Brazilian agriculture

Efforts on modeling to estimate greenhouse gas emission and C dynamics

Forestry and Agriculture Greenhouse Gas Modeling Forum
Workshop # 3: Modeling to Support Policy
Shepherdstown, WV, USA, 12-15 October 2004

Content

- Background - Brazil in the context of Global Climate Change Policy
- Agrogases network – Carbon dynamics and Greenhouse Gas Emission from Brazilian Agricultural, Livestock, Forestry and Agroforestry Systems
- Efforts in using modeling for estimate scenarios of greenhouse gas and C fluxes from agricultural systems in Brazil

Background

- Brazil belongs to the No Appendix I parties

- Commitments:
  - Elaboration of periodic National Inventories of Greenhouse Gas Emissions
  - Efforts to mitigate greenhouse gas emissions
  - Measures for adaptation to climate change
  - Public awareness about global climate change
  - Pre-analysis of projects developed under the Clean Development Mechanism - CDM

Programs & Actions

- Ministry of Science and Technology - MCT
  - ►In charge of the Brazilian commitments related to UNFCCC
  - ►Coordination of the National Program of Climate Change, which includes 7 actions
  - ►Secretariat of Interministerial Committee on Global Climate Change – Designated National Authority

- Ministry of Agriculture, Livestock and Supply – MAPA
  - ► Brazilian Agricultural Research Corporation – Embrapa

    “Carbon Dynamics and Greenhouse Gas Emission from Brazilian Agricultural, Livestock, Forestry and Agroforestry Systems” Project (Agrogases Network)
  - ► Biofuel network (in construction)

- Ministry of Environment - MMA
  - ► Biodiversity

Agrogases network

Brazilian Corporation for Agricultural Research - Embrapa

- A set of research groups and institutions that work in an integrated and interdisciplinary approach.

- Created in 2003 to develop the project “Carbon Dynamics and Greenhouse Gas Emissions from Brazilian Agricultural, Forestry and Agroforestry Systems”, coordinated by Embrapa Environment, Jaguariuna, SP, Brazil.

Main objectives

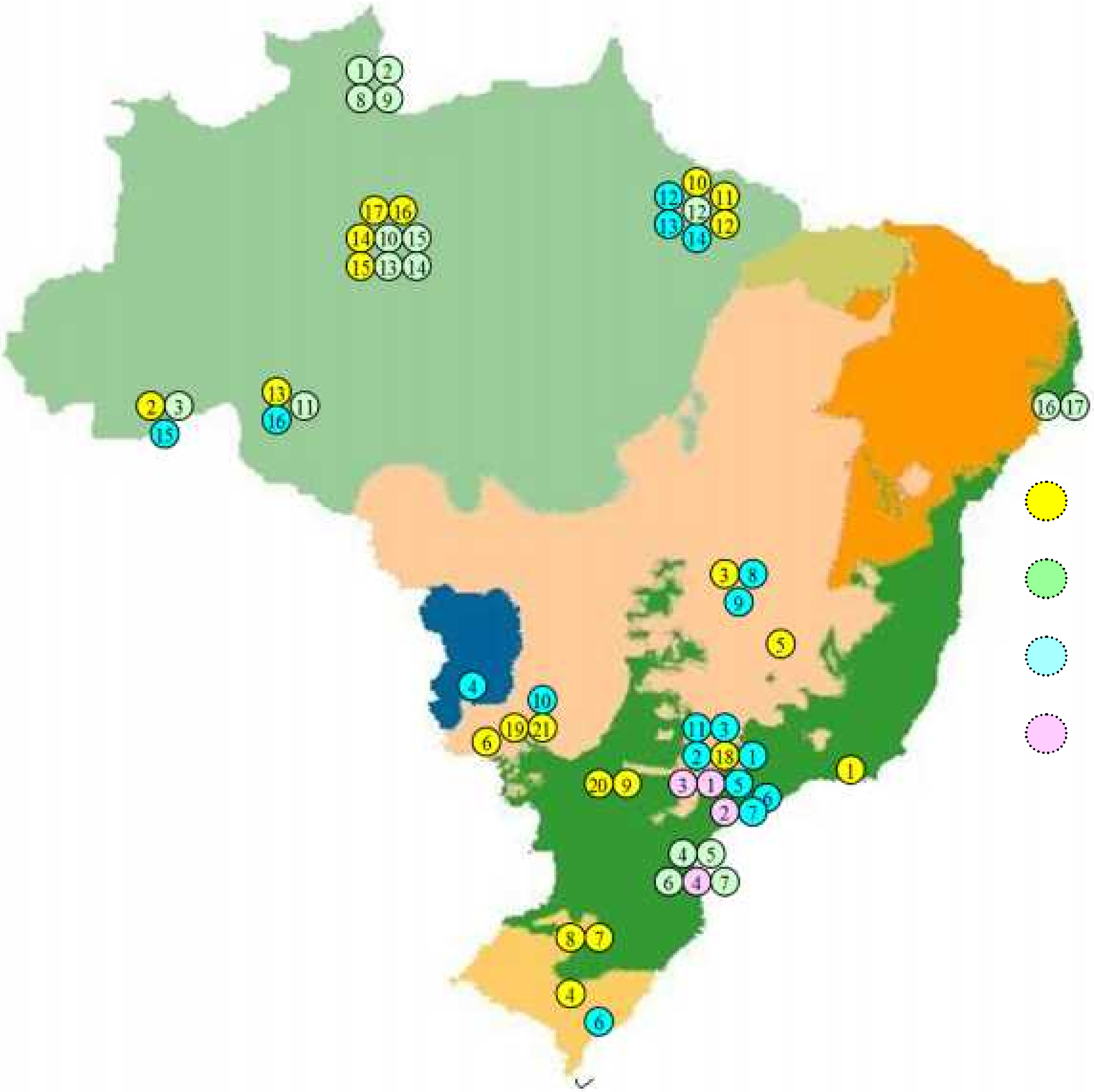
► To quantify and evaluate the carbon stocks and greenhouse gas emissions from different land use systems in Brazil.

► To establish an integrated information network that will subsidize the generation of sustainable technology for reducing greenhouse gas emissions, as well as to support to the formulation of public politics.

Specific objectives

- Quantification of GHG fluxes in agricultural, livestock, forestry and agro-forestry production systems;
- Characterization of C dynamics under Cerrado vegetation, crops management systems, pastures, native and planted forests, and agroforestry;
- Evaluation of the effect of agricultural and forestry production practices on gas emissions and atmospheric carbon absorption;
- Improvement of the GHG national inventory;
- Evaluation of the options for mitigating greenhouse gas emissions by improving sustainable land use from the social, economic and environmental standpoints

Study areas



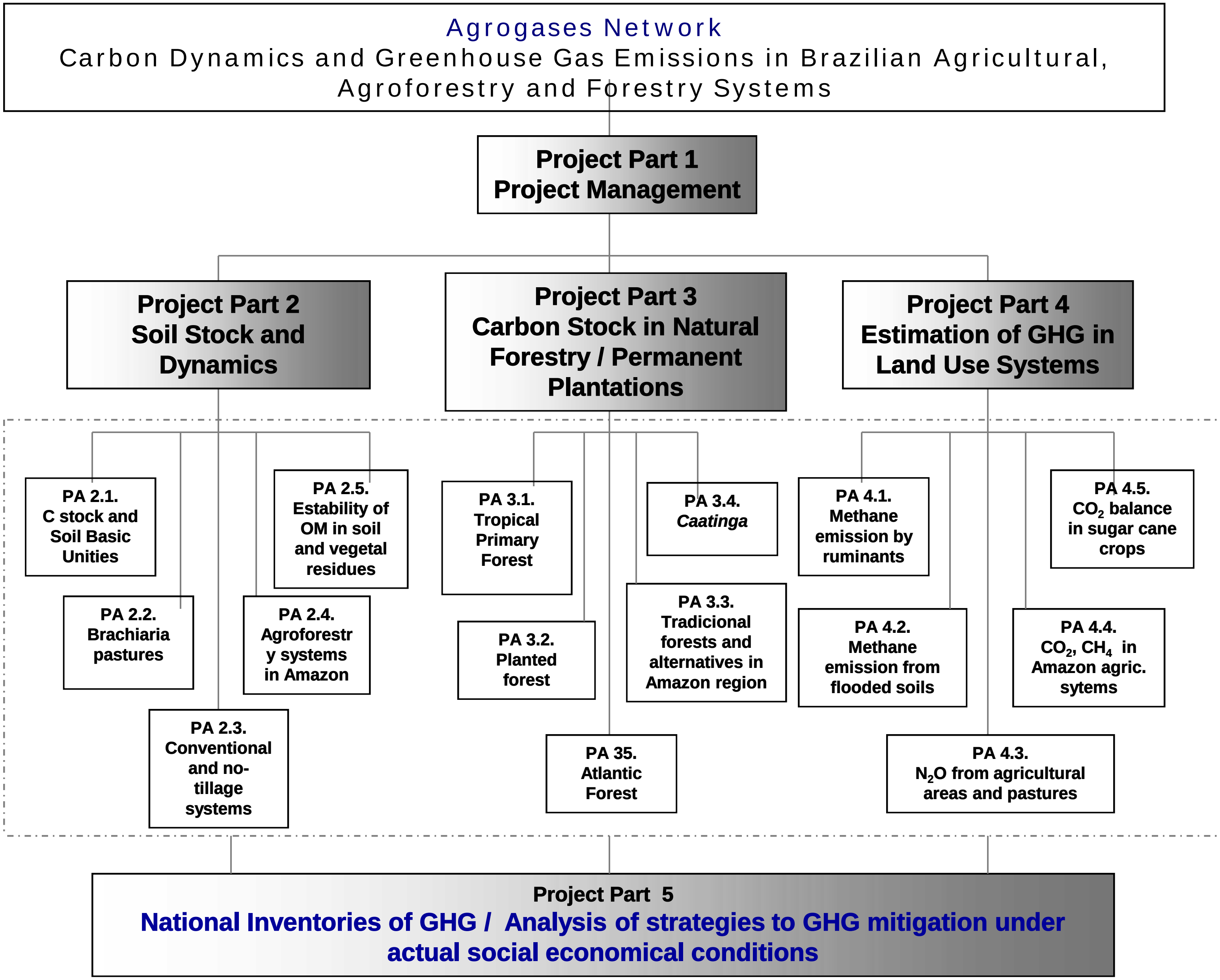
- C stock and dynamic in soils
- C stock and dynamic in vegetation
- Measurement of GHG
- GHG Inventories and Social-Economical analysis

Embrapa's Centers

Acre
Agrobiology
Western Agriculture
Western Amazon
Eastern Amazon
Cerrados
Forests
Beef Cattle
Information Technology
Agriculture Instrumentation
Environment
Maize & Sorghum
Pantanal
Southeast Embrapa Cattle
Rondônia
Roraima
Soybean
Soils
Soils/Recife
Wheat
LABEX

Partners

IRGA
UFRJ
Univ. F. Santa Maria
WHRC
LANL
UNESP
IPAM
UFAC
APTA/SP
MOMBASA
INPA
SPVS
IAG/USP
US.EPA


Agrogases Network
Carbon Dynamics and Greenhouse Gas Emissions in Brazilian Agricultural, Agroforestry and Forestry Systems
Project Part 1 Project Management
Project Part 2 Soil Stock and Dynamics
Project Part 3 Carbon Stock in Natural Forestry / Permanent Plantations
Project Part 4 Estimation of GHG in Land Use Systems
PA 2.1. C stock and Soil Basic Unities
PA 2.2. Brachiaria pastures
PA 2.3. Conventional and no-tillage systems
PA 2.4. Agroforestry systems in Amazon
PA 2.5. Estability of OM in soil and vegetal residues
PA 3.1. Tropical Primary Forest
PA 3.2. Planted forest
PA 3.3. Tradicional forests and alternatives in Amazon region
PA 3.4. *Caatinga*
PA 35. Atlantic Forest
PA 4.1. Methane emission by ruminants
PA 4.2. Methane emission from flooded soils
PA 4.3. N_2O from agricultural areas and pastures
PA 4.4. CO_2, CH_4 in Amazon agric. sytems
PA 4.5. CO_2 balance in sugar cane crops
Project Part 5
National Inventories of GHG / Analysis of strategies to GHG mitigation under actual social economical conditions

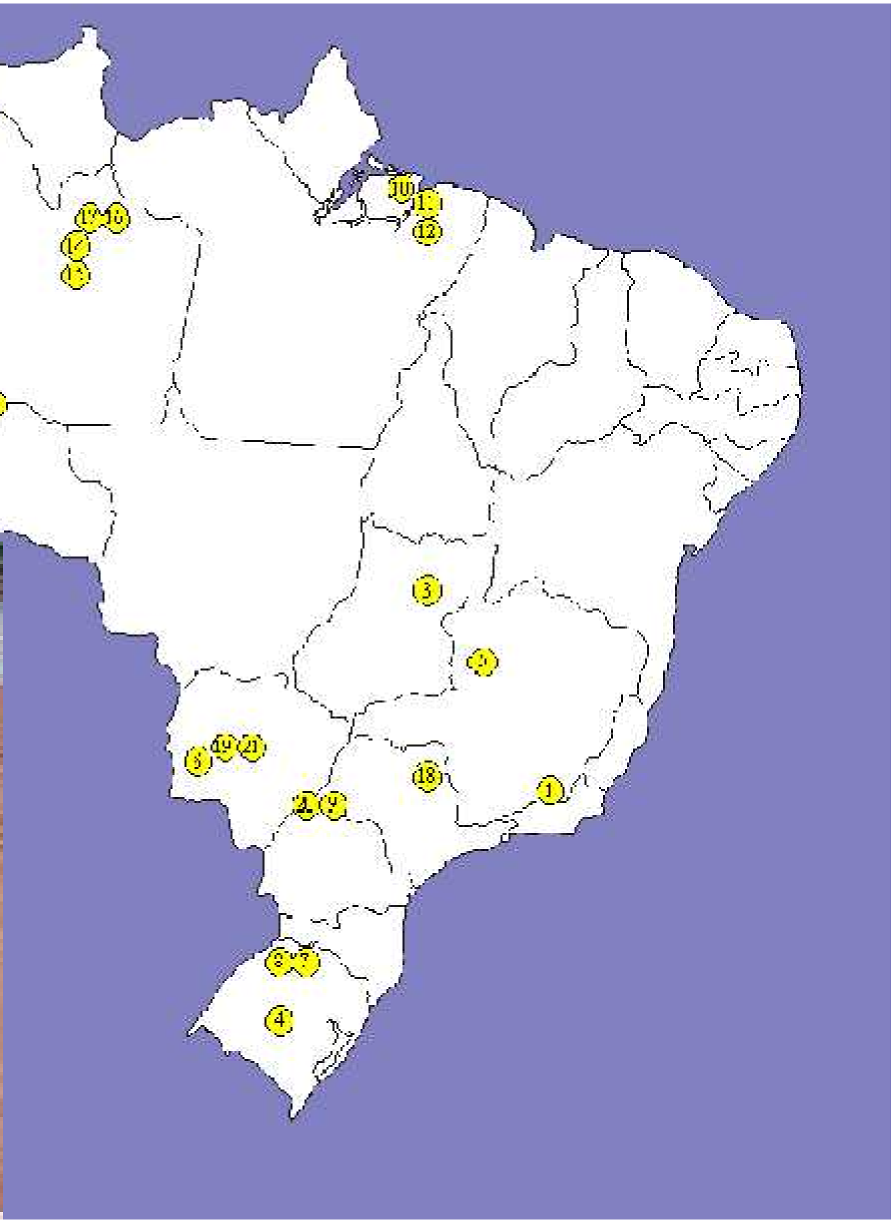
AP 2.1. Assessing of Soil C stock in Comparing Basic Unities

2.1.1. **Systematization of the information on soil C stocks in Brazil (data base)**

2.1.2. **Soil C stock in Amazon**

2.1.3. **Soil C stock in Cerrados region**

2.1.4. **Soil C stock in the South region of Brazil**



AP 3.2. Assessing of Carbon stock in Permanent Plantations

- Estimation of Carbon stock of vegetation, soils and litter
- Forest inventory
- Database using RS and GIS
- Survey of available inventories

3.2.1. **Development of modeling of C stock and dynamics per compartment of individual trees**

3.2.2. **Remote sensing applied to the assessment of biomass of planted forests**

3.2.3. **Study of C dynamics in relation to forestry management practices**

3.2.4. **C stock related to scenarios of reduction or increment of reforested areas and the final use of forestry production**

3.2.5. **Study of C fixation in comercial plantations under different stages of initial growth in areas of Cerrado region in Roraima**

3.2.6. **Study of C fixation in experimental forestry areas in Roraima**

3.2.7. **Modeling and determination of C stock and fixation in the forestry production in Central Amazon**

A.P. 4.1. Evaluation of methane emission from ruminants

4.1.1. **Evaluation of methane emission from the rumen of dairy cattle**

4.1.2. **Evaluation of methane emission from the rumen of beef cattle in the Southeast region**

4.1.3. Evaluation of methane emission from the rumen of crossbreed dairy cattle with controled ingestion of forage

4.1.4. **Evaluation of methane emission from the rumen of beef cattle in the Pantanal region**

4.1.4. **Methane analysis and sulfur hexafluoride by gas chromatography**

4.1.5. Evaluation of nitrous oxide emissions from pasturelands

A.P. 4.2. Evaluation of methane emission from flooded areas

4.2.1. Evaluation of methane emission from flooded rice crops in the southern and southeast regions

4.2.2. Simulation of methanogenic processes in flooded rice crop systems (Huang et al. 1998)

4.2.3. Sazonal evaluation of methane and CO_2 fluxes in humid fields in Cerrado region

Closed chamber technique (Sass et al., 1991, 1992) - 60 cm x 60 cm

Modeling GHG emission from agricultural activities

In the Agrogases project, modeling is being used to:

1- better understand the process involved in GHG emissions and C dynamics

2- Improve our ability to predict GHG emissions for different conditions and environments

3- study “ what if” scenarios and optimal solutions in order to analyze mitigation strategies

Modeling in the Agrogases project

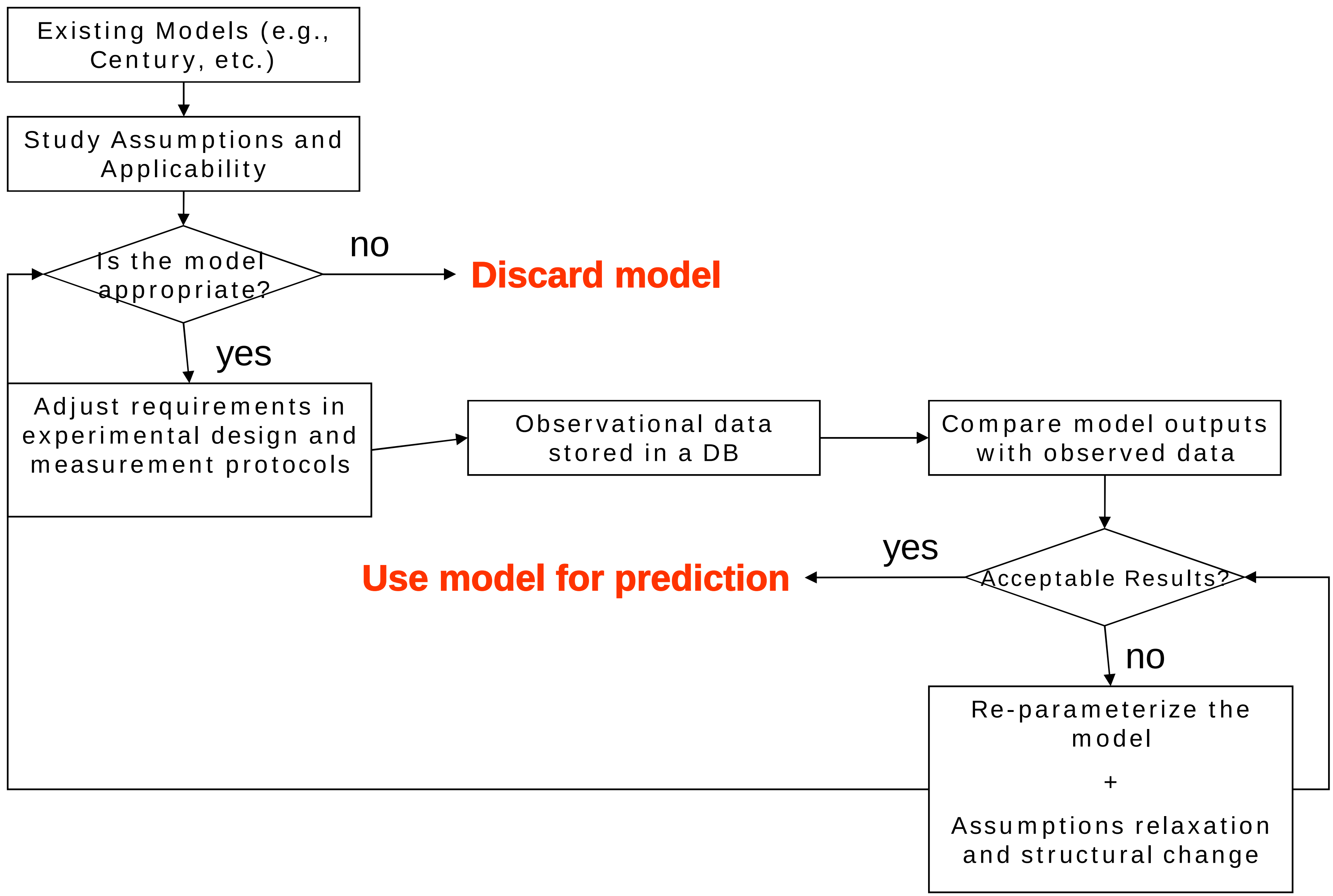
Applications:

1- Soil Carbon Dynamics (Based on the Century Model)

2 - Fluxes of CO_2 (SiB2 model)

3 - Methane Emissions by Ruminants (Based on Dijkstra's Rumen Model)

4- Methane Emissions from flooded rice crop systems (Huang et al., 1998)



Iterative model development flow diagram adopted in Agrogases project (Barioni, 2004)

Once the existing models (e.g. the Century model for soil carbon dynamics) are introduced, the validity of some the assumptions for the Brazilian production systems and the feasibility of parameter estimation are evaluated.

Then, the variables defined in the model under study drive the design of experiments by demanding compatible experimental procedures and measurements.

Experimental data is then stored in a database and the model is evaluated and re-parameterized from that data.

Software is being developed to allow rapid and effective parameterization of the models.

In the case of biases, sensitivity to structural changes and relaxation of some of the model assumption are tested in relation to overall error of prediction and its components.

Once model is evaluated, it is supplied to input data monitored from actual systems.

Results are used for prediction of GHG emissions in different environments and for study of scenarios to drive interventionist actions.

Examples of the use of modeling for estimating scenarios of greenhouse gases and C fluxes from agricultural systems in Brazil

- Sugarcane crops
- No tillage system

Daily totals of CO_2 Net Ecosystem Exchange observed in a sugarcane plantation

- Observed by the eddy correlation method and estimated by SiB2 model (Simple Biosphere Model)

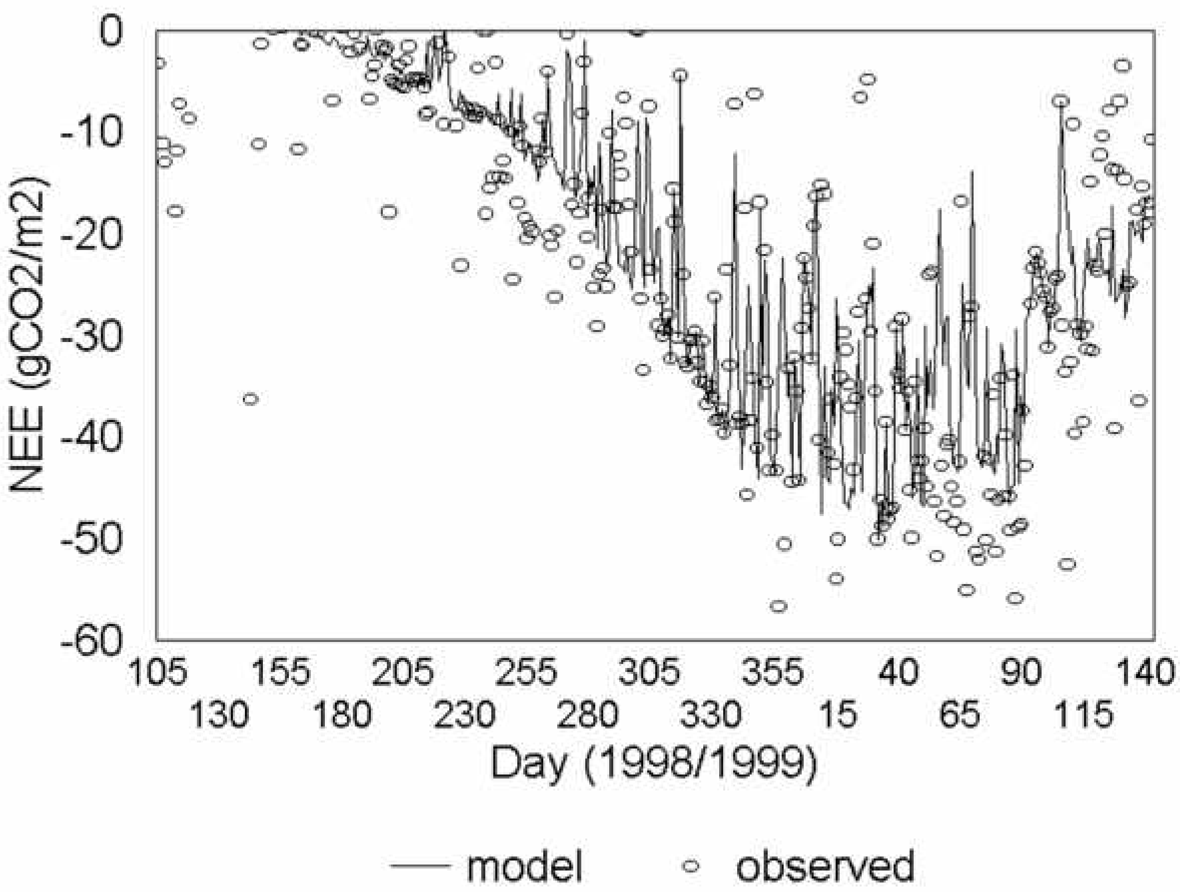
Rocha et al., 2000, Atmospheric CO_2 fluxes and soil respiration measurements over sugarcane in southeast Brazil. In: Global Climate Change and Tropical Ecosystems. R. Lal, J.M. Kimble, B.A. Stewart eds., CRC Press, Boca Raton, 405-414

Sugarcane crop system

- Long term observations of energy balance, CO_2 and soil moisture were undertaken in a sugarcane plantation in Sertaozinho, SP, Brasil during the years 1997-1999.
- The eddy covariance method was used to measure the fluxes of energy and CO_2 and a neutron probe provided the soil moisture data.
- The sugarcane soil-vegetation-atmosphere system was modelled with SiB2 (Simple Biosphere Model), which utilized as driving forcings the meteorological variables measured on the top of a tower at the plantation area.

Results

- Total evaporation simulated for the 1998/1999 cycle was 1,027 mm, 9% greater than the observed.
- The measured above-ground biomass was 7.3 kg CO_2 m^{-2}, which coefficient of variation was about 30% higher, and the simulated assimilation was 9.9 kg CO_2 m^{-2}, although 35% higher, it shows the same order



Daily totals of CO_2 balance between sugar cane plantation and the atmosphere (Net Ecosystem Exchange)

Century model applied to simulation of soil organic carbon of an Acrisol under no-tillage and disc-plow systems

- Experimental monitoring and application of Century Model

Leite, L.F.C., Mendonca, E.S., Machado, P.L.O., Fernandes Filho, E.I., Neves, J.C.L. 2004. Simulationg trends in soil organic carbon of an Acrisol under no-tillage and disc-plow systems using the Century model. Geoderma, p. 283-295.

No-tillage system in Brazil:

- Is widely used over an area of 14 million ha (Pereira, 2002)
- Combined with crop rotation involving cover crops, no-tillage favors the accumulation of plant residues of soil surface
- Represents a potential contribution to the atmospheric C fixation

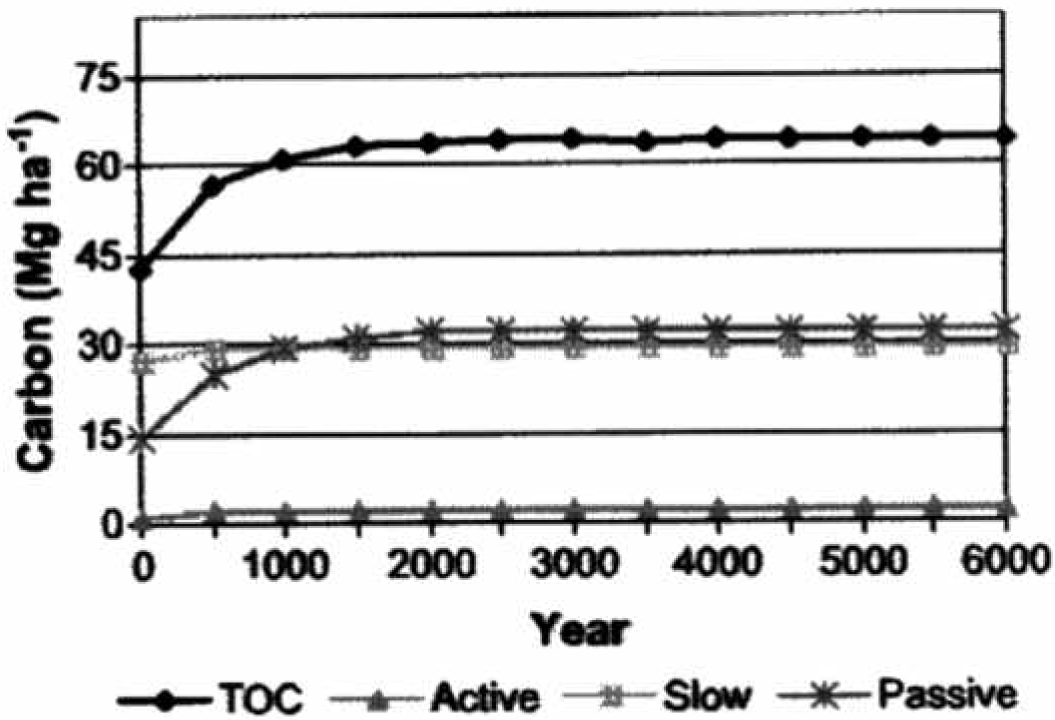
Model input for simulation of tillage using v. 4 of the Century Model (Leite et al., 2004)

Model input for simulation of tillage systems using version 4 of the Century model

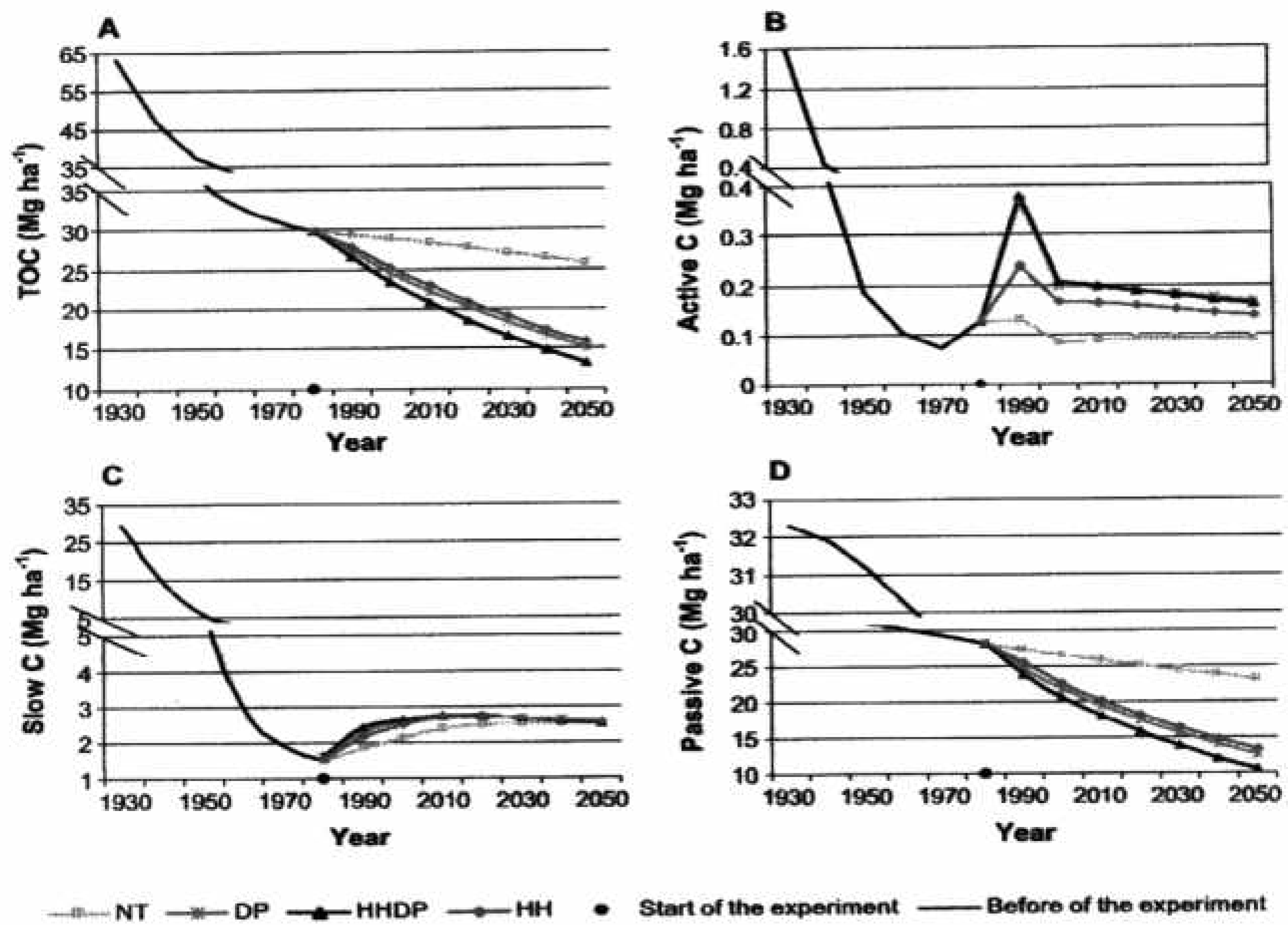
	Value
Soil variables	
Texture (% sand, % silt, % clay)	38, 16, 46
Bulk density (mg m^{-3})	1, 13
Initial SOM ($g C m^{-2}$; C/N)	
Active surface	50, 12,5
Active soil	159, 9
Slow soil	1776, 22
Passive soil	4460, 12
Monthly weather variables	
Mean total precipitation ($cm month^{-1}$)	14
Mean maximum temperature (°C)	14.8
Mean minimum temperature (°C)	26.4
Cultivation variables	
Multiplier for increased decomposition	
Active pool	1.0 (NT); 1,8 (DP); 2.0 (HHDP); 1.6 (HH)
Slow pool	1.0 (NT); 4.0 (DP); 5.0 (HHDP); 3.0 (HH)
Passive pool	1.0 (NT); 1.8 (DP); 2.0 (HHDP); 1.6 (HH)

Carbon pool values were obtained from direct method. NT: no tillage; DP: disc plow; HHDP: heavy disk harrow + disk plow; HH: heavy harrow.

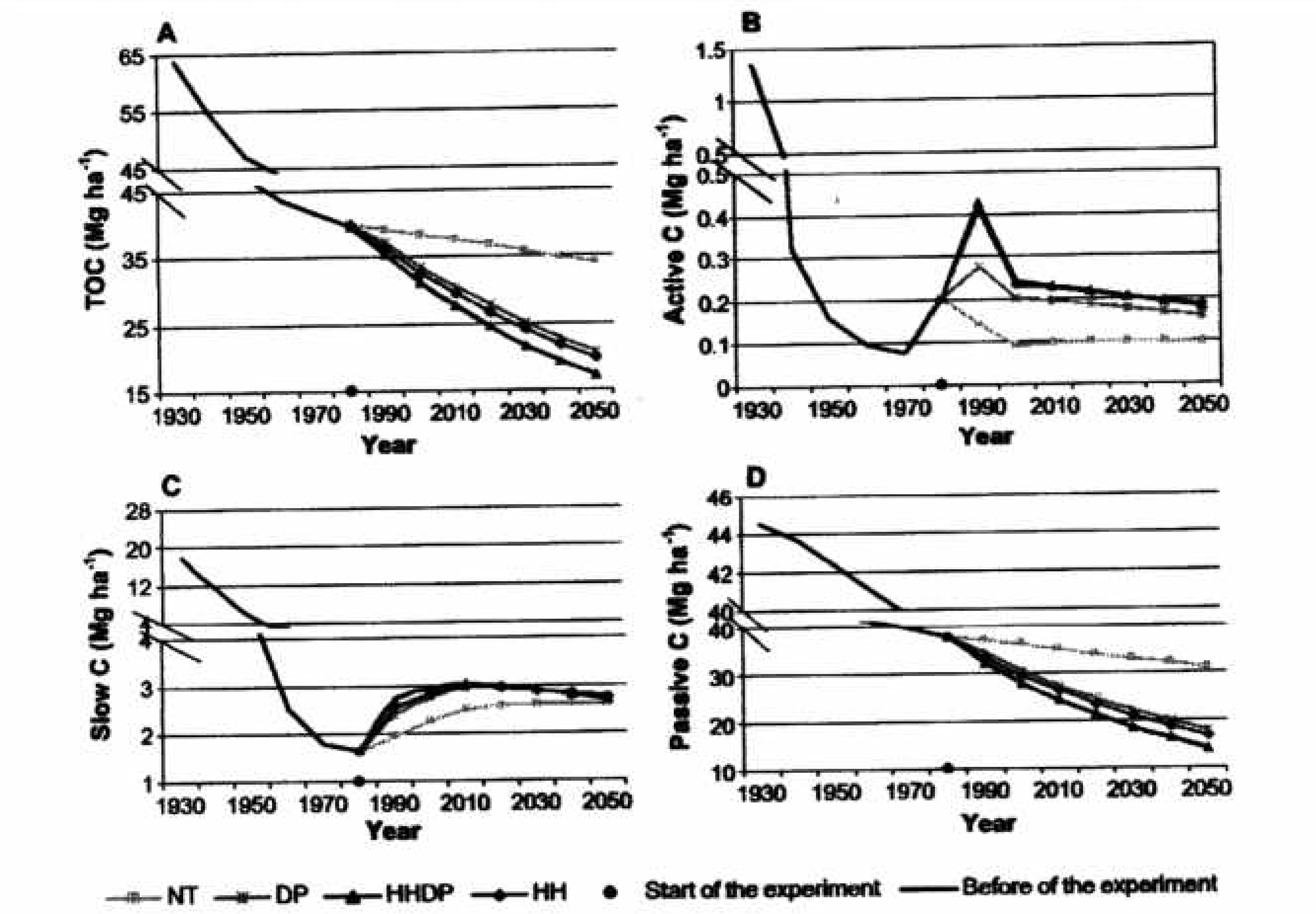
Modeled stocks of SOC (TOC) and organic carbon pools of an Acrisol (0-20 cm) under Atlantic Forest (Leite et al., 2004)



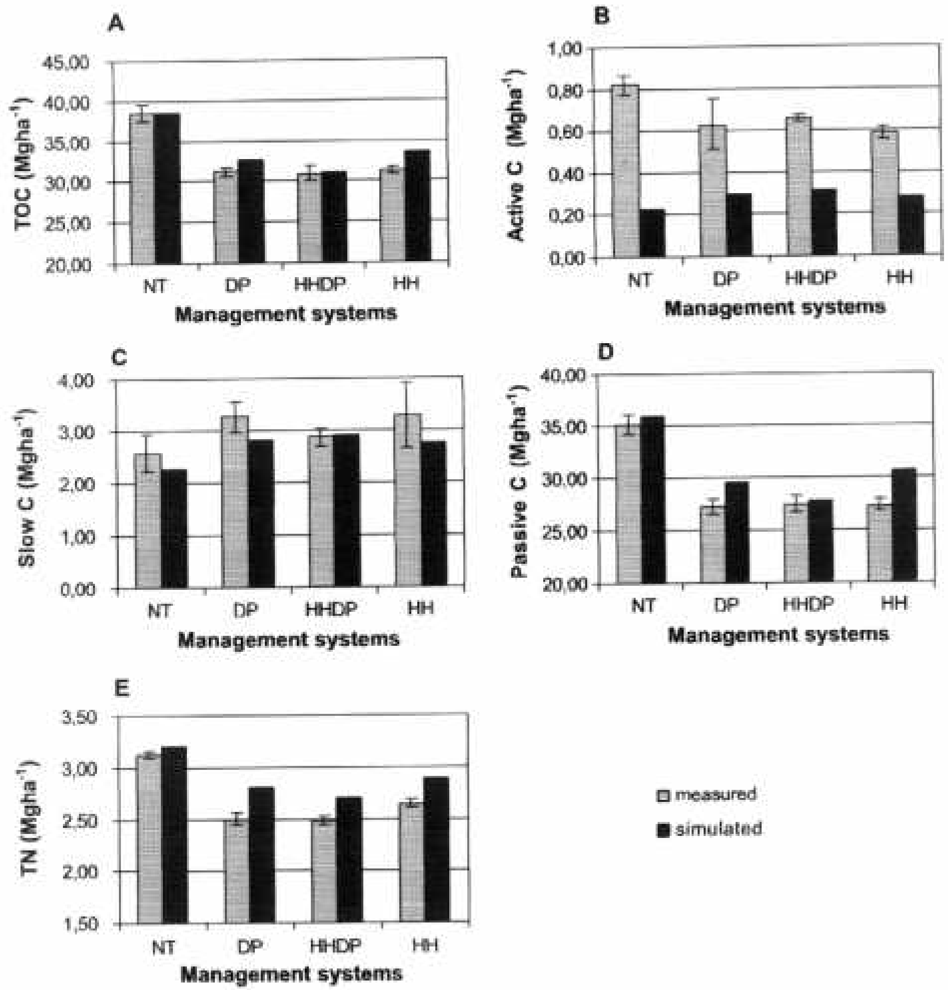
Time variation of the stocks of TOC (A) and active (B), slow (C) and passive (D) carbon pools simulated by Century based on the initial values obtained from the equilibrium in the no-till (NT), disc plow (DP) and heavy harrow followed y disc plow (HHDP) and heavy harrow (HH). (Leite et al., 2004)



Time variation of the stocks of TOC (A) and active (B), slow (C) and passive (D) carbon pools simulated by Century based on the initial values obtained from direct method in the no-till (NT), disc plow (DP), and heavy harrow followed y disc plow (HHDP) and heavy harrow (HH). (Leite et al., 2004)



Measured and simulated total organic carbon (TOC) (A), active (B), slow (C) and passive (D) carbon pool, and total nitrogen (TN) (E) in different soil management systems. NT= no-tillage, DP= disk plow and light harrowing, HHDP=heavy harrow followed y disc plow, HH= heavy disk harrowing (n=4 for measured values) (Leite et al., 2004)



Conclusions (*Leite et al., 2004*)

- Both active and slow C pools were more sensitive to soil management systems than total organic carbon pool.
- The Century model simulated changes in the total organic carbon content and obtained a good fit to measured data.
- Underestimation of the stocks of slow and active C pool, so that other processes must be included in the Century model for acid tropical soils.

Application of the Dijkstra' rumen model to evaluate dietary effects on methane emissions by dairy and beef cattle under tropical conditions

Objective: to simulate whole-animal methane emissions for a range of dietary inputs, aiming to verify the potentiality of methane mitigation and the increment of production efficiency

Dijkstra, J., Neal, H.D.St.C., Beever, D.E.,.France, J. 1992. Simulation of nutrient digestion, absorption and outflow in the rumen: model description. *Journal of Nutrition* 122, 2239-2256.

Current challenges:

- Include all inputs (fossil fuel, grains, fertilizers, etc.) and outputs (animal wastes, including animal visceral) of the animal production systems and their correspondent contribution of GHG

- Consider the balance of C, GHG fluxes, urea volatilization, beyond CH_4 by enteric fermentation

- Include the social and economical parameters to the conceptual model

Contacts

Magda Lima (magda@cnpma.embrapa.br)

or

rede.agrogases@cnpma.embrapa.br

Website

http://www.cnpma.embrapa.br/clima/rede_agrogases

Acknowledgments

Pedro Arraes – LABEX- Embrapa/ ARS

Luis Barioni – Embrapa Cerrados

Osvaldo M. R. Cabral – Embrapa Meio Ambiente

Pedro L. Machado – Embrapa Solos

Jan Lewandrowisk – USDA/ARS, for the invitation

Thank you