# DYNAMICS INDICATORS OF SUSTAINABLE AGROPASTORAL SYSTEMS



## DYNAMICS OF SOIL ORGANIC MATTER AND PHYSICAL PROPERTIES IN SUSTAINABLE AGROPASTORAL SYSTEMS

**A Proposal for** Bundesministerium fur Wirtschaftliche Zusammenarbeit (BMZ)

Special Project Funding

**Submitted by.**

CIAT
Centro Internacional de Agricultura Tropical
Cali, Colombia

**Collaborating Partners·**

Universitat Bayreuth

International Fertilizer Development Center (IFDC)

Empresa Brasileira de Pesquisa Agropecuaria Centro de Pesquisa Agropecuaria dos Cerrados (EMBRAPA-CPAC)

*August 1993*

# Table of Contents

## Table of Contents (Con'td)

## List of Figures



## List of Tables



## List of Appendices

## Acronyms

| | |
|---|---|
| BMZ | Der Bundesminister fur Wirtschaftliche Zusammenarbeit |
| CIAT | Centro Internacional de Agricultura Tropical |
| EMBRAPA-CPAC | Empresa Brasileira de Pesquisa Agropecuaria-Centro de Pesquisa Agropecuaria dos Cerrados |
| IFDC | International Fertilizer Development Center |
| SOM | Soil Organic Matter |

# 1.0 Summary

**Title:** *Dynamics of soil organic matter and physical properties in sustainable agropastoral systems*

**Short title** *Soil indicators of sustainable agropastoral systems*

## Objective:

The objective is to generate knowledge on the dynamics of soil organic matter and physical processes in agropastoral systems that are either degrading or improving in terms of soil quality and agricultural productivity

## Abstract

This project proposal is a result of the CIAT Project Identification/Development of Area Based Strategic Resource Management, which was approved by BMZ in October 1992

There is evidence that some of the existing cropping systems in the savannas of Latin America are not sustainable either in biophysical or economic terms Soil erosion, compaction and general low levels of fertility limit agricultural production on the acid-soil savannas CIAT has prototype technologies using legume-based pastures and upland rice which can improve soil conditions, increase agricultural productivity and reverse degradation Indicators of changes in soil quality are needed which can be used as both "early warning" signals of degradation and also as a means to estimate soil improvement This project will determine the relationships between soil organic matter and soil physical properties in soils under different land uses and will build on information obtained by the University of Bayreuth on which factors in the soil can be used to assess changes in soil quality

## Cooperating Partners:

The Centro Internacional de Agricultura (CIAT) Cali, Colombia

Universitat Bayreuth

International Fertilizer Development Center (IFDC)

## National Institutions·

EMBRAPA Research Centers Brazil

## Names of principal scientists

*Senior staff from the Savanna Program of CIAT*

Dr R Vera, Program Leader

Dr R J Thomas

Dr M A Ayarza, Project coordinators

Prof W Zech, Lehrstuhl fur Bodenkunde und Bundengeographie, Universitat Bayreuth

Dr D Friesen, Soil Scientist from IFDC currently at CIAT

## Name of staff to be financed·

### *CIAT staff*

One junior assistant
One field technician

Dr R Vera, Leader Savanna Program will be responsible for the budget necessary for EMBRAPA staff

### *German staff*

Two Ph D students (3 years)
Two student helpers (3 years)

## Source of budget·

| Budget | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| Bayreuth Univ | 118,750 | 118,600 | 118,325 | 355,675 |
| CIAT | 78,925 | 94,066 | 101,915 | 274,900 |
| EMBRAPA | 39,975 | 44,200 | 47,775 | 131,950 |
| **Total Request** | **237,650** | **256,860** | **268,015** | **762,525** |

# 2.0 Background and Justification

*Food production in Latin America needs to be increased in an economically efficient and ecologically benign way*

## 2.1 Production needs

Latin America is attempting to come out of the severe economic crisis of the 80's. During this period the debt burden had reached enormous proportions, terms of trade had deteriorated, capital inflow had slowed, and inflation had soared further slowing economic growth. As a result the low-income strata of the population, especially the urban poor, have been particularly affected and average caloric intake is below recommended levels in many countries.[2] At the same time, an exodus of people from rural areas has pushed the proportion of city-dwellers from 49% in the early 1960s to 69% in 1986.[1] Many countries in Latin America are confronted by inadequate rates of growth in the production of staple foodstuffs. Thus there is a critical need to increase food production. However, this will be possible only if production is increased in an economically efficient and ecologically benign way.

## 2.2 Production Strategies

Production increases in the Amazon countries from 1960 to 1980 were based almost exclusively on area expansion.[3] As the more accessible lands have come into cultivation, expansion of agricultural frontiers has increasingly focused on the tropical rain forests and the acid soil savannas.

*Current options for increasing agricultural production in Latin America bring about environmental degradation and pollution*

There are essentially two options for increasing agricultural production in Latin America:

- the extensive approach of expansion on to previously uncultivated lands in frontier areas with the corresponding environmental degradation, and
- the intensive approach of increasing yields per unit area on currently cultivated land but usually associated with soil degradation and environmental pollution.

## 2.3 Deforestation

Deforestation of the Amazon is a major concern. Although agricultural production in deforested areas is initially satisfactory, it declines rapidly as **loss of soil organic matter and fertility lead to the physical and chemical degradation of the soil resource base.** The associated ecological, environmental and social costs of deforestation are major causes for concern.

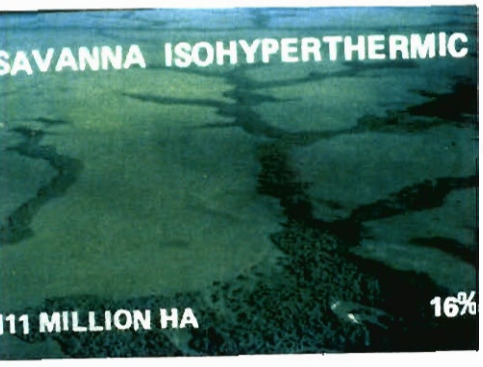
## 2.4 The Acid-Soil Savannas —An Alternative

*Increased sustainable agricultural productivity on the acid soil savannas is an obvious alternative to agricultural expansion*

While some hold that deforestation is inevitable and that its increasing rate is a necessary cost of development,[4] a more optimistic view[5] advocates incentives to relieve migrant pressures on the Amazon by promoting better production opportunities elsewhere, particularly the acid soil savannas.

The obvious alternative to agricultural expansion into the Amazon rainforest is increased sustainable agricultural productivity on the acid soil savannas. Selection of the savannas (llanos in

*Acid soil savannas represent a substantial land resource to arrest pressures on South American rain forests*




*Sustainable cropping systems applicable to acid soil savanna environments need to be generated*

Bolivia, Venezuela and Colombia, and Cerrados in Brazil) as the target land resource on which to promote economic growth is based on:

- Geographical proximity to the humid tropics and the fact that they represent a substantial land resource for the four countries that control 88% of the South American rain forests[6,7]
- Current use for agricultural production, albeit at different levels of intensity[8,9,10]
- Relative ease of access, requiring little additional infrastructure for the supply of inputs and the movement of production to markets.

The savannas are more attractive to production-oriented farmers, particularly if incentives to land speculation are curtailed in the Amazon.[11,12] However, the technological basis for this strategy requires the generation of sustainable cropping systems applicable to acid soil savanna environments.

## 2.5 Savanna Development --Constraints

Production systems in the Latin American savannas range from low through restricted to high inputs, and from native savanna through improved pastures to crop rotations and monocropping, and occasionally to integrated crop/pasture systems. Intensive annual cropping systems with high inputs in the Cerrados of Brazil and the Llanos of Venezuela have been profitable in the short-term,[13] but there are indications that they are not sustainable as currently practiced and ultimately lead to soil degradation[14].

The degradation in high input mechanized cropping systems is characterized by:

- Nutrient deficiencies
- Soil compaction
- Soil loss (erosion)
- Loss of soil organic matter
- Pests and diseases, although information on the latter is scanty.

*There is an urgent need to stabilize the soil physical conditions in the Latin American Savannas*

Soil physical condition influences plant rooting patterns and hence water and nutrient extraction, as well as water dynamics including infiltration and runoff, and soil erosion.

There is an urgent need to stabilize these systems and halt or reverse these trends in soil degradation and declining productivity. To do so requires an understanding of how alternative cropping practices influence soil physical conditions and the dynamics of soil, water, and nutrients in the environment.

## 2.6 Approaches to alleviate the constraints

*CIAT and EMBRAPA have evaluated technologies in collaboration with national partners and farmers*

For the acid soils of the savannas and other agroecosystems in the region CIAT has been selecting acid-soil tolerant forage and upland rice germplasm and has studied the role of the forage legume and the judicious use of inputs such as lime and fertilizers[15]. Since 1989 the technologies associated with the use of acid-soil tolerant forage and rice germplasm has been combined and tested in rice-pasture systems [16]. In collaboration with ICA and FEDEARROZ, the technologies involving rice-pasture have been evaluated with farmer

*CIAT's Savanna Program has developed prototype technologies to improve soil conditions, increase agricultural productivity and reverse degradation*

collaborators in the Colombian llanos. EMBRAPA/ CNPAF has developed the Barreirão system for the recuperation of degraded pastures using a rice crop[17], although a legume component is not included.

Thus CIAT's Savanna Program already has prototype technologies, using legume-based pastures in combination with crops, which can improve soil conditions, increase agricultural productivity and reverse degradation[18]. These technologies are based on the simultaneous sowing of grass/legume pastures and upland rice. This system is more efficient in land preparation and fertilization and reduces erosion and nutrient leaching by establishing a ground cover faster and more completely than the separate establishment of either pasture or rice alone.

There remains the need however to research and document the beneficial effects of such integrated crop-pasture systems on soil properties using, as a basis, the preliminary results obtained.

*The University of Bayreuth has studied soil differences in the Amazon*

The University of Bayreuth has been studying differences in soil organic matter from fertile and infertile soils in the Amazon[20] and has identified soil fractions which may be more sensitive to changes in soil quality than the usual bulk soil measurements (e.g., total C, N or organic matter). The project will use the methods developed at Bayreuth on soils under different land uses.

The proposed research project will be a part of CIAT's efforts to develop alternative models for sustainable agro-pastoral systems, based on an understanding of the bio-physical processes and is specifically aimed at soil physical processes and organic matter dynamics.

# 3.0 Overall Project Objectives

*The project has clearly defined objectives*

This project is part of a larger set of activities that aim to develop sustainable farming systems based on different temporal and spatial combinations of crops and forages.

## 3.1 Specific objectives

To better understand soil physical processes such as compaction, erosion, aeration and water dynamics, as they are influenced by contrasting cropping practices and soil texture in representative sites of the neotropical savannas.

To contribute information for use in a conceptual model of soil physical changes in alternative prototype systems involving monocropping and crop-pasture rotations.

To relate soil degradation/aggregation to readily identifiable soil physical and/or chemical parameters.

### 3.1.1 Outputs

*Outputs include data bases, indicators and conceptual / mathematical models of soil processes in prototype agropastoral systems*

- Quantification of the dynamics of soil organic matter in alternative cropping systems and their relationship to soil physical conditions
- Identification and quantification of trade-offs between contrasting cropping practices, in terms of soil physical conditions
- Identification of soil management practices that are compatible with increased and sustained agricultural productivity

- Identification of indicators of degradation/ enhancement of soil quality
- Estimates of soil losses at the watershed level in relation to cropping practices
- Conceptual and mathematical models of soil physical processes in prototype agropastoral systems

## 3.2 Targeted Beneficiaries

*Beneficiaries of the project will be consumers of maize, rice, beef and milk*

Over 70% of the population in Latin America is urban, and poverty is higher in the cities than in the rural sector. The proposed agropastoral systems would lead to increased productivity of staple urban foods such as maize, rice, beef and milk, at reduced costs.

## 3.3 Anticipated Impact

An economic model using one-half of the experimental results obtained with rotations of rice and pastures for beef production (1800 kg/ha of rice and 120 kg/ha of beef) suggests that the contribution of four states in the Brazilian Cerrados to national beef and rice production would increase by 43% and 18% respectively. Estimates are based on an increase in area planted to grass-legume pastures from 30 million in 1980 to 50 million in 2000, and that 60% of them use the proposed technology.

# 4.0 Workplan and Activities

*EMBRAPA and CIAT will carry out the project, including on-farm participatory research activities, with active support of local institutions*

The major activities and sub-activities of the project as they relate to the project's outputs are shown in Figure 1. The implementation schedule for the proposed activities is shown in Appendix A. The project management structure is shown in Figure 2 and Appendix B contains the C.V.'s of the project participants.

- The project will be based on the hypothesis that maintenance, and even enhancement, of soil structure in acid Oxisols subject to intensive cropping and cattle systems is related to management of organic matter residues, and that this can be achieved through the use of either deep-rooting tropical legume green manures or legume-based mixed pastures.

- The project will initially be located in the area of influence of Uberlandia, State of Minas Gerais, Brazil (see Figure 3). A joint EMBRAPA-CIAT agroecological characterization of the Cerrados of Brazil indicated that the area represented by a circle of 60 km around Uberlandia includes 6 different agroecological classes found throughout the Cerrados. Five of these represent approximately 50% of the area of the Cerrados surveyed, or a total of 501,000 km$^2$. The region of Uberlandia was therefore selected on the basis of its representativeness, and the fact that it is one of the areas with the longest tradition in mixed cropping-livestock systems.

- EMBRAPA and CIAT are jointly carrying out a number of on-farm participatory research activities in the region with active support of local institutions. A number of contrasting farming systems that differ greatly in input and

*The project will carry out on-farm research involving tillage practices and use of alternative sources of organic residues*

management practices, and in overall productivity, are being monitored in biophysical and economic terms with the aim of generating research hypotheses regarding processes underlying system degradation and system sustainability. Some of these systems are based on highly sandy soils that *a priori* would have been judged as very fragile; nevertheless, in a few isolated cases, these systems appear to be extremely successful. It is currently hypothesized that two factors may be involved, namely, management of crop- and pasture-residues that contribute to soil organic matter build up, and appropriate use of agricultural machinery to maintain soil physical conditions. These two factors may be related to each other. Previous on-station research[19] had already identified physical constraints on high clay-content savanna Oxisols as one of the major factors affecting system performance; isolated observations in various parts of the Cerrados suggest that sandy soils are also subject to rapid deterioration of soil physical conditions.

- The project will initially monitor trends in soil organic matter and physical structure in selected contrasting cropping systems at various levels of external inputs in existing farms, and relate these trends to overall crop and cattle productivity. Simultaneously, it will carry out on-farm research involving contrasting soil tillage practices and the use of alternative sources of organic residues such as crop residues, green manures and forages, including the use of no tillage techniques. The dynamics of organic matter decomposition and the effects on soil physical conditions will be assessed. Trade-offs between soil enhancement and immediate and long-term crop productivity will be estimated by

recourse to the use of long term records of input use and crop productivity that are available for a few isolated cases.

Figure 1 shows the breakdown of the project structure with descriptions of the activities. Detailed descriptions of the proposed activities follow:

*Proposed activities include selection, sampling and characterization of experimental plots and measurement of root dynamics*

(a) The experimental plots will be selected and set up within the range of different cropping systems available on farms in the Uberlandia area. These include rice-pasture systems, pasture-soybean and pasture-maize systems together with the monocropping counterparts and pasture only systems. The native savanna vegetation will be used as the reference or control system on similar soil types as the pasture-cropping systems. Both degrading pasture and cropping systems will also be selected.

(b) The experimental plots will be sampled and characterized in a stratified manner by 1), bulk soil sampling and 2), in soil fractions.

In bulk soil samples the following will be measured; physical parameters including aggregate stability, bulk density, infiltration rates, resistance to penetration, pore size distribution and texture. Chemical parameters including pH, total C, N, P, CEC, carbon species using $^{13}$C-NMR, phosphorus species using $^{31}$P-NMR, lignin degradation products, polysaccharides, lipids, C- and N-mineralization potentials.

Root dynamics will be measured by coring and root nutrient concentrations. Yield and biomass production will also be measured.

## 4.1 Statistical evaluation of the results

**Analysis of variance** will be employed to check if the soil analysis (physical and chemical properties and root data) show significant differences among the different cropping systems.

## 4.2 Multivariate analysis

Multiple regression and principle component analyses will be used to check if specific parameters such as biomass production, aggregate stability, infiltration rates in different cropping systems are significantly correlated with other soil factors (e.g. SOM parameters).

*The project includes the participation of German scientists and students*

The above activities will be done by the first German Ph.D. student in collaboration with the other partners. The second German Ph.D. student will be more concerned with the analysis and interpretation of the data obtained from soil fractions of a few of the cropping system treatments. These measurements will be based on the recent finding that the SOM characteristics of soil fractions are much more sensitive than data from the bulk soil samples with respect to the ability to identify changes in soil properties resulting from different land uses.

(c) Characterization of different carbon pools in soil fractions which are based on texture and density separations, will be done using chemical analysis e.g. $^{13}$C-NMR, $^{31}$P-NMR, lignin, polysaccharides, lipids, C- and N-mineralization potentials.

The data obtained in these studies will be subjected to the same statistical analyses outlined under b) above.

*Field work will be carried out with the cooperation of all participants*

(d) Modelling of carbon budgets using established models such as CENTURY and biomass productivity using models such as CERES, SOYGRO to take account of the data obtained from soil chemical and physical parameters and crop yield data.

(e) Soil losses will be estimated as indicated in Figure 1 but starting in the second year depending on site selection and available funding.

There will be little or no need to develop new methods as all are currently available at the University of Uberlandia, EMBRAPA-CPAC and CIAT. More specialized methodology e.g., NMR, lignin degradation, polysaccharides, etc., is available at Bayreuth University.

The field work will be done in cooperation with all participants in the project. Standard chemical and physical characterization will be a shared activity among EMBRAPA-CPAC, CIAT and Bayreuth University.

# 5.0 Training

*Brazilian and German scientist will be trained in soil dynamics*

## 5.1 Training of Brazilian scientists

- Participation at the Third Agropastoral Workshop to be held in Venezuela, 1994
- On site training in the field in root dynamics, soil sampling
- Preparation of a Master's Thesis
- Training in specialized methodologies at Bayreuth University

## 5.2 Training of German scientists

- Doctoral theses on the following subjects:
- Relationship between soil physical properties and SOM dynamics in bulk soil samples from different cropping systems
- Influence of different cropping systems on SOM dynamics in "sensitive" soil fractions and their relationships to soil physical parameters
- The two German student helpers will work in Brazil for four months during the wet season contributing to field work and laboratory analyses. Selected results can be used as part of the requirements for a Master's degree at Bayreuth University

# 6.0 Expected Patentable Results

*The information generated by the project will be made available through publication*

CIAT endorses the principle of free access to research results. It supports this through publication of research findings in international journals and in-house documents.

There are no patentable results anticipated in this project.

# 7.0 Required Resources and Budget

The optimum team from Germany will consist of two pre-doctoral students with an expertise in soil organic matter/physics and up to two student helpers in the areas of soil fertility management and cropping systems. The pre-doc students would work with counterparts from CIAT and EMBRAPA with expertise in cropping systems, nutrient cycling and soil chemistry.

In addition to salaries of the two pre-doctoral and two student helpers, the project should cover operational expenses including junior and field staff, small field and laboratory equipment, travel for national counterparts and consumables. Budget breakdowns are given in Tables 1 and 2.

Table 1: **Budget CIAT + EMBRAPA**

## Centro internacional de agricultura tropical – CIAT

BMZ – Soil indicators of sustainable agropastoral systems
Proposed budget in US$ Dollars

| Line Item | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| **CIAT** | | | | |
| **1. Personnel** | | | | |
| Junior assistant (1) | 15,000 | 16,000 | 17,000 | 48,000 |
| Technician (1) | 7,000 | 7,500 | 8,000 | 22,500 |
| Occasional labor | 5,000 | 8,000 | 9,000 | 22,000 |
| **Total personnel** | **27,000** | **31,500** | **34,000** | **92,500** |
| **2. Travel** | | | | |
| Local travel | 6,000 | 6,000 | 6,000 | 18,000 |
| International travel | 4,000 | 8,000 | 8,000 | 20,000 |
| **Total travel** | **10,000** | **14,000** | **14,000** | **38,000** |
| **3. Research and operations** | | | | |
| Supplies and services | 5,000 | 6,000 | 8,000 | 19,000 |
| Laboratory analysis | 5,000 | 6,000 | 6,500 | 17,500 |
| Maintenance | 1,000 | 1,200 | 1,300 | 3,500 |
| **Total research and operations** | **11,000** | **13,200** | **15,800** | **40,000** |
| **4. Interinstitutional cooperation** | | | | |
| Cooperative costs for field research | 9,250 | 10,000 | 10,750 | 30,000 |
| **Total interinstitutional cooperation** | **9,250** | **10,000** | **10,750** | **30,000** |
| **5. Vehicle lease** | **4,500** | **4,750** | **5,000** | **14,250** |
| **6. Indirect costs** | **17,175** | **20,610** | **22,365** | **60,150** |
| **Total CIAT** | **78,925** | **94,060** | **101,915** | **274,900** |
| **EMBRAPA** | | | | |
| **1. Training** | **2,500** | **3,000** | **3,500** | **9,000** |
| **2. Research and operations** | | | | |
| Laboratory analysis | 5,000 | 6,000 | 6,500 | 17,500 |
| **Total research and operations** | **5,000** | **6,000** | **6,500** | **17,500** |
| **3. Interinstitutional cooperation** | | | | |
| Operational costs EMBRAPA | 14,000 | 15,000 | 16,000 | 45,000 |
| Cooperative costs for field research | 9,250 | 10,000 | 10,750 | 30,000 |
| **Total insterinstitutional cooperation** | **23,250** | **25,000** | **26,750** | **75,000** |
| **4. Indirect costs** | **9,225** | **10,200** | **11,025** | **30,450** |
| **Total EMBRAPA** | **39,975** | **44,200** | **47,775** | **131,950** |
| **TOTAL CIAT – EMBRAPA** | **118,900** | **138,260** | **149,690** | **406,850** |

## Table 2: **Budget Bayreuth University**

# Centro internacional de agricultura tropical – CIAT

BMZ – Soil indicators of sustainable agropastoral systems
Proposed budget in US$ Dollars

| Line Item | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| BAYREUTH UNIVERSITY | | | | |
| 1. **Personnel** | | | | |
| PhD student ( bulk soil studies ) | 28,750 | 30,000 | 31,250 | **90,000** |
| PhD student ( soil fractions ) | 28,750 | 30,000 | 31,250 | **90,000** |
| Student helpers ( 2 ) – 6 months/year | 10,000 | 11,250 | 12,500 | **33,750** |
| **Total personnel** | 67,500 | 71,250 | 75,000 | **213,750** |
| 2. **Travel** | | | | |
| Local travel ( 2 PhD students + 2 helpers ) | 6,250 | 7,500 | 8,750 | **22,500** |
| International travel ( 1 PhD student ) | 2,500 | 2,800 | 3,125 | **8,425** |
| Supervisor, 4 weeks yr 1, 2 weeks yr 2 & 3 | 4,700 | 3,900 | 4,200 | **12,800** |
| Airfreight soil samples | 1,250 | 1,250 | 1,250 | **3,750** |
| **Total travel** | 14,700 | 15,450 | 17,325 | **47,475** |
| 3. **Training** | | | | |
| 1 Brasilian to Bayreuth | 5,300 | 5,650 | 6,000 | **16,950** |
| **Total training** | 5,300 | 5,650 | 6,000 | **16,950** |
| 4. **Research and operations** | | | | |
| Supplies and services | 12,500 | 6,250 | 6,250 | **25,000** |
| Laboratory analysis | 18,750 | 18,750 | 12,500 | **50,000** |
| **Total research and operations** | 31,250 | 25,000 | 18,750 | **75,000** |
| 5. **Publication costs** | – | 1,250 | 1,250 | **2,500** |
| **Total Bayreuth University** | 118,750 | 118,600 | 118,325 | **355,675** |
| GRAND TOTAL | 237,650 | 256,860 | 268,015 | **762,525** |

ABRAHAM E. ESPINO
FINANCIAL CONTROLLER

BMZ-PROPOSED
27-Jul-93
PROPOSED

CIAT

# 8.0 References


[1] Centro Internacional de Agricultura Tropical (CIAT), 1989. **CIAT in the 1990's; Appendices**. CIAT, Cali, Colombia, September, 1989. p.13.

[2] Maguirre, A. and J.W. Brown, 1986. Introduction *in* **Bordering on Trouble: Resources and Politics in Latin America**. Adler and Adler Publishers, Inc., Bethesda, Maryland. pp.1-11.

[3] Valdéz, A. and E. Muchnik, 1989. Estructura y tendencias en la producción, consumo y Comercio de productos agrícolas en América Latina *in* **Seminario sobre Fortalecimiento de la Investigación Agrícola en América Latina y el Caribe (México, 1989)**, *cited in* E.J. Trigo and D. Runsten, 1989. **Hacia una Estrategia Tecnológica para la Reactivación de la Agricultura de América Latina y el Caribe**. Instituto Interamericano de Cooperación para la Agricultura, San José, Costa Rica. p.16.

[4] Fearnside, P., 1984. A floresta pode acabar. **Ciencia Hoje 2**(10):42-52.

[5] Sawyer, D. 1993. The future of deforestation in Amazonia: a socioeconomic and political analysis *in* **Alternatives to Deforestation: Steps Toward Sustainable Use of the Amazon Rainforest**. Columbia University Press, New York. In press.

[6] Centro Internacional de Agricultura Tropical (CIAT), 1989. Agro-ecological Database.

[7] Cochrane, T.T., L.G. Sánchez, L.G. de Azevedo, J.A. Porras, and C.L. Garver, 1984. **Land in Tropical America**. CIAT, Cali, Colombia. p.59.

[8] Goedert, W.J., 1986. **Solos dos Cerrados**. EMBRAPA-CPAC, Planaltina, Brasil. pp.19-31.

[9] Vera, R. and C. Seré eds., 1985. **Sistemas de Producción Pecuaria Extensiva: Brasil, Colombia, Venezuela**. CIAT, Cali, Colombia.

[10] Teixeira, S.M. and L.R. Sainint, 1989. Arroz em Minas Gerais, situação atual e contribuçoes da pesquisa. **Informe Agropecuário 14**(161):5-11.

[11] Goodland, R.J.A., 1980. Environmental ranking of Amazonian development projects in Brazil. **Environmental Conservation 7**:9-26.

[12] Anon., 1989. Hope reaches the Amazon. **The Economist 312**(7611)(15 July):41-42.

[13] Empresa de Pesquisa Agropecuária de Mato Grosso (EMPA), 1987. **Diagnóstico e Priodades de Pesquisa para a Agropecuária do Estado de Mato Grosso**. EMPA, Cuiabá, Mato Grosso, Brasil. p16ff.

[14] Seguy, L., S. Bouzinac, A. Pacheco, V. Carpenedo and V. da Silva, 1988. **Perspectiva de Fixação da Agricultura na Região Centro-Norte do Mato Grosso**. EMPA-MT, EMBRAPA-CNPAF, CIRAD-IRAT, Cuibá, Mato Grosso, Brasil. pp.10-11.

[15] CIAT, 1992. Pastures for the tropical lowlands: CIAT's contribution. CIAT, Cali, Colombia, 238p.

[16] Vera, R.R., R.J. Thomas, R., L.R. Sanint and J.I. Sanz, 1993. Development of sustainable ley-farming systems for the acid-soil savannas of tropical America. **Symposium on the Ecology and Sustainable Agriculture in Tropical Biomes, Rio de Janeiro, Brazil 2-9 February, 1992**. (In press).

[17] Kluthcouski, J., A.R. Pacheco, S.M. Teixeira and E.T. de Oliveira, 1991. **Renovação de Pastagens de Cerrado com Arroz: I. Sistema Barreirão**. Documento 33, EMBRAPA-CNPAF, Goiania, Goias, Brasil. 20pp.

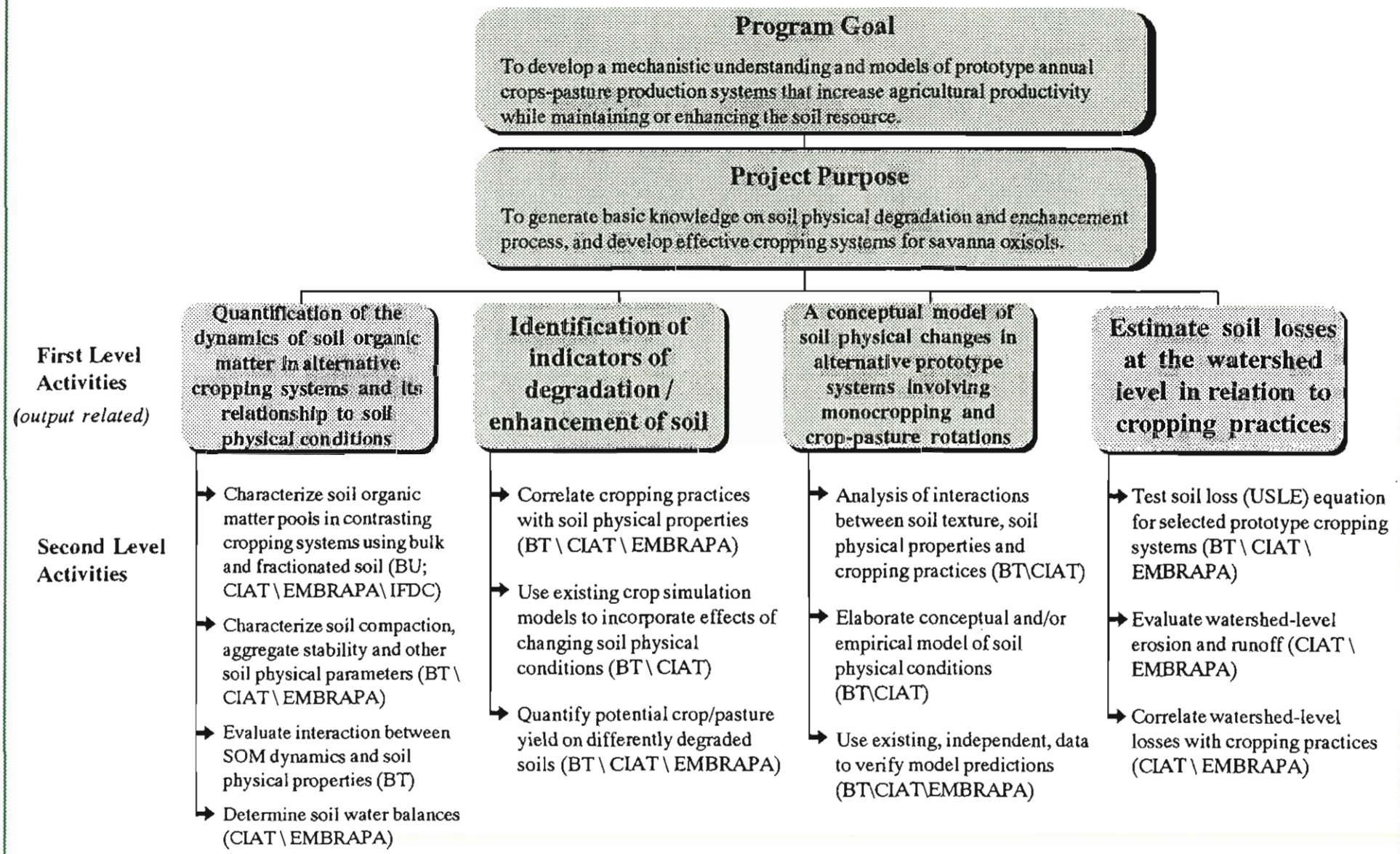
[18] Thomas, R.J., Fisher, M.J., Ayarza, M.A. and J.I. Sanz 1993. Productivity of acid tropical soils in Latin America and the role of forage grasses and legumes. **Workshop on long-term soil management experiments in the tropics,** Ohio State University June 16-18, 1993 in press.

[19] Stoner, E.R., de Freitas Jr, E., Macedo, J., Mendes, R.C.A., Cardoso, I.M., Amabile, R.F., Bryant, R.B. and D.J. Lathwell. 1991. Physical constraints to root growth in savanna oxisols. TropSoils Bulln 91-01, North Carolina State University, Raleigh, NC. 28p.

[20] Zech, W., Haumaier, L. and R. Hempfling. 1990. Ecological aspects of soil organic matter in tropical land use. In: Humic substances in soil and crop science". P. MacCarthy, C.E. Clapp, R.L. Malcolm and P.R. Bloom (eds.) pp. 187-202. American Society of Agronomy, Madison, Wisconsin, USA.

Figure 1

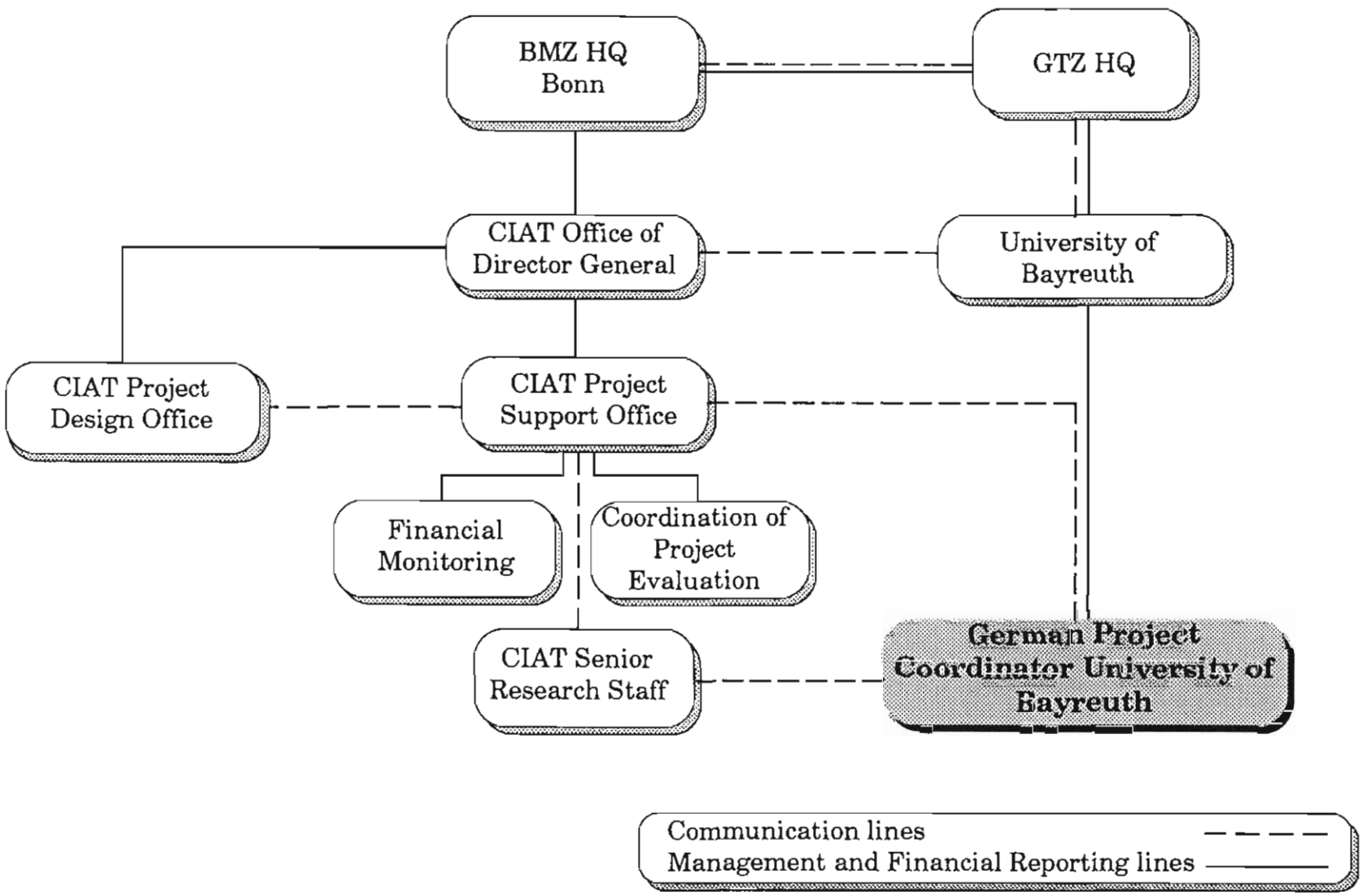
## Work Breakdown Structure Linking Project Activities to Project Outputs




Proposal\Thomas\wbs.pm4
Project Development Office

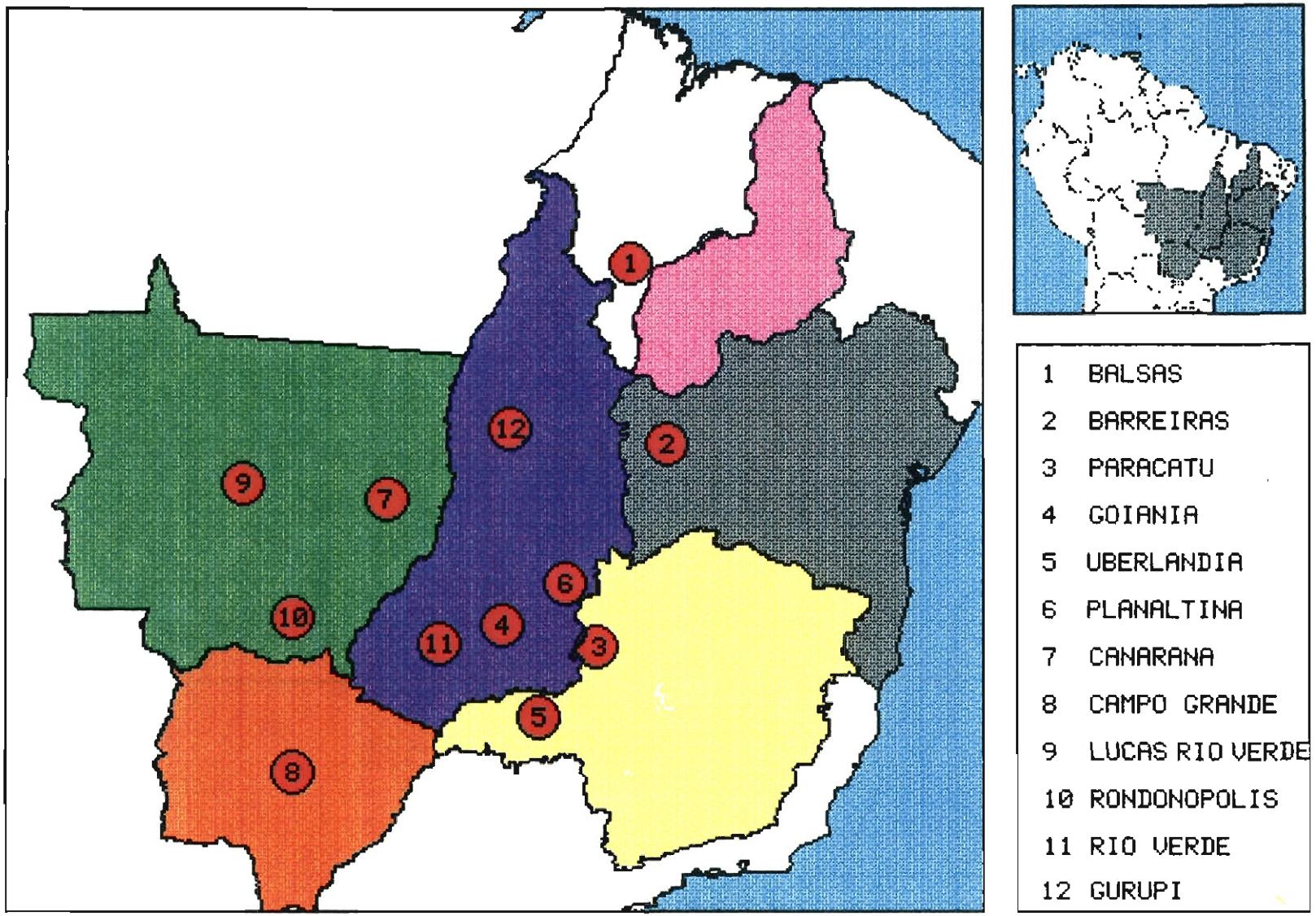
Figure 2

## Project Organization Chart




C:\Proposal\Thomas\Fig-2.pm4
Project Development Office

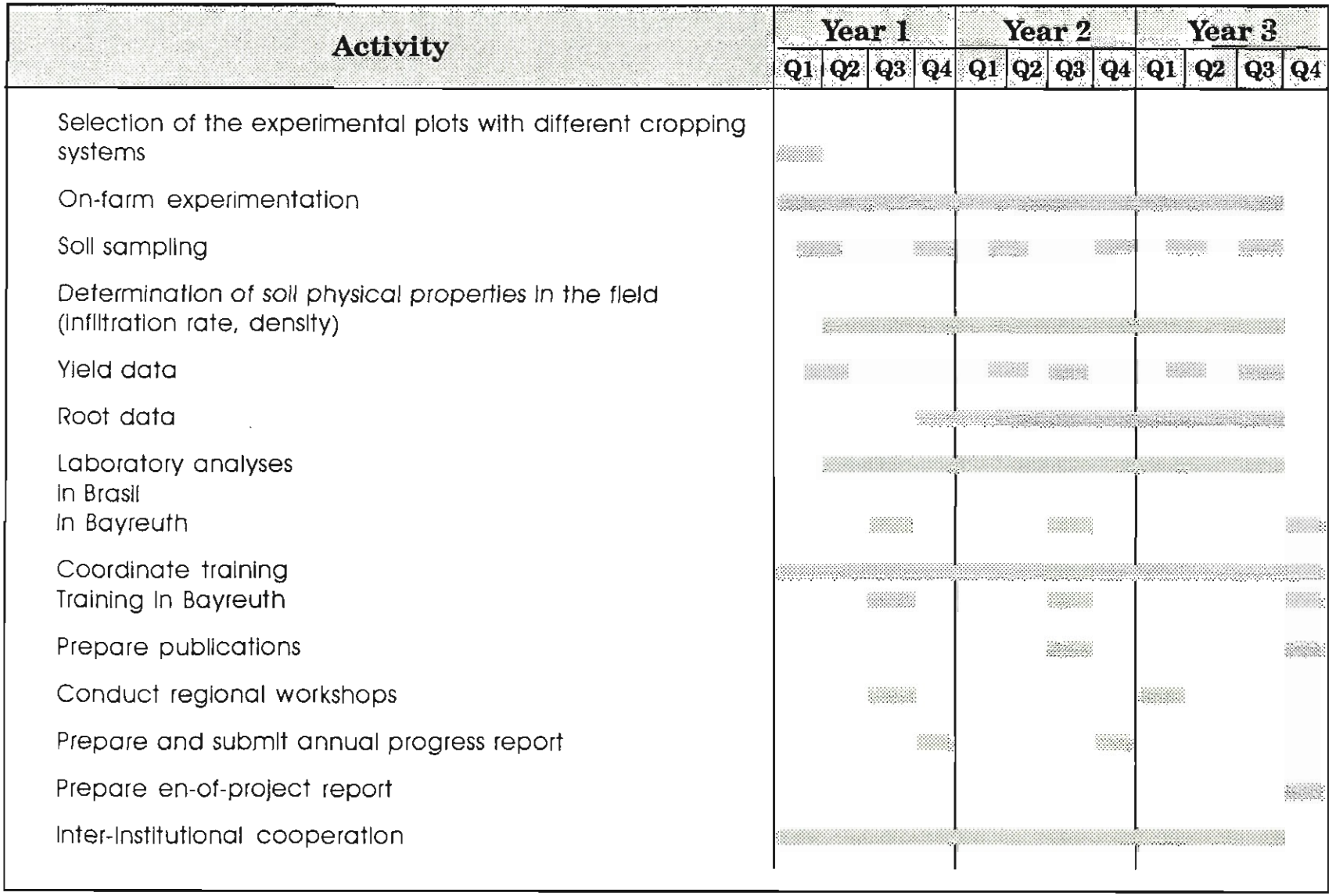
# Figure 3




SAVANNAS STUDY AREAS

*Proposal-Thomas fig-3.pm4*
*Project Development Office*

# Appendix A: CHRONOGRAM OF PROJECT ACTIVITIES BY YEAR



# Appendix B-1

## CIAT C.V.

Centro Internacional de Agricultura Tropical

| | |
|---|---|
| **Name:** | **Raúl R. Vera** |
| **Position in Project:** | Project Supervisor, Leader, Savannas Program |
| **Citizenship:** | Uruguayan |
| **Country of Residency:** | Colombia |
| **Education:** | Ph.D., Nutrition with minor in Biomathematics<br>University of California, Davis, 1976.<br><br>M.S., Animal Science<br>University of California, Davis, 1968.<br><br>B.Sc., Agriculture<br>Universidad de la República, Uruguay, 1966. |
| **Languages:** | Spanish -Native<br>English -Native<br>Portuguese -Fluent<br>French -Reading |
| **Management and Administrative Experiece:** | **Centro Internacional de Agricultura Tropical (CIAT)**<br>Leader, Savannas Program<br>Cali (1992 - present)<br><br>**Centro Internacional de Agricultura Tropical (CIAT)**<br>Leader, Tropical Pastures Program<br>Cali (1990 - 1992) |
| **International Research Experiece:** | **Centro Internacional de Agricultura Tropical (CIAT)**<br>1981-present<br>Research on savanna production systems and the role of forages in cattle systems in Brazil, Colombia, Ecuador and Perú. |

**Teaching and Thesis Supervisory Experience:**

- Teaching various courses in CIAT
- Supervision of several thesis including Ph.D., M.Sc. and B.Sc. at CIAT
- Associate Professor, Universidade Federal de Minas Gerais, B. Horizonte, MG, Brazil (1977 - 1981)
- 1969-1973 Assistant Professor, U. Nacional del Sur, Bahía Blanca, Argentina.

**Major Publications and Reports:**

*Editor of three books*:

(1) Sistemas de Producción Pecuaria Extensiva: Brasil, Colombia, Venezuela - Proyecto ETES. 530p. 1985.

(2) Panorama de la Ganadería de Doble Propósito en la América Tropical. 313p. 1989.

(3) *Andropogon gayanus* Kunth: a grass for tropical acid soils. 406p. 1989.

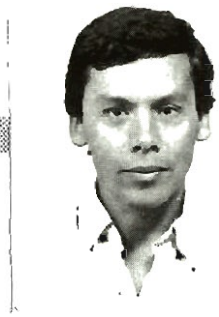
**Professional Memberships:**

- British Grassland Society
- Asociación Latinoamericana de Producción Animal (ALPA).

**Publications:**

see list enclosed

# Appendix B-2



## CIAT C.V.

Centro Internacional de Agricultura Tropical

**Name:** **Miguel Angel Ayarza**

**Position in Project:** Coordinator in Brasil/Soil Scientist

**Citizenship:** Colombian

**Country of Residency:** Brasil

**Education:**

Ph.D. Soil fertility North Carolina State University, 1986
M.Sc. Soil Science, University of Reading, U.K., 1980
B.Sc. Agronomy, National Univ. of Colombia, 1974

**Languages:**

English -Conversational
Portuguese -Conversational
Spanish -Native

**Management and Administrative Experiece:**

**Centro Internacional de Agricultura Tropical (CIAT)**
Cali, Colombia, (1992 - present)
Savanna Program, Coordinator of outposted activities

**International Research Experiece:**

**North Carolina State University**
TropSoils Mission, Yurimaguas, Perú (1984 - 1986)
Research on pasture production and fertility

**Centro Internacional de Agricultura Tropical (CIAT)**
Cali, Colombia, (1989 - 1992 - present)
Research Fellow Pasture and Savanna Programs
Research on soil fertility especially phosphorus in acid oxisols.

**Centro Internacional de Agricultura Tropical (CIAT)**
Planaltina, Brasil (1992 - present)
Senior Research Fellow Savanna Program

Research and coordinating activities with EMBRAPA-CPAC on agropastoral systems in the cerrados. Research on soil fertility and site selection using rapid rural surveys

**Teaching:**

**Centro Internacional de Agricultura Tropical (CIAT)**
Cali, Colombia (since 1989)
Instructor / lecturer in courses on tropical pasture management.
Supervisor of various under-graduate research projects.

**Professional Memberships:**

- Soil Science Society of America
- Colombian Soil Science Society

**Awards, honors:**

- British Council Scholarship 2 years (1978 - 1980)
- Rockefeller Foundation Scholarship 4 years (1982-1986)

**Publications:**

see list enclosed

# Appendix B-3

## CIAT C.V.

Centro Internacional de Agricultura Tropical

**Name:** **Richard James Thomas**

**Position in Project:** Researcher on nutrient dynamics in agropastoral systems

**Citizenship:** British

**Country of Residency:** Colombia

**Education:**

Ph.D. Plant/Microbial Physiology, University of Wales U.K. (1978)

B.Sc. Botany/Microbiology, University of Wales U.K. (1973)

**Languages:**

| | |
|---|---|
| English | -Native |
| Spanish | -Conversational |
| German | -Reading |
| French | -Reading |
| Portuguese | -Reading |

**Management and Administrative Experiece:**

University of Wisconsin-Madison
Dept. of Agronomy

Management of research grants from U.S.D.A. Competitive Grant, American Soybean Growers Association, Allied Chemicals (1979-1981)

Hill Farming Research Organisation / Macaulay Land Use Research Institute
Program Leader with responsibility for budgetary / administrative control of 18 research objectives and 8 research objective leaders (1983 - 1989)

Centro Internacional de Agricultura Tropical (CIAT)
Head of Nitrogen fixation/recycling section CIAT's pasture and savanna programs.

**International Research Experiece:**

University of Bern
Research Assistant, Institute of Plant Physiology, Switzerland (1977-1979)

University of Wisconsin-Madison
Department of Agronomy, Research Associate
USA (1979 - 1981)

University of Dundee
Department of Biological Sciences, Senior Research Assistant
UK (1981-1983)

Consultant for British Council-CNPQ bilateral convenium at EMBRAPA-PNPBS
Rio de Janeiro, Brazil (1983)

Senior Scientific Officer
Hill Farming Research Organization/Macaulay Land Use Research Institute, UK (1983-1989)

Centro Internacional de Agricultura Tropical (CIAT)
Senior Scientist, Pasture and Savanna Programs
Cali, Colombia (1989 - present)

**Teaching and Thesis Supervisory Experience:**

Research demonstrator and lecturer at the University of Swansea (Wales), University of Bern (Switzerland), University of Wisconsin-Madison (USA), University of Dundee (UK)

Honorary Lecturer at University of Dundee, UK.
Supervisor of undergraduate theses in UK, USA and Colombia.

Examiner of Ph.D. Thesis, Univ. of Dundee, UK.

**Professional Memberships:**

- American Society of Plant Physiologists
- American Society of Agronomy
- British Grassland Society

**Publications:**

see list enclosed

# Recent Relevant Publications from CIAT


Ayarza, M.A. 1991. Efecto de las propiedades quimicas de los suelos acidos en el establecimiento de las especies forrajes. In: C.E. Lascano and J.M. Spain (eds.), Establecimiento y renovacion de pasturas. pp. 161-185. CIAT, Cali, Colomiba.

Ayarza, M.A. and Spain, J.M.. 1991. Manejo del ambiente fisico y quimico en el establecimiento de pasturas mejoradas. In: C.E. Lascano and J.M. Spain (eds.), Establecimiento y renovacion de pasturas. pp. 189-208. CIAT, Cali, Colombia.

Thomas R.J. (1992) The role of the legume in the nitrogen cycle of productive and sustainable pastures. Grass and Forage Science 47, 133-142.

Thomas, R.J., Lascano, C., Sanz, J.I., Ara, M., Spain, J., Vera, R. and Fisher, M.J. (1992) The role of pastures in production systems. In "Pastures for the tropical lowlands: CIAT's contribution". p123-146. CIAT.

Thomas, R.J., Fisher, M.J., Lascano, C., Rao, I.M., Ayarza, M. and Asakawa, N. (1993) Nutrient cycling via forage litter in tropical grass/legume pastures. XVII International Grassland Congress, New Zealand/ Australia, Feb 8-21, 1993.

Miles, J.W., Thomas, R.J., Lascano, C., Fisher, M.J., Vera, R. and Sanz, J.I. (1993) Evaluation of *Stylosanthes* for selected farming systems of tropical America. African Livestock Research Journal in press.

Fisher, M.J., Lascano, C.E., Thomas, R.J., Ayarza, M.A. and Rao, I.M. (1993) An integrated approach to soil-plant-animal interactions on grazed legume-based pastures on tropical acid soils. XVII International grassland Congress, New Zealand/Australia, Feb 8-21, 1993.

Rao, I.M., Ayarza, M.A., Thomas, R.J., Fisher, M.J., Lascano, C.E. and Borrero, V. (1993) Adaptation responses of tropical grass-legume associations in acid soils. XVII International Grassland Congress, New Zealand/Australia, Feb 8-21, 1993.

Vera, R.R., Thomas, R.J., Sanint, L. and Sanz, J.I. (1993) Development of sustainable ley-farming systems for the acid-soil savannas of tropical America. In "Ecology and Sustainable Agriculture in Tropical Biomes" Rio de Janeiro, Feb 3-6, 1992. FAO Publns in press.

Thomas, R.J. and Asakawa, N.M. (1993) Decomposition of leaf litter from tropical forage grasses and legumes. Soil Biology & Biochemistry, in press.

Rao, I.M., Ayarza, M.A., Thomas, R.J., Fisher, M.J., Sanz, J.I., Spain, J.M. and Lascano, C.E. (1992) Soil-plant factors and processes affecting productivity in ley farming. In "Pastures for the tropical lowlands: CIAT's contribution" p.145-175, CIAT.

Ayarza, M.A., Rao, I.M., Thomas, R.J., Fisher, M.J., Lascano, C.E. and Herrera, P. 1993. Standing root biomass and root distribution in *Brachiaria decumbens / Arachis pintoi* pastures under grazing. XVII International Grasslands Congress, New Zealand/Australia, Feb 8-21, 1993.

Thomas, R.J. 1993. Rhizobium requirements, nitrogen fixation and nutrient cycling. In "Workshop on *Arachis*" CIAT May 25-28, 1993 in press.

Thomas, R.J., Fisher, M.J., Ayarza, M.A. and J.I. Sanz. 1993. The role of forage grasses and legumes in maintaining the productivity of acid soils in Latin America. Advances in Soil Science. in press 1994.

Thomas, R.J. and Lascano, C.E. 1994. The benefits of forage legumes for livestock production and nutrient cycling in pasture and agropastoral systems of acid-soil savannas of Latin America. In "Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa." Nov 22-26, 1993.

# Appendix C
--German Partner Confirmation-- **University of Bayreuth**

TO:
Name: Dr. R. Thomas
Address: CIAT, Columbia

Phone No: .....
Fax No: 00 57-23-647243

FROM:
Name: Prof. Dr. W. Zech
Address: Lehrstuhl Bodenkunde und Bodengeographie
Institute of Soil Science and Soil Geography

Phone No: ++921 55 22 48
Fax No: ++921 55 22 46

27 JUL. 1993
CIAT
CENTRO DE TELECOMUNICACIONES
TELEX [ ] CABLE [ ]
E. MAIL [ ] FAX [ ]
Recibido_____ Enviado_____

Number of pages: 1

Remarks: Dear Dr. Thomas,

I confirm my willingness to participate in the project "Dynamics of soil organic matter and physical properties in neotropical agropastoral systems"

Date: 26.7.93

Signature: J. Zech