of or low in tannins. To test this hypothesis Rusitec-experiments were performed.

Main results show that apparent organic matter degradation was twice as high in the diet of *C. argentea* alone (35.5%) as in the diet with *C. calothyrsus* alone (17.4%). Daily methane release increased linearly from 0.16 to 3.53 mmol/d when the proportion of *C. argentea* increased from 0 to 100%. When 25 or 50% of *C. calothyrsus* were replaced by *C. argentea* no changes occurred in apparent crude protein degradation and only minor changes were observed in ruminal N turnover.

In general our results suggest that even though *C. calothyrsus* and *F. macrophylla* have similar chemical compositions and tannin contents, the nutritional value of *F. macrophylla* is higher than that of *C. calothyrsus* when these species are used in combination with a good-quality legume, but that is less effective in suppressing methane emission than *C. calothyrsus*.

3.6.3 Effect of supplementing low quality grasses with legumes and soluble carbohydrates on in vitro rumen fermentation parameters and methane production. F.L. Valencia (National University of Palmira), L.M. Monsalve (University of Pereira), H.D. Hess (ETH Zurich), C.E. Lascano (CIAT), M. Kreuzer (ETH Zurich)

In this *in vitro* experiment a grass-alone and three legume supplemented (50% of DM) diets were evaluated (*C. calothyrsus*, *C. argentea* or a 1:1 mixture of both legumes). All four basal diets were evaluated with and without the addition of sugarcane molasses (10% of DM).

When the low-quality grass diet was supplemented with the mixture of *C. calothyrsus* and *C. argentea*, daily methane release was increased by 30% but methane release relative to organic matter degraded remained unaffected. On average among all diets, molasses addition increased organic matter degradation and methane release and reduced fiber degradation. Results of this experiment confirmed the methane suppressing potential of the tannin-rich *Calliandra calothyrsus* and suggest that supplementing mixtures of legumes with high and low contents of condensed tannins could be a useful alternative to improve nutrient supply and ruminal organic matter degradation avoiding the dramatic increase in methane release typically observed when low-tannin legumes are supplemented alone. Additionally, results indicate that supplementation with molasses could be an alternative to partially reduce the negative nutritional effects of feeding legumes with high concentrations of condensed tannins as it enhances N turnover.

3.7 Other activities developed by project staff

The Amazon Initiative (AI). Since 2002, CIAT in collaboration with EMBRAPA, CORPOICA other research Institutions from Amazonian countries and CIFOR, ICRAF and IPGRI and various advanced research institutions, has promoted the conformation of the Amazon Consortium. The main goal of the consortium is to undertake research to analyze current policies that affect land use changes and thus to develop, and introduce sustainable land use systems, practices and policies for the Amazon which would reduce or reverse present resource degradation and environmental damage while creating attractive opportunities for the rural poor.

In 2002, and early in 2003 M. Rondón, was responsible for coordinating CIAT contribution for the Amazon Initiative. During that time, major efforts were dedicated to approach member institutions and get consensus among them, regarding priorities and mechanisms of operation. A Concept note document has being prepared for the project, main thematic areas have been identified as well as partners in each country.

During this year, staff from PE6 was actively involved in the selection and appointing of a joint CIAF-ICRAF natural resource economist based in Belem, Brazil, who was appointed in June and is now coordinating the initiative. Efforts are now targeted at approaching donors to seek funds for the proposed activities. The new Land Degradation Program from GEF is seen as the most promising potential donor. In the meeting of the steering committee next month in Bogotá, a concrete fund raising strategy will be delineated.

3.8 Problems encountered and their solutions

The main obstacle we encountered this year to increase activities in the project, was limited access to funding. The fact that the Climate change challenge program failed to get approval from the GCIAR science council, closed an important channel through which several project activities were expected to seek funding. In search for solutions, project proposals were prepared and submitted to different donor agencies, to try to capitalize some funds especially in the topic of Nitrification Inhibition. Unfortunately, a joint proposal submitted with JIRCAS to the water challenge program

and to RITE in Japan failed to get through. It was also not endorsed by CIAT selection committee to be submitted to BMZ. Components of the farming future proposal were submitted to the Water challenge program but failed to get approved in the final cut. Some funds were however secured for next year from a collaborative project with CONDESAN funded by GTZ to explore the suitability of using resources coming from environmental externalities to enhance rural livelihoods in the Andean communities. Some additional funds may come for that activity if the CONDESAN proposal get final approval by the Water CP later this year. The project participated in the preparation of the successful Quesungual proposal for the Water CP. Some funds will be available for the project to initiate activities in 2004.

The long delays in the ratification process for the Kyoto protocol has negatively affected the development of intended projects in the agroforestry systems to be targeted to CDM funds. The process is now on standby, but some indications of the future possibilities will be known after the COP 9 meetings towards the end of this year. In case the international agreements would allow that, projects will be prepared in collaboration with the Colombian Ministry of Environment, Corpoica and private associations.

Given the reduced budget in the project, there is little staff time directly associated to the project. The solution given to this has being to develop collaborative activities within and outside CIAT. Several researchers at CIAT have collaborated for advancing activities related to CC this year. Several partnerships have being developed and strengthened in Colombia and other countries in Latin America to advance the research program.

Limited availability of specialized equipment for measurements of special gases and to characterize charcoal has being also a constraint. To deal with these limitations, agreements were made with the Charcoal Laboratory of the National University in Bogotá and with the advanced NMR facility at Cornell University for collaborative activities. Some funds of capital were received to purchase equipment to measure nitric oxide, a soil released gas which is important in atmospheric chemistry.

3.9 Proposed plans for next year

Major efforts will be dedicated next year to seek funding and to develop collaborative activities with other partners in Latin America and Africa. The proposal for the Nitrification Inhibition work will be submitted jointly with JIRCAS next year to the Japanese Ministry of Environment in Japan for funding. A proposal will be prepared in relation with adaptation of farmers to anticipated negative impact of climate change to food security in the most vulnerable regions in Africa and Central America.

Research activities will be continued to understand the mechanisms responsible for nitrification inhibition activity of root exudates. If funds are secured, activities will move into the field.

Activities will be started in relation with the Quesungual Proposal for Central America and the GTZ Condesan project for the Andes. Staff from the CC project has being invited to participate in a workshop on adaptation to CC to be held at CATIE in March. The workshop is sponsored by the Swiss Organization for Development and Cooperation and it is expected that outcomes from that event could result in formulation of joint projects.

Ongoing activities will be continued with Cornell University for understanding the interaction of charcoal with soils. Research will be conducted to produce and characterize charcoal from selected species and to study their interaction with soils of contrasting characteristics.

Time will be allocated to write and publish manuscripts from the research conducted this year.

4. Project Performance Indicators

Technologies, Methods, Tools:

- **Forage and crop cultivars released:** The *Brachiaria* hybrid Mulato, developed by the IP5 project, which in addition to be a fast grower and having high forage quality is also very tolerant to drought, was released commercially by a seed Company (Semillano) in the Llanos and the Caribbean cost of Colombia.

- **Advanced lines of drought tolerant beans developed**: Field evaluation done by the IP1 project of 16 elite lines showed that a bred line (SEA 15) was outstanding in its adaptation to drought stress conditions. The superior performance of this bred line is the result of efficient utilization of acquired nutrients for grain production.

- **Elite *Brachiaria* hybrids developed:** Field evaluation (IP5) of the most promising *Brachiaria* hybrids and accessions over 3 years in the Llanos of Colombia indicated that a germplasm accession *B. brizantha* CIAT 26110 (cv Toledo) and one *Brachiaria* hybrid FM9503, were superior in their adaptation to acid soil conditions and drought due to greater acquisition of nutrients from infertile soil conditions.

Methodologies:

- The bioassay for quantifying nitrification inhibition activity was further refined and standardized. Optimum age culture and temperature conditions were defined. Effect of plant age on the release of active NI compounds was established for *B. humidicola.*

- A fast, simple and inexpensive methodology was developed and tested to study the effect of addition of root exudates to incubated soils and monitoring of inorganic nitrogen and emissions of nitrous oxide.

- A protocol was established to characterize charcoal produced from individual plant species in relation with properties that could affect interaction with soil particles.

Data bases, maps and web pages:

- Field data was collected which will significantly improve current inventories of GHG emissions at the national levels in areas such as methane emissions by rice and sugarcane sectors in Colombia.

- Maps of expected effects of climate change on yields of maize for Colombia were developed.

- The climate change web site is at an advanced internal trial period before being officially launched later this year.

Publications: (full list in the annex)

- Referred journal papers: 10
- Published: 6
- Accepted: 4
- Conference and Workshop proceedings: 2
- Non-refereed presentations: 7
- Refereed book chapters: 3

Strengthening NARs

Training Courses:
Curso Internacional de Agroclimatología Tropical. CORPOICA, July 5-10, 2003, Bogotá, Colombia. Atended by 35 participants from CORPOICA, CENICAFE, CENICAÑA and Universities in Colombia.

Encuentro Regional de ONG Ambientalistas del Valle del Cauca. Cali, Colombia, August 22, 2003. Attended by 50 participants from a wide range of NGOs from Valle, Cauca and Nariño Departments in Colombia.

Taller Nacional de la Sociedad Colombiana de Ingeniería (ACIEM) sobre el mecanismo de desarrollo limpio (DML) del protocolo de Kyoto. Cali, May 10, 2003. Atended by 100 participants from the private sector and Universities from Colombia.

Practical training course for Corpoica staff from the Regional-8 to monitor Carbon stocks in soils and biomass on forestry and agroforestry systems in the Colombian Llanos. Bogotá, June, 2003. Two Staff trained.

Thesis

Undergraduate Thesis.
Angela Muñoz. Balances de Carbono y gases de efecto invernadero en un sistema intensivo de producción de ganado de leche en la Hacienda Pasoancho (Valle, Colombia). Universidad Nacional de Colombia, Palmira. In progress.

Enna Díaz and Liliana Patricia Paz. Evaluación del regimen de humedad del suelo bajo diferentes usos en los Páramos "Las Animas y Piedra de León", Departamento del Cauca. Universidad del Cauca., Popayán, Completed.

Mera Monica Lorena. Efecto de reducción de taninos en leguminosas forrajeras tropicales en producción de metano en un sistema de fermentación *in vitro*. Universidad Nacional de Colombia, Palmira. In progress.

Monsalve, Lina M. Suplementación de una gramínea tropical con leguminosas y *Sapindus saponaria*: efecto sobre fermentación ruminal y metanogénesis *in vitro*. Universidad de Santa Rosa de Cabal. Pereira, Colombia. In progress.

MS thesis.
Abreu S. Andrés. 2003. Utilización del fruto de *Sapindus saponaria* como fuente de saponinas para reducir la metanogénesis y mejorar la utilización del alimento en rumiantes con dietas tropicales. Universidad Nacional de Colombia. Bogotá. Completed.

Valencia Francis Liliana. Determinación del efecto de la calidad de la dieta en relación con la presencia de taninos y emisiones de metano en un sistema *in vitro*. Universidad Nacional de Colombia. In preparation.

Workshops/ Conferences/Meetings (atended by at least one staff of the project):

Annual Meeting of the Japanese Soil Science and Plant Nutrition Societies, August 21-24, 2003 at Yokohama, Japan.

Eighth Conference of the Parties to the UN Framework Convention on Climate Change in New Delhi, India, October, 2002. Made a poster presentation in conjunction with UNEP, explaining the work of the CGIAR on Climate Change, including distribution of a two-page summary of the Challenge Program Pre-proposal. Made a presentation of Climate Change in the CGIAR at a side-event meeting chaired by Dr Klaus Topfer, UNEP Executive Director.

Third International Coordination Meeting of 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,* at CATIE, Costa Rica, December, 2002. Presented a summary of activities on Climate Change in the CGIAR.

Fourth International Coordination Meeting of 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,* at CIAT.

Curso Internacional de Agroclimatología Tropical. Corpoica, June 5-10, 2003, Bogotá, Colombia.

International workshop on no-tillage agriculture on tropical lowlands. Bogotá, Procitropicos, June 10, 2003.

Taller Nacional de la Sociedad Colombiana de Ingeniería (ACIEM) sobre el mecanismo de desarrollo limpio (DML) del protocolo de Kyoto. Cali, May 10, 2003.

Encuentro Regional de ONG Ambientalistas del Valle del Cauca. Cali, Colombia, August 22, 2003.

Partnerships with NARS, Universities, NGO's and Producer associations

Environmental services of silvopastoral systems in the Carribean Region, Colombia. Corpoica, Universidad de Córdoba, Asociación Nacional de Ganaderos.

The role of a prototype intensive cattle production systems in net balances of greenhouse gases in Valle, Colombia. Universidad Nacional, Palmira, Hacienda Pasoancho.

Production and chemical characterization of charcoal generated from selected tree species. Universidad Nacional de Colombia, Bogotá.

Carbon storage on pastures in different agroecosystems. CIPAV, CATIE, Universidad del Amazonas.

Quesungual slash and mulch agroforestry system. MIS consortium, Universidad Nacional de Honduras, ESNACIFOR Honduras, FAO.

Environmental externalities to promote sustainable development of rural communities in the Andes. CONDESAN, Universidad de Caldas, CENICAFE, Universidad Nacional, Bogotá, GTZ,

Partnerships with ARO's

Cornell University: Interaction of charcoal with soils

ETH, Zurich, Switzerland: Effect of saponin-rich fruits on methane emissions by ruminants.

GTZ, Germany: Environmental externalities to promote sustainable development of rural communities in the Andes.

ILRI, Nairobi, Kenya: Modelling of expected effects of climate change on yields of main food crops.

JIRCAS, Japan: Nitrification Inhibition by tropical grasses

Wageningen University, The Netherlands and CATIE, Costa Rica: Carbon storage on pastures in different agroecosystems.

Resource Mobilization:

Proposals being funded or approved:
Unravelling the mysteries of the Quesungual slash and much agroforestry system. 3-year project (2004-2006) grant from the CGIAR Water Challenge Program. Led by PE2 in collaboration with PE6, MIS Consortium, Universidad Nacional de Honduras, ESNACIFOR-Honduras, FAO.
Total pledge: US$ 650.000

Bean genomics for improved drought tolerance in Latin America. 3-year project (2003-2006) approved to CIAT bean project, funded by BMZ-GTZ, Bonn, Germany.
Total pledge: 740,000 (Euros)

Environmental externalities to promote sustainable development of rural communities in the Andes. 5-year project funded by GTZ Germany to CONDESAN in collaboration with a large number of partner Institutions in Colombia, Ecuador, Peru, Venezuela and Bolivia.

The forage potential of tanniniferous legumes: 3-year project funded by SDC – ZIL Switzerland to IP5 in collaboration with ETH, ILRI, and Universidad Nacional de Colombia.
Total pledge: US$ 221,000.

Proposals Submitted
Nitrification Inhibition by tropical grasses as tools to improve nitrogen use efficiency and reduce nitrous oxide emissions. Submitted to the Water Challenge program and to the New energy and Industrial technology development Organization (NEDO, Japan). Proposal were not approved.

Farming Futures: Submitted to the Water Challenge program. Proposal was not approved.

Annex

List of Publications

Refereed journal articles:

Carol M. Schwendener, Johannes Lehmann, Marco Rondón, Elisa V. Wandelli and Erick C.M. Fernandes. Soil mineral N dynamics beneath mixtures of leaves from legume and fruit trees in Central Amazonian multi-strata agroforests. *Acta Amazonica.* Special LBA Issue. In press.

Christienne N. Pereira, Erick C.M. Fernandes, Johannes Lehmann, Marco Rondón, Flavio J. Luizão. Agroforestry trees increase phosphorus availability in an Oxisol of the Brazilian Humid Tropics. *Acta Amazonica.* Special LBA Issue. In press.

Cajas-Girón YS and Sinclair FL (2001) Characterisation of multistrata silvopastoral systems on seasonally dry pasture in the Caribbean region of Colombia. *Agroforestry Systems* 53:215-225.

Feldpausch, Ted, M. Rondón, E. Fernández, S. Riha, E. Wandelli, 2003. Carbon and nutrient accumulation in secondary forest regenerating from degraded pastures in Central Amazonia. *J. Ecol. Applic.*

Fisher, M.J. and Thomas, R.J. (2003). Case studies of land use changes in the central lowlands of tropical South America. *Environment, Development and Sustainability* (in press).

Hess D., Kreuser M., Diat T., Lascano C., Carulla J., Soliva C. Machmuller A. (2003) Saponin rich tropical fruits affect fermentation and methanogenesis in faunated and defaunated rumen fluid. *Animal Feed Science and technology* 109:79-94.

Hess D., Monsalve L., Lascano C., Carulla J., Diaz T., Kreuzer M. (2003) Supplementation of a tropical grass diet with forage legumes and *Sapindus saponaria* fruits: efeccts of *in vitro* ruminal nitrogen turnover and methanogenesis. *Australian Journal of Agricultural Research* 54: 703-713.

Ishikawa T., G.V. Subbarao, O. Ito, and K. Okada. 2003. Suppression of nitrification and nitrous oxide emission from soil by a tropical grass, *Brachiaria humidicola. Plant and Soil* (in press).

Jarvis A., A. Ferguson. D. Williams, L. Guarino, P. Jones, T. Stalker, J. Valls, T. Pittman, C. Simpson, P. Bramel. (2003). Biogeography of wild *Arachi:* Assessing conservation status and setting future priorities. *Crop Sci.* 43:1100-1108.

Jones, P.G. and P.K. Thornton (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global Environmental Change* 13: 51-59.

Refereed book chapters:

Rao, I. and G. Cramer. 2003. Plant nutrition and crop improvement in adverse soil conditions. In: M. Chrispeels and D. Sadava (eds). *Plants, Genes, and Crop Biotechnology.* Published in partnership with the American Society of Plant Biologists and ASPB Education Foundation. Jones and Bartlett Publishers, Sudbury, Massachusetts, USA, pp 270-303.

Rychter, A.M. and I.M. Rao. 2003. Role of phosphorus in photosynthetic carbon metabolism. In: M. Pessarakli (ed). Handbook of Photosynthesis. 2nd Edition. Marcel Dekker, Inc., New York (in press).

R.J. Thomas, M. Rondón, E. Amézquita, D.K. Friessen. Overcoming Soil Constraints in Latin American Savannas: New Approaches and Potential Trade-offs. In: Agropastoral Systems for Tropical Savannas in Latin America: E. Guimaraes; J.I. Sanz; I.M. Rao; M.C. Amézquita, E. Amézquita (Editors). CIAT, in press.

Conference proceedings:

Amede, T., E. Amézquita, J. Ashby, M. Ayarza, E. Barrios, A. Bationo, S. Beebe, A. Bellotti, M.Blair, R. Delve, S. Fujisaka, R. Howeler, N. Johnson, S. Kaaria, S. Kelemu, P. Kerridge, R. Kirkby, C. Lascano, R. Lefroy, G. Mahuku, H. Murwira, T. Obertur, D. Pachico, M. Peters, J. Ramisch, I.M. Rao, M. Rondón, P. Sanginga, M. Swift and B. Vanlauwe. 2002. Biological nitrogen fixation: A key input to integrated soil fertility management in the tropics. Position paper by CIAT-TSBF Working Group on BNF-CP for " International Workshop on Biological Nitrogen Fixation for Increased Crop Productivity, Enhanced Human Health and Sustained Soil Fertility". ENSA-INRA, Montpellier, France (10-14 June, 2002).

Hess D., Monsalve L., Lascano C., Carulla J., Diaz T., Kreuzer M. (2003) Potential of forage legumes and of saponin containing fruits as tropical feed resources to manipulate rumen fermentation and to improve ruminant nutrition. The Sixth International Symposium on the Nutrition of Hervibores, October 17–24, 2003. Yucatán, México.

Subbarao G.V., Nakahara K., Ishikawa T., Ito O., and Okada K. 2003. The Biological Phenomenon of Nitrification Inhibition in *Brachiaria humidicola* – Possible Mechanisms and Active Compounds. Soil Science and Plant Nutrition Annual Meeting, Vol. 59, Abstract No.9-58; August, 2003 at Yokohama, Japan.

Ishikawa T., Subbarao G.V., Okada K, Ito O. 2003. Nitrogen status and plant growth stage influence nitrification inhibitory activity of root exudates in *Brachiaria humidicola*. Soil Science and Plant Nutrition Annual Meeting, Vol. 59, Abstract No. 9-57; August 2003 at Yokohama, Japan.

Non-refereed conference presentations:

Beebe S., I.M. Rao, H. Terán and C. Cajiao. 2003. Breeding concepts and approaches in food legumes: The example of common bean. Invited paper presented at the "Second National Workshop on Food and Forage Legumes". Addis Ababa, Ethiopia. 22-27 September, 2003 (in press).

Beebe S., Rao I.M., Terán H., Cajiao C., Ricaurte J., and Beltrán J. 2003. Progreso en Aumentar Tolerancia a Estrés Abiótico en Frijol Común. Paper presented in the XLIX Meeting of the PCCMCA, Programa Cooperativo Centroamericano de Mejoramiento de Cultivos y Animales. La Ceiba, Honduras.April 27-May 3, 2003.

Fisher, M. Case studies of land use changes in the central lowlands of tropical South America. Internal CIAT Seminar, October 2003.

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