Global Environment Facility

GEF

MOHAMED T. EL-ASHRY
CHIEF EXECUTIVE OFFICER
AND CHAIRMAN

November 28, 2001

Dear Council Member:

I am writing to notify you that we have today posted in the GEF's website at www.gefweb.org, a medium-sized project proposal from UNEP entitled *Global (Brazil, India, Jordan, Kenya): Assessment of Soil Organic Carbon Stocks and Change at National Scales.* The GEF will contribute $978,000 towards a total cost of $2,002,000.

This project intends to improve national assessment methodologies relating to land use options and UNFCCC requirements, and to support core activities of the GEF Integrated Ecosystem Management Operational Programme and IPCC by developing and demonstrating generic tools which quantify the impact of land management and climate scenarios on carbon sequestration in soils.

The project proposal is being posted for your information. We would welcome any comments you may wish to provide by December 18, 2001, in accordance with the procedures approved by the Council.

If you do not have access to the Web, you may request the local field office of the World Bank or UNDP to download the document for you. Alternatively, you may request a copy of the document from the Secretariat. If you make such a request, please confirm for us your current mailing address.

Sincerely,

M. Samuel T. El-Ashry

cc: Alternates, Implementing Agencies, STAP

GEF SECRETARIAT, 1818 H STREET NW, WASHINGTON, DC 20433 USA
TELEPHONE (202) 473 3202 FAX (202) 522 3240/3245

United Nations Environment Programme

برنامج الأمم المتحدة للبيئة · 联合国环境规划署

PROGRAMME DES NATIONS UNIES POUR L'ENVIRONNEMENT · PROGRAMA DE LAS NACIONES UNIDAS PARA EL MEDIO AMBIENTE

ПРОГРАММА ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ ПО ОКРУЖАЮЩЕЙ СРЕДЕ

UNEP

GEF COORDINATION OFFICE

P.O. Box 30552, Nairobi, Kenya • Tel:[254 2] 624166• Fax:[254 2] 624041•
E-mail: Ahmed.Djoghlaf@unep.org@unep.org • Http: { HYPERLINK http://www.unep.org/unep/gef/ }

TELEFAX TRANSMISSION

To: **Kenneth King**
Assistant CEO
GEF Secretariat

Fax No: 1 202 522 3240

Emma Torres
Deputy Executive Coordinator
UNDP/GEF

Fax No: 1 212 906 6998

Lars Vidaeus
Executive Coordinator
World Bank

Fax No: 1 202 522 3256

Madhav Gadil
Chairperson STAP

Fax: 91 80 334 1683

Date: **4 September 2001**

From: **Mr. Ahmed Djoghlaf**
Executive Coordinator
UNEP/GEF Coordination Office

Subject: **MSP entitled "Assessment of Soil Organic Carbon Stocks and Change at National Scale"**

Please find attached a revised version of the UNEP MSP proposal "Assessment of Soil Organic Carbon Stocks and Change at National Scale". The proposal been revised following the comments received from UNDP.

Regards.

MEDIUM-SIZED GEF TARGETED RESEARCH PROJECT BRIEF

PROJECT SUMMARY

PROJECT IDENTIFIERS	
1. Project name: Assessment of Soil Organic Carbon Stocks and Change at National Scale	**2. GEF Implementing Agency:** UNEP
3. Country/ies in which the project is being implemented: Brazil, India, Jordan and Kenya in close collaboration with research groups in USA, UK, Netherlands and Austria working under co-financing.	**4. Country eligibility:** Brazil: UNFCCC and CBD 28 Feb 1994 India: UNFCCC 1 Nov 1993; CBD 18 Feb 1994 Jordan: UNFCCC and CBD 12 Nov 1993 Kenya: UNFCCC 30 Aug 1994; CBD 26 Jul 1994
5. GEF Focal Area: Multi-focal addressing Climate Change, Biodiversity and Land Degradation	**6. Operational Programme/short-term measure:** This targeted research project relates to carbon sequestration and is aimed at Integrated Ecosystem Management (OP #12). It cross-cuts over the GEF climate change, biodiversity and land degradation programmes thereby linking, and adding value to all three. This project will assist Brazil, India, Jordan and Kenya establish their current soil organic carbon stock and determine how much carbon would be sequestered in soil under various ecosystem managements in these countries. In so doing, it will develop a generic tool which can be applied to other countries and/or regions as the data necessary are assembled in suitable GIS format. From a national perspective, it will offer an important methodology to: (i) improve national assessment methodologies relating to the UNFCCC for carbon emissions and sinks; (ii) help national agencies analyse the impact of a range of land management scenarios for biodiversity conservation vis à vis carbon sequestration; and (iii) allow national agencies to make quantitative estimates of carbon sequestration potential for use in international negotiations. From an international perspective, it will:

	(i) provide GEF with tools for quantitative, predictive assessment of potential consequences of land management interventions on carbon sequestration in soils; (ii) help GEF assess and develop projects which conserve and improve biodiversity, especially in soils; (iii) be complementary to, and input into, the IPCC process by providing a detailed, soil-based assessment of land-use impacts which is currently insufficiently developed; and (iv) develop international collaboration in land management scenario generation; capacity building and analysis.

7. Project linkage to national priorities, action plans and programmes:

This research topic is a high priority for many nations, including Brazil, India, Kenya and Jordan. Specifically:

Brazil: The Commission of Policies Related with Sustainable Development and the National XXI Agenda (Comissão de Políticas de Desenvolvimento Sustentável e da Agenda XXI Nacional, established by the Casa Civil da Presidência da República on 28 February 1997) includes a national priority concerning an inventory of the main greenhouse gases in different sectors including land use change, agroforestry and agriculture. In 1997 the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, which falls under the Ministry of Science and Technology) started a national project "Programa Integrado de Ecologia" (Integrated Project of Ecology) with an overall plan aimed at "(1) assessment of fluxes of energy and nutrients; and (2) creation of databases for the amazon region and others ecosystems".

India: The Perspective Plan of the Government of India's National Bureau of Soil Survey and Land Use Planning states that "The major emphasis in future programmes is given on basic and applied research in land evaluation, land use planning, remote sensing, pedology, soil degradation and human resource development." (NBSS&LUP, Nagpur, December 1997). While the proposed research will help various aspects of the overall Plan it is directly relevant to two major programmes and areas of priority research: (1) Organic Carbon Status: Monitoring and Management, especially "assessment of organic carbon status of different soils and their stock, and establish correlations with environmental factors"; and (2) Geographical Information Systems, especially "generation and dissemination of digital soil map of the country; and multi-criteria based decision making for land evaluation and land use planning at watershed/district level".

Jordan: The National Science and Technology Policy (STP) document highlights under Research and Development "undertaking studies and research for the development of land use" and "utilising remote sensing and geographical data to develop and improve natural resources, including soil, water and plant cover". Environmental priorities include "documenting and protecting the natural environment, curbing desertification and assessing the environmental impact of exploiting agriculture natural resources" and "utilising new technology for the documentation of information related to soil, plant and animal classification and their characteristics".

Kenya: The Kenya Soil Survey (KSS) under the Kenya Agricultural Research Institute has established a Geographic Information System for storing natural resources data including soils, soil nutrients, climate

and land use. KSS sees the use of this facility to optimise the management of severely limited agricultural land to supply the need of the estimated 3.4% per annum population growth (Republic of Kenya, 1986) as a central component in its programme of monitoring soil organic matter levels as related to carbon sequestration and soil productivity.

8. GEF national operational focal point and date of country endorsement:

Submitted: Acknowledged: Endorsed:

Letters of endorsement received from Brazil, Kenya, Jordan and India.

PROJECT OBJECTIVES AND ACTIVITIES

9. Project rationale and objectives:

Goal:

To improve national assessment methodologies relating to land use options and UNFCCC requirements, and to support core activities of the GEF Integrated Ecosystem Management Operational Programme and IPCC by developing and demonstrating generic tools which quantify the impact of land management and climate scenarios on carbon sequestration in soils.

Purpose:

Signature countries to the UNFCCC are required to make estimates of national carbon stocks. Methods to estimate carbon stored in above-ground vegetation are relatively well developed (*cf*. as discussed in UNEP project GF/4102-92-01: Country Case Studies on Sources and Sinks of Greenhouse Gases) in comparison to methods for estimating carbon stored in soils (which in most soils is mainly in the form of soil organic carbon, SOC). SOC is a principle constituent of soil organic matter, the quality and quantity of which significantly influence biodiversity both in the soil and above-ground; and the soil's erosion threshold.

In addition to the need to develop methods for estimating current SOC stock at national level, robust methods for quantifying change in SOC stock as a consequence of land management – i.e. carbon sequestration potential – are urgently needed to help national planners determine the feasibility, impact and cost-effectiveness of GEF Operational Programmes related to climate change, carbon sequestration and integrated ecosystem management. These will allow governments to explore possible management scenarios to determine the cost-effectiveness and environmental consequences of feasible management options. For instance, the sequestration potential in biomass of a radical, large-scale forestry programme is relatively easy to estimate from forestry productivity tables, but changes in carbon sequestered in soils under this land-use could not be similarly estimated. The net impact of this management at the ecosystem-level needs a method to estimate changes in soil organic carbon contents, and to derive potential carbon sequestration at landscape-level this needs to be linked with forestry production information and geographical information in a GIS. The economics of the loss of income from non-forestry use vis à vis gain in income from forestry products can be included in a further calculation, which also helps to estimate the net "worth" to the nation of the possible scenario. The methodology developed in the project will also help select GEF programmes and projects to ensure that those undertaken under one focal area will also benefit another focal area: potential conflicts in biophysical outcomes of land management objectives could be "spotted" in advance of implementation. For instance, the methodology will help to determine whether a GEF project aimed at minimising land degradation will likely sequester or release soil carbon. The research will also help identify potential areas of disagreement on land use planning with local communities and allow the *a priori* exploration of alternatives. This will be done by including national policy makers and land managers in the preparation of land-use scenarios, and identifying issues that need to be taken into account in their preparation.

National datasets for soils, climate and land-use (all of which exist for the four countries, but in distributed form) would be collated in standardised GIS format. Although only an "interim" product of this targeted research project, these GIS structures will also be suitable for other aspects of natural resource planning, which will add to the value of the research. This will also demonstrate the value of systematically formatting natural resource data in this manner for other countries to consider.

Background:

Very large quantities of carbon are currently stored in soils in the form of soil organic carbon (SOC). SOC provides a vital ecosystem function, contributing to inherent soil fertility, water holding capacity, structure, biological activity and carbon sequestration. Carbon stored as SOC is however highly sensitive to changes in land management and SOC levels almost always falls following the conversion of native ecosystems to agricultural use. This is well documented in a range of environments, and is primarily driven by (i) reduced organic matter inputs; and (ii) increased oxidation of SOC due to aggregate disruption and increased aeration. A range of factors determine the stabilisation of carbon in soils, but key variables are clay content and type, pH, hydrology, climate and organic matter inputs. For a given climate, three principle mechanisms account for SOC decline: reduced organic matter input, increased erosion, and increased oxidation as a result of tillage. In the tropics, both intensification of existing cropping land and land clearance for new cropping land are responsible for substantial net losses of soil carbon. In addition, anticipated increases in global mean temperatures will also tend to deplete SOC stocks through enhanced oxidation. The net result of both processes is an increase in carbon flux to the atmosphere. Conversely, application of innovative agricultural management practices, promoting the recovery of soil C stocks, and reduced rates of land clearance can either reduce soil CO_2 emissions or actively sequester carbon in soil.

From a biodiversity perspective, SOC, a principle constituent of soil organic matter, is known to significantly influence biodiversity both in the soil and above-ground. Soil organic matter has a direct correlation with soil organism density and hence soil biodiversity. Critical to any model for sustainable soil management is the role that soil organisms play. Soil organic matter affects a wide range of processes such as the movement of nutrients through plants and the movement of soil and water in catchments, thus resulting in different levels of vegetation stress and in turn, ecosystem functioning as a whole. This correlation points to the importance of SOC for vital ecosystem function, contributing to inherent soil fertility, water holding capacity, structure, biological activity in addition to carbon sequestration.

Regional, spatially-explicit estimates of SOC stocks and changes are needed to quantify CO_2 fluxes under various climate/soil/land-use conditions. Suitable tools for estimating these changes and further carbon sequestration possibilities as a consequence of land management at national and sub-national scale are however lacking as mapping methods are not dynamic and therefore cannot be used in a predictive capacity. Further, such tools need to be developed and systematically evaluated for the wide range of soils found in the tropics, especially for vertisols and oxisols (given the high P fixation of this highly weathered soil type). The need to have reliable data on present SOC stocks, and an estimate of how these might change under different environmental and management scenarios is of high priority for many nations.

Reliable tools to quantify change in carbon sequestration in soils would therefore be a very valuable addition to existing methodologies for carbon offset negotiations and will help identify the most promising strategies for decreasing losses (or increasing C stocks) and where they can best be applied. It is particularly urgent to have these tools developed and evaluated so that they can be used to help select projects to be submitted under the GEF Integrated Ecosystem Management Operational Programme; and to analyse how such projects would result in mutual benefits for work under other GEF focal areas.

Relationship of the GEF financed activities to the baseline or co-financed activities:

Scientists in the UK and Europe are already beginning to develop and demonstrate techniques for coupling SOC models with GIS assemblies of data on SOC controlling variables. Building on this work through co-financing by agencies in the US and Europe (see letters of support), and initial data gathering exercises currently underway in the four case countries as part of their respective National Action Plans, the GEF component will allow these techniques to be extended and refined in regions which are significantly different in three main ways: physical and socio-economic environment; levels of scientific

infrastructure; and data availability. The GEF input will be fundamental to demonstrating that this powerful methodology is both applicable in these regions and can be used as an important tool for selecting and guiding natural resource management in national and GEF financed development programmes in these and other countries were suitable data exists.

Research Objectives:	***Indicators:***
1. To identify and use long-term experimental datasets to systematically evaluate and refine modelling techniques to quantify carbon sequestration potential in tropical soils.	Long-term experiments suitable for use in model evaluation will have been identified in Amazon-Brazil, India, Kenya and Jordan, and their datasets converted to standard formats. ROTH-C and CENTURY soil carbon turnover models will have been evaluated and any necessary adjustments will have been made to simulate the long-term data.
2. To define, collate and format national-scale soils, climate and land-use datasets and to use them in the development of coupled modelling-GIS tools to estimate soil carbon stocks.	National-scale datasets on the state variables needed for estimating soil organic carbon stocks collated in standardised GIS layers suitable for model linkage; and GIS-model interfaces prepared. The GIS format will also allow national- and sub-national assessments for other natural resource management issues to be more effectively conducted.
3. To demonstrate these tools by estimating current soil organic carbon stocks at country-scale (using India, Jordan, Kenya and Amazon-Brazil as case studies) and to compare these estimates with the existing techniques of combining soil mapping units and interpolating point data.	Estimates will be available of national level soil organic carbon stocks for Amazon-Brazil, India, Kenya and Jordan critically compared with estimates obtained by non-modelling methods.
4. To Quantify the impact of defined changes in land use on carbon sequestration in soils with a view to assisting in the formulation of improved policies to optimise resource use in the four case-study countries.	Estimates will have been made of the impact of a range of scenario-based, national-scale land-use changes on soil organic matter stocks.

10. Project outcomes:	**Indicators:**
1. Data from national data sources of variables relating to the control of carbon stocks in Brazilian, Indian, Jordanian and Kenyan soils systematically collated and formatted in standardised GIS formats.	National data sets for different variables which control soil organic matter stocks (e.g. soils, climate, land-use) which are currently held by different institutions, will have been brought together in a form suitable for modelling studies and other natural resource management issues.
2. Regional-/National-scale quantities of carbon stored in Amazon-Brazilian, Indian, Jordanian and Kenyan soils estimated and critically compared with soil mapping methodologies, and maps of land-use and carbon density derived.	The ability to quantify national-scale soil organic carbon stocks will have been assessed, and model calibration parameters for national conditions established. GIS-derived maps of carbon density will be available.
3. Capacity building in the use of GIS-model interfaces and soil organic carbon stock assessment.	Scientists and technicians in national institutions in Brazil, India, Kenya and Jordan will have received training in data management, GIS construction and model-GIS coupling both in-country and by undertaking exchange missions to the US and Europe.
4. Generic tools designed to help in formulating national and sub-national land management and carbon sequestration policy by (i) quantifying current soil organic carbon stocks at national and sub-national level; and (ii) analysing the impacts of land management options on carbon storage, GHG emissions and sequestration possibilities.	The generic nature of the modelling/GIS tools will have been established by showing their adaptability across the widely varying conditions found in the four study countries. User-defined scenarios of land-use change will have been used as case studies to demonstrate how these tools can be used in helping to formulate national policy by quantifying the impact of given management changes on soil organic carbon stocks.
5. Tools developed to help GEF identify and select possible national carbon sequestration projects, and guide their development and implementation.	Case studies in the contrasting environments will have demonstrated how GEF could use the model-GIS tools to evaluate *a priori* the potential of GEF national projects to sequester carbon in soil. The value of investing in data assemblage will be clearly demonstrated for other countries to consider. The tools will also assist in assessing the interactions between given land management scenarios across GEF Focal Areas.

11. Planned activities to achieve outcomes (including cost in US$ or local currency of each activity):	**Indicators:**
The project will be implemented as a series of interlinked steps which address the four successive objectives (see above). The steps will include a series of interdisciplinary workshops specifically designed to either assess progress and gain targeted feedback from acknowledged experts or prepare for the next step. Case studies for selected regions of the four countries to be conducted during the project will be used to refine methodologies and test applicability (see attached "Time Line"). Discussion with national agencies responsible for land-use planning will be conducted at each Step of the project to ensure the project ultimately delivers policy-relevant tools in a form suitable for the end users. *Note: While these steps are phased their overlapping design means a simple cost breakdown is not possible. The figures (US) listed below, which are for full costs (i.e. GEF + co-financed), are therefore indicative and were derived from pro-rata calculation of activities and time needed to complete each step. The attached budget estimate gives full details of proposed GEF and co-financing contributions.*	
Step 1. *(Addressing Objective 1)* Format long-term datasets and evaluate and refine SOC turnover models for India, Jordan, Kenya and Brazil. A review of data already collated through the National Communications work of each participating country will first be carried out. Months 1 - 6. ($300k) Model Evaluation Workshop in Month 6. ($27k)	Modellers and long-term experiments data holders will have met at the workshop in month 6 and a detailed model evaluation will have been conducted using the regional datasets. Multi-authored, scientific publication planned. Training will have been conducted in use of long-term data in model evaluation.
Step 2. *(Addressing Objective 2)* Define necessary spatial databases of SOC controlling variables (data "layers" in GIS) and collate and format national datasets. Months 6 - 24. ($450k) GIS Definition Workshop in Month 6. ($25k)	Modellers, long-term experiments data holders and GIS technicians will have collaboratively designed the working GIS structure at the workshop to launch this step. Datasets will have been systematically collated and detailed descriptions will be published as an interim product. Training will have been conducted in GIS development and data formatting.
Step 3. *(Addressing Objective 2)* Develop methods to couple models with GIS to assess current SOC stocks. Conceptual development phase. Months 6 - 18. ($300k) Model/GIS coupling review workshop in Month 12. ($25k)	Modellers and GIS technicians will have jointly developed the conceptual design of the model/GIS interface, and, following critical review at the mid-step workshop, will have fully developed the coupled tool. Training will have been conducted in GIS-model coupling.
Step 4. *(Addressing Objective 3)* Quantify	All groups will have collaborated to produce maps

current SOC stocks using modelling/GIS methodology and compare with non-modelling methods ("uncertainty analysis"). Months 18 – 30. ($300k) Peer review and uncertainty analysis Workshop in Month 24. ($30k)	and of current carbon density and derived national/regional totals based on model/GIS methods, and will have compared these with maps and estimated totals produced by other methods. Model calibration will have been completed.
Step 5. *(Addressing Objective 4)* Develop "realistic" environmental and land-management change scenarios. Months 24 - 30. ($160k) Land-use scenario workshop in Month 30. ($35k)	All groups + relevant users (e.g. ministries, national and regional land-use planners), IGBP/IHDP-LUCC, IIASA, etc. will have developed a set of agreed "case study" scenarios of future land-use for the four countries, and the Workshop will deliver standard sets available for use in Step 6. Training will have been conducted in land-use change modelling and scenario development.
Step 6. *(Addressing Objective 4)* Estimate of scenario-based change in SOC stocks and development of guidelines for implementing the methodology and national scale. Months 30 - 36. ($300k) Project presentation at final "Open" Workshop in Month 36. ($50k)	Estimates of changes in regional-/country-level soil organic carbon stocks as a consequence of different management scenarios will be available for discussion with national planners and policy makers. A report will be produced giving guidelines for using the model/GIS tools, and for interpreting the results. The final workshop will present demonstration studies for the contrasting regions to show how the developed modelling/GIS capability can be used to quantify changes in soils organic carbon stocks as a result of a range of "realistic" land management scenarios. It will also highlight how the output needs to be considered in the context of national planning so that wider socio-economic implications can be gauged in the light of possible carbon sequestration strategies.

12. Estimated budget (in US$ or local currency):

PDF: Nil (provided by co-financing and "in-kind" contributions of expert time)

GEF: US$978,000

Co-financing: US$1,024,000 (see letters of support)

Total: US$2,002,000

13. Information on project proposer:

The project is proposed by the International Development Centre of the University of Reading, UK (with the Department of Soil Science taking the lead) on behalf of the international consortium of institutes involved in the proposal. Established in 1995, the non-profit making Centre is an interdisciplinary collaboration between several University departments all active in the development field. The Centre has built up substantial ties with numerous countries in the developing world though its research and teaching components, and its activities include the coordination of research into major issues of development policy.

14. Information on proposed executing agency (if different from above):

The project will be managed and executed by the International Development Centre of the University of Reading, UK (with the Department of Soil Science taking the lead) on behalf of the international consortium comprising scientific agencies in Brazil (Centro de Energia Nuclear na Agric, Universidade de Sao Paulo[1] and Ministry of Science and Technology - Convenção-Quadro sobre Mudanças do Clima) (National Bureau of Soil Survey and Land Use Planning), Jordan (Higher Council for Science and Technology/Badia Research and Development Programme) and Kenya (Kenya Soil Survey) together with representatives from scientific collaboration groups in the US (Natural Resources Ecology Laboratory, Colorado State University), UK (Rothamsted Experimental Station), the Netherlands (International Soil Reference and Information Centre), Austria (International Institute for Applied Systems Analysis) and UNEP. International co-ordination and technical back-up will be administered by the International Development Centre of the University of Reading, UK in close contact with all partners. The hope is to recruit a suitably qualified national scientist to the post of International Coordinator. Co-financing is being sought from donor agencies for scientific work in the USA and European countries (see Budget Estimate outline, attached) and no GEF funds will be used in this regard.

15. Date of initial submission of project concept: 13 October 1998

16. Project Identification number: *tbd*

17. Implementing Agency contact person: Ahmed Djoghlaf, Executive Coordinator, GEF Coordination Office; Sheila Aggarwal-Khan, Medium sized Projects, UNEP GEF Coordination Office.

18. Project linkage to Implementing Agency program(s): The World Meteorological Organization (WMO) and UNEP established the Intergovernmental Panel on Climate Change (IPCC) in 1988. It is open to all members of the UNEP and WMO. The role of the IPCC is to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. It does not carry out new research nor does it monitor climate related data. It bases its

[1] Universidade de Sao Paulo acts as a representative for the Ministry of Science and Technology with respect to greenhouse gas inventories, India

assessment mainly on published and peer reviewed scientific technical literature. On the subject of land use, land-use change and forestry (LULUCF), the IPCC is considering methodological issues, such as rules for monitoring accounting for carbon stock changes and for emissions and removals of greenhouse gases from LULUCF activities, including which carbon pools to include, how to implement "since 1990," "direct human-induced," and "human-induced," how to ensure accuracy, precision, and uncertainties in tracking carbon stocks and greenhouse gases, among others. The methodologies refined during this project will be put to the IPCC for their consideration and to the CCD discussions on land use. The same is intended through UNDP's involvement in the project. UNEP is establishing a key centre on land cover and land assessment in Sioux Falls which will become involved in soil carbon stocks which this project will be linked into. UNEP is also leading a process on harmonisation of assessment methodologies which this project would contribute to.

PROJECT DESCRIPTION

1. Project rationale and objectives

Very large quantities of carbon are currently stored in soils in the form of soil organic carbon (SOC). A total amount of 1462 - 1548 Gt (10^9 tons) in the top 100 cm has recently been calculated by estimating the carbon content per unit area of each soil type and multiplying by its total area, though uncertainties about soil depth, stoniness and bulk density introduce errors. Carbon stored as SOC is however highly sensitive to changes in land management and SOC levels almost always fall following the conversion of native ecosystems to agricultural use. Recent data averaged over 100 sites throughout the tropics shows how SOC amounts in the top 30 cm of the soil profile differ under different managements: a few years after converting original forest to crop land, SOC levels fell from the original equilibrium level of about 65 t/ha to a reduced equilibrium level of about 40 t/ha, a loss of 20 t/ha primarily to the atmosphere. If forest was converted to bush fallow, however, SOC levels fell to only about 55 t/ha, a loss of half that from conversion to cropped land. Subsequent land management will control whether SOC levels remain stable, continue to decline, or partially or fully recover. The application of innovative agricultural and land management practices, promoting the recovery of soil C stocks, and reduced rates of land clearance can either reduce soil CO_2 emissions or actively sequester carbon in soil.

The degree to which SOC stocks are changed by management is now largely understood and, given information on the variables responsible for carbon stabilisation and land use history, equilibrium SOC levels can be successfully modelled at the experimental plot scale. Spatially-explicit estimates of SOC stocks and changes are now needed to quantify CO_2 fluxes under various climate/soil/land-use conditions, but tools for estimating these changes and hence further carbon sequestration possibilities as a consequence of land management at national and sub-national scale are however lacking as mapping methods are not dynamic and therefore cannot be used in a predictive capacity. The need to have reliable data on present SOC stocks, and an estimate of how these might change under different environmental and management scenarios is of high priority for many nations. Calibrated modelling (i.e. where the estimation of *absolute* SOC values is less critical) is the only way to undertake such analyses. Suitable methods have recently been developed in the US and UK and research is now needed to develop applications at sub-continental scale is viable. In terms of data availability and contrasting environments, Brazil, India, Jordan and Kenya are particularly well placed to be central in what needs to be an international collaborative research programme, and the proposed work falls well in line with their respective national priorities (see Annex 1). The four countries have diverse environments and soils, and rapidly changing agricultural demands and landuse. Together they cover significant portions of the earth's land area. They all have comprehensive datasets of both (i) key driving variables (for model parameterisation) and (ii) SOC measurements (for model calibration and evaluation). Finally, they span the range of issues from extensification (land cover change) to intensification (land use change).

Reliable tools to quantify the impact of various management options on carbon sequestration in soils would be a very valuable addition to existing methodologies for carbon offset negotiations and will help identify the most promising strategies for decreasing losses (or increasing C stocks) and where they can best be applied. It is particularly urgent to have these tools developed and evaluated so that they can be used to help determine the feasibility, impact and cost-effectiveness of GEF Operational Programmes related to integrated ecosystem management and climate change; and to analyse how such projects would result in mutual benefits for work under other GEF focal areas. Further, due to the numerous key ecosystem functions that soil organic carbon (in the form of soil organic matter) fulfils, the project will also have considerable relevance for GEF research and implementation programmes in biodiversity, agriculture and forestry, and land degradation/desertification. In particular, it will relate to the "Alternatives to Slash and Burn" project; to the proposed GEF

Targeted Research project "Management of Agrobiodiversity for Sustainable Land Use and Global Environmental Benefits"; to PLEC; to LUCID; to the CGIAR ICWG-CC; and to the proposal under development on the use of *Atriplex* spp. in the arid regions of Jordan for ecosystem protection and carbon sequestration. IPCC also see the proposed research of direct relevance in their preparation of the Special Report on Land Use, Land Use Change and Forestry requested by SBSTA of UNFCCC.

Project:

To improve UNFCCC national assessment methodologies and to support core activities of the GEF Integrated Ecosystem Management Operational Programme and IPCC by developing and demonstrating generic tools for quantifying the impact of land management options and future climate scenarios on carbon sequestration in soils.

Research Objectives:

1. To identify and use long-term experimental datasets to systematically evaluate and refine modelling techniques that allow the estimation of carbon sequestration in tropical soils.
2. To define, collate and format national-scale soils, climate and land-use datasets and to use them in the development of coupled modelling-GIS tools to estimate soil carbon stocks.
3. To demonstrate these tools by estimating current soil organic carbon stocks at country-scale (using India, Jordan, Kenya and Amazon-Brazil as case studies) and to compare these estimates with the existing techniques of combining soil mapping units and interpolating point data.
4. To quantify the impact of defined changes in land use on carbon sequestration in soils with a view to assisting in the formulation of improved policies to optimise resource use in the four case-study countries.
5. To improve national reporting of developing countries on carbon emissions and sinks in the context of soil organic carbon.
6. To work with the IPCC on improving their guidelines on soil organic carbon stocks estimation.

General methodological approach:

Data on the variables that control soil carbon stabilisation in soil (i.e. soil parameters, climate and land use) will be compiled in a geographic information system (GIS). Techniques for running SOC stabilisation models when explicitly coupled to the GIS data will simultaneously be refined. Equilibrium levels of SOC will then be modelled for each polygon in the GIS and summed to give landscape SOC amounts. Modelled estimates will be compared with mapped estimates and an uncertainty analysis conducted with the modelled values providing an independent check on mapping methods for estimating *current* stocks and suitable calibration undertaken. This will allow (i) the quantitative comparison with other methods, and thereby (ii) provide a framework for integrating results from modelling with the other methods. "Realistic" scenarios of land use change will be developed in close consultation with national land use planners using latest land use change modelling techniques. The model-GIS tools will then be used to undertake analyses of *change* in SOC levels for the given land management scenarios.

The collation and organisation of regional datasets for Brazil, India, Jordan and Kenya will be a central element of the project and will involve a concerted effort by national scientists working with relevant government departments and agencies. The project will also build substantially on methods developed by ongoing studies of a similar nature in the central US (NREL group, Colorado State

University); in Hungary (BBSRC-Rothamsted group, UK); and in the UK (NERC-CEH group). The International Soil Reference and Information Centre (ISRIC) in the Netherlands will provide expertise in data management, GIS development and applications.

Early collaboration with national land use planners and with the Land-Use and Cover Change programme of IGBP and IHDP will be sought to help develop realistic scenarios of land use change. All groups will be involved in both the detailed planning and implementation. While this research project will concentrate on Amazon-Brazil, India, Jordan and Kenya as case studies, the methods developed will be generic so they can be used for other regions of the globe as datasets are forthcoming. The geographical extent of India and Brazil means that the project will need to concentrate on selected sub-regions in these countries, at least initially - for India: the Indo-Gangetic Plain; and for Brazil: Rondonia State. Rondonia State was selected for this project as it is the state in the Amazon basin with the highest rate of deforestation; there is also a large body of work done already on soil carbon stocks in Rondonia state than other areas that this project would be able to draw from which does not exist for other states. It therefore serves as an ideal representative site for the Amazon basin.

Much of the required soils data already exists for India, Jordan and Kenya, but it needs organising and formatting in GIS for use in modelling analyses. This will essentially be a "desk" exercise, led by national scientists working with the relevant soil survey organisations. Additional field sampling will however be needed in Rondonia State, Brazil. Geo-referenced soil profiles under forest and pastures of different ages will be sampled. This samples will be taken at 0-5 cm; 10-20 cm and 20-30 cm, air dried, and prepared for analysis in the Soil Biogeochemistry Laboratory at CENA/USP, Piracicaba, SP, Brazil. The carbon will be analysed by combustion by a LECO CR412 analyser. The other elements will be analysed according to the analytic protocol of this lab. A Soil Data Base will be established with data which will be stored in an Excel spreadsheet. The following profile descriptives variables will be included: profile number, latitude, longitude, altitude, local, bibliographic references, soil type, parent material, relief, slope, vegetation; and soil horizons descriptives analyses: horizon number, depth, bulk density, texture, structure, sand, silt, clay, Ca, Mg, Na, S, H+Al, CEC, P, pH, C, N, C/N.

In general data is already available and further chemical analyses are not required. If however further data is needed, standard methods will be used at detailed in ASA Monographs and specialist literature (e.g. Anderson and Ingram, "Tropical Soil Biology and Fertility: A Handbook of Methods").

Implementation (see attached "Time Line"):

The project will be implemented as a series of interlinked steps which are specifically designed to address the four successive objectives (see above). The steps will include a series of interdisciplinary workshops to either assess progress and gain targeted feedback from acknowledged experts or prepare for the next step. Case studies for selected regions of the four countries to be conducted during the project will be used to refine methodologies and test applicability (see attached "Time Line"). Discussion with national agencies responsible for land-use planning will be conducted at each Step to ensure the project ultimately delivers policy-relevant tools in a format suitable for the end users. Close contact will also be maintained with GEF staff as the Integrated Ecosystem Management Operational Programme develops to fine-tune the research strategy as necessary to ensure the final product is of a suitable form for GEF analyses and project identification. Output will be in several forms: through capacity building, links to national programmes and agencies; open scientific literature; WWW-based products; and an Open Science Workshop to present the projects findings and final report. The link to decision makers and the policy proponents of the project are particularly important. Clearly the final workshop will be a key element of this aspect, but contact with policy-makers will be maintained throughout the project. In the case of Brazil, for

instance, the co-execution of the project by the Universidade de Sao Paulo and Ministry of Science and Technology will allow frequent interaction between science and policy development.

2. Current situation (baseline course of action)

Signature countries to the UNFCCC are required to make estimates of national carbon stocks. Methods to estimate carbon stored in above-ground vegetation are relatively well developed (*cf*. as discussed in UNEP project GF/4102-92-01: Country Case Studies on Sources and Sinks of Greenhouse Gases) in comparison to methods for estimating carbon stored in soils (which in most soils is mainly in the form of soil organic carbon, SOC). In addition to the need to develop methods for estimating current SOC stock at national level, robust methods for estimating change in SOC stock as a consequence of land management - i.e. carbon sequestration potential - are urgently needed in readiness for GEF Operational Programmes related to integrated ecosystem management and climate change.

The four study countries currently estimate regional soil organic carbon stocks by estimating the carbon content per unit area of each soil type and multiplying by its total area. While uncertainties about soil depth, stoniness and bulk density introduce errors are well recognised, the fundamental problem with these methods is that that are not dynamic, and therefore cannot be used to estimate how different land management will affect soil carbon stocks.

Extrapolation from small-scale field trials has the inherent problems of site-specificity of results and lack of a mechanistic, predictive capability, so coupled model/GIS tools provide the only viable means for estimating the effects of changed management at region level. Several factors influence the carbon stock in soil, and the study countries have put considerable effort into collating data on these into coherent soils and climate maps. These data now need to be combined with data on the other controls on SOC stabilisation (e.g. land use), in a format suitable for linking with soil carbon turnover models.

Without GEF funding, the course of action would be not to develop this methodology, thereby leaving a serious gap in quantitative assessments. The GEF incremental cost would allow this work to be conducted in an internationally coordinated manner, drawing on expertise from many nations and developing and demonstrating the robustness of the product in widely contrasting situations. This will both help achieve national objectives for the case study nations and develop a generic tool for other regions of the world.

3. Expected project outcomes, with underlying assumptions and context (alternative course of action)

The expected outcomes from this targeted research project include:

1. Data from national data sources of variables relating to the control of carbon stocks in Brazilian, Indian, Jordanian and Kenyan soils systematically collated and formatted in standardised GIS formats and fed into national greenhouse gas inventories.
2. Regional-/National-scale quantities of carbon stored in Amazon-Brazilian, Indian, Jordanian and Kenyan soils estimated and critically compared with soil mapping methodologies, and maps of land-use and carbon density derived.
3. Capacity building in the use of GIS-model interfaces and soil organic carbon stock assessment.
4. Generic tools designed to help formulate national and sub-national level policy by (i) quantifying

current soil organic carbon stocks at national and sub-national level; and (ii) analysing the impacts of land management options on carbon storage, GHG emissions and sequestration possibilities.

5. Tools developed and demonstrated for guiding the selection of national GEF projects and monitoring their implementation at national and sub-national scale.
6. Consideration by the IPCC of improved methodologies on soil organic carbon stocks estimation;
7. Interim and final scientific findings and developments published in the peer-reviewed scientific literature and, where appropriate, on the WWW; and Final Project Report for supporting agencies.

Assumptions are that the methodology initially developed in the US and UK will be equally applicable to tropical regions (there is no intrinsic reason why this should not be so, the main issue being data availability); and therefore that sufficient data can be assembled in suitable format. The current approaches to regional soil carbon estimation cannot be used for scenario-based assessments due to their "non-dynamic" nature, so if this targeted research project did not proceed, such analyses based on existing techniques would be qualitative at best.

4. Activities and financial inputs needed to enable changes (increment)

The alternative course of action will be implemented as a series of overlapping phases of "Steps". All Steps will include a training component either conducted "in-country" or as part of an exchange visit programme under funds pledged by START (see attached Letters of Support). See attached "Budget Estimate" for other necessary financial inputs.

Step 1. ***Long-term dataset formatting and evaluation and refinement of SOC turnover models for Brazil, India, Jordan, Kenya. Months 1 - 6. Modelling and long-term experiments groups.***

CENTURY and ROTH-C are the most widely used and tested models of soil organic matter dynamics and have been successfully applied in a variety of ecosystems. While both models are sensitive to CO_2 and N, the real impact on SOC will come from changes in vegetation cover and amount. The selected models (two models are advocated: CENTURY and Roth-C, not just one) are specifically designed for SOC analyses. The potential land management options for consideration chiefly affect the organic fraction (SOC). Countries have been selected specifically to offer a wide range of soil types.

Both models have been used in tropical environments but no systematic analysis of either model for Brazilian, Kenyan, Indian or Jordanian conditions has been done. Datasets from several long-term experiments appropriate for conducting this work exist in each country but they need to be collated and formatted. The work will be conducted by the national groups working with the UK and US modelling groups and a model evaluation workshop (Workshop 1) will review progress after 6 months.

Under the Enabling Activities for each participating country, it is noted that there is already the collection of data on forest soil type and soil carbon content, and estimation of changes in soil carbon due to various land use and land cover change activities. In the case of India for example, the output is a database of collated, validated and mapped data on soil carbon by region and forest type. Jordanian scientists have already estimated emissions from soils for different types of vegetation. Thus, an initial parallel step in this exercise will be a review of existing National Communications for each country involved in the project to assess the compatibility of this work to that proposed in this MSP. Thus Workshop 1 will include involving the participating of the national project co-ordinators for each participating country's climate enabling activities. UNDP's and

UNEP's GEF task managers for climate change enabling activities will also be invited to participate in the workshop. In addition, the task manager's for UNDP's PDF Block B - Regional Africa Coping with Drought and Climate Change (at least for Kenya), for the World Bank's MSP targeted research project on Impacts of Climate Change on Agroecological Systems in Africa, and for the Kenya PDF Block B Integrated Ecosystem Management will be invited to the workshop. This is to ensure that lessons learned can be shared between these projects as they all focus on the Interface between climate change, land use and carbon sequestration. The task manager for the World Bank targeted research MSP for carbon sequestration in different types of agricultural systems in Oaxaca, Mexico will also be invited to the workshop and asked to prepare a paper to share some lessons on soil conservation and land use.

In addition, this workshop will include a discussion on how best to test the model in other regions. Of particular context, is the UNDP-GEF regional projects on GHG inventories in Eastern Europe and West Africa where the model may be tested. Thus, UNDP-GEF (Bo.Lim@undp.org) has agreed to serve on the project steering committee in this context.

Step 2. ***Definition of necessary spatial databases of SOC controlling variables (data "layers" in GIS) and data acquisition and formatting. Months 6 - 24. All groups.***

The necessary datasets are known to exist for all four countries, but their (i) completeness and quality need to be assessed and (ii) data layer structure and format needs to be established to allow suitable coupling to models. This will comprise a GIS definition workshop (Workshop 2) and a technical working group will be convened to monitor and refine the approaches and determine the best strategy for accessing the data. Workshop 2 will launch the concerted data layer assembly phase which will require frequent iteration with the technical working group, including scientific exchange and training visits.

Step 3. ***Model/GIS coupling for assessing current SOC stocks. Conceptual development phase. Months 6 - 18. All groups.***

This step will be launched after Workshops 1 and 2 and will review existing techniques and refine them as necessary for building the model links with the data layers designed in Workshop 2. A technical workshop (Workshop 3) will review progress after 6 months.

Step 4. ***Quantification of current SOC stocks. Months 18 - 30. All groups.***

A pilot project will be undertaken for each region, in which estimates will be made and compared with the other methods (interpolation of point data and soil mapping units). Workshop 4 will provide a mid-term, peer-reviewed check on the overall design and implementation of the project. Workshop 4 will also undertake an uncertainty analysis of the three carbon stock assessment methods and launch the concerted action phase of Step 5. Step 4 will culminate in a synthesis workshop (Workshop 5) and report.

Step 5. Development of environmental and land-management change scenarios. Months 24 - 30. All groups + relevant users (e.g. ministries), IGBP/IHDP-LUCC, IIASA, etc.

It is essential to develop consistent and "realistic" scenarios of changes in land use and management representing a plausible range of anticipated environmental impacts as well as demographic and economic development. The scenarios will need to be established and defined in close collaboration with the project's end users. To ensure comparability and consistency, scenario development will be based on rigorous modelling methods such as developed at IIASA

in Austria. The quantification of scenarios will proceed in two steps. First, the IIASA World Food System Model will be applied to estimate at country level trajectories of agricultural production to meet export and domestic food demands over a 30-year time frame. These results will then be translated to sub-national scale by major physiographic and soil unit, and for specific geographic regions within the three pilot countries. This second step will apply multi-criteria optimisation techniques based on an assessment of land characteristics and production capability of land with FAO's agro-ecological zones approach and with boundary conditions defined by the national results. The work will culminate at Workshop 5 where the scenarios for the four countries will be finalised. The sub-national scenarios will then be used as drivers in Step 6 and are thus a prerequisite to achieving Objective 4.

Step 6. ***Estimate of scenario-based change in SOC stocks. Months 30 - 36. All groups.***

The scenarios established in Step 5 will be used to estimate carbon sequestration for Amazonas-Brazil, India, Jordan and Kenya. A final "Open" workshop (Workshop 6) will present the project's demonstration studies to a wide range of scientists and policy makers. It will also outline a final report detailing how the developed modelling/GIS capability can be used to quantify changes in soils organic carbon stocks as a result of a range of "realistic" land management scenarios; and plan any follow-up activities for the contrasting regions. It will also highlight how the output needs to be considered in the context of national planning so that wider socio-economic implications can be gauged in the light of possible carbon sequestration strategies.

The project's "exit strategy" will involve demonstrating the utility of the methodology in decision making at a range of scale up to national. This will also highlight the added value of assembling appropriate natural resource information in suitable GIS format to encourage this approach in countries currently lacking this benefit.

1. **Sustainability analysis and risk assessment**

This targeted research project if aimed at developing a computed-based methodology rather than implementing a field-based programme, and so risks are essentially limited to technical issues and data availability. However, there is a risk that the newly-developed tool may not be adopted by end users (i.e. national agencies in planning exercises and GEF in project selection) due to the contentious nature of land use management; it may be used to help identify land management options which are socio-economically unacceptable to local communities. This will be guarded against by ensuring national agencies are fully involved in developing the scenarios to test and demonstrate the methodology, and that these are therefore "realistic" possibilities rather than "extreme".

The transferability of the methodology to other countries depends on suitable datasets being available at appropriate scales. Having a demonstrable product will encourage other countries to embark upon this investment. In addition, UNDP GEF will serve on the steering committee for the project with the view towards testing the model in two of its regional projects on GHG inventories in Eastern Europe and West Africa.

One of the issues concerning the use of the models for national reporting is the lack of transparency. Thus, the guidance material for the models will include reporting of the quality of the underlying data and model parametization.

2. **Stakeholder involvement and social assessment**

Senior representatives of the principle agency in each collaborating country have confirmed their agency's willingness to be an integral part of this project (see attached letters of support). Steps 5 and 6 will draw heavily on national policy makers, and the results will be widely distributed in the both the scientific and policy-making arenas.

INCREMENTAL COST ASSESSMENT

The baseline situation is noted above in which the participating countries currently estimate regional soil organic carbon stocks by estimating the carbon content per unit area of each soil type and multiplying by its total area. Investment in survey work to undertake this type of analysis has been very large over the decades during which this work has been undertaken. While these methods can define a current stock, their fundamental problem is that that are not dynamic, and therefore cannot be used to estimate how different land management will affect future soil carbon stocks. The 'alternative' scenario (the GEF MSP) will improve national assessment methodologies relating to land use options and UNFCCC requirements thereby addressing a serious gap in current assessments. The GEF incremental cost would allow this work to be conducted in an internationally co-ordinated manner, drawing on expertise from many nations and developing and demonstrating the robustness of the product in widely contrasting situations. This will both help achieve national objectives for the case study nations and develop a generic tool for other regions of the world. Details on the baseline scenario and the alternative are presented in the sections above.

Since the project deals with the development of a methodology that is then of wider applicable use to other countries, the activities described can be considered to be incremental. However, in recognition that there will also be national benefits for the participating countries, the project relies on substantive co-financing cash and in-kind contributions in the order of US$1024k .See attached budget for further details.

IMPLEMENTATION PLAN

**** SEE ATTACHED TIME LINE***

PUBLIC INVOLVEMENT PLAN

Being a targeted research project to develop a methodology there will be no "first order" involvement by the public at large. However, recognising the need for this methodology to ultimately be targeted toward helping decision-making at a wised range of scales, the participating national agencies need to ensure adequate contact is made with local communities and other stakeholders when developing scenarios of land use change to ensure they are realistic and viable. Thus the sustainability of given scenarios needs to be addressed for demonstration purposes – both "good" and "poor" scenarios should be developed to show how the tool can help evaluate carbon sequestration potential against social acceptability. These scenarios could be developed by national agencies in discussion with representatives of local communities through information gathering and analysis. This will help to ensure the products are demand driven, rather than supply driven.

The scientific and policy implication outcomes of the project will be widely distributed to the scientific community thought publication of scientific literature; and thought national agencies respectively. It will feed into the IPCC process through scientific channels and interim reports will be sent to SBSTA via the GEF Secretariat and STAP.

Presentations will be made in international scientific and policy-related fora to help disseminate the product for use in other regions and countries interested in adopting this approach to help them build national carbon sequestration strategies. In addition, in Brazil, for instance, the Coordinator of Global Change Research at the Ministry of Science and Technology will act as the main liaison between the science related outputs of the project and the policy makers.

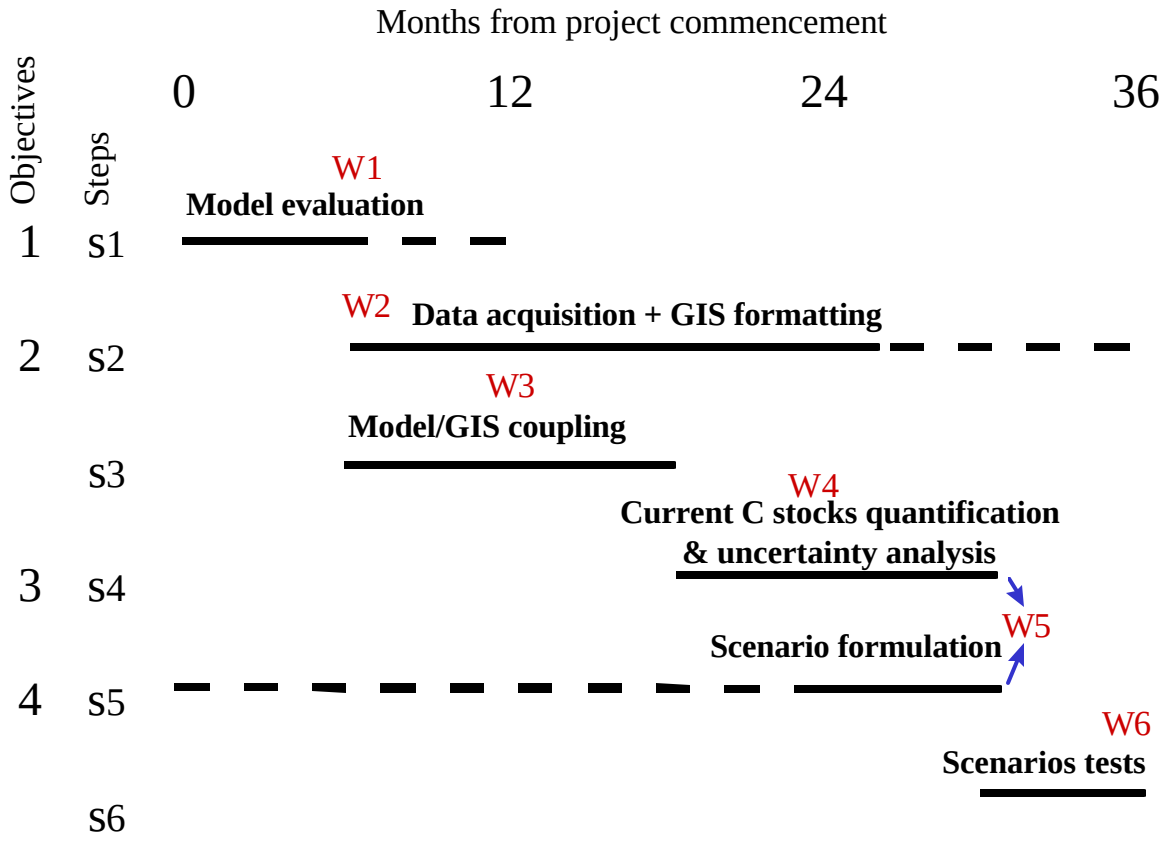
MONITORING AND EVALUATION PLAN

A monitoring and evaluation plan will be developed at the first meeting of the Steering Committee and include provisions for:

1. collecting and reporting data on performance indicators identified for the project;
2. scheduling of any planned mid-term reviews, self-evaluations, and/or end-of-project evaluations (in addition to already planned workshops);
3. describing how monitoring and evaluation activities will involve project participants and stakeholders;
4. identifying any additional resources that will be needed for monitoring and evaluation;
5. determining how monitoring and evaluation results will be used in project management;
6. holding discussions with national policy makers and GEF about how the project can be tailored as it evolves to their respective needs;
7. testing the model in other scenarios. Of particular relevance is the UNDP-GEF regional projects on GHG inventories in Eastern Europe and West Africa. Consultations will be held with the UNDP and UNEP task managers for climate change enabling activities with the view towards identifying additional channels for testing the model within other projects.

Specifically, Workshops 3, 4 and 6 are designed as "peer-review" events to ensure the developing project is (i) scientifically credible and (ii) the end-product is suitable for end user requirements. Funding is budgeted for these workshops. Further, the scientific steering group (comprised of representatives from all partner research groups) will provide constant oversight and guidance to the Executing Agency.

"Assessment of Soil Organic Carbon Stocks" Time Line



Workshops:

W1 - Model evaluation
W2 - GIS definition
W3 - Model/GIS coupling review
W4 - Peer review and uncertainty analysis
W5 - Synthesis and scenario definition
W6 - Final "Open" meeting and next steps