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PREVENTION OF LAND DEGRADATION, ENHANCEMENT OF CARBON SEQUESTRATION AND CONSERVATION OF BIODIVERSITY THROUGH LAND USE CHANGE AND SUSTAINABLE LAND MANAGEMENT WITH A FOCUS ON LATIN AMERICA AND THE CARIBBEAN

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Preface

Lands in the tropical and subtropical regions of the world are severely affected by land degradation due to deforestation, inappropriate land use and land mismanagement. Strong demographic pressure and unsustainable land use systems have increased the demand for land resources, pushing the limits of production to drier and more marginal lands. Soil fertility loss and accelerated erosion cause land degradation and lead to reduced land productivity. Deforestation entails loss of biodiversity and contributes to increased carbon emissions. Recent reports of the Intergovernmental Panel on Climate Change (IPCC, 1995) indicate that there is mounting evidence that these increased carbon emissions can result in global warming which is expected to have a detrimental impact on life on earth.

In UNCED Agenda 21, Chapter 14 "Sustainable Agriculture and Rural Development" (SARD) encourages integrated planning at watershed and landscape level to reduce soil loss and protect surface and groundwater resources. The SARD Committee on Sustainable Development (CSD) expressed the centrality of land in what is called the land cluster of Chapters involving Chapter 10 "Integrated planning and management of land resources", Chapter 11 "Combatting deforestation", Chapter 12, "Combatting desertification and drought", Chapter 13, "Mountain areas", and Chapter 15 "Conservation of biological diversity".

The Convention to Combat desertification and the Convention on biodiversity emphasize the importance of tropical lands in terms of sustaining production systems and livelihood of poor farmers through land conservation and the enhancement of agro-biodiversity.

The Convention on Climate change and the Kyoto protocol (December 1997) also make specific reference to the need for improved land use systems, soil conservation and watershed management, agroforestry, afforestation, conservation of natural habitats, and the management of buffer zones adjacent to tropical forests. All factors which would concurrently enhance carbon sequestration.

FAO and IFAD convened the present expert consultation in order to obtain guidance on the action they need to take in the above domains. Advice was sought on how programmes should be implemented in the light of the state-of-the-art knowledge on carbon sequestration related to soil, land use and land management. Advice was also sought on the economics of carbon sequestration and of previous experiences. One major purpose of the consultation was to agree upon the framework and orientation of the project in Latin America and the Caribbean and work out practical recommendations for its implementation. Another objective was to initiate development of a partnership for the implementation of the programme within the context of an informal network.

Acknowledgements

This publication contains the summary report of the expert consultation on “prevention of land degradation, enhancement of carbon sequestration and conservation of biodiversity through land use change and sustainable land management, with a focus on Latin America and the Caribbean” and the papers presented and discussed at the consultation.

IFAD and FAO jointly took the initiative to organize this expert consultation. Bahman Mansuri, IFAD, and Parviz Koohafkan, FAO, were instrumental in providing direction, technical guidance and logistic support. The agenda of the consultation was prepared by R. Brinkman. The participation of experts from all parts of the world is greatly appreciated for their technical contributions to the meeting which ensured fruitful brainstorming sessions and valuable recommendations for follow-up activities.

Thanks are due to the staff of IFAD and FAO who participated in the consultation and contributed to the deliberations. Special mention is due to the members of the Secretariat from IFAD and FAO who organized and ran the workshop: Ms. M. C. Brunet and Messrs N. Schultze, J. Antoine, J. Benites, F. Nachtergaele and A. Mermut.

The summary report was prepared by J. Antoine on the basis of the verbatim transcript of the consultation and the contributions and comments of the participants. The report and the technical papers were edited by R. Dudal.

Contents

Acronyms and abbreviations

ACIAR	Australian Council for International Agricultural Research
AEZ	Agro-ecological Zones
ASB	Alternatives to Slash and Burn
CBD	Convention on Biodiversity
CCAD	Central America Environment and Development Commission
CCC	Convention on Climatic Change
CCD	Convention to Combat Desertification
CDM	Clean Development mechanism
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIFOR	Center for International Forestry Research
CLU	Current Land Use
CSD	Commission on Sustainable Development
ENI	Ente Nazionale Idrocarburi
FAO	Food and Agriculture Organization of the United Nations
FCCC	Framework Convention on the Control of Climate Change
FS	Food Security
GEF	Global Environmental Facility
GEMCO	Global Emission Management Consortium
GIS	Geographic Information System
ICRAF	International Center for Research on Agroforestry
IEM	Integrated Ecosystem Management
IFAD	International Fund for Agricultural Development
IIASA	International Institute for Applied Systems Analysis
IITA	International Institute for Tropical Agriculture
IPCC	Intergovernmental Panel on Climate change
IPNS	Integrated Plant Nutrition Systems
ISCO	International Soil Conservation Organization

ISRIC	International Soil Reference and Information Centre
LUC	Land-use Change
LUT	Land-use Type
NAP	National Action Plan
NGO	Non-governmental Organization
RELACO	Red Latino Americana de Agricultura Conservacionista
SARD	Sustainable Agriculture and Rural Development
SEZ	Socio-economic Zones
SFI	Soil Fertility Initiative
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SPFS	Special Programme forFood Security
TSBF	Tropical Soil Biology and Fertility Programme
UNCED	UN Conference on Environment and Development
UNEP	United Nations Environment Programme
WFS	World Food Summit
WOCAT	World Overview of Conservation Approaches and Technologies

Summary report, conclusions and recommendations

BACKGROUND

IFAD and FAO have signed a Memorandum of Understanding for collaboration on Poverty Alleviation and Food Security. Within the context of this understanding IFAD and FAO started a programme on the implementation of the Convention to Combat Desertification (CCD). Through this programme the Land and Water Development Division of FAO is assisting a number of countries in the tropics and subtropics in the preparation of National Action Programmes (NAPs) on land development under the Convention to Combat Desertification and the Convention on Biodiversity, initially in Latin America and the Caribbean.

The importance of desertification and other land and environmental degradation processes have motivated Governments in Latin America to adopt in 1994 the "Central American Alliance for the Sustainable Development" as a national and regional strategy to lead the region towards peace, democracy and development to ensure the build up of a political, economic and social, cultural and environmental sustainable model.

The Central American Environment and Development Commission (CCAD) was established to deal with environmental and development matters at sub-regional level. It is composed of the regional Ministers of Natural Resources and Environment and acts through a number of specialized regional councils. The CCAD is the principle institutional instrument of the Central American countries to plan and implement the carbon sequestration related activities. The CCAD has so far played a substantial role in the adoption of various sub-regional agreements related to the implementation of the plans and strategies outlined in Agenda 21, such as the Central American Agreements on Biodiversity, on Climate change and the Management and Conservation of Natural Forest Ecosystems.

At the request of the CCAD a first programme was initiated under which funds provided by IFAD are used in implementing a joint programme "National Action Plan for Combatting Desertification: Integrated Natural Resources Management Plan for the Cauto River, Cuba" with financial resources provided also by the CCD.

In March 1998 the Ministers of Environment of Latin America and the Caribbean met in Peru to discuss, amongst other subjects, the significance and opportunities offered by the Kyoto Protocol. The meeting recognized the need for projects to quantify the capacity of soil and vegetation as carbon sinks and promote land use systems which will lead to mitigation of CO_2 emissions and contribute to sustainable development, taking into consideration national policies and priorities.

Subsequently CCAD requested FAO assistance in the preparation of a Carbon Sink Programme for the Central America region. The main objective of this programme is to strengthen regional and national capacities to define policies and strategies focused on absorbing and reducing greenhouse gas emissions for the benefit of sustainable management of natural resources of the region. Within the framework of this request FAO and IFAD agreed to implement a second programme on "Prevention of land degradation, enhancement of carbon sequestration and

biodiversity conservation through land use change and sustainable land management in Latin America and the Caribbean" with FAO and IFAD co-funding the programme.

The aim of this programme is to promote improved land use systems and land management practices which are expected to provide economic gains and environmental benefits to poor farmers in the Latin America and Caribbean Region. This includes greater agro-biodiversity, improved conservation and environmental management and increased carbon sequestration. It is intended to also contribute to the development of regional and national programmes by linking the Convention on Climate Change (CCC)-Kyoto Protocol, the Convention to Combat Desertification (CCD), and the Convention on Biodiversity (CBD), especially focusing on synergies among these three Conventions. Therefore, this programme has a close link with the other on-going FAO/IFAD collaborative programme on the implementation of the Convention to Combat Desertification (CCD).

ISSUES AND FINDINGS

The present consultation brought together international experts from research institutions and Universities, IFAD, the World Bank, and FAO. To maximize the exchange of ideas among the participants and capture a large number of the very major conceptual issues on carbon sequestration which are under discussion in many quarters within the international community, the consultation used an informal and participatory approach. It consisted of brief presentation sessions during which the invited experts introduced the selected topics, followed by extended discussion and the formulation of conclusions.

The consultation addressed the following three main objectives:

- how to stabilize the atmospheric concentration of $CO_{2;}$
- how to increase agricultural productivity and reduce rural poverty;
- in view of the Global Mechanism for Desertification Convention, how to activate the flow of new funds for the benefit of Convention implementation through carbon sequestration.

Main issues which arose during the discussions were:

- What strategies could be developed to highlight and use the synergies among the objectives of the above mentioned three Conventions and the objectives of sustainable land use and management and household food security?
- Which contrasting, promising and less promising land use systems or sets of land management practices could be analysed with respect to their benefits for food security, prevention of land degradation, carbon sequestration, improvement of soil and above-ground biodiversity, with a view to identify and quantify demonstrable benefits?
- Which successful examples have been identified to date?

In order to answer the above questions the consultation reviewed its collective experience about the following specific topics:

- What pilot studies or examples of carbon sequestration by land users, and in which environments, could most rapidly provide a clear and convincing case for more general application?
- What data are available for the estimation of net carbon flows under various uses in different agro-ecological zones?

- Which improved land management practices are currently spreading without, or with limited specific incentives, in which countries and environments, and what are the main policy, economic and biophysical conditions that have led to the successful spread? What are the main benefits perceived by the farmers that have led to the adoption of the practices?
- How could values of carbon sequestration by individual farm households or rural communities be most effectively packaged into a volume of interest to the national or international actors wishing to purchase carbon emission entitlements?
- For which land uses might there be a case for biodiversity stewardship payments and how could they be most effectively developed?
- What government policies could effectively internalize into the farm household part of the environmental benefits from improved land management? How could this information be expanded over more uses and agro-ecologies, rapidly and at limited cost?

A considerable number of conceptual and methodological approaches on the assessment of carbon sequestration and practical suggestions for the implementation of the FAO/IFAD programme were reviewed.The findings and conclusions of the consultation are presented below in terms of major issues which emerged during the discussions.

Poverty alleviation and food security

Prevention of land degradation was emphasized as an important activity of IFAD which is imbedded in their programme of poverty alleviation in Latin America.

The Conventions on climate change, combating desertification, and on biodiversity each provide new options to stimulate beneficial changes in the land use and management system of an aggregate of farm households. The total benefits of the individual policy interventions of the Conventions may well be greater if they are designed with a view to optimize multiple objectives in synergy: improvements in household food security and income; land and water conservation and improvement; carbon sequestration; biodiversity in its several aspects.

The identification of these synergies has helped to strengthen the wide range of IFAD and FAO activities and in particular the established priorities of food security and poverty alleviation among the poorest sections of the world community.

Carbon sequestration in relation to soil fertility, land productivity and biodiversity

Biodiversity, soil fertility and carbon sequestration are interlinked and should not be considered in isolation from one another. Above ground and underground biodiversity changes with land use changes over time.

Soils contain more carbon than the world's biota. In developed countries, such as in North America, the soil carbon pool is in static equilibrium. The carbon stock in soils is either not changing or may be increasing. Great part of global carbon emission is coming from tropical agricultural deforestation area, where resource-poor farmers live on mining the soil nutrients and where most land degradation is occurring.

Maximizing carbon sequestration in soils can probably best be done in so called set-aside lands. However the set-aside lands are only relevant in practice to industrialized countries, where there is a surplus of agricultural lands. In areas where the soil organic matter has been depleted, in part historically, the local farming community can receive government support, not just to leave the land uncultivated, but to use these set-aside lands to consciously increase soil organic matter content without any crops. The issue of maximization of carbon sequestration is less applicable to

the developing countries where the combination of carbon sequestration with other purposes is much more relevant, although it may not produce the maximal storage of soil carbon.

A major element is improving soil productivity by increasing soil fertility and simultaneously facilitating carbon sequestration. FAO for the last 20 years has been promoting an integrated plant nutrition system (IPNS) approach in which the major emphasis is to optimize the benefits from all sources of plant nutrients (organic, biological and mineral) which implies a very essential linkage to carbon sequestration.

By applying organic fertilizers, soil organic carbon content can be enhanced resulting in increased biomass production. This biomass, when recycled, restores carbon into the soil. Land management practices, like conservation tillage and mulching, play a very important role in soil organic matter restoration.

Role of land use and land management in carbon sequestration

It was estimated that the CO_2 concentration in the atmosphere is increasing at the rate of 3.3 thousand million tons a year. Therefore, stabilizing the CO_2 concentration in the atmosphere is a very big objective which may not be achievable for a long time - hundreds of years, maybe millenia. What can be achieved, the experts argue, is to control emissions which have not been recognized very widely but which came from land management, land use and land cover change. Estimates were given of about 50-100 thousand million tons from soils and another 100-150 thousand million tons from vegetation, giving a total of 150-250 thousand million tons. A considerable amount of emission, approximately 1.6 to 2.0 thousand million tons per year is attributed to deforestation, poor land management and land degradation by resource-poor farmers. This source of emission can be arrested by agricultural intensification on existing land, reducing deforestation and improving agricultural and forestry practices and by adopting conservation tillage. Carbon sequestration is, therefore, related to agricultural productivity, because it is also linked with poverty especially rural poverty. However the exact nature of the relationship is not yet clear, and in all likelihood it will not be the same in different environments and societies.

An achievable objective is to try to decrease CO_2 emissions from land, especially on activities such as deforestation, preventing land degradation, soil erosion control. It is necessary to narrow the problem down to decreasing emission from land and counter or reverse the effects of the emission process by sequestering carbon. That may be a doable objective. There should be less concern for carbon sequestration *per se* and more attention given to addressing the problem of carbon emission through land use.

Two options were proposed to reduce emissions from land use change. The first option is to increase the sequestration potential of forests and land use mainly to compensate for the increased emission in industrialized countries from fossil energy use. The second option is to capture atmospheric carbon through photosynthesis and through calcification. By so doing both organic carbon and inorganic carbon in the form of calcium carbonate are returned to the soil. These are related but separate issues. And the potential of the second option through sequestration in soil and the vegetation can be as much as the amount of carbon returned to the atmosphere every year, an estimated 3 thousand million tons but for a limited period of time (20 to 25 years).

A range of land management practices associated with conservation tillage in several Latin American countries appears to increase the range and numbers of meso- and microfauna in the soil; improve soil structure, permeability, moisture holding capacity and stability of the soil; and increase the amount of organic matter cycling in the soil and storing nutrients, gradually releasing them to crops. Within a few years, these practices have resulted in clearly raised land productivity and increased effect of added nutrients. The effect of the improved land management on carbon

sequestration and the direct and indirect effects on biodiversity should be seen in the context of such a range of other benefits, which are in the direct interest of the land users and their households. The great expansion of land use and management systems based on zero- or minimum-tillage in Brazil was driven by the widespread recognition of their direct, short- and medium-term benefits to farm households and commercial farms alike, even in the absence of transfer payments for carbon sequestration or biodiversity conservation.

Empirical evidence in field projects that involve land use planning and management in developing countries, has shown that demographics play a rather important role in determining land-use changes (e.g. in the Texcoco watershed in Mexico, or the Cauto river watershed in Cuba, or the Amazon basin). Particularly, population density has shown to be highly correlated with the existence of certain land-use patterns. It is clear that demographic variables can be the most determining factors of land-use, and thus they have a high explanatory value of land use conversions. Although demographic factors are usually underestimated and bundled up under the umbrella of "social and economic factors" they should be explicitly recognized and examined in carbon sequestration projects where long-term land-use changes may be envisaged.

Economics of soil and land use carbon sequestration

The build up of soil organic matter content should be considered as a capital investment in soils. Soils constitute a national and community-level resource which also implies a significant source of sequestering of human-induced atmospheric CO_2 which would diminish the hazard of global climate change.

The need for more knowledge about soils as carbon sinks and the importance of keeping the carbon in the soil was stressed. If carbon is stored and then released because of inappropriate land use, then that effort is fruitless from the carbon sequestration point of view. An additional problem is that with increasing temperatures, the stored carbon may be more unstable and more difficult to maintain in stock. Therefore, it is essential to look at the dynamics of carbon, particularly the time of carbon residence in soil and vegetation and try to extend it as much as possible.

The most important aspect of carbon sequestration is the cost of carbon storage in soil and above ground vegetation. Maintaining the carbon in storage may be a costly exercise which requires the provision of incentives to the farmers through the international mechanism.

There is synergy among the objectives of reduced carbon emissions, rural poverty and sustainable development well highlighted in the clean development mechanism (CDM). The CDM has a main role to play in that industrialized countries can pay for their failure to fulfil the requirements to which they have signed in Kyoto, by buying up rights and stimulating the sequestration in developing countries. And it was stressed that the funds should not come from ministries or other agencies in the developing countries. Rather, new funds from environmental ministries in the industrialized countries should fund this initiative and the funds should not be mixed with development cooperation funds.

The objective is to generate activities and programmes to be financed through.the Clean Development Mechanism. CDM has the potential of generating large amounts of funds into restoring soil fertility and productivity and, therefore addressing the poverty problem. It is an additional potential source of funds for the three Conventions, in particular for the Desertification Convention which addresses land degradation and desertification. There is a strong link between land restoration and CDM. Land restoration programmes are clean development measures which can have a tremendous impact on the Clean Development Mechanism.

Clean development mechanism and carbon trade

Carbon sequestration now appears to have potential as a tradable good, that can be used to pay off a "bad", emission of carbon dioxide, which is similarly becoming tradable. More recently, conserved biodiversity of a large forested area has also become the subject of negotiation and monetary compensation for use rights by a pharmaceutical industry. Also, the international conventions on climate change and biodiversity place certain obligations on governments, some of which can be discharged by mere decree, but which may need more positive stimulation measures.

Clear indications of increased biodiversity or of its conservation by specific land use options or specific land management systems could be used in negotiation to capture land users' part of their added value to society, government or the international community. Similarly, part of the benefits of carbon sequestration achieved by practising certain land uses or management systems, and which are paid to a government by an industry in compensation for carbon dioxide emissions, should be paid to the land users concerned – as is the case already in Costa Rica.

A Global Emission Management Consortium (GEMCO) which consists of ten power companies in the United States, is willing to give credit to farmers for longterm commitment to carbon sequestration over 20 year periods. A price of about US$ 1.5 per tonne C to be sequestered in areas to be reforested is currently being paid by the consortium of electricity companies. Countries like Holland, Belgium, Germany and the Scandinavian countries are ready to spend much funds on Joint Implementation or Clean Development Mechanism activities in developing countries. Once such public benefits are internalized in the economy of the individual land users, the probability increases that sustainable uses or land management systems with these benefits will spread and tend to supplant unsustainable alternatives.

Carbon accounting

One of the requirements for a widespread application of carbon dioxide transfer payments is a semiquantitative estimate of net carbon flow to the soil and to perennial biomass under different kinds of use and management. For biodiversity, at least qualitative indicators are needed for the benefits from different land uses.

The meeting discussed a mechanism to assess carbon sequestration based on the establishment of some benchmark sites and experiments to quantify the contribution of different land uses to carbon sequestration, biodiversity, and desertification control.

The mechanism would be a land use based system of monitoring and accounting which is correlated with carbon balance on an ecoregional basis. Remote sensing can be used to establish areas of different land uses within a given ecoregion, a given community, district, county or region. Using GIS and scaling procedure it is possible to scale up from small to large scale, to produce general scenarios. Eventually, it would be possible to relate carbon sequestration on a land use to soils through benchmark evaluation, but actual monitoring would not involve detailed soil sampling and analysis. This mechanism would provide a carbon accounting precise enough to enable agreement on the use of the generated numbers for the assessment, evaluation and monitoring of carbon sequestration. It will enable the kind of standardized accounting rules with the appropriate guidelines required to prepare incentive programmes. This kind of full accounting is needed to ensure long-term sequestering without leakage on a stable basis. It might take ten years to establish the mechanism.

The development and calibration of a methodology of carbon sequestration would be an important component of the mechanism . This could be done region by region and would involve:

- organizing a regional workshop;

- identifying data needs;
- delineating bright spots with large and easy potential;
- developing a plan of action;
- preparing a report on potential of carbon sequestration; and
- organizing a field programme through governments and NGOs

Priority regions were suggested as follows:

- Central America,
- South America,
- Central Asia,
- South Asia,
- West Asia and North Africa,
- Sub-Saharan Africa, and
- Eastern Asia

These regions can be covered over a seven-year period (one per year) and potential of carbon sequestration assessed for each region. In addition it may be a good strategy to evaluate the tropical regions and the world croplands.

Implementation of recommended practices as a follow up program is extremely important. Therefore, this work should be undertaken jointly by FAO, IFAD and other funding organizations.

Land carbon sequestration in relation to the Kyoto protocol

The problems of implementing the Kyoto Protocol, in particular the uncertainties of the protocol with respect to quantification of carbon sequestration were discussed. There is the problem of the vagueness of definitions of the Kyoto Protocol and also uncertainties on how to ensure permanency of any carbon sequestration effort. It was mentioned that IPCC, the Inter-Governmental Panel on Climate Change, has created a separate programme to come up with a special report, a so-called "sinks report" on the two implications of the Kyoto Protocol, the one on the Kyoto Forest and the other on the Kyoto aspects of carbon sequestration in agricultural lands. And that includes a full chapter on the definitional items and the aspects of verification.

When implemented the Kyoto protocol will establish "Kyoto forests" and "Kyoto lands" or "Kyoto soils", financed by the industrialized countries, which would be used for many years as a storage capacity for carbon. These Kyoto forests and Kyoto lands will have a special long-term status as reserves, having a degree of international status at least with respect to the monitoring aspects. In practice, this may cause a lot of problems at national level, because land cover and soil are considered by most countries to belong to the national patrimony. There are many places, such as Brazil, where there are enormous mass movement of landless people who move around the whole country trying to settle somewhere including land reserve for Kyoto and it will be difficult if not impossible to stop these people from occupying the reserved areas.

It was emphasized that, when talking about carbon sequestration in relation to climate change, there must be a link to the international conventions and that makes it a lot more complicated than just talking about carbon sequestration in relation to improved agricultural productivity.

CARBON SEQUESTRATION AT FIELD LEVEL

Scale and scope

Discussing the state-of-the art in carbon sequestration the majority expressed the view that the current state of knowledge and the existing technologies were adequate to tackle the issues at hand. The real challenge is the practical implementation, that is the operationalization of a mechanism for implementing carbon sequestration through land-use changes and land management practices at the field level.

Carbon emissions worldwide may involve large fluxes in the order of 7-8 petagrams per year from various sources, but ultimately when it comes to implementing a programme the question is not to handle large emissions. Action is taken on limited areas and concerns a few hectares at a time. It is a matter of a 0.2-0.5 Mg/ha/yr, or less per year for small farmers.

Carbon sequestration should be addressed at different scales as it has various dimensions. There are at least two levels of analysis or assessment: the international and global level as climate change is a global concern and the farm level which is the level at which farmers take decisions.

The issue is not to solve the entire carbon emission problem or the entire climate change problem because that can never be the realistic objective of any single activity. Rather the immediate goal is to determine the benefits that can be obtained from carbon sequestration through land use change and how the gains compare to other possible benefits. At the operational level, the focus should be on local level comparison of.different land use types in terms of carbon sequestration and of income to the farmers. In this way the land use decisions can be understood and decisions can be made in an appropriate manner. Ultimately individual farm results will accumulate to contribute to the reduction in global carbon emission.

The issue of policies conducive to farmers behaving in a way that is consistent with the three objectives in a sustainable manner was debated. In this context, the objective related to increased farm productivity and reduction of poverty should take priority in relation to the other two objectives of carbon sequestration and land degradation. That objective will have to be optimized. The others might be sub-optimized. A weighting system should be used to establish priorities while optimizing. Such prioritizing system ought to be based on stake-holder participation.

An appropriate policy framework is needed to address this question at different levels, both the micro-economics at the farm level and the broader macro-economic picture related to the Clean Development Mechanism.

Economics of carbon sequestration

The economics of carbon sequestration involve the transfer of money from the collators or buyers of carbon to farmers in developing countries in such a way that they are confident that the investment is sustainable.

The challenge is to find land uses which can be both profitable, and therefore adoptable by the land users, and also have long term environmental benefits. It is expected that, at the initial stages of adoption,.farmers will face difficulties which have to be compensated through financial support or other incentives.

One idea that was discussed as a way of operationalizing “subsidy”payment to farmers is the concept of contract; specifically long term contracts with farmers for improved land management to sequester carbon over a period of at least 20 years, with a penalty to be paid in case of break of contract, similar to what is practiced with bank certificates of deposit.

It was recognized that, on the basis of past experiences in field projects, the contract approach would work only in exceptional situations but would not be applicable for period longer than five years in most cases. Administering such a scheme would be very costly in the common situations where a very large number of small farmers are dispersed all over the landscape. Experiences from soil conservation programmes in the last 50 years have shown the unresolved problems. Through mechanisms similar to contracts, farmers were provided with subsidy, in kind, in cash, or through access to credit to build terraces, grass strips or other structures. But the practices have collapsed because it was too costly to maintain the established practices and structures.

There are many similar experiences with land degradation control projects, soil conservation projects worldwide. The track record is pretty dismal, and by now there exists a fair numbers of lessons from past failures which are going to be relevant when attempts are made to operationalize the mechanisms.

Another problem is that if, in a project activity, a given land use which happens to sequester carbon is already in the farmer's interest, it is going to be very hard to meet the incremental costs criteria set by the GEF. In a sense, the practices that can be implemented easily are almost by definition not eligible for GEF funding. Ultimately it will be necessary to transfer resources to the farmers who are already following the practices as well as to those farmers who would adopt the practices without subsidy.

The example of Costa Rica was cited, where the World Bank is preparing a project and the ground work has been laid to arrange for the payments of carbon sequestration by a number of mechanisms. Some of them are joint implementation activities; there is a prototype carbon fund that the Bank is working on in which the Bank will basically sell carbon sequestration to investors who in turn can then sell those to third parties. A contract approach was envisaged, in which farmers would get a payment for five years to adopt specific land use practices, and would commit to continue with the practice for 15 more years. There were obvious concern about the sustainability of this approach, however, and efforts are underway to devise payment mechanisms that will produce long-term incentives to change land use in a sustainable way.

The price of carbon sequestration

Preference should be given to the "commodification" of carbon rather than to subsidy. Carbon is considered a product with a price just like any other produce. A carbon price must be paid to a farmer to adopt practices that increase carbon sequestration but may decrease farm output. A five-year period was suggested.

The question is: what is that price? The price can be considered to have two components. One component is related to the improvement in soil quality which will provide accrued benefit to the farmer. Another component is the benefit to the society in terms of improvement in the environmental conditions. This includes: reduction in irrigation and sedimentation problems, wind-blown erosion, water erosion, water quality problems and also control of carbon in the atmosphere and global warming. So society needs to pay the farmer for providing these benefits. This is a global externality for which a range of prices could be found which reflects the principle behind the flexibility mechanisms defined in the Kyoto Protocol, directed to obtain minimum global mitigation costs through joint implementation in countries with lower abatement costs. A carbon price could be established in various ways: for example, by the economists in consultation with the biological scientists or arbitrarily decided. In the long run there will be more private sector involvement with an increasing number of carbon funds such as already prototyped at the World Bank. There will also be periodic market statements of the price of carbon.

The establishment of a commodity price for soil and land use carbon is the easy part. The hard part is how to determine payments to a given farmer, whether it is to change a land use or to change a management or cultivation practice or changing the way of farming. The payment that farmers should receive is the price of carbon times the quantity that is being sequestered and that is difficult to determine as each kind of change is associated with a different carbon sequestration potential. And as discussed above, finding a way to make payments that will lead to long-term changes in a sustainable manner is difficult as well.

The educated commercial farmers in the developed countries could take benefit from such arrangements whereby farmers sequester carbon and find private firms ready to pay for it. That would benefit both sides: the farmers who sell carbon and the buyers who not have to fulfil the compliance requirements. Benefits are not obvious to small farmers in the developing countries.

Integrated approaches

One possible avenue of operationalization of the mechanism is the so-called "Integrated Ecosystem Management " (IEM) approach which is being experimented with, and has worked well, so far, in Mexico and Ecuador as well as in some areas of Ontario in Canada. It is a watershed consortium which embraces several components and involves key representatives from different sectors, the interaction of government at various levels, including the local government, the municipality, Universities, research NGOs and local communities. Participatory decision-making from the start is the key to the success of this approach.

The level of intervention was also discussed and there was a broad understanding that the interventions should be at the community level rather than the level of individual farmers. There is a need for a holistic approach which considers the provision of economic goods which have an impact at the community level. Interventions at the community level rather than the level of individual farmers can help overcome two problems simultaneously, firstly by bundling small contributions to make them attractive to international investors, and secondly by avoiding a collision with the "additionality"criteria established by the Clean Development Mechanism. According to the "additionality"criteria, improved practices, which are being adopted by individual farmers in a region for other reasons than carbon sequestration, become the "baseline"for that region and are not further eligible for funding. At the community level, however, it is possible to negociate carbon sequestration as a package and then induce farmers to adopt them gradually.

Many studies have shown that in order to link the farm level or village level to the biogeochemical cycles it is useful to include the watershed or landscape level because it allows the inclusion of some of the externalities which are not visible or treatable effectively by examining only the farm level. As a planning unit to represent local markets, watershed is a very appropriate level that should be considered in an integrated study.

The incentive scheme should be applied at the community level. It is at such a level that the overall balance of exploitation and degradation versus growth and storage across the landscape is maintained as an aggregate of individual farms. This is particularly true of communal forest lands. This is a difficult task which requires a lot of imagination and ingenuity. There is also a need to prioritize, that is to identify the hot spots where the actions will bring immediate returns.

Replicability and upscaling become the major challenge and are linked not only to incentive *per se,* but also to the technology available at the level of the farmers and to existing infrastructure and the economic goods which are available to the farmer. It is doubtful, however, whether such mechanisms will have some effect on the CO_2 concentration without any qualitative statements whether it should increase, be stabilized or decrease.

The role of farmers

The starting point, it was emphasized during the discussions, is to understand that ultimately land use decisions are made by individual land users, the individual farmer, the individual pastoralist, and other individuals and not by governments, NGOs, the World Bank, FAO or IFAD. Only land users themselves can change their land use or land management practices, and except in the case of force or coercion, they will only do so after they have clearly perceived adequate short-term and ongoing benefits from such a change to themselves or to their households. Once that is the case, improved land management methods may spread rapidly.

Land users take decisions.on the basis of a range of influences - the available technology, the policies they face, their particular household characteristics. These decisions are only indirectly affected by government policies or by World Bank projects, or by IFAD projects. Activities must be profitable as the costs and benefits to the farmers are the critical point in their decision making. If this is not taken into account the initiatives are likely to fail as they have failed in the past.

Farmers' decisions will affect land quality which in turn affects crops and livestock production, and consequently the farmers have a very strong incentive to take land quality improvements into consideration. Offsite costs linked to global problems and benefits will not be taken into consideration by farmers unless incentives are provided. Now the big difference here is that, whereas local governments have an incentive to do something about national offsite costs by trying to create a policy framework that discourages degrading practices and encourages conserving practices, this is not the case for the global problems.

The various initiatives to establish prototype carbon funds, joint implementation activities and the various mechanisms such as the GEF, by which these benefits are translated into money going into the system to try to change these land use decisions in an appropriate way, are very important discussions. However, at the end of the day there is no direct way to effect farmers' decision on land use. The same problems that governments have been facing in trying to motivate farmers to adopt particular land use practices for national reasons will affect any effort to get farmers to act for global reasons.

The crucial point is the involvement from an early stage of the stakeholder and identification and involvement of the stakeholders in the planning unit whether they may be macro-watershed, watershed or the farm. Peoples'participation is required and the land users need to be involved, not only in the present stage but also in the short and long term. In trying to move from macro-planning to the farm level planning the key question is to develop some type of participatory process with the farmer.

Linkage of private and public sector

The importance of partnership between farmers or land users and the private sector was emphasized. Several examples from Brazil, Costa Rica, Ecuador, Zambia and Zimbabwe were described in which the private sector initiative has made intensive agriculture a viable economic opportunity for farmers to do better and more sustainable agriculture through the introduction of more crop diversification and improved land management. Such an initiative started a farmer-driven conservation tillage business in Brazil as an entry point for sustainable agriculture which went from zero to nine million hectares in a few years. The farmers practised conservation tillage based production systems, because they are more profitable and environmentally sound. In Latin America the changes occurred in all areas where there was a partnership between farmers and private sector with economic and environmental benefits, and with indirect improvement of carbon sequestration through the increase of organic matter. This experience is being extrapolated to other countries,

such as Costa Rica, Honduras, Mexico and Cuba, through FAO projects and together with IFAD using the CCD.

PROJECT PROPOSALS

Type of projects: selection of case studies

Some experts argued that, in addition to launching new separate carbon sequestration projects, a component to assess carbon sequestration or land preservation and other factors should be inserted in on-going projects or planned projects. Examples from Argentina were cited, where attempts are made to insert a relevant component to analyze carbon sequestration aspects in World Bank-financed projects about native forests and protected areas. As this approach appears to be problematic, it is clear that further discussion and awareness is needed, both.within multilateral organizations involved in project development and between the funding and national institutions.

It was felt that separate projects are necessary, specifically to provide information to address at least four or five objectives simultaneously: carbon sequestration, biodiversity reduction, land degradation control, rural poverty and food security. Of primary interest are the activities whose main objectives are to reduce rural poverty and improve the welfare of small farmers and can also contribute to carbon sequestration.

Comparative land use projects whose objective is to analyse different types of land uses were mentioned as the type of relevant projects. The projects could have the following characteristics:

They could offer the opportunity to do some of the measurements and monitoring necessary to investigate the links between agricultural development and carbon sequestration issues by looking at the types of land use systems that are currently being adopted and which might have implications for carbon sequestration. By so doing it is possible to identify the circumstances and the type of land management where there is an opportunity for win-win situations. Such projects could relate to existing experiences. The projects could be small projects linked to IFAD development projects in Africa for instance. At present, in different parts of Africa, there are people who are seeing tremendous impact, in addition to the no-till systems, of improved fallows in areas where land pressure is not so great, but where land degradation has taken place. There are places where green manure cover crops relayed or intercropped with or rotated with cropping systems are increasingly adopted by farmers. The soil fertility initiative in Africa and similar projects such as the pilot project in Western Kenya combining phosphorus fertilization and other fertilization to the soil in order to gain carbon as well as organic matter inputs from various components, are gaining success in some places.

One objective could be to investigate the interface between the objective of carbon sequestration and poverty alleviation and reducing food insecurity; and address rural poverty and the problems of small farmers.

Another objective could be to identify the bright spots where the potential of reinstating carbon through adoption of improved agricultural practices exists and which can provide the biggest return back to poverty-striken farmers.

A third objective concerns the policies that will enable successful implementation of the Clean Development Mechanism and the use of existing technologies and information to implement ground action plans to address the poverty of the resource-poor farmer. The projects should provide good information for the policy guidelines and participative land use planning and management.

To address these objectives pilot studies are required to determine the historic loss of carbon by resource-poor farmers due to desertification and other causes in different eco-regions: desertified

areas, humid areas, sub-humid areas, and to steep lands and elaborate adequate policies to capture the considerable potential for carbon sequestration.

In order for the pilot studies to be used as a means of arguing for policy, it is necessary to strengthen the spatial aspect of the pilot areas. These sample areas should be selected on the basis of agro-ecological zones.

But depending on the specific objectives, there will be a need for different kinds of pilot studies with different data collection mechanisms and priorities.

Data requirements

There is a need to consider the social and economic environment within which carbon sequestration takes place. In addition to scientific information on the biophysical resources base social and economic information addresses the livelihoods of the land users and the costs and benefits of adoption of specific land management options and land use systems should be collected.

Biophysical data sets on land use, land cover, soil and land degradation and biodiversity are needed. These data sets include data on the effect of erosion on soil carbon build-up or sequestration as well as data about the effect of erosion on loss of carbon, loss of soil fertility and loss of soil productivity and data on comparative stocks in the different land uses that are relevant to farmers' choices. Remote sensing data access would be useful. Related basic socio-economic data should give information on poverty and land availability and access.

Datasets should be in the form of spatial GIS data layers assembled to facilitate data integration and downscaling to larger areas needed for global carbon balances. One issue discussed was the lack of data. There are numerous data gaps and available data are often not reliable and not representative for all areas. There is a need to review and fill the data gaps giving particular attention to data quality and reliability.

Data collection should lead to guidelines for project development and more importantly for the use of the information for policy advocacy, addressed specifically to decision-makers in ministries and others who are dealing with the allocation of financial resources.

Sources of data

During the discussions the necessity to use existing data to avoid duplication and save costs was stressed. The case studies should use existing inventories or make an inventory of recent past and ongoing related projects from FAO and other agencies that are taking care of the various aspects related to carbon sequestration, biodiversity, and the synergies.

These studies could include experiences in Latin America in a number of projects on joint implementation ecostudies in Belize, Guyana, the Rio Grande Project, in Ecuador, Guatemala, Honduras and Mexico, which refer mainly to experiences in forestry and agroforestry , and to a lesser extent to cases of conversion of land from agriculture and pasture into forest. Links should be established to existing networks in Latin America, such as the Latin American network of agro-ecological agriculture that has activities in most countries in Latin America, and data should be drawn from their pilot research and demonstration sites. The International Potato Centre, which has a network of experience supported by Canada, and the RELACO conservation tillage network should also be included. The RELACO network is preparing a state-of-the art report on erosion-induced loss of soil productivity based on a lot of experimental work in Latin America and in other countries. The Ohio State University in the United States has compiled data in at least ten countries from around the world with regard to C pools in soil and the impact of management.

The World Resources Institute is assembling an agro-ecosystem status study on Latin America and seeking to collate recent data from SEAT/CIAT and from global holdings, in order to derive the best possible picture of current agro-ecosystems in Latin America.

The case studies should exploit activities in Brazil, both from the largehold farmer sector where a transition to reduce tillage is in course and the smallholder systems in Santa Caterina, such as the land management projects supported by the World Bank. There are opportunities to obtain farm level data and make real comparisons with other countries and regions, such as conservation farming with NGOs in Zambia in the moist savannah areas.

The Ecoregional Programmes of the CGIAR both in East Africa and West Africa maintain very useful sites. In particular the alternatives to slash and burn projects have benchmark sites in various countries in Latin America, including Brazil and Peru and provisionally Mexico as well, which could be useful. These sites are located in the humid agro-ecological zone but they could be extended outside Latin America in Africa and Southeast Asia.

Other initiatives under the CGIAR system in Africa, including IITA, have established seven or six benchmark sites where biophysical assessment of land resources, surveys and socio-economic assessments are carried out.

Linkages should be made to initiatives and programmes on the CCD and SFI. In particular it was mentioned that the work conducted in some fifteen countries in sub-Saharan Africa on soil fertility decline and soil productivity improvement has produced valuable data.

It was reported that the United States Department of Agriculture for the last ten years has been funding projects on global change in connection with major US universities and consequently there are 23,000 sites where complete soil characteristics data have been collected; and all of those data are available for use in these types of studies. USDA's international projects have an international database available for use by the international community in the carbon sequestration programmes.

German GTZ has many on-going and completed local area projects which could yield useful information on the determination of an effective carbon sequestration. It was suggested that, to gather information, several donors could collaborate to get a comprehensive inventory of the locations, purposes and practical outcomes of all these village level activities

Data emanated from the very comprehensive publications of the various ISCO conferences would also constitute a good source for additional information.

AN FAO/IFAD INITIATIVE

Project scope and justification

The main issue discussed was whether the project should cover carbon sequestration, biodiversity, land degradation and related aspects or whether it should be limited to carbon sequestration in relation to the Clean Development Mechanism.

Some experts argued that biodiversity would be a field too broad to cover in the current initiative. Instead the focus should be on carbon sequestration and carbon emissions from agricultural land and related aspects of soil biodiversity and its effects on soil-crop interface. Better agricultural practices on existing lands reduce the pressure to put new areas under cultivation by deforestation. Improving savannah lands and restoration of degraded and marginal lands can provide an important contribution to biodiversity as biodiversity is built into these processes. In this

way the linkage with the CCD, the GEF and the question of rural poverty is established. So there would be no need for a separate mechanism to address the biodiversity issue.

A second line of argument was to view the issue as consisting of a hierarchy of objectives : the number one objective is farm productivity combating rural poverty from which the other benefits derive. The next step down is carbon sequestration and its linkage with the.Climate Change Convention and the Clean Development Mechanism. Biodiversity is placed at the third level, not because it is unimportant, but because in the particular context of the project a hierarchy of objectives would be desirable.

The counter argument, which was supported by the majority of the participants, stressed the need to keep the synergies, which are embedded in the Clean Development Mechanism. CDM is aimed primarily at sustainable development which can not proceed with growing desertification and without biodiversity conservation. Most international instruments for funding are attached to the synergies. It is also necessary to bring these together to enhance all aspects of farming systems and land management, including biodiversity. Biodiversity indirectly and directly contributes to carbon sequestration as it concerns living organisms which bring more carbon in the crops and in the soil. Most countries in Latin America and the Caribbean have endorsed the three Conventions. Therefore in considering the "voluntary participation" stated by the CDM the countries must assess the synergies and the benefits to national development.

IFAD's multi-million dollar portfolio, which aims at increasing the smallholder's productivity, so far does not include the explicit objective of carbon sequestration. The project is an opportunity to include that dimension by looking for carbon sequestration options which could lead to increased productivity. Many options for increased agricultural productivity are known to have also an impact on carbon sequestration. The objective is to optimize carbon sequestration by analysing the options both in terms of their productivity and their practical feasibility.

The issue of "enhancement" of biodiversity versus "conservation" of biodiversity as specified in the project title was discussed. Conservation of biodiversity would be achieved by preserving the natural vegetation and forests. There is a pressing urge to conserve the natural forests as automatic carbon sinks. Biodiversity conservation is implied in natural forests conservation. A quantitative and qualitative increase in the soil organic matter of agricultural soils means enhanced soil biodiversity with enhanced soil fauna and microbial activity. Here there is the possibility of win-win situation by combining the building of soil organic matter and carbon to enhance productivity and soil biodiversity.

The scope and activities of the project should depend on the ultimate goal. Examples were given in the context of the World Bank being an implementing agency for the GEF. In the World Bank programme the focus is on all aspects of land degradation that are potentially of interest to the GEF and those are biodiversity, conservation, climate change mitigation and reducing damage to international waters. Each one of these topics have a specific set of GEF priorities and a specific set of rules. The Bank tries to see how possible projects might address the synergies among these different items.

Finally it was recognized that the project was innovative as it addresses the root causes of three global problems, desertification, degradation of biological diversity and carbon emissions. It was agreed to keep conservation of biodiversity in the project title but not as separate component and to establish the synergy among the three objectives rather than prioritizing them.

The project should be kept flexible and emphasize the benefits derived from carbon sequestration or biodiversity protection or combatting desertification, according to the agro-ecological systems selected for the specific pilot studies.

It was also emphasized that the project is not a development project. Rather it is intended as a normative activity to develop a methodology to examine the carbon issue in relation to poverty and.food security by linking the synergies. The field tested methodology would be applied in larger projects in a second phase with additional resources, for instance through co-financing from the Global Mechanism.

The Latin American region is chosen as test case because a lot of information is available from FAO and IFAD projects, national and regional institutions that can be used.by the project to develop the methodology.

Project objectives

A number of questions were raised with respect to the objectives and activities of the project.

There is a large amount of inventories on soil technology, soil and water conservation technologies,carbon sequestration and projects addressing one or two of the objectives,.but little knowledge exists about projects or inventories where the three objectives are linked together. It was proposed, therefore, that the project should inventorize the promising technologies which would meet the three objectives simultaneously, including available technologies on biomass and soil change. It should provide a quick synthesis of proven technologies and their economic viability. It should describe success stories. It should also address information gaps regarding the economic viability of proven technologies or socially acceptable technologies.

The meeting highlighted the aspect of a comprehensive inventory of all the field projects on joint implementation or sustainable agricultural projects in which an element on carbon sequestration monitoring could be built. Such an inventory could serve as a basis to identify the gaps and existing stocks in order to advise governments on appropriate action.

A source of information on technologies is the WOCAT, World Overview of Conservation Techniques programme, in which FAO participates. WOCAT tries to inventorize area-wise methodologies where conservation is most successful. Concern was expressed about continuing stocktaking of past experiences. It was suggested that the project should also generate new data, identify and fill data gaps

One element of the project could be to help narrow down uncertainty which has been recognized as one of the handicaps of the Kyoto process. To establish the bands of uncertainty that are related to the issues of carbon sequestration from different land management practices it is suggested that as many as possible of the available models should be used. Some examples of these models are the EPIC model used to predict carbon flows and carbon pool quantification, the DNDC model which has been developed at the University of New Hampshire and the Century Model, the SCUAF model for prediction of soil changes under agriculture, agroforestry and forestry, developed by ICRAF and ACIAR, and other similar models. The role of the project could be to test as many of these models as possible and to calibrate and validate the models. Validation of methodology has to be done on benchmark sites which involve agricultural practices, forestry practices, desertification control, poverty alleviation, education of women and other indicators. It could identify the rules and the measurements necessary for carbon accounting and evaluate projects. One limitation is the difficulty to put socio-economic aspects in the models.

It was suggested that the project go beyond the technical questions and look at the policy environment for implementation of carbon sequestration programmes. The policy analysis should enable analyses to draw conclusions and facilitate transfer from one set of circumstances to another. It was stressed that there is a need to develop a methodology that addresses processes rather than products applicable in a site-specific context. But it should be possible to upscale to policy formulation for country and regional plans of action in Latin America and the Caribbean.

Project approach and strategy

The approach proposed is to concentrate on the most appropriate agroecological zones for increased carbon sequestration in relation to land use practices and select the socio-economic zones (SEZ) where the small farmer groups will benefit most. High priority SEZs are the zones with the larger incidence of poverty. Country selection would occur subsequently in agreement between FAO and IFAD Latin America Division, taking into account the typology of the areas, the National Action Programmes to combat desertification.

The institutional set up in implementing the programme should be clearly defined. It should be based on partnership with institutions at regional, sub-regional and at national level. The project should be the starting point for such partnership and collaboration on data and information gathering. Partners should be identified who have information and can contribute to the analysis. There should also be a linkage with the strategies of the National Action Programmes to combat desertification. The partners should include research networks, Universities, technology transfer networks in Latin America and the Caribbean and the NGO networks working in this field and are promoting or advising farmers with different approaches.

The University of Trent in Canada, for instance, has formed a network of universities in Canada, Mexico and Ecuador ("INSTRUCT" project) and is using the Integrated Ecosystems Management approach. It is also carrying out an inventory of models and tools and produced partial results presenting the kind of existing tools, their data requirements and case examples of the applications of those tools. The review inventory should provide information on tools, methods and procedures and enable researchers to identify successful ones, not only in terms of the tools but also in terms of possible land utilization types, to avoid overlaps. TSFB would be ready to collaborate on data exchange and methodology for evaluating and assessing soil and land use in relation to carbon sequestration.

CONCLUSIONS AND RECOMMENDATIONS

From the review and discussions a general consensus was reached on the following:

There is a gap of a real information and a divergence of view about land degradation and its links to global problems such as CO_2 emission and carbon sequestration. Therefore, there is a need to examine problems and demonstrate their importance for human survival on the planet earth.

The objective of the programme is to interface food security, carbon sequestration and combatting desertification. To achieve that goal concerted action from World Bank, UNEP, IFAD and FAO is needed with convincing cases and adequate evidence of linkage of the three conventions from which guidelines for project development and policy advocacy can be developed.

Another objective is to promote and develop measures for carbon sequestration which are related to the increase of agricultural productivity through smallholders and the rural poor in such a way that it would contribute to the improvement in land management and reducing land degradation. This objective is aimed at changing farmers'cropping pattern or the type of farming to production systems which would have the characteristics to meet these combined objectives.

A key element is the market, its impact, the scope of its influences, and market integration. The incentive framework must be market-oriented because farmers always rationalize their decisions responding to the existing market conditions, regardless of how fragmented or distorted the markets are. It should aim at improving the markets so the farmers can respond with appropriate decisions which also address the problem of carbon sequestration or improved land management.

The type of policy incentive needs to be identified. A possible option is the so-called "judicious use of subsidy" or strategic use of subsidy promoted by the World Bank, whereby a subsidy is applied for a certain time as a demonstration to farmers. The new lending framework of the World Bank which is called "adaptable lending framework" applied to environmental type of the projects with an investment cycle going beyond ten years, is an example which could be applied. Utilization of subsidy in a judicious manner was not ruled out but no specific recommendation and solution could be proposed on how this judicious utilization of the subsidy could be operationalized.

Any programme should be cost effective in two ways, one for the farmers themselves at the level of their farm and another in the context of a specific project or programme which is being supported and promoted by the public sector or by external financing. Cost effectiveness at the two levels would help the replicability and upscaling of the recommended measures.

The available technologies for carbon accounting are sometimes very expensive. While they are applicable in developed countries, such as Canada and the USA, they are not replicable in developing countries. However, the need to seek for applicable and replicable technology in the context of developing countries was also identified. In particular there is a need for more research to identify the available technologies and to develop technologies affordable to the farmers through a combination of the use of local and modern technology.

The approach should be field-oriented and look at the implications for policies which will promote the win-win of agricultural productivity and carbon sequestration, enhancement of biodiversity and soil fertility improvement.

It is necessary to secure the sources of funding to support the policies and to ensure the longevity of such practices.

It was recommended to establish an Informal Network as a continuous process for exchanging procedures, data sets, models, software and maintain the synergies as the funds are limited. The network should interact with those who are discussing carbon sequestration under the umbrella of the Kyoto Protocol and the Climate Change Convention. A followed-up e-mail consultation is to be organized with additional persons as the next activity of the network.

The FAO team in consultation with the Latin America Division of IFAD and the participating experts will prepare the proceedings presenting the essence of the discussions for distribution. The Senior Adviser to IFAD's President will also be available for further consultation and assistance as it may require, including interaction with the panel of experts.

The project document is to be revised according to the advice received during the consultation. The experts are requested to provide any additional contribution to the secretariat. The FAO team should contact the Director of the Latin America Division and the Managing Director of the Global Mechanism at IFAD to agree on a process to select the countries for the pilot studies.

A panel of experts, consisting of three or four experts, including at least one economist should be constituted to continue to provide advice to FAO and IFAD during the course of the project.

The initial project will concentrate on the following main outputs:

- A catalogue of land management practices that can be used in the region as well as elsewhere in tropical areas to maintain land productivity and provide economic benefits for rural populations, while at the same time conserve biological diversity and the environment, and also enhance carbon sequestration.

- Case studies which contribute to a better understanding of the relationship among three important environment and development conventions, namely land degradation-desertification; loss of biological diversity, and carbon sequestration capabilities of major land use systems. It will provide information, decision support, strategy and policy options for the use of sinks to transfer or acquire carbon emission reduction from agricultural and forest lands.

Keynote addresses

Challenges and opportunities for reducing rural poverty in Latin America and the Caribbean

Contrary to what it was expected, the recent increase in the average growth rate of Latin America and the Caribbean Region has not reduced either aggregated poverty levels or the absolute number of the poor population in rural areas. With increasing urbanisation, more poor people live now in urban areas, but rural poverty is more severe than urban poverty. (33 percent of indigents in rural areas versus 12 percent in urban areas). The nature of rural poverty is also more complex than urban poverty, a fact that is reflected, for example, in the lack of any perceptible effect of countries's macro-economic performance on rural poverty.

It is unfortunate that prospects for improving economic and social conditions of the rural poor looks now dimmer that some years ago because of the devastating consequences of natural disasters, such as El Niño and the hurricane Mitch as well as the pervasive impact of the Asia's financial crisis. An additional unexpected factor is the declining trend in international financial aid directed to rural poverty.

All these conditions call for a better understanding of current constraints to and opportunities for reducing rural poverty and for a careful examination of new instruments and approaches for improving international and national collaboration centered on the rural poor.

The present discussion, focused on the Prevention of Land Degradation, the Enhancement of Carbon Sequestration and the Conservation of Biodiversity through Land Use Change and Sustainable Land Management, with a Focus on Latin America and the Caribbean is of paramount importance for IFAD. In this brief exposition I will attempt to examine these issues from the point of view of IFAD's experience and concerns, which as you know, are closely linked to the need and opportunities of a particular target population, that is, the most disadvantaged and marginalized groups of the rural world.

THE CHANGING NATURE OF RURAL POVERTY

The most striking characteristic of rural poverty in the region is the rising degree of heterogeneity in survival and income generating strategies among households. In 1978, approximately 75 percent of the rural population were small commercial farmers, subsistence farmers, minifudists or members of collective agricultural-forestry-livestock peasant enterprises (i.e. cooperatives, *ejidos*, etc.).

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Recent estimates indicate that nearly all of Latin America's 80 million rural poor belong to three categories: small-scale family producers (38 percent), landless farm-workers (31 percent), and indigenous ethnic groups (27 percent). Artisanal fishermen, although small in quantity, are among the most disadvantaged groups of the rural population. The percentage of women headed household is particularly high and cut across all categories (17 percent).

A significant implication of the above-mentioned trend is that the vast majority of peasants can be considered "producers", and to this can be added "multiple producers", referring to their multiple economic activities for generating income. Thus, their viability relates not merely to their agricultural activities, but also to their capacity as micro-entrepreneurs, wage farmers, and ultimately to all activities which rural families, men and women, initiate to increase and diversify their source of income. It is also important to note that the fastest growing peasant categories area landless or near landless peasants. Moreover, in many countries of the region (Peru, Mexico, Brazil, Guatemala, Ecuador, Colombia, etc.) there is a close relationship between rural poverty and ethnicity. This calls for a broader set of instrumentalities that takes into account the special cultural requirements of minority groups as well as the complex interactions existing within multiethnic societies.

The causes of rural poverty are not well known, as it is reflected in the disproportionate rate of failure of international and national poverty eradication programmes compared to other types of development initiatives. Today, the main problem in the region is not food production, as it was during the green revolution, but agricultural diversification at reasonable prices, without destroying the environment, as well as access to a secure source of income generation. Large segments of the rural population face the so called "double squeeze", consisting in the impossibility of getting out of rural poverty due to a limited resource base (land), while their low educational levels and technical abilities severely constraint their insertion in the competitive urban labour markets. It follows that a first condition for helping the rural poor to get out of the poverty trap is twofold: (a) increase the resource base of the poor, particularly land; and (b) increase productivity of land and labour at the same time.

However, as poverty is a multi-dimensional socio-economic phenomenon, usually interventions directed to improve the use of or the access to essential production factors, such as land, capital and technology are not sufficient. Evidence from poverty eradication initiatives indicate that at least two other groups of variables should be taken into account in the poverty analysis: (i) issues related to how the rural poor, as individuals or as a group, reveal first their needs, constraints and priorities for development, and second, how they intend to participate in the design and implementation of alternative solutions; and (ii) issues affecting national societies at large, such as human rights, customary laws and/or institutional barriers to ethnic minorities. These observations suggest that a second condition for helping the rural poor is to identify and gradually remove policy, institutional and organisational constraints restricting the rural poor to materialise his production potential by facilitating their access to the mainstream of the economy in an effective and equitable manner.

Two trends observed throughout the region are likely to worsen the prospects for the rural poor. The first is the massive migration of peasant population toward ecologically fragile zones, pushed by drastic social events such as civil wars, rural *guerrillas*, violence associated to drug production or illegal land expropriation induced by large ranchers and timber corporations. As a result, today a vast majority of the peasant population is located in semi-arid zones; mountainous regions or tropical areas with low agricultural/livestock potential. The second trend is the fast growth of the rural population that now depends on rural labour markets, seasonal migration and off-farm incomes. A major implication of these trends is that a large share of the rural poor cannot be helped exclusively by land-based production oriented development projects. This calls for a

wider concept of rural development with a flexible approach to respond to changes taking place in the rural-urban regional *continuum*.

From the beginning of the 90s, a new and all-encompassing socio-economic phenomenon is altering the prospects of eradicating poverty in developing countries: the globalisation process. It is acknowledged that globalisation generates risks and opportunities for rural poverty reduction. Lack of reliable field information from rural areas preclude a full understanding both of the impact of globalisation on rural poverty and of promising options to be capitalised by the most disadvantaged rural groups. It is fair to say that globalisation has expanded income-generation opportunities at least in two main areas: (i) export expansion for countries with well established comparative advantages in certain products and which had already initiated a process of insertion in international markets; and (ii) import substitution, mostly in the agro-industrial and food-processing sectors thanks to the strong political support that these activities have received in most countries of the region. While there is no inherent reason impeding small-scale producers from accessing these opportunities, the hard reality is that they are threatened by increased competition from larger enterprises that have closer and solid links with the market. It is estimated that more than 2.5 million small landholders and agricultural workers from the MERCOSUR area (Brazil, Argentina, Uruguay and Paraguay), might lose their plots and/or jobs between the years 2000 and 2006 unless appropriate policies are specifically designed to protect them.

CURRENT STRATEGIC FOCUS OF IFAD

As already stated, the heterogeneity of poverty prevent the design of a single rural poverty alleviation strategy and will require, by contrast a multipronged and flexible set of initiatives which, to a large extent, can only be identified by the poor themselves given the different access to information. This observation provides the rationale of IFAD's approach to support highly participative, demand driven rural development projects. At the heart of this approach is the notion that in Latin America and the Caribbean today rural poverty can be eliminated or drastically reduced by enhancing the rural poor capacity to participate in the market of products, inputs or services. Thus, the primary objective of IFAD interventions is to achieve income security, and through this other valuable objectives such as food security or improvements in the quality of life.

In the current IFAD's perception there are at least three major determinants of the most rural poverty situations:

- the insufficient productive base of small rural producers, mainly land;
- the predominance of unskilled human resources; and
- the extremely weak links of many rural groups with critical institutional assets and market opportunities that are already available to non-poor rural populations.

From its foundation IFAD has used targeting as a powerful instrument to minimize the risk of leaving the weaker segments of the rural population unattended. Our concern, in this respect, is related more to how to define a portfolio of approaches that correspond to the specific determinants of poverty for each social group and region than to the implementing cost of targeting. A connected question is whether or not a poverty reduction strategy can be solely focused on the poorest farmers and rural entrepreneurs. On practical ground, IFAD investment projects, *inter alia*, deals with this issue through a threefold strategy:

- a productivity-enhancing strategy directed to individual producers who own a sufficient amount of productive assets;

- upgrading of the technical and managerial capacity of human resources; and
- a community or village development strategy directed to fill the huge institutional and social capital gaps that preclude the materialization of the economic potential of the rural poor as individual or as a group.

Both individual and community strategies are needed for overcoming environmental constraints. Resource use in some rural communities, in spite of the traditional wisdom in the use of natural resources, is generally characterized by intense ecological stress as a consequence of demographic pressure and poverty. Poor knowledge of modern soil protection technologies and the lack of appropriate economic incentives are accelerating the loss of valuable natural resource assets. In traditional or ethnic rural communities there are, in addition, serious conflicts regarding land titles. These situations can be effectively dealt with by stressing the importance of interventions that reinforce the traditional or ethnic bases of the community as a cohesive factor. Thus, traditional or ethnic communities should be seen as an asset and a national heritage to be preserved. Its organizational capacity, in particular, is seen by IFAD as an important mechanism to reduce transactions cost, both for the management of the community projects and for the successful participation of the community members in products and labour markets.

To be effective, IFAD's approach to poverty reduction select as elementary unit of analysis the farm, the household or the rural community according to the nature of the constraint that it attempts to remove. Complex issues cutting across the whole community such as gender, environmental protection or beneficiary's participation in the design implementation and co-financing of projects activities need a strategic framework beyond the boundaries of farms and households. Moreover, issues such as clearance of land right, gender-bias of customary low, or civil rights of minority ethnic groups may require an intense policy dialogue at the community, regional or even national level.

It is fair to say that globalization is making more prominent the role of international donors in supporting rural development and poverty eradication programmes in developing countries. Large segment of smallholders are at a clear disadvantage in facing two risky situations at the same time:

- the challenges of modernization and competitiveness relative to commercial farmers of the same country due to low quality assets, market failures for credit and insurances, reduced government support and limited access to new technologies and information; and
- low ability to cope with new forms of protectionism in the importing countries. In this context, poverty reduction programmes supported by international donors can be interpreted as targeted initiatives at capitalising the rural poor to reach the minimum threshold needed to enter income earning activities that will bring them above the poverty line.

IFAD's concern on issues related to natural resource management, and protection of the environment is well reflected in our participation, not only in the Rio Conference and the role the institution had in the Convention to Combat Desertification, hosting the Global Mechanism, but also and mainly through our lending programme and technical assistance grants.

IFAD's experience in collaboration with other UN institutions, like FAO, and financial institutions, like the regional banks and the World Bank, has allowed the IFAD to promote innovative institutional mechanisms oriented to income and employment generating activities as a condition to reduce the pressure of rural poor over natural resources.

The abrupt withdrawal of the state from the rural scene has shrunk government programmes oriented to support rural development and to mitigate rural poverty. The issue here is not the downsizing of the public sector in agriculture but the blurring boundaries of state and marked roles

and the unrealistic assumption that what was formerly done by the state would be automatically filled by an equivalent intervention of the private sector.

The relationship between poverty and environmental degradation is narrow and complex, and is characterized by processes of causality, that not always allow to clearly distinguishing between cause and effect. The evidence available in Latin America, however, refuses the simplistic explanation that the rural population is the main responsible of environmental degradation in the region. Whenever there is a case of negative effects on the environment linked to the economic activities of rural poor – fact that goes against their own interests in the long trend – there is always a rational attempt to change their adverse physical and economic conditions defining their surviving strategy. These attempts do not succeed when the poverty level is such that the farmers are not able to sustain themselves.

The irrationality of this situation does not lay in the surviving strategies, but in the social and economic context behind them, or, to say the same in other words, in the structural conditions and the macroeconomic and sectoral policies that generate poverty in a continuous and extensive form. We can then conclude that the reduction of environmental degradation requires, as a prerequisite, a rational solution to the rural poverty problems. The essential condition to obtain a positive result is to put into practice institutional mechanisms involving not only groups of rural poor, but also the rest of the society, being these Government and private organizations.

In this context, the joint FAO/IFAD initiative, intended to prevent land degradation, to enhance carbon sequestration and biodiversity conservation through land use change and sustainable land management is an strategic initiative, which I am sure will pave the way to larger financial interventions, but its importance is mainly related to constitute the point of departure of building synergies between the Convention on Climate Change and the Kyoto Protocol, the Convention to Combat Desertification and the Convention on Biodiversity.

IFAD and FAO are playing a leadership role in Latin America and the Caribbean, and we hope that this new joint effort would contribute to reverse land degradation and carbon losses. These efforts will contribute to alleviate rural poverty by providing sustainable agricultural production practices, thus both institutions could assist governments in the region in their efforts for long-term sustainable agriculture.

Incentive frameworks toward poverty alleviation

I would like to share with you IFAD's perspective and its objectives in following up the excellent initiative of this joint expert consultation which is one step further in strengthening collaboration between IFAD and FAO.

Of course the main theme of this brainstorming session is land degradation, the prevention of land degradation and in relation to this exploring options for carbon sequestration and the potential to influence the atmospheric concentration of greenhouse gases through the land use activities. But what has brought us here today indeed is poverty and food insecurity and the options that we have in addressing these two major problems through the management of terrestrial ecosystems. In this context, human-induced activities and the policies, practices and most importantly the incentive frameworks which would influence the pattern of such activities should be among the most important issues to receive our attention during this session.

Let me put this challenge in a global perspective. As it has been referred to by Raquel Peña Montenegro, our Director, Latin America Division, over the past decades, efforts towards poverty alleviation (with certain qualifications) have been successful. In many parts of the world, the ratio or the percentage of the people living at the absolute poverty level has been reduced, but the aggregate number of those people has increased, in particular in Southeast Asia and in Sub-Saharan Africa. We also have evidence that in Latin America, the same trend has started to develop.

The gains towards poverty alleviation and reducing food insecurity has been also fragile. What has been gained is being lost due to economic upheavals and instability of the financial regime in certain regions and even the spill-over effect of this phenomenon to the other regions. Weather calamities - the El Niño and repeated droughts - reversals in some of the macro-economic reforms, and civil strives have contributed to the loss of the gains which have been made over the past three or four decades.

The face of poverty has also changed over the past two decades, in particular - if I may put it in this way - the face of poverty has become more feminized. The number of women, and in particular households headed by women, under the absolute poverty level has increased. It has also become more geographically concentrated in two ways. Firstly, because of the accelerated rate of the urbanization, the number of poor in the urban and pre-urban areas has increased, but still a major part of the poor are living in the rural areas and if we add the pre-urban area, where there are major activities on land utilization, it is much higher. In many countries, it is as high as 80 percent and in Ethiopia it might be near to 90 percent of the poor who are residing in the rural and pre-urban areas. Therefore, rural poverty still remains a major challenge for all of us.

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Second, the incidence of poverty has become increasingly concentrated in dryland. There has been a major policy shift and emphasis by the international committee in the development effort. Poverty is therefore receiving increasing attention and along with that of course, the reduction of food insecurity. The OECD has set a target to reduce the poverty by half by the year 2015. The World Food Summit of FAO has also endorsed this objective. Of course, one particular head of a state, I think it was Mr. Fidel Castro, who said that this objective is half good. However, still it remains a daunting challenge. Therefore, we need to concentrate all of our efforts and to look.for all options which can contribute towards this "half good" objective and to be certain that at least we have achieved what has been set.as a target for ourselves.

Now, let us have a look at the rural scene and the major causes of rural poverty. Primarily, the major causes of rural poverty are associated with land and two particular aspects of the land. First, skewed land distribution in the rural areas and the problem of the land tenureship and second, land degradation, loss of land fertility, and its capacity to support life. I said that there has been a geographic concentration of the poor. There are statistics which indicate that nearly 60 to 65 percent of the poor are residing in the dryland area (the area subject to desertification), arid, semi-arid and sub-humid zones. If we also count the number of population who are living in mountainous and the upland areas which are also subject to heavy degradation, almost 80 percent of the poor are living on a fragile ecosystem. The causes of poverty associated with land, i.e: access to land and land degradation are more acute under a fragile ecosystem.

We need, therefore, to ensure that there is adequate policy attention, resource allocation and programme development, which would be addressing the two major causes of poverty associated with land, that is, a skewed land distribution and land degradation. We need a holistic effort; the combined efforts of all international organizations, bilateral donors, civil societies and the private sector. I am very happy to see that today, a representative from ENI is participating in this meeting. This organization recently had initiated an excellent seminar on the zero emission which was very well attended. ENI has a lot of the characteristics of the private sector.

As far as IFAD is concerned, our main objective is the reduction of poverty and enhancing food security. In this context, the problem of the dryland and development of the dryland is receiving increasing attention in IFAD, along with problems facing small scale food producers in their fragile ecosystem. IFAD is housing the Global Mechanism of the Convention to Combat Desertification. The overall objective of the Global Mechanism is to facilitate or to ensure the mobilization of substantial resources towards implementation of the Convention to Combat Desertification, and therefore, addressing the problem of land degradation in the dry areas. The Global Mechanism has a facilitation committee consisting of the World Bank, UNDP and IFAD. Recently, UNEP and the Regional Development Banks have joined this Facilitation Committee and FAO has also been invited to join this joint endeavour in supporting the Global Mechanism of the Convention.

The Facilitation Committee recently decided that the issue of carbon sequestration and options for carbon sequestration through the land use, including afforestation and reforestation, is one of the important issues which should be considered by the Global Mechanism. Mr. Per Ryden has been asked to undertake a stock-taking exercise. All agencies would hopefully provide him with information on their initiatives. He will be preparing a strategy for the Facilitation Committee, for their consideration. Therefore, this meeting is also of great interest and great benefit to the Global Mechanism.

In brief, one of the main objectives of this meeting is to look for practical and programmatic linkages between the three main Conventions which are borne under Rio.conference. You know that the CSD-VIII.would be convened in the year 2000. It will be a major meeting. One of the main issues that the CSD-VIII is going to consider and review is how the issue of land degradation, in

association with the challenge of agricultural production, is going to be addressed in an holistic manner as I referred to before.

In brief, while the Conventions, such as the Climate Convention are helping us to take care of the roof over our heads, ie:.the atmosphere- we should not forget that the floor under our feet, that is the land, is also crumbling and that needs very important attention and active consideration on our part. This meeting is one step towards that direction and I would like to thank FAO, which has initiated this meeting. Thank you very much for your listening to my points, presented to you without Power Point.

Sustainable land use toward food security

Sustainable land use is embedded in the functionality of land which encompasses the economic, social and environmental functions of land and aims to reconcile these different perspectives in order to supply people with food and other agricultural products in adequate quantity and quality, alleviate poverty, generate employment, protect environment and maintain natural resources for present and future generations. This is the definition, which was adopted in Agenda 21 and later on taken up in the World Food Summit. This is the departure point, so we will start from that departure point within which the whole issue of land management and land use in this programme is going to be framed.

If we take a given agricultural zone, we have a number of studies and good work which has been done for the last 30 years in zoning the world in different agricultural zones. We have a.very substantial database which divides the countries and regions by agricultural zones and,.within the agricultural zones, by a number of land use systems. Within this framework are the farmers, who basically work on a land use system and manage the soil. Soil management is for crop production and crop management, but generally the links between land use system and soil management are basically related to soil fertility and to its enhancement linked in turn to organic matter. These linkages are quite complex but particularly very synergetic. All of these elements in an ecosystem, or systemic environment, are necessary to create the conditions for, at the same time, enhancing soil fertility, which also is related to soil biota, and soil biodiversity and organic matter. Furthermore a particular soil and a particular land use system have a level of carbon stock but also a potential for carbon sequestration. All these could lead to soil productivity because of the interactions between all the elements within the soil and vegetation. Soil biota and soil biodiversity are of course related to agricultural biodiversity or agrobiodiversity which is in one part crop but also weeds. Within this context especially poor farmers are using this kind of interaction for household food security.

The objective of this programme is basically optimizing these synergies between on one hand improvement in household food security and income, soil fertility enhancement, land and water conservation and improvement, carbon sequestration, biodiversity conservation above and below ground in several aspects, including soil biodiversity, crop biodiversity and of course genetic resource diversity. We know that the health and production of a plant are intimately related to the health and functioning of communities of organisms in soil, which is the four-dimensional rooting environment.

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The nutrition and management of soil organisms is essential to sustaining and improving the productivity of soil. That is also another very important element. We know that the soil is always mined particularly in a small farmer situation where the restitution of organic matter is not well done because there is a sort of breakdown in the system. Basically in the traditional system we had a fallow period, we had also animal integration which has been in some cases lacking.

Keeping appropriate porosity of a soil at every level is a key to healthy functioning and a medium for roots and soil organisms. We know that the role of water is.very important in plant production and food security, particularly the water movement, water dynamic into soil is directly related to the content of the organic matter and especially porosity in the soil. Its capacity to accept, retain and transmit water into a profile enhances its resilience in the face of erosive or other damaging forces. Basically, if a soil has a good condition, it is certainly more resilient to erosion but it is also.more balanced in terms of nutrition and plant production. It functions best as a rooting environment when appropriate dynamic balances are maintained between its physical, biological and chemical components and where the outflow of plant nutrients is regularly compensated by an inflow from a combination of sources and plant nutrients. Of course there are lots of arguments about the use of fertilizer, non-use of fertilizer, organic matter, organic agriculture. These debates are of course are very important and we have to look at again how this flow of nutrients are running through the soil and crops and how we can.restate and balance the system.

Soil organic matter is the source and sink in the global carbon cycle in nature. We know that the composition of soil organic matter is influenced by management practices and particularly by tillage system. The physical disturbance and the mixing of soil, exposing and disrupting soil aggregates, induce a more rapid turnover of organic matter. Hence, reduced or no tillage practices may prolong the residence time of carbon in the upper layer of the soil. An additional advantage of reduced tillage is the lower consumption of fossil fuel and the lower emission of CO_2 from agriculture. There has been a number of research and studies conducted on this issue in different areas. One example is a computer prediction which gives the relationship between total levels of organic matter and the top 30 centimetres of a prairie soil under no till, with and without fertilizer, and under conventional tillage without fertilizer. The study shows a carbon balance when there is no till and with a limited amount of nitrogen added to the soil.

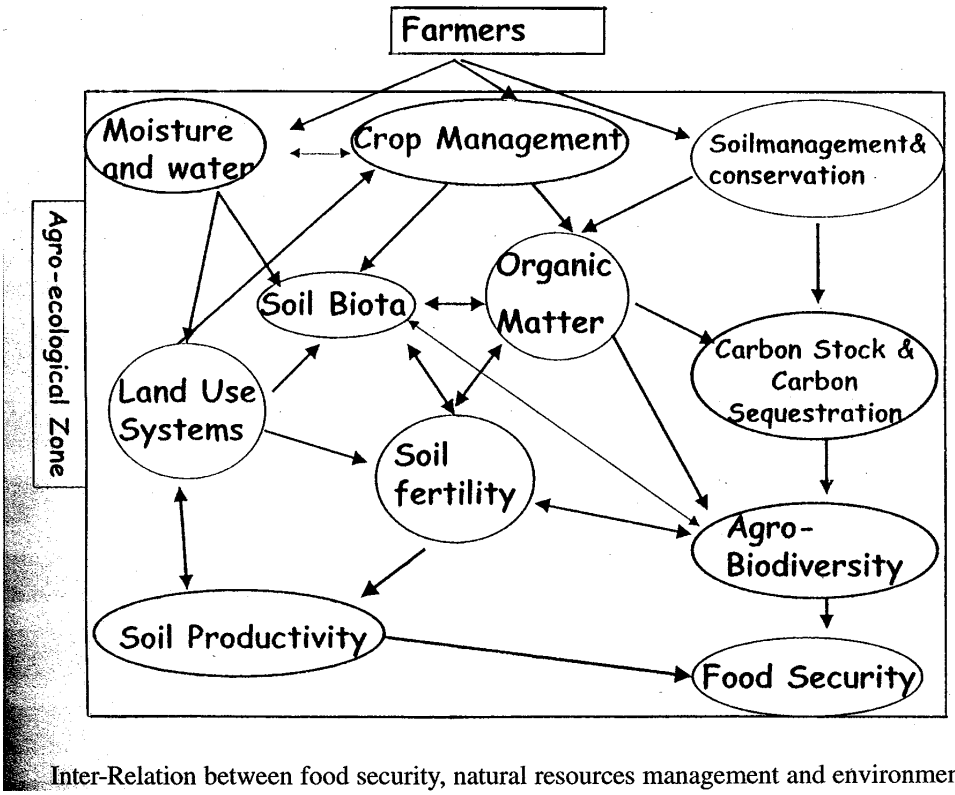
With regard to land degradation, particularly in America and the Caribbean, we have a very important and good database at country level and by type of the severity of land degradation. This work has been conducted by ISRIC and UNEP with FAO inputs which have beenn instrumental in the preparation of this work. We also have database information, geographical information system which gives the different type of degradation either by other type other type of degradation. Land degradation particularly in Latin America and Caribbean is serious. Except for a relatively small proportion of countries where land is directly managed by the state, decisions about land use are taken by people, by millions of individual land users. Therefore, governments and the community as a whole can only influence land use indirectly through their ability to modify the economic, social and legal environment within which land users make their decisions. Hence action for sustainable land husbandry will necessitate active participation of farmers, the strengthening of local and national technical assistance institutions and regional and international agreements which are fundamental for the exchange of information, training and technical assistance, appropriate agricultural policy, legislation for equitable land distribution and viable soil conservation measures. Of course this could eliminate the cause of inappropriate land use, and concurrently contribute to reducing CO_2 emission and to lowering the concentration in the atmosphere through a slowing or stopping deforestation. One of the major activities to be done is the creation of.large living terrestrial carbon reservoir by reforestation, afforestation and agroforestry. I want to emphasize agroforestry, increase the carbon content in arable and grassland soil, to enhance biomass

production and the effective use of organic residues. Increasing the carbon stored in durable wood products, particularly linked to the Kyoto Protocol.

Specific techniques for carbon sequestration are the autofertilization, commercial fertilization, organic fertilization and other organic inputs, conservation tillage and reduced summer fallow, crop rotation, agroforestry, integrated forest management and fire suppression. For carbon sequestration measures should not be a stand-alone agro-technique so this is the importance of linking food security and global environment. Its objectives should be in accord with these of other international action programmes so also to enhance impact and ensure a basic interaction between conventions and international instruments. They should be implemented in synergy. It is for this reason that FAO particularly with IFAD, wants to take advantage of this huge database on agricultural zones and land use. Basically, we could really look at the countries and divide them by a number of land use systems. In each land use system, there is a possibility to work out both the carbon stock, above ground and below ground, and to look at the potentials by land management practices and improved land management.

Synergy among various international programmes is important: the three Conventions which I have mentioned before, but also a number of action programmes which are ongoing, a special programme for food security, with its two dimensions (one is sustainable intensification and the other is diversification), soil fertility initiatives on which we had a meeting very recently with the World Bank to ensure restoration and enhancement of soil fertility through a number of activities including fertilizer use, and national forest action plans. CGIAR system wide there are many initiatives, among which IPGRI on agro-biodiversity conservation, but also ICRAF and TSBF.

These were a few technical inputs to set the stage for further brainstorming during this consultation.



Inter-Relation between food security, natural resources management and environment

Land, the platform for local food security and global environmental protection

Anthropogenic emissions of the so-called 'greenhouse gases', of which CO_2 is a major component, are considered to lead to a temperature rise at the earth's surface. The temperature rise of 0.7°C since 1860 is acknowledged by most scientists. However, there is no general agreement as to the role of the greenhouse gas concentration in triggering the upward trend of temperature. A correlation is also suggested with the solar and sun spot activity which influences atmospheric moisture levels and cloud cover, that are the major factors in the earth's basic greenhouse effect. It will take time to obtain scientific certainty about the mechanisms involved. In the meantime it would be wise, on account of the 'precautionary principle', to mitigate the possible adverse effect of greenhouse gases.

One of the measures that could be taken is to lower the CO_2 level of the atmosphere through a reduction of emissions and the sequestration of carbon in the form of biomass. In order to achieve this objective enabling policies will need to be instated. Account will need to be taken of different environmental conditions so as to ensure both global and local benefits at an affordable cost.

There are numerous studies about the technical aspects of carbon sequestration. The following 'notes' are an attempt to highlight some general issues which may need to be addressed when action plans for carbon sequestration are envisaged. They are based on an edited 'readers digest' of various sources referred to in the list attached.

Emissions resulting from human activities are substantially increasing the atmospheric concentration of carbon dioxide, methane and nitrous oxide. These increased emissions enhance the so-called 'greenhouse effect' which is alleged to increase the average temperature of the earths' surface. Carbon dioxide is considered to have a major responsibility for the enhanced greenhouse effect. Sources of carbon dioxide emissions include burning of fossil fuels, industrial production, deforestation and agriculture. Estimates of the total contribution of deforestation and agriculture (through emissions of carbon dioxide, methane and nitrous oxide) to the greenhouse effect vary widely. However, emissions of carbon dioxide generated through the agricultural and forestry sectors are evaluated at only 5 percent of the global total. On the other hand the potential of agriculture and forestry for carbon sequestration is significant. In order to do so effectively there is an urgent need to qualify and quantify the measures which could be taken.

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Global figures for greenhouse gas emissions mask considerable differences between countries and between different environments. Emissions from all sources need to be inventoried per country. Contributions ascribed to agriculture and deforestation may be overestimated. Figures compiled in developed countries for mechanized agriculture are often extrapolated to arable areas in developing countries which rely mostly on manual labour or on animal draught power. Actual rates of deforestation are not known with certainty. The definitions of what constitutes a 'forest' and 'deforestation' vary considerably. Statistics that are quoted are often outdated and tend to become hallowed by frequent repetition. They often include areas of shifting cultivation overlooking that these areas mostly revert to secondary stands through regeneration.

Land use and soil management can contribute to reducing CO_2 emissions and to lower its concentration in the atmosphere through:

- slowing or stopping deforestation in order to preserve current carbon reservoirs
- enlarge living terrestrial carbon reservoirs through reforestation, afforestation and agroforestry
- increase the carbon content in arable and grassland soils through enhanced biomass production and the effective use of organic residues
- increase the carbon stored in durable wood products
- replace fossil fuels by sustainable biomass energy thus reducing the net emission of greenhouse gas

It must be acknowledged that these measures would reduce only a small fraction of the emissions caused by the current massive use of fossil fuels. However, all relevant contributions should be encouraged especially since the above measures concurrently promote an improved land use and more sustainable agriculture.

Carbon sequestration measures should not be a stand-alone undertaking. Its objectives should be in accord with these of other international action programmes. They should be implemented in synergy:

- convention on climate change: reduction of greenhouse gas emissions
- convention on biodiversity: reduction of deforestation and preservation of natural habitats
- convention on desertification: increasing vegetative cover and prevention of land degradation
- special programme for food security (SPFS): sustainable agricultural practices toward increased food production (FAO)
- tropical forest action plan (TFAP): protection and improved management of tropical forests (FAO)
- Soil Fertility Initiative (SFI and partners): ensure restoration and enhancement of soil fertility (WB/FAO)
- CGIAR system-wide Alternatives to Slash and Burn Programme (ASB)

Forestry and agroforestry can compensate for greenhouse gas emissions by creating new sinks for carbon dioxide (forestation and the use of wood for durable products) and by protecting natural forests that are present carbon stores. Estimates of the cost of carbon sequestration, through forest and agroforestry management practices, vary from $1 to 30 per ton of C. It is obvious that this option will need to be economically viable or sponsored by major C emitters.

Enforcement of **protected forest areas** will be possible only by providing alternatives to forest conversion, e.g. by creating an enabling environment for more productive agriculture on lands located in forest fringes or by ensuring increased income from forest management to replace farming. Deforestation is inevitable unless local populations perceive tangible benefits from standing forests. These benefits can only be realized where there is a capacity to plan, organize and manage forest exploitation rationally and economically. The development of productive farm/community forestry or agroforestry may be more easy to implement than achieving a consensus for managing communal areas of forest.

Conservation, or avoided deforestation, offers the greatest confluence of climate and biodiversity benefits. Indeed it is more economical to slow down deforestation than to undertake reforestation or afforestation to stimulate emission reductions. It should be realized, however, that C sequestration stops when a forest reaches a mature stage. The 'temporary' utility of a forest stand should be assessed, possibly as a gain in time until alternatives to fossil fuels can be developed. The advantages of sustainable forest management should be evaluated in comparison with mere 'conservation'.

In some countries campaigns have been launched to limit the use of **tropical woods** for construction and the manufactoring of furniture. This approach may be counter productive and misleading since carbon stored in wood products is more durable than in living stands. Another view is that only a small percentage of the trees removed become wood products and that even selective logging damages the surrounding forest. Improved logging techniques may ensure carbon storage from wood products while also improving income of the workforce involved.

Insufficient attention seems to be given to the use of **biomass as an energy substitute** for fossil fuels. Renewably-grown biomass is a CO_2-neutral source of energy which can be converted to electricity, heat, liquid and gaseous fuels. The biomass is grown perennially, creating a source of income for rural communities without the need for removing land from productive use to only sequester carbon. Consideration should also be given to use the biomass of carbon sinks that have come to maturity as sources of energy rather than losing their impact through decay or uncontrolled burning. Against the background of current low prices of fossil fuels the use of biomass energy may not be economic, however, it should be part of a medium to long term strategy and be included in action plans from now onwards.

Sequestration of carbon in above ground biomass is by nature a temporary phenomenon. Crops are consumed and trees decay beyond their maturity stage. A more durable sequestration takes place in the **underground biomass** of the rooting systems. The latter are the source, in addition to the incorporation of surface residues and litter, of soil organic matter or 'humus'. Soil organic matter is actually the largest global terrestrial pool of carbon.

Increasing the organic matter content of soils is actively advocated in order to enhance soil fertility and hence productivity. Ways which are generally recommended to increase soil organic matter are incorporation of crop residues, application of animal manures, composting of organic wastes, grass and legume cover crops, green manure. These practices, which at first glance seem simple, meet with limitations in small farmer environments. Furthermore organic residues have alternative uses. Farmers do not consciously manage their crops and soils for their effect on soil organic matter and carbon sequestration. Their effort will be restricted in the absence of rapid and tangible returns, which seldom occur with a progressive increase of soil organic matter. It is significant that traditional farming on acid soils in the tropics is not based on incorporating organic matter into the soil but on burning it. Immediate ash fertilization is given preference over a slow building up of humus. The additional advantage is weed control which is imperative to ensure a yield.

The question still to be answered with regard to the effectiveness of soil organic matter as a sink for carbon is the residence time of 'humus'. It is subject to the decomposition rate which differs considerably under different climatic and soil conditions.

For instance in Vertisols, Andosols and Podzols, interactions occur between organic matter and the inorganic matrix, leading to complexeation and chelation. On the other hand soils dominated by kaolinitic clays and high in iron and aluminium oxides are less prone to C storage. Latin America and the Caribbean is a region of extremes with regard to the diversity of soils and agro-ecologies. C sequestration measures will need to take this diversity into account in order to be rational and effective. Long term human occupation has generated 'plaggen soils' in N.W. Europe and 'terra-preta' in the Amazon region which appear to be stable carbon stores. Research on the mechanisms involved could provide useful indicators for prolonging residence time of soil organic matter. However most soils are characterized by a specific organic matter 'profile', a level beyond which it is difficult to push organic matter content.

The **decomposition of soil organic matter** is influenced by management practices, in particular by tillage. The physical disturbance and the mixing of soil, exposing and disrupting soil aggregates, induce a more rapid turnover of organic matter. Hence, reduced or no-tillage practices may prolong the residence time of C in the upper layers of the soil, provided that crop production is not adversely affected by soil compaction or weed infestation. An additional advantage of reduced tillage is the lower consumption of fossil fuel and the ensuing lower emission of CO_2 from agriculture. The latter benefit occurs especially in industrialized countries where agriculture is heavily mechanized. The same results would not apply where minimal hand tillage is already prevailing as is the case in many developing countries. In these instances weed control, rather than stocking of organic matter, is a prime requisite. The major impact on C sequestration of reduced tillage in developed countries can not readily be extrapolated to the developing world.

Changes of land use, e.g. from forest or grassland to arable land, can reduce organic matter content of soils through reduced detritus, decomposition or erosion. However only surface layers are affected with a lesser decrease of organic matter in depth. It should equally be recognized that changes in landuse can increase soil organic matter content through increased production of biomass, both above and underground, as a result of intensive agriculture. The claim that soils have lost organic matter following the reduced use of manure in modern farming is not always justified. Higher yields, being obtained with a combination of (reduced) organic and (increased) inorganic plant nutrients, have resulted in higher soil organic matter contents. The need for improved cropping systems with high biomass production and effective groundcover to control erosion are essential for both C sequestration and beneficial agriculture. Soil conservation measures should be preventive rather than corrective. 'Conservation agriculture' which is presently advocated aims at minimizing soil damaging practices. Common-interest groups, around the concepts and practices of conservation agriculture, are developing in Latin American countries.

Carbon sequestration alone will not be a sufficient motivator for changes in land use or in soil management practices. It appears that carbon sequestration has the potential to become a **tradable good**. For instance consortia of energy producing companies are willing to finance C sequestration in areas to be reforested. Projects are ongoing in Belize, Costa Rica, Guatemala, Mexico, Panama and the Western Amazon, which have as objectives the retention of standing forests, the addition of biomass C storage, the promotion of rational forest management, the protection of vegetative and animal biodiversity.

The **'Clean Development Mechanism'** (CDM), foreseen in the Kyoto protocol of the Convention on Climate Change, provides an opportunity to identify and finance low-emission development paths in developing countries.

The CDM allows project-based trading between developed and developing countries. The latter would be assisted in achieving sustainable agricultural development thus contributing to stabilizing greenhouse gas emissions and concurrently assist industrialized countries to comply with their binding emission targets.

The decisions relating to the treatment of forests and changes in land use have yet to be finalized but it is generally recognized that increased agricultural production in developing countries could substantially contribute to slowing down deforestation. Hence CDM guidelines should clearly allow for projects that seek to enhance C sequestration through enhancing soil productivity towards forest preservation.

The effectiveness of action plans of C sequestration will depend **on inducing the thousands of farmers** to change their farming systems toward reducing greenhouse gas emissions and storing organic matter. Measures to ensure farmer's participation will require special attention. The application of improved practices will depend on ensuring a return to farmer's investment in cash and labour. These returns will need to be commenserate with production risks inherent in changing farming practices and be obtained in the short term, within the short 'investment horizon' which applies in situations with limited cash reserves. These conditions can be met only if governments adopt policies which are conducive to agricultural intensification and the protection of natural resources. Hence a 'participatory approach' does not involve farmers only but encompasses increased commitment of policy makers, scientists, technicians and the general public. Resource allocations for C sequestration should be based on a combination of local economic returns and global environmental objectives.

It should be kept in mind that lowering the CO_2 concentration of the atmosphere would imply a foregoing of the **'CO_2 fertilizing effect'**. Current CO_2 levels in the atmosphere are a limiting factor to plant growth. Higher CO_2 levels would enhance photosynthesis, resulting in higher yields of food crops, and in increased biomass production in general, thus ensuring a higher carbon sequestration. Another aspect of the CO_2 fertilizing effect is that higher atmospheric concentrations of CO_2 induce reduced stomatal conductance and an increase in plant's water use efficiency. Foregoing the CO_2 fertilizing effect will not only weaken carbon sequestration but also reduce the potential for increased crop production. It is on account of this important issue that the role of CO_2 in the greenhouse effect needs to be objectively clarified and that trade-offs need to be assessed.

Even though the C sequestration potential of forests, grassland and agriculture is considerable it should be realized that it represents only a **fraction of the emissions** from the use of fossil fuels. The support of industrialized countries to promote C sequestration in the developing world should be highly welcomed and encouraged. However trading measures should in no way divert attention from the obligations of developed countries which are responsible for the major share of the greenhouse gas emissions.

Should it later be proved that the global warming trend is not essentially due to the effect of greenhouse gases but rather to the natural effect of fluxes in solar energy and ensuing variations in atmospheric moisture levels and cloud cover, the C sequestration efforts of forestry and agriculture should have **no regrets**. The increased storage of soil organic matter and improved land use will result in enhanced agricultural productivity and its sustainability which are major benefits as such, apart form mitigating climatic change.

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Summaries of presentations by participants

Global carbon pools and fluxes and the impact of agricultural intensification and judicious land use

The climate, or the long-term mean weather conditions prevailing in a region, has a strong influence on the biosphere and vice versa. The weather conditions are influenced by temperature, relative humidity, precipitation and the radiation balance. The climate of a region is governed by several factors that govern cyclic patterns ranging from decades to millenia. An important among these factors is the radiation balance of the earth-atmosphere system.

Earth is sheathed (blanketed) in an envelope of gases called the atmosphere. Solar radiation reaching the earth's surface passes through the atmosphere. The latter is about 1000 km thick and comprises four distinct layers. The Troposphere extends from the earth's surface to about 10 km above. The temperature in the Troposphere decreases from an average of 15°C at the surface to about -50°C at 10 km. The Troposphere is heated from below by convective processes. The Stratosphere extends from 10 to 50 km above the earth's surface in which the temperature increases with height from -50°C to about 0°C. The Mesosphere extends from 50 km to 100 km above the earth's surface and the temperature decreases from 0°C to -100°C. The Thermosphere extends from 100 to about 1000 km above the earth surface, and the temperature increases with height above the earth's surface. About 80 percent of all air is in the Troposphere, and the radiation balance of the earth-atmosphere system is influenced by the gaseous composition of the Troposphere, and to some extent of the Stratosphere.

The Troposphere contains several naturally occurring gases including highly variable water vapor, two major gases and several minor or trace gases. Disregarding water vapor, two major gases are nitrogen (N_2, comprising 78.1 percent by volume) and oxygen (O_2, comprising 20.9 percent by volume). The Tropospheric composition of these two major gases have been steady for a long period. Important among numerous trace gases in the Troposphere are argon (Ar, 0.93 percent), carbon dioxide (CO_2, 0.0365 percent or 365 ppm), neon (Ne, 0.0018 percent or 18 ppm) helium (He, 0.0005 percent, or 5 ppm), methane (CH_4, 0.000174 percent, or 1.74 ppm), krypton (Kr, 0.00011 percent or 1.1 ppm), hydrogen (H_2O, 0.00005 percent or 0.5 ppm) nitrous oxide (N_2O, 0.311 ppm or 311 ppb), and ozone (O_3, 0.000001-0.000004 percent.or 0.01 to 0.04 ppm). Most of the atmospheric O_3 occurs in the Stratosphere. The Stratospheric O_3 concentration protects earth's biota from harmful effects of the ultraviolet radiation.

In addition to these naturally occurring gases, there are also synthetic gases produced through industrial activities. These synthetic gases are collectively called halogenated hydrocarbons, of which there are two types: fully halogenated (CFCs) and partially halogenated (H-CFCs). Some of these natural and synthetic trace gases (e.g. CO_2, CH_4, N_2O and CFCs) have the ability to change the radiation balance of the earth, and its climate.

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THE GREENHOUSE EFFECT

All natural bodies emit radiation, and wave length of radiation emitted is inversely proportion to the temperature. Therefore, sun with high temperature (6000 °C) emits short-wave radiation, and the earth with low temperature (15 °C) emits long-wave radiation. The radiation balance of the earth-atmosphere system is influenced by the balance between the incoming short-wave solar radiation and the outgoing long-wave radiation from the earth's surface. Trace gases in the Troposphere influence the radiation balance by absorbing the out-going long-wave radiation. These gases act similar to the glass within a greenhouse. The glass permits the short-wave radiation to enter but does not allow long-wave radiation to reflect out of the greenhouse. Therefore, temperature within the greenhouse is warmer than the ambient temperature. Trace gases in the atmosphere possess properties similar to glass, and warm the earth by not allowing long-wave radiation from the earth to escape into space.

Before human-induced disturbances of the biosphere and lithosphere, earth's radiation balance was in equilibrium, resulting in the mean average temperature of the earth at 15 °C. If the earth's atmosphere contained only N_2 and O_2, the earth's average surface temperature would have been Ð18 °C rather than its present average global temperature of 15 °C. This difference in 33 °C. (-18 °C to 15 °C) is due to the natural greenhouse effect due to the presence of radiatively-active trace gases in the atmosphere (e.g., CO_2, CH_4, N_2O, O_3). Therefore, the natural greenhouse effect has made the earth a habitable planet. Without this natural greenhouse effect, the life as we know it would not have evolved on planet Earth.

Trace gases differ with regard to their ability to absorb the long-wave radiation depending on several factors including radiative forcing, and the life span or residence time in the atmosphere etc. This relative ability of gases is called the "global warming potential" or GWP. The GWP is computed relative to CO_2 and is 1 for CO_2, 58 for CH_4, 206 for N_2O, 1800 for O3, and 4000-6000 for CFCs. It means that in comparison with CO_2, gas-effectiveness in absorbing outgoing long-wave radiation is 58 times more for CH_4, 206 times more for N_2O, 1800 times more for O_3 and 4000-6000 times more for CFCs.

GLOBAL WARMING

The term global warming refers to the acceleration of this natural greenhouse effect due to human-induced changes in the earth-atmosphere system. Consequently, the Tropospheric concentration of these trace gases has been increasing since the on-set of the industrial revolution. For example, the pre-industrial concentration of CO_2 at 280 ppm has increased to 365 ppm and is currently increasing at the rate of 0.5 percent (1.8 ppm) per year. The concentration of CH_4 has increased from 0.8 ppm to 1.74 ppm and is increasing at the rate of 0.75 percent.(0.015 ppm) per year. The concentration of N_2O has increased from 288 ppb to 311 ppb and is increasing at the rate of 0.8 ppb (0.25 percent) per year. Thanks to the successful implementation of the Montreal Protocol in 1987, the atmospheric concentration of CFCs and H-CFCs has stabilized. Because of the rapidly increasing concentration of these radiatively-active gases, it is feared that the radiation budget of the earth may drastically change within a short span of decades to a century with attendant increase in mean earth temperature of 1 to 4°C. The projected increase will be less in low latitudes (tropics) and more in high (temperate, boreal and cold regions) latitudes. Since the industrial revolution, the Tropospheric increase greenhouse gases has influenced global warming of about 0.5 °C as follows: 50 percent.by CO_2, 20 percent by CFCs, 16 percent.by CH_4, 8 percent.by O_3, and 6 percent.by N_2O.

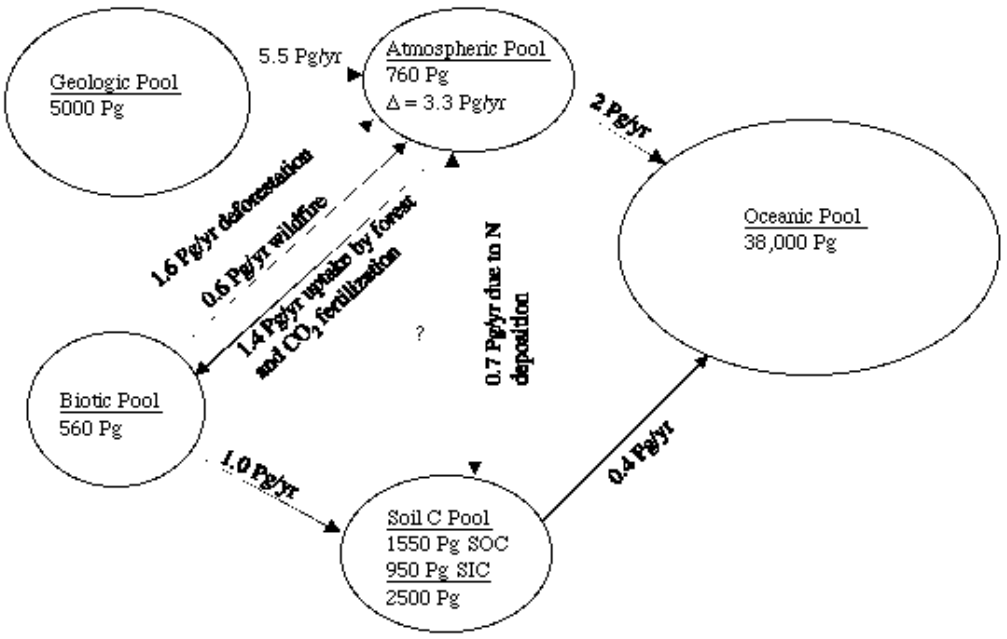
The accelerated greenhouse effect or the global warming can have drastic adverse effects on world's biome or ecosystem, because of the lack of sufficient time to adjust to the rapid change. The greenhouse effect is tolerable (i.e. the biomes can adjust) if the rate of increase in earth's mean

temperature is about 0.1 °C/decade or about 1 °C/century, because the ecosystems or biomes can adjust to this gradual change. The greenhouse effect is excessive leading to global warming if the rate of increase in the earth's mean temperature exceeds 0.1 °C/decade. In the event of global warming, the biome may shift outward by 200 to 300 km per 1 °C increase in temperature. Therefore, the global warming or accelerated greenhouse effect may have drastic adverse impact on the ecosystems.

IMPORTANCE OF WORLD SOILS IN THE GLOBAL C CYCLE

World soils constitute one of the five large global C pools (Figure 1). Ocean is the largest C pool at 38,000 Pg C (1 Pg = petagram = 10^{15} g = 1 billion ton). The second largest pool is the geologic pool comprising 5000 Pg C containing 4000 Pg as coal, 500 Pg as gas and 500 Pg as oil. Soil C is the third largest pool estimated at 2500 Pg. The estimate of soil C pool are very tentative and approximate because the data on soil C pool to at least 2 m depth are not known for all soils and regions. The information is especially incomplete for organic (peat) soils of northern latitudes. Estimates of the soil C pool are also constrained by the lack of information on charcoal C in the soil. Relative amounts of charcoal C may be substantial in fire-dependent ecosystems (e.g., tropical savannahs). The fourth largest C pool is that of the atmosphere at 760 Pg C. The atmospheric pool is increasing at the rate of about 3.3 Pg C/yr. The smallest of all pools is the biotic pool estimated at 560 Pg C. Similar to the soil, the estimates of the biotic C pool are also tentative. Some foresters and biologists argue that dead wood is not considered in the biotic pool, which may be an additional 150 to 200 Pg.

FIGURE 1
Principal global C pools and fluxes between them (1 Pg = petagram = 10^{15} g = thousand million tons)



The soil C pool comprises two components:

- soil organic C (SOC), and (ii) soil inorganic carbon (SIC) pool. The SOC pool is estimated at 1550 Pg and the SIC pool at 950 Pg. The SOC pool comprises three constituents: the labile or readily changeable pool with life span of less than 1 year;
- the intermediate pool with life span of decades to centuries; and
- the passive pool with very slow turnover rate and life span of centuries to millenia. The passive pool comprises extremely resistant material that is not easily decomposed or mineralized.

Therefore, the soil C pool is an important pool and is directly linked with the atmospheric C pool. In fact, the soil C pool is about 3.3 times the atmospheric pool and 4.5 times the biotic pool. The atmospheric pool has been increasing at the expense of the soil and biotic pools since the dawn of settled agriculture, and of the geologic pool since the on-set of industrial revolution.

AGRICULTURAL ACTIVITIES AND THE GREENHOUSE GAS EMISSIONS

There are several agricultural activities that lead to the emission of greenhouse gases from agricultural ecosystems to the atmosphere.

Carbon dioxide: Emission of CO_2 from soil to the atmosphere is related to the mineralization of C in soil organic matter through microbial processes that use it as a source of energy, combine C with O_2 leading to release of CO_2 and H_2O. In addition to this biotic process, decomposition of the soil organic matter can also occur abiotically. Both mineralization and decomposition rates are influenced by temperature, and their rates double with every 10 °C increase in soil temperature. The CO_2 emission from soil is accentuated by plowing, mixing crop residue and other biomass in the soil surface, and providing sub-soil or surface drainage to remove excess water from the soil surface. Biomass burning is another source of CO_2.

Methane:.In contrast with the oxidation process that leads to emission of CO_2, lack of O_2 in soil and prevalence of reducing conditions (anoxia) lead to methanogenesis or production and release of CH_4. Therefore, CH_4 is produced and release from wetlands, swamps, marshes and bogs. In the tropics, cultivation of rice paddies leads to emission of CH_4. Methane is also emitted by ruminants through enteric fermentation, by composting organic matter or biosolids, landfills, and biomass burning.

Nitrous oxide:.Soil-N, both inherent and applied through inorganic fertilizers and organic manures, is the principal source of atmospheric N_2O. The release from soil is accentuated by anaerobiosis (anoxia), soil compaction and other degradative processes. In addition, N_2O is also released by biomass burning.

Land misuse and soil mismanagement exacerbate the emission of radiatively-active gases from soil to the atmosphere through on-set of soil degradation or decline in soil quality. Principal soil degradative processes which enhance the emission of radiatively-active gases are accelerated soil erosion, decline in soil structure and compaction, depletion in plant nutrient reserves, salt and water imbalance including leaching, acidification and salinization. Soil degradation leads to reduction in biomass production, low or no plant residue returned to the soil, depletion of soil carbon pool, and emissions of CO_2, N_2O and CH_4 to the atmosphere.

SOURCES AND SINKS OF TROPOSPHERIC CO_2 AND OTHER GREENHOUSE GASES

There are three principal anthropogenic activities that lead to emission of greenhouse gases to the atmosphere. These are:

- fossil fuel combustion;
- cement manufacture; and
- land use change and agri-cultural activities (Table 1).

In addition, wild fires also contribute substantially to CO_2 emissions. With an exception of the emissions from land use, the data from other sources are reasonably accurate. The magnitude of emis-ions from land use, deforestation and soil cultivation are approximate at best.

TABLE 1
Approximate sources of atmospheric CO_2.

Activity	Pg C/yr
Fossil fuel combustion and cement manufacture	5.5
Tropical deforestation and land use change	1.6
Wild fires	0.6
Total	7.7

TABLE 2
Known sinks of C

Sink	Pg C/yr
Increase in atmospheric concentration	3.3
Uptake by ocean	2.0
Forest regrowth and CO_2 fertilization effect	1/6
Uptake due to N deposition	0.8
Total	7.7

The global sinks of C are not very well defined. The data in Table 2 outline some known sinks. The atmosphere is currently absorbing CO_2 at the rate of about 3.3 Pg C/yr. The ocean uptake is estimated at about 2.0 Pg C/yr. The uptake due to forest growth and CO_2 fertilization effect is estimated at 1.6 Pg C and that due to N deposition at about 0.7 Pg. The so-called missing C is probably accounted for by the forest regrowth in the northern hemisphere, CO_2 fertilization effect, and uptake due to N deposition. Therefore, the atmospheric concentration of CO_2 is increasing due to fossil fuel combustion, deforestation and soil cultivation, wild fires, and cement manufacturers.

HISTORIC LOSS OF C FROM SOIL AND VEGETATION TO THE ATMOSPHERE

It is difficult to make an accurate estimate of the historic loss of C from soil and biota to the atmosphere. There is a lack of extensive data on soil C pool and dynamics, especially from developing countries. The data are also not available for undisturbed ecosystems so that a comparable baseline can be established. With all uncertainties of the available information, the historic loss of C is estimated at 50 to 100 Pg from world soils and 100 to 150 Pg from world biota. These estimates, crude as they are, provide a reference point about the potential of C sequestration in world soils and biota. The potential of C sequestration is high even if only 75 percent of the historic loss (110 Pg to 190 Pg) can be resequestered. The C sequestration potential of world soils alone is 40 to 75 Pg, or an equivalent to 12 to 25 years of atmospheric increase in CO_2.

STRATEGIES OF C SEQUESTRATION IN SOIL

Soil C balance, in both natural and managed ecosystems, depends on the difference between input and losses.

carbon balance in soil = (input) Ð (losses)

Input of C in soil includes residue returned including root and above-ground biomass plus weeds, deposition of C from water and wind blown material, and biosolids applied to soil as compost, sludge or urban waste. Losses of C from soil include depletion of C due to erosion, leaching, mineralization and decomposition.

TABLE 3
Strategies of C sequestration in soil.

Strategy	Practices
Reduce losses from soil due to:	
(i) Accelerated erosion	Mulch farming, conservation tillage cover crops, terraces, low stocking rate, improved pasture
(ii) Mineralization	Enhancing aggregation, deep placement of biomass, providing N, P and S for humification
(iii) Decomposition	Increasing lignin content in plant
Increase carbon concentration in soil by:	
(i)Returning biomass to soil	Mulch farming, conservation tillage use of biosolids on land, compost etc.
(ii) Enhance water use efficiency	Soil-water conservation, water harvesting, supplemental irrigation through appropriate techniques
(iii) Improving nutrient use efficiency	Integrated nutrient management, new formulations, judicious rate and timing of application, precision farming
Improvement in crop yield and biomass production	
(i) Improved cropping/farming system	Improved varieties, proper crop rotations and crop combinations
(ii) Cultivars with high lignin content and deep root system	Biotechnology, soil management, P placement, liming
(iii) High yield and biomass	IPM, INM

Three principal strategies of C sequestration in soil are outlined in Table 3. These include the following:

Reducing losses of C from soil: Losses of soil C pool are caused by accelerated soil erosion, mineralization and decomposition. Erosion management can lead to maintaining and eventually increasing soil C pool. Some effective erosion control measures include conservation tillage, mulch farming, cover crops, terracing and other engineering devices, and improved pasture management. Improving soil structure and enhancing aggregate stability, and providing balanced soil nutrient pool (N, P, S) are important to decreasing mineralization. Improving plant varieties that have high lignin content through biotechnology and other measures can cause decrease in the decomposition rate.

Increasing C concentration in soil:.Soil C pool can be enhanced by returning large quantity of biomass to the soil, and improving water and nutrient use efficiencies. Practices that return biomass to the soil include mulch farming, conservation tillage, use of compost and farm yard manure, and application of biosolids to the soil. Decreasing losses of water and nutrients from agricultural soils are important to enhancing water and nutrient use efficiencies. Soil-water conservation, decreasing losses of water due to runoff and deep seepage and/or evaporation, is crucial in arid and semi-arid regions. Efficient use of water resources may involve water table management through tile drainage and sub-irrigation in humid regions, supplemental irrigation (e.g. drip irrigation) in arid and semi-arid regions, and appropriate techniques of water harvesting and recycling in semi-arid and sub-humid regions. Similar to water efficient use of plant nutrients is also crucial to improving biomass production and converting biomass to soil organic matter. Strengthening nutrient cycling mechanisms through integrated nutrient management (e.g., judicious use of inorganic fertilizers and organic amendments) and precision farming are important strategies of C sequestration in soil.

Improving C yields through agricultural intensification: the positive balance leading to soil C sequestration in agricultural lands can be achieved through adoption of intensive agricultural

practices. Agricultural intensification implies adoption of the recommended (scientifically proven) agricultural practices on prime agricultural land, so that marginal agricultural lands can be reverted back to restorative land uses. The strategy of agricultural intensification improves soil quality on prime and marginal lands, increases biomass production, returns more plant residue to the soil, increases soil C pool and improves soil quality.

TECHNOLOGICAL OPTIONS OF C SEQUESTRATION IN AGRICULTURAL LANDS

The basic principles of agricultural intensification through adoption of recommended agricultural practices are the same for temperate or tropical regions, and developed or developing economies. However, the application of these principles differ from region to region and place to place. Accordingly, the rates of C sequestration through adoption of recommended agricultural practices also differ among ecoregions. Potential rates of C sequestration in soil by conversion to recommended agricultural practices for different ecoregions are listed in Table 4. All other factors remaining the same the rate of C sequestration in soil are high for humid compared with dry climates, cool than warm regions, and for severely degraded than undegraded soils. Important practices with high potential for C sequestration include conversion from plow till to conservation or no till, bare fallowing to growing cover crops (grasses or legumes), low input or subsistence agriculture to commercial agriculture based on judicious use of off-farm inputs, and soil degradative systems to land restorative practices.

TABLE 4
Technological options for C sequestration in soil (ton/ha/yr)

Technological options	Temperate climate		Tropical and sub-tropical	
	Humid	Semi-arid	Humid	Semi-arid
1. Conservation tillage	0.5-1.0	0.2-0.5	0.2-0.5	0.1-0.2
2. Mulch farming (4-6 Mg/ha/yr)	0.2-0.5	0.1-0.3	0.1-0.3	0.05-0.1
3. Compost (20 Mg/ha/yr)	0.5-1.0	0.2-0.5	0.2-0.5	0.1-0.2
4. Elimination of bare fallow	0.2-0.4	0.1-0.2	0.1-0.2	0.05-0.1
5. Integrated nutrient management	0.2-0.4	0.1-0.2	0.2-0.4	0.1-0.2
6. Restoration of eroded soils	0.5-1.0	0.2-0.5	0.2-0.5	0.1-0.2
7. Restoration of salt-affected soils	---	0.1-0.2	--	0.05-0.1
8. Agricultural intensification	0.05-0.10	0.05-0.10	0.2-0.4	0.10-0.20
9. Integrated nutrient management	0.05-0.10	0.05-0.10	0.2-0.5	0.1-0.3
10. Water conservation and management	0.05-0.10	0.1-0.3	0.01-0.1	0.1-0.3
11. Afforestation	0.2-0.5	0.1-0.3	0.2-0.5	0.05-0.1
12. Secondary carbonates	---	0-0.2	---	0-0.2
13. Improved pasture management	0.2-0.5	0.1-0.3	0.1-0.2	0.05-0.10

POTENTIAL OF WORLD SOILS FOR C SEQUESTRATION

There is a vast potential of C sequestration in world soils. Intensification of agriculture on 1.5 billion hectares has a potential to sequester 0.75 to 1.0 Pg C/yr. The potential of C sequestration through desertification control in arid, semi-arid and sub-humid region is another 1.0 to 1.2 Pg C/yr. The restoration of all degraded soils (desertified, eroded, compacted, salinized, and polluted lands) has a potential to sequester as much as 3.0 Pg C/yr. Realization of these potentials, through coordinated international effort, can have a drastic impact on the global land resources and the environment.

There are several characteristics of this potential of C sequestration that must be understood.

1. The potential of soil C sequestration is finite. The world soils have lost 50 to 100 Pg of C and it is possible to resequester 70 to 80 percent of the lost. Similarly, afforestation and reforestation on appropriate lands may lead to resequestration of 50 to 75 percent.of the historic loss of 100 to 150 Pg from world's biota. Further, this finite potential can be realized over a 25- to 50-year period. Therefore, during this period, we must find alternatives to fossil fuel by developing other sources of energy (e.g., wind, solar, H2, biofuel etc.). Carbon sequestration in soil is not a permanent solution. It merely buys us some extra time while alternatives to fossil fuels are developed.

2. C sequestered in soil can be easily lost again through misuse and mismanagement because it is highly labile. In fact, it is more difficult to sequester C in soil than to lose C already sequestered. Therefore, establishing channels of communication with public at large and land managers is important to developing and implementing strategies for enhancing and maintaining soil C pools.

3. Widespread adoption of recommended agricultural practices and techniques of land restoration will require a coordinated effort at global scale. The problem of soil degradation and use of subsistence (degradative/exploitative) agricultural practices is more severe in the tropics than in temperate regions and in developing than in developed economics. Resource-poor farmers cannot afford to adopt some needed agricultural practices. In addition to education and information exchange, some monetary and non-monetary incentives may be needed for widespread adoption of desirable agricultural and land use practices.

Purposes and modes of carbon sequestration

CO_2 is an important greenhouse gas. Its concentration in the atmosphere has increased from 280 ppm to 365 ppm in the last 150 years, because of strongly increased use of fossil fuel, deforestation and cement production. Further increase, together with that of some other trace gases (CH_4, N_2O, among others) will most likely result in an increase of global temperatures with 2°C by the year 2100, an increase in sea level of 50 cm and an increase of average rainfall with 10-15% (IPPC, 1996).

Such a change is considered to be negative for the global human life-supporting system. Therefore a Framework Convention on the Control of Climate Change (FCCC) was developed, with the Kyoto Protocol of 1997 as first practical agreement on controlling the national emissions of CO_2 and other greenhouse gases.

The Kyoto Protocol recognizes that reduction can be effectuated through curbing of gross CO_2 emissions - difficult to be realized in industrialized countries with a growing economy, but also by increasing the CO_2 uptake in ocean waters and on land, thereby reducing the net emissions. The uptake on land can be through increasing the biomass of vegetation (planting of forests), through enhancing the organic carbon in soils, or a combination of the two.

This terrestrial uptake or "sequestration" can be in and between industrialized countries themselves ("joint implementation", already formal) or in developing countries through use of environmental protection funds of any industrial country ("Clean Development Mechanism"; proposed)

The forest planting scenario has as advantage that biofuels and construction materials can be harvested periodically, replacing fossil fuel, cement etc. The sequestering of carbon in organic matter of agricultural soils would result in additional CO_2 storage, as well as an increase in quality of the soil for the production of food, fibre, feed, etc. on a sustainable basis. More soil organic matter (SOM) increases the storage capacity for plant nutrients, makes the plant less susceptible to droughts and provides more resistance to physical land degradation through strengthening of the soil structure.

The total carbon already stored in the plant-soil complex varies per biome, per agro-ecological-zone and per predominant land use system. But in general there is more stored in the soil as soil organic carbon (SOC) than in the above and below ground vegetational biomass. Even in humid tropical forests there is as much carbon in the soil as in the whole above-ground luxurious vegetation.

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In its atmospheric concentrations, CO_2 is not a pollutant or a dangerous gas. It is an essential element for plant growth and is right now in the minimum if the other essential conditions (temperature, daylight, moisture , nutrients, foothold) are adequate. During the growing season CO_2 becomes bound to the green plant through the daytime assimilation process, while at nighttime the plant and the surrounding soil releases again some CO_2 through respiration. In summertime the net CO_2 uptake in the terrestrial biosphere is large, and as a consequence the CO_2 concentration in the atmosphere decreases temporarily. The summer-winter difference in concentration is most conspicuous where the land mass is largest and the other growth conditions have a large seasonal difference.

Being normally the limiting factor for plant growth, any increase in atmosphere CO_2 concentration causes an increase in plant growth. This is the so-called "CO_2 fertilization effect" which is particularly active in C4 plants, such as wheat, rice and most woody plants. It would account for the "missing Carbon sink" of 1.5 Tg per year of global carbon flux modellers. Higher Carbon concentrations also cause an increase in the water use efficiency of plants through regulation of stomatal conductance. This is the so-called "CO_2 anti-transpiration effect" which is particularly active in C3 plants such as sorghum, maize and many tropical grasses.

Both effects, locally combined with increased Nitrogen availability from atmosphere deposition, form a so-called "negative feedback" mechanism in the human-induced forcing of climate change. They are a start-bonus at efforts to sequester CO_2 in vegetation and soils. One can argue that they are a blessing-in-disguise at human-induced global change, and that the earth is moving to a higher trophic level - as it has been in some periods - this time concurrently with, and as a consequence of the strong global human population increase and its basic needs for well-being.

It is already known for some ten years that planted or natural forests in temperate and cool regions grow faster than before (when not too old, on too poor soil, or too near polluting sites). Only in the last 2-3 years it has become apparent that nowadays also the primary forests in tropical regions may act as a net sink of CO_2, instead of just a store (except in situations of periodic drought, such as El Niño). The biodiversity and local climatological/hydrological regulative functions of these forests can be safeguarded easier if this additional function of an active carbon sink will be confirmed scientifically, and recognised politically.

The above surmised indirect positive human influence on forest growth will not be open-ended. Trees will not grow into heaven; rather, they will have earlier senescence and end up, for a good part, in increased stable organic matter in the forest soil (if selective timber harvesting from these natural forests takes place) then the net increase may be negligible.

Agricultural soils have usually less soil organic matter (SOM) and therefore less soil organic carbon (SOC) than their natural counterparts. They are degraded in the biological sense, and it is a feasible proposition to lead them back towards their original SOC level through adapted practices (see Lal and Young , this publication; Batjes 1999).

In some situations the agricultural soil has historically increased its SOC. Accidental or conscious lateral import of SOM to the surroundings of towns and villages, with their century long, intensive and manure-based.agriculture, has produced soils with approx. double the natural amount of stable SOM. It has moreover a higher colloidal activity level in the form of higher nutrient exchange capacity (CEC). This process can conceivably be emulated, as one of the measures to sequester carbon in agricultural soils, in a matter of decades instead of centuries, and without depleting the SOM of the wider countryside.

Carbon sequestration in vegetation (forests), in biofuel, crops and in soils should be integrated in over-all sustainable rural development, with full participation of the local population; "Kyoto forests" and "Kyoto lands" should not become foreign bodies.

Soil Organic Matter enhancement, where necessary with other soil conditioners such as lime and rock-phosphate, should be considered as a capital investment in soil and land quality.

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Land-use change, biodiversity and carbon sequestration in tropical forest margins

In the opening comments to this meeting, there was reference to the convergence between the different Conventions on Climate Change, Biodiversity and Desertification around the issue of land degradation. Mention has also been made of the relationship of these conventions to rural poverty and livelihoods in farming regions. I wish to address this convergence with reference to studies of the relationships between environmental impacts and agricultural intensification in tropical forest margins. In doing so I hope to help in answering the challenge which was made in the very opening address by Ms.Peña Montenegro about the need for further information from the farms, from the smallholder farming communities, and from the rural areas.

I am going to describe a package of methods which has been developed by scientists contributing to the Alternative to Slash and Burn Consortium (ASB) which has been working in the tropical rainforest margins in different parts of the world. This project has been seeking sustainable ways for land management which bring profitability for farmers, but at the same time take into account impacts in terms of biodiversity, carbon stocks and greenhouse gas emissions. My main focus will be on the methodology which we have developed and which we think can be utilized under other agro-ecological conditions to help answer some of the questions raised in this meeting.

The ASB Consortium has membership of about sixteen international and national agencies and is led by ICRAF. My own organization, TSBF, has been responsible for the carbon, greenhouse gas and below ground biodiversity measurements; CIFOR for the above ground biodiversity.

Let me say something about the structure of what we are doing. We have been comparing the biodiversity, carbon stocks and a variety of other environmental, agronomic and economic measures across a spectrum of land use types representing land use intensification. Let me use the results for above ground biodiversity as an example. A rapid assessment technique, Plant Functional Attributes (PFA) has been used as an index of plant biodiversity in these studies. This correlates very closely with species richness. Across a wide range of systems from near primary forest and secondary forest down to intensive cropping systems, pastures we see marked differences in the above ground biodiversity.

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We have also been looking at the below ground biodiversity which is usually neglected in biodiversity assessments. We have selected a number of key functional groups, such as the macrofauna - earthworms and termites - which are very important in the modification of the physical structure of soil, and the micro-symbionts like the nitrogen-fixing bacteria and mycorrhizal fungi. Just to give you a couple of results in this area: the diversity below ground is extremely high. In one sampling area in Brazil we found 139 different genera of nematodes. How many species there are I cannot tell you at the moment, but it is certainly likely to be more than 500. For the termites across different land uses in Indonesia there was a change from about 30 species in primary forests down to only one in cassava gardens or two in degraded Imperata grasslands. A very important feature of these results is that the soil feeding termites, which are extremely important both in soil physical structure and in organic matter dynamics in the soil, are reduced from about ten species to either one or zero. This change therefore has a very important functional significance.

Now we look at the results for greenhouse gas emissions. We have data for methane and nitrous oxide over the same range of land uses. We can use the results for net methane flux as an example. The data are averaged over months. We do have data tracking through time, but this is averaged over months and you see here that practically all the tree based systems, both the forests, the fallows, the agroforests, the plantations and even the low input crops which are still reasonably diverse, are net sinks of methane. But the moment you switch to high input agriculture in these systems, you begin to stimulate methane emissions.

These are only of course snapshot results but the one that perhaps is of most interest is in relation to the carbon stocks. Our results shows both the above ground and the below ground carbon stocks in tons per hectare across the same series of different types of land use systems. You can see, of course, as you would expect, a very significant shift in the amount of carbon per system. While the cropping systems and the grasslands and pastures have very low carbon stocks compared with the forests, we do get intermediate levels in the agroforestry and shifting cultivation systems. I am not so much concerned with the results here as the fact that the methods are available to accurately determine these differences at this scale. I want to point particularly to this term “time averaged above ground and soil carbon stocks”. It is not sufficient to just look at what is there at a particular point in time, but to account for what has happened over time. For instance if there has been a clearing of the forest, you must allow in your calculation for the changing biomass of the vegetation, whether a plantation or a fallow, during the period of re-growth. By this means we are able to calculate what the average carbon stock of the area is over time. That then enables us to make a much more rigorous assessment of what the sequestration potential for different land use systems is - a calculation which I believe to be of great interest to this meeting.

On the basis of this type of result, we can show that any conversion of new land from forests, even to plantations or simple agroforests, does result in net carbon loss or emission. That is to say any new conversion of land, as previous speakers have reported, is going to have a negative effect in terms of carbon balance. Looking at this in reverse (i.e. examining the potential for carbon sequestration), however, shows the significant gains that can be made by using agroforestry or other tree based systems to sequester carbon on degraded lands, such as Imperata grasslands or the degraded pastures such as are common in large areas of Brazil. I should like to make one further point on carbon sequestration – that is that almost all the potential in this respect lies in the biomass and not in soil carbon gain. The rate of change in the latter is almost undetectably slow and does not offer much potential for significant impact over the short to medium term.

The real point for these studies however is whether farmers or other land users are likely to adopt these type of systems with positive carbon or biodiversity values. They will only do so if the

systems are also profitable. In the Slash and Burn Project we have therefore been assessing the trade-offs between biodiversity, carbon and other environmental issues with and the profitability of the system as far as the farmers are concerned.

An example from the Cameroon shows the trade-offs between carbon stocks and profitability for a variety of land-use systems. What we would all like is a system that is high in carbon and also has high profit margins - but we have not found one under the current economic circumstances. On the other hand what we want to avoid is low carbon and low profit. The warning signal here is that some of the current food cropping systems are of this type. They may be food self-sufficient for individual farmers but in terms of overall profitability, they are certainly not very desirable systems and they sequester very little carbon so have no attractions from that perspective.

But we do find some types of system, the smallholder cocoa, fruit, agroforests, and oil palm systems, which under current economic circumstances are profitable and also sequester a significant amount of carbon. Whilst the carbon stock is low compared with forests it is sufficient that this type of land use system might be both adoptable by farmers and satisfy some of our criteria with regard to carbon sequestration and also, incidentally, with biodiversity.

So in summary: what I have been trying to demonstrate is a methodology which we believe could be transferred elsewhere for assessment of the potential of different types of land use system for carbon sequestration and conservation of biodiversity as well as for agricultural production and profitability and indicators of land degradation.

Linking land use, land management and carbon sequestration

OBJECTIVE

This paper reviews changes in land use or land management which will, at the same time:

- increase human welfare;
- reduce land degradation;
- promote carbon sequestration.
- increase biodiversity.

Two further criteria are needed. First, the proposed changes must be realistic: economically viable and socially acceptable. Secondly, in the framework of the project under consideration, the changes must be of reasonably wide applicability within Latin America and the Caribbean.

A reservation on carbon sequestration and global warming is given in the following Note.

A NOTE ON CARBON SEQUESTRATION AND GLOBAL WARMING

In the context of carbon sequestration, it would be scientifically unethical not to include a reservation. The political community and the media have decided firmly that: (1) global warming is taking place; (2) the major cause is the emission of greenhouse gases, primarily CO_2; (3) the effects of global warming are adverse to human welfare. Within the scientific community, there is some degree of doubt over (1), and substantial reservations, in some cases disagreement, over (2) and (3) (e.g. FAO, 1994; Hulme, 1999). Because of continuing industrialization, the rise in atmospheric CO_2 will almost certainly take place. It is in the highest degree unlikely that action by governments can check global warming, or deliberately affect world climate in any way.

Change has always been part of the human environment, and will continue to be so. The proper response is not to oppose but adapt to it, in particular to reduce vulnerability (cf. Bazzaz and Sombroek, 1996). Hence the good which could come from land use changes discussed here stems primarily from the improvements in human welfare and reduction of degradation.

LAND USE AND LAND MANAGEMENT

A basis for discussion is provided by the classification of land use reached as an output from the UNEP/FAO project on harmonizing land use and land cover classifications (Table 1).

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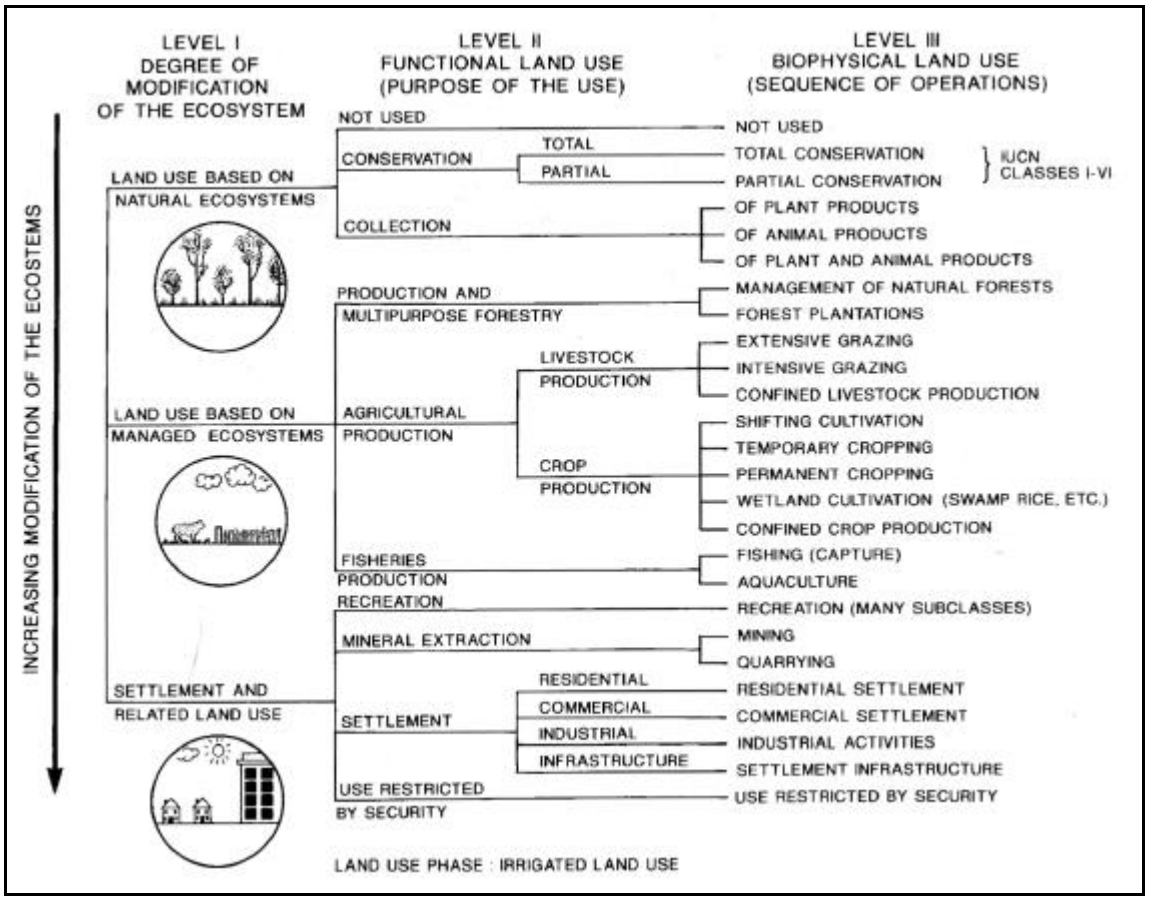
The principle on which this is based is one of increasing degrees of modification of ecosystems, from natural plant communities at one extreme to urban use at the other (downwards in the table, at all levels). Because of this principle, the classification is highly suited to the present purpose, since an increasing modification of ecosystems leads also to changes in the direction of decreasing biodiversity and reduced plant and soil carbon.

TABLE 1
An international classification of land use (Young, 1994, p. 25; 1998, p. 53)



Although Level III of this classification does include elements of land management, a high-level classification such as this cannot be expected to be sufficient for more specific purposes. The following ad hoc classes of land management, chosen and defined on grounds of relevance to the present objectives, will be added (SOM = soil organic matter):

- SOM-promoting agriculture (e.g. conservation tillage, organic residue management, agroforestry; see Draft Project Document, Section G, Activity 8).
- SOM-reducing agriculture (e.g. continuous cereal cropping without inputs, cultivation of sloping land without conservation).
- Land-degradation (continuation of SOM-reducing agriculture to a point which leads to a severe degree of degradation).
- Agroforestry: systems in which trees are grown on farms.
- Reclamation forestry.
- Reclamation agroforestry (Young, 1997, 83-86).
- Degraded land: a term of convenience, covering severely-degraded land, whatever its use or non-use.

CHANGES IN LAND USE AND MANAGEMENT WITH RESPECT TO CARBON STORAGE AND BIODIVERSITY

Table 2 is a selected list of changes in land use and management, chosen for relevance to the objectives. It is possible to separate changes in land use from land management, but there are overlaps, and the distinction does not appear useful for present purposes. For each change the table shows, in qualitative terms, the likely effects upon carbon storage and biodiversity. Carbon storage is divided into short-term storage, as vegetation, and medium-term storage, as soil organic matter.

TABLE 2
Effects of land use and land management changes on carbon storage and biodiversity.

	Change from	Change to	Effect on CO_2 storage		Effect on biodiversity
			short-term (veg.)	Medium-term (soil)	
Environmentally negative changes:					
Forest clearance	Natural forest	Agriculture	--	-	--
	Natural forest	Extensive	-	-	-
	Savanna agriculture	grazing	-	--	
Agricultural intensification	Fallow systems	Continuous cultivation	-	-	-
Agricultural disimprovement	SOM-promoting agriculture	SOM-reducing agriculture	o	-	-
Land degradation	SOM-reducing agriculture	Degraded land	-	--	-
Environmentally positive changes:					
Check forest clearance	Forest otherwise cleared	Natural forest	++	++	++
Irrigation	Rainfed agriculture	Irrigated agriculture	o	+	o
Afforestation	Natural forest or woodland	Managed forest	o	o	-
	Extensive grazing	Managed forest	+	+	-
Agricultural improvement	SOM-reducing agriculture	SOM-promoting agriculture	o	+	+
Introduction of agroforestry	SOM-reducing agriculture	Agroforestry	+	+	+
Reclamation agroforestry	Degraded land	Agroforestry	+	++	+
Reclamation forestry	Degraded land	Managed forest	++	++	+

The first group, environmentally negative changes, have net negative effects both on carbon storage and biodiversity. Forest clearance has by far the greatest negative effect, with large reductions in plant carbon, soil carbon, and biodiversity. Agricultural intensification continues this process, through elimination of forest fallows. If SOM-promoting practices give place to SOM-reducing practices, there will be a further decline in soil carbon. Continuation of this trend may lead to land degradation, with negative effects on all three criteria, particularly soil carbon.

Among the environmentally positive changes, irrigation will normally improve carbon storage. The effects of afforestation depend on the previous land use. Replacement of natural forest by plantations may not increase carbon storage (Lundgren, 1978) but will reduce biodiversity. Forest plantations on former grazing land increase carbon storage.

The set of management practices here grouped as SOM-promoting agriculture will only slightly increase short-term carbon (as better crops), but will raise soil carbon, and biodiversity of the soil fauna. The introduction of agroforestry will increase plant biomass, and hence short-term

carbon storage, to an amount dependent on the types of agroforestry systems; it has also been shown to have a clear potential to improve soil organic matter (Young, 1990, 1997, ch.5). The largest improvements both to carbon storage and biodiversity come from reclamation agroforestry or forestry on previously degraded land.

SEMI-QUANTITATIVE ESTIMATES OF CHANGES IN CARBON STORAGE

For any of the land use and management changes in Table 2, it would be possible, for a given region, to obtain quantitative estimates of the changes in carbon storage. Table 3 shows an outline basis for such estimates. All data should be taken as approximate, or indicative. Further information relevant to soil carbon may be found in Sombroek (1995, and this volume).

TABLE 3
Semi-quantitative estimates of the magnitude of changes in carbon storage with changes in land use and management. Forest clearance after Houghton *et al.* (1983), other data estimated.

	Carbon storage (tonnes per hectare)								
	Vegetation			Soil			Both		
	Before	After	Diff.	Before	After	Diff.	Before	After	Diff.
Environmentally negative changes:									
Forest clearance:									
Moist forest	200	5	-195	117	58	-59	317	63	-254
Seasonal forest	160	5	-195	1217	58	-59	277	63	-214
Savanna[1]	27	5	-195	69	34	-35	96	39	-57
Agricultural disimprovement	5	2	-2	60	30	-30	65	32	-33
Land degradation	5	1	-4	60	10	-50	63	11	-54
Environmentally positive changes									
Check forest clearance[1]	5	200	=195	58	117	+59	63	317	+254
Irrigation	5	8	+3	30	70	+40	35	78	+43
Agricultural improvement	2	5	+33	30	60	_30	32	65	+33
Introduction of agroforestry	2	20	+18	30	60	+30	32	80	+48
Reclamation agroforestry	1	20	+19	10	60	+50	11	80	+69
Reclamation forestry	1	1--	+99	10	+50	11	160	+149	

'Before' in this case refers to unchecked clearance, i.e. land under agriculture.

The largest negative changes in carbon storage come, of course, from forest clearance. There are also substantial falls in soil and plant carbon from poor agricultural practices, still more so if these lead to land degradation. By far the largest increases in carbon storage and biodiversity come from checking forest clearance. Other positive changes come from irrigation, adoption of improved agricultural practices, particularly agroforestry, and from reclamation of previously degraded land through reclamation agroforestry or forestry.

REALISTIC POSSIBILITIES FOR LAND USE AND MANAGEMENT CHANGE

Table 4 shows, for the positive changes in land use and management, the effects upon the objectives: increase in human welfare, in carbon storage, and in biodiversity. The last column gives the realistic potential for the change, a combination of the economic and social viability with the area over which it could potentially be applied.

TABLE 4
Realistic possibilities for desirable changes in land use and management and synergies among their effects

Change in land use or management	Increase/reduce human welfare	Increase land degradation	Increase carbon storage	Realistic biodiversity	
Check forest clearance	-	++	++	++	Limited
Irrigation	++	o	+	o	Limited
Agricultural improvement	++	+	+	+	Very high
Introduction of agroforestry	++	+	++	+	Very high
Reclamation agroforestry	+	++	++	+	Substantial
Reclamation forestry	o	++	++	++	Substantial

In every case except one there is a strong synergy of effects. The exception is the checking of forest clearance, which, whilst leading to the greatest improvements in carbon storage and biodiversity, would deprive society of the use of land for agriculture.

On grounds of realistic potential, irrigation suffers from its high cost; an exception is small-scale irrigation. The various types of agricultural improvement, as changes from SOM-reducing to SOM-improving practices, could be applied very extensively, and have substantial positive effects. Among the SOM-improving practices, the introduction of agroforestry has the largest increase in short-term carbon storage, together with proven potential to check land degradation and improve soil organic matter (Young, 1997, Ch. 3 and 5). It has been estimated that the median carbon storage by agroforestry systems is 9 tC ha^{-1} in the semi-arid zone, 21 tC ha^{-1} in the subhumid zone, and 50 tC ha^{-1} in the humid zone (Schroeder, 1994); and that worldwide, the introduction of agroforestry systems onto 500-800 M ha of land could sequester 0.5-1.5 Bt carbon (Dixon, 1995, 1996).

Reclamation agroforestry and forestry have a potential on a less extensive area, that of already degraded land, but a correspondingly higher potential for improving carbon storage. Reclamation agroforestry allows for the return of land to productive use after an initial period of reclamation under trees; for this reason it is often preferable to reclamation forestry.

A further synergy is found, in the potential of agroforestry for checking pressures for forest clearance, through on-farm production of tree products. In several parts of the world, projects are in progress to encourage agroforestry in buffer zones around remaining forests, with this objective.

CONCLUSIONS

Examination of the major options for changes in land use and management shows that there is, in fact, a high degree common beneficial effects, or synergy, between the objectives. Most of the changes which would improve human welfare would also tend in the direction of increases in carbon storage, especially medium-term storage in the soil, and in biodiversity. If increased carbon storage and improved biodiversity were to be considered as the only objectives, then all efforts should be concentrated on checking further forest clearance. However, this is probably unrealistic, and arguably undesirable of those areas of forest which occupy suitable agricultural land.

On land already under agricultural use, appreciable positive effects comes from adoption of the several SOM-promoting practices. Agroforestry has a particular potential, in combining improved and more diversified production with reduction on pressures on forests. Reclamation forestry can restore degraded land; reclamation agroforestry adds to this a potential, now proven, for combining reclamation with a transition to productive use of the land.

In the pilot studies envisaged in the project document, it would be possible to obtain better information on the effects outlined in two respects, quantitatively and with respect to area. First, the changes in plant and soil carbon storage per unit area could be estimated for specific land management improvements. Secondly, the areal extent of the potential for such improvements could be determined for specific countries or agro-ecozones. The GLASOD survey of land degradation (Oldeman *et al*., 1990) would provide a starting-point for areal estimates, taking light and moderate degrees of degradation to represent the area with potential for agricultural improvement, and a strong degree of degradation the area with potential for reclamation.

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Some experiences from IIASA's research related to land use and carbon sequestration

The UN Conference on Environment and Development (UNCED) held in 1992 was a milestone in promoting public recognition of global environmental problems. Subsequently, the political process has yielded various international agreements, including the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biodiversity, and the Convention to Combat Desertification. Increasingly, the understanding emerged that global environmental change is also closely linked with sustainable development.

LAND USE/COVER CHANGE IN THE CONTEXT OF GLOBAL ENVIRONMENTAL CHANGE

Land-use and land-cover change are both recognized as significant to a range of themes and issues central to the study of global environmental change. Land-cover, the natural or artificial occurrences on the Earth's surface, is closely related to land use, i.e. why and how people work the land and how vegetation cover and soils are affected during this process. On a global scale, the cumulative impacts of land-use/cover changes alter how the Earth's system function through their impacts on:

- *Biogeochemical cycles*: since pre-industrial times, deforestation due to human activity accounts for nearly half the carbon dioxide released to the atmosphere, the other half being a result of burning fossil fuels. Current land-cover changes contribute about one fifth of annual carbon releases. Nitrous oxides from fertilizer application, such as large amounts of low-grade and highly volatile ammonium bicarbonate fertilizers used in China, are a big influence. Methane released from rice paddies, ruminant livestock, and land-fills are another;
- *Radiation balance*: land-cover change directly modifies the characteristics of the Earth's surface, such as albedo and surface roughness, thereby altering heat fluxes and exchange; and
- *Ecological complexity*: intensifying land use has generally brought with it a simpli-fication and reduction of biodiversity. Amongst the causes and disturbances are deforestation, fragmentation of ecosystems, regulation of water streams, monocultures, selective breeding, abandoning traditional crop varieties and livestock breeds, intensive application of agro-chemicals, etc.

As human systems depend critically on the state of the environment, managing sustainable transitions of land-use systems at regional scale concerns various themes of vital importance:

- To achieve *food security,* agricultural production will need to be expanded and intensified in harmony with demographic and socioeconomic changes, calling for prudent land management to maintain healthy agro-ecosystems.

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- Land-use/cover changes affect the *hydrological cycle* both qualitatively and quantitatively by influencing how precipitation is intercepted, evapotranspired and retained in soils, determining the amount and speed of runoff. Locally this influences soil erosion and nutrient losses. At the scale of river basins, it determines water availability and the intensity and frequency of flooding.
- Ecosystems and land store human waste materials and provide critically important purification services. The provision of these services is threatened by *pollution and land degradation* due to inappropriate land use, or over-exploitation transgressing capacity thresholds.
- Land use changes alter the functioning of terrestrial sources and sinks of greenhouse gases. Vegetation is mitigating *global warming* through carbon sequestration and will be directly affected by a changing climate.

Land-use/cover change and the Kyoto Protocol

The importance of ecosystems and soils in the global carbon budget is (at least partly) reflected in the Kyoto Protocol to the UNFCCC. Article 3 (Nos. 3 and 4) states that:

> ... The net changes in greenhouse gas emissions from sources and removals by sinks from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks ... shall be used to meet the commitments under this Article of each Party included in Annex I. ...
>
> *and*
>
> *... each Party included in Annex I shall provide ... data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. ...*
>
> Experience at IIASA and elsewhere suggests that fulfilling these commitments may not be straightforward, because of various legal shortcomings in the Kyoto Protocol as well as due to unresolved science questions.

SOME LESSONS FROM CARBON ACCOUNTING

The Forest Resources Project at IIASA is involved in developing a methodology for full carbon accounting at national level. The work is intended to support the implementation of the Kyoto Protocol. Experiences with available methods and data, both in the case of Austria's and Russia's carbon balance, indicate that the requirements posed by the Kyoto Protocol, namely that countries precisely calculate net changes in greenhouse gas emissions and removals based on changes in carbon stocks, may be based on some unrealistic expectations.

The carbon-relevant human activities, pools, fluxes and feedbacks of importance in the example of Austria fall into four broad categories: a) anthropogenic activities related to energy use in form of fossil fuels, C storage and substitution, b) the terrestrial biosphere including the important carbon pools (and fluxes) of forests and forest soils, grassland soils and soils of cultivated land, c) anthropogenic activities related to land use and cover, such as forest management, land conversion, and soil degradation, and d) global feedbacks, in particular CO_2 fertilization, temperature increase and nitrogen fertilization. The detailed analysis coordinated by the Austrian Research Center Seiberdorf indicates that emissions from the use of fossil fuels can be adequately

quantified but that it is not currently possible to estimate net fluxes of the biosphere equally well due to large scientific uncertainties and data gaps.

The study has produced some empirical findings which are particularly relevant to Article 3 of the Kyoto Protocol. Five key issues can be discerned:

- First, any accurate inventory of greenhouse gas emissions and removals from the biosphere requires the use of *complete and consistent land use and land cover databases* providing coverage for a country's total territory. Even in a relatively data-rich environment, such as Austria, reliable and harmonized LUC information reaching back sufficiently long in time is not easily available.
- Second, assessing the *combined effects of past land use changes* on the carbon fluxes in a given inventory year is almost impossible without making use of direct measurements of changes in carbon stocks. The Austrian study provides a clear example that the first-order approach currently being recommended by the IPCC, i.e., to make simple assumptions about the effects of land-use changes on carbon stocks can easily be misleading. From aggregate data it is easy to conclude that the carbon content in Austria's agricultural soils may have increased between 1960 and 1990 because of 'carbon-positive' land use conversions (from cultivated land and grassland to forestry, but also from grassland soils to cultivated land) and higher crop yields (and consequently higher plant carbon content). Recently published data from large-scale measurements of carbon in humus of cultivated land undertaken between 1965 and 1991 clearly indicate decreases in soil carbon content, on average more than 10 percent. Obviously, impacts from unaccounted land management factors, e.g., changed tillage practices and soil compaction, have contributed to the carbon losses from cultivated soils.
- Third, the Kyoto Protocol requires to define a boundary between *biosphere and technosphere* in order to classify sources and sinks of emissions as human-induced or natural, a distinction that cannot always be firmly introduced into real-world emission estimations.
- Fourth, the Kyoto Protocol rests on the assumption that carbon sequestration activities are real and additional, i.e., over and above what would have occurred in the absence of an emission reduction program. This raises the question of how to quantify/verify additionality, or in other words, how to construct scientifically sound baseline scenarios from which any additionality could be derived.
- Fifth, a comparison of the magnitude of net carbon fluxes with the magnitude of uncertainties in estimating the individual components that contribute to the carbon balance led the authors of the Austrian study to conclude that at present the incomplete knowledge about biospheric processes and data in particular makes it impossible to carry out rigorous estimations of net emissions.

The Land Use Change Project at IIASA

Issues of global change are long-term, as are questions of resource development and investment planning. Current demographic and socioeconomic trends suggest that the next 30-50 years will be decisive for managing economically viable transitions towards sustainable land-use systems. For instance, China's population growth will most likely come to a halt around 2030, and pressures on the food system will ease. The LUC project therefore concentrates its analysis on the medium term period up to 2050. However certain analyses (such as of possible climate impacts) do extend beyond that.

THE REGION OF NORTHERN EURASIA WAS SELECTED AS A GEOGRAPHICAL FOCUS BECAUSE IT COMPRISES HUGE LAND MASSES, IS LIKELY TO EXPERIENCE MAJOR IMPACTS DUE TO GLOBAL WARMING, IS HOME TO ROUGHLY ONE FOURTH OF THE WORLD'S POPULATION, AND HAS REACHED A CRITICAL STAGE IN ITS RAPID SOCIOECONOMIC, ENVIRONMENTAL AND POLITICAL DEVELOPMENT.

The LUC project's research objectives have resulted in a broad set of activities including integration of diverse statistical and geographical data sets within a Geographical Information System (GIS), multivariate statistical analyses, model-based appraisal of land resources, novel approaches for integrating land and water assessments, and development of tools for evaluating policy options and development strategies related to land and water.

It is well recognized that the lack of readily accessible and consistent data has hindered a better understanding of the processes that drive diverse land-use systems around the world. Yet, there has also been a deficit in transdiciplinary research which, until to now, has permitted only modest advances in closing the gap between environmental and economic analysis. LUC has been aiming to fill this niche with a balanced research effort:

LUC's strategy has been to explore a hierarchy of modeling approaches, each well established within their disciplines, which could enrich and provide information to the formulation of a land use model based on intertemporal *welfare optimization*, constituting the conceptual center piece of the project's economic analysis. In this research, LUC has benefited greatly from the collaboration with the Centre for World Studies at the Free University in Amsterdam, The Netherlands.

In collaboration with FAO, and M. Makowski of IIASA's Risk, Modeling and Policy (RMP) project, LUC has been developing software tools for *multi-criteria model analysis* related to agricultural land use. These models provide insight into the nature of tradeoffs among conflicting objectives, informed by a strong biophysical basis. In the application to China, the multi-criteria model is being extended to include water in the decision analysis.

LUC has been widening the implementation of a set of *land evaluation techniques* known as the agro-ecological zones (AEZ) methodology. LUC compiled detailed sets of results for the territory of the former Soviet Union, Mongolia and China employing the most recent digital databases. We also quantified agricultural production risks based on historical climate variability and possible impacts of climate change. These results have been embedded in LUC's economic analysis and estimation of China's agricultural production relationships. The broad and spatially complete coverage of agriculture and grassland areas using the AEZ methods has been complemented with detailed crop modeling studies that examine input-output relationships and environmental effects over a range of production conditions.

A *water assessment* that generates in-depth information on availability and demand is indispensable, particularly when producing land-use projections and food system prospects for China. Geographical detail is essential given the heterogeneity in environmental conditions, and vastly unequal distribution of rainfall and surface water in China. Similar to the project's AEZ land component and crop modeling activities, the hydrological assessment provides the biophysical backbone for parameter levels and relationships within the economic model used for welfare analysis.

Conclusions

There are undoubtedly important synergies among measures and management practices to achieve the objectives of the major international environmental agreements. Programs to enhance carbon sequestration in vegetation and soils are likely to be beneficial in improving sustainability of a land

use system, to increase above-ground and below-ground biodiversity, to arrest soil erosion, and to benefit soil fertility and productivity.

In its current form, however, the Kyoto Protocol takes only selective and partial account of the carbon sequestration potential provided by the biosphere by limiting land use activities eligible for carbon credits to afforestation, reforestation and deforestation. Thus, without taking a more holistic few of carbon sequestration, the mechanisms of the Kyoto Protocol are likely to provide only limited incentives to farmers for changing their land management. Past attempts of setting up full carbon balances at national levels have demonstrated that realization of such a more holistic view will depend on further research and in particular on an improved factual basis obtained from coordinated data collection.

ACKNOWLEDGEMENTS

I am grateful to my colleagues from IIASA's Forest Resources Project, Dr. Matthias Jonas and Dr. Vladimir Stolbovoi, for providing me with their research insights and comments on some critical issues of carbon accounting related to the Kyoto Protocol.

The global environmental benefits of land degradation control on agricultural land

The World Bank has recently completed a major research effort on the global dimensions of land degradation as part of its Global Overlays Program, and the results of that are published in a report, entitled *The Global Environmental Benefits of Land Degradation Control on Agricultural Land*. This report covers quite a bit of ground, including a lot of material that some of the earlier speakers at this meeting have also covered. It also describes the results of a collaborative program that we have undertaken with IFAD to develop a series of project concepts that seek to integrate global considerations in land degradation control efforts.

The audience at this meeting is clearly one that already knows and understands the problems of land degradation, and already knows and understands their links to global dimensions. To some extent, therefore, my remarks here will probably be most useful if I err on the side of caution rather than on that of advocacy. Please keep that in mind as I make my comments.

Professor Lal asked this morning, how do we operationalize the linkage between land degradation and global problems? I think where we need to start is by understanding that land use decisions are ultimately made by individual land users. They are not made by governments, they are not made by NGOs, they are not made by the World Bank or by IFAD—they are made by the individual farmer, the individual pastoralist. And they are made on the basis of a large variety of influences, including their available technology, the policies they face, their particular household characteristics. These decisions are certainly influenced by government policies, or by World Bank-financed projects, or by IFAD projects—but often only indirectly so. This is shown in Figure 1.

Now these individual land use decisions will, in addition to producing crops and livestock—which is what they aim to do—also have land quality effects. Some of those land quality effects will affect production itself. Erosion or loss of nutrients, for example, will affect the yields that farmers are able to obtain in the future. When this is the case, farmers, because of this feedback loop, have a very strong incentive to take these effects into consideration and to do something about them. Others effects will not necessarily have such a feedback. Offsite costs such as sedimentation, for example, will not be taken into consideration by farmers because they do not affect them. This is something we have long known, and over the decades there have been a multitude of projects and policies designed to address this problem.

The global problems caused by land degradation are very similar to that. Farmers have no incentive whatsoever to take them into consideration, just as they have no incentive to take any other off-site effects into consideration. Now the big difference between off-site effects that have national consequences and those that have global consequences is that in the case of national offsite costs, local governments *do* have an incentive to do something about them, and to try to create a policy framework that discourages degrading practices and encourages conserving practices. For global problems that is not the case. This 'missing link' is shown in Figure 1 by the dotted line.

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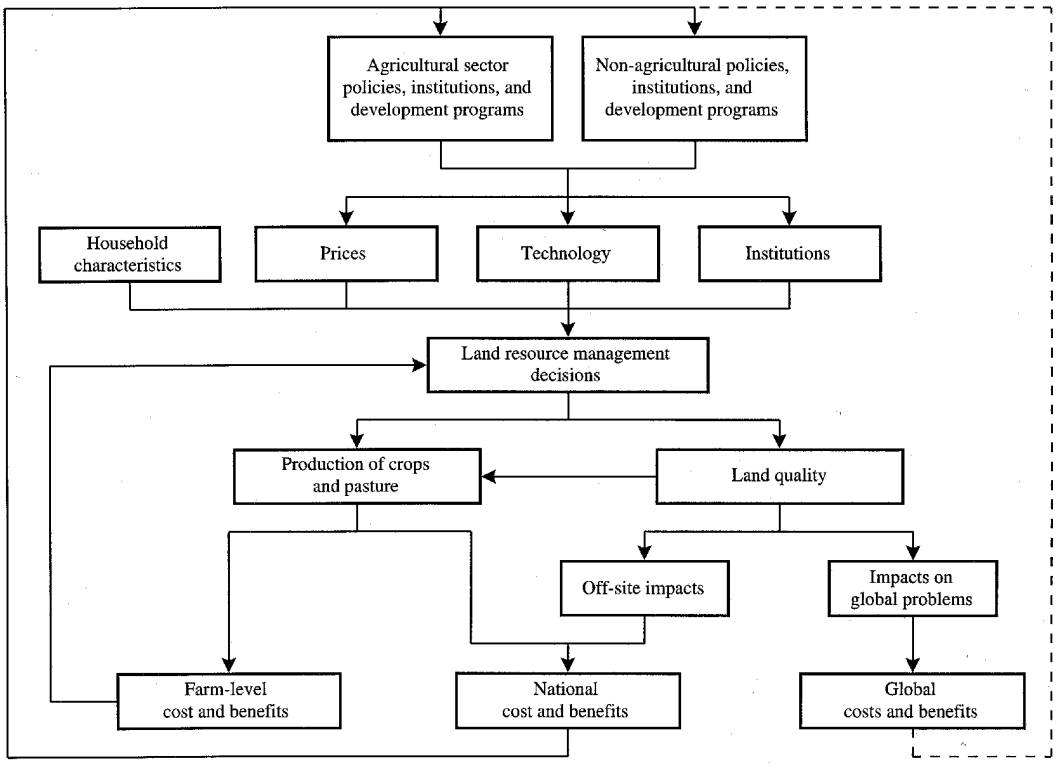
FIGURE 1



There have been a lot of efforts to try to find ways of making this link. These efforts have led to programs such as those financed by the GEF, the prototype carbon fund, joint implementation activities, and so forth—a lot of mechanisms which attempt to bring money into the system to try to change these land use decisions in an appropriate way. These are all very important efforts, and we need to continue to develop them. But we must not forget that while these efforts will make resources available, they will only have the desired effect if they are channeled to land users in ways which induce them to change their land use decisions in the desired direction. And this part of the problem remains a very difficult one. The same problems that governments have been having to get farmers to adopt particular land use practices for national reasons such as reducing downstream sedimentation will also face any effort to get farmers to do something for global reasons such as conserving biodiversity.

There has been a lot of experience of land degradation control and soil conservation projects worldwide. Frankly, the track record is pretty dismal. We do have, by now, a fair number of lessons from these past efforts, and they can be summarized as follows:

- farmers act rationally
- farmers have considerable knowledge about their soils
- need to focus on costs and benefits of conservation measures to farmers, not on their technical efficiency
- need to understand specific constraints faced by farmers
- need to ensure policy environment is favorable
- need to design conservation programs in a participative way
- neither coercion nor subsidies to conservation can substitute for the above

All of these issues are going to be relevant when we try to operationalize the linkage between land degradation and global problems.

Ultimately, as has already been pointed out several times, the key is that activities need to be beneficial to farmers. The costs and benefits to farmers are the critical point in their decision making. And if we do not take that into account we are not going to get very far, as we did not get very far in the past. Now there are many land use practices that would have beneficial global effects by sequestering carbon, but these are not necessarily the most profitable from the farmers' perspective. If we wish farmers to adopt these practices, there obviously needs to be some from of compensation for them to do so. Whether you call it a "subsidy", or a "transfer", or a "payment for environmental services", ultimately you have to transfer resources to the farmers who are doing something you would like them to do that they would not otherwise have done.

Unfortunately, we have had fairly poor success in the past with that kind of scheme and we must be very careful if we are not to repeat some of the mistakes that were made in previous efforts. We have a case that we are working on right now in Costa Rica, for example, where the Bank is helping the government prepare a project that will, among other objectives, also aim at increasing carbon sequestration. There already has been a lot of ground work in terms of arranging for payments for carbon sequestration by a number of mechanisms, including mechanisms such as joint implementation activities and the prototype carbon fund that the Bank is working on. And that is all very good, but once you've collected the money to pay for carbon sequestration, you're still left with the question of how do you use it in a way that affects individual land use decisions so as to generate the required carbon sequestration in a sustainable way? And that is very difficult. The initial plan was to have a five-year payment to farmers who adopt the prescribed practices, and have them commit to continuing them for 20 years—that is, farmers would sign up to plant a certain area to forest, or to maintain a certain area in the forest, they would get a payment for five years, but then they would have to continue with the practice for 15 more years. Well, if any country in Latin America can do it, it is probably Costa Rica, but even in Costa Rica, that sounds extremely unlikely to be sustainable. If you front-load all the payments and then after 5 years say, okay, we are no longer going to pay you anything, but you need to continue using this practice for another fifteen years, where is the pressure? Where is the incentive?

So we need to think very carefully about putting in place payment mechanisms that will produce long-term incentives to change land use in a sustainable way. It is not enough to identify global benefits and to develop mechanisms to get the global community to pay for these benefits, which is where most of the effort has been. We also need to think very carefully about how we use the money collected by these mechanisms, in a way that will sustainably result in the land use changes we want. And that is extremely difficult. Finding good technical solutions is another area in which there has been a lot of work—including a lot of examples cited at this meeting—and this too is extremely important. But this too is not by itself sufficient.

The need to understand the costs and benefits to farmers is extremely important—to understand why they make the decisions they do, and if we do want them to do something different, because there is an additional global benefit that they would not have taken care of, how do we arrange for that to happen in a way that is sustainable? Those are key questions.

Again I want to make it clear that in raising these questions I am very much in a devil's advocate mode, and that the main objective is to make sure that things work. Land degradation problems are extremely serious in many areas, and they can have important effects both locally and globally. Land degradation control activities can play an important role in increasing the welfare of rural populations as well as in addressing global problems. But to find these synergies and design programs that work we must be very careful about how we work on them and not let our enthusiasm for these things let us rush into some of the same errors that we have made in many of our previous land degradation control efforts.

REFERENCE

Pagiola, S. 1999. *The Global Environmental Benefits of Land Degradation Control on Agricultural Land*. World Bank Environment Paper No.16. Washington D.C.: World Bank.

Assessing the carbon stock and carbon sequestration potential of current and potential land use systems and the economic rationality of land use conversions

The awareness of the international community about the real possibility of climate change through, among other causes, an increased concentration of greenhouse gases (GHG), particularly CO_2, in the atmosphere has brought about concerted international efforts that resulted in the signature of the so-called "Kyoto Protocol". Accordingly, land use changes that enhance carbon "sequestration" by vegetation and soils are now seen as a practical instrument for the implementation of the so called "clean development mechanism" (CDM) of the Kyoto Protocol. That is, the "sequestration" or capture of atmospheric carbon masses through plant photosynthesis and biomass accumulation. The CDM envisages the transfer of funds (i.e. "carbon credits") from the industrialized world to any given developing country, equivalent to the value of the carbon mass over and above the reduction target established by the so called "joint implementation mechanism" of the Kyoto Protocol. The commitment of the developing nation will be to "sequester" an equivalent carbon mass through implementing land-use changes (LUC) that enhance the photosynthetic capacity of vegetation to retain atmospheric carbon.

However, due to the intimate interdependencies that are characteristic of ecosystems, other compartments of the environment may be also significantly affected by land use changes. These need to be recognized and considered before implementations are made. The losses of biodiversity are a global concern (UNCED, 1982). Therefore, the effects of LUC on the diversity of life or biodiversity need to be assessed for they may be significant. So is the status of degradation or conservation for it could also be also significantly affected by LUC. Thus, the enhancement of carbon sequestration, the conservation of biodiversity, and the prevention of land degradation are seen in this paper as interdependent issues as far as land-use changes are concerned. Such interdependencies need to be recognized and examined carefully.

On the other hand, in rural areas of Latin America and the Caribbean, where, for the most part, different degrees of subsistence agriculture are practised, food security is also a major concern associated with existing land-use patterns and land-use changes. If the local farmers are to be the agents of materializing realistic land use plans, food security ought to be included in the list of concerns. So, the synergies between actions concerning the prevention of land degradation, the enhancement of carbon sequestration, the conservation of biodiversity and food security through land use change can be explored and used to benefit farmers, related social groups and the environment simultaneously. These concerns are treated in this paper as a set of objective functions that need to be simultaneously optimized so as to generate some form of quantified economic rationality that is tagged to computer-generated (GIS) scenarios, which would be the basis for decision-making regarding land-use conversions.

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THE PROBLEM

The determination of what a given land-use pattern, at the sub-watershed or landscape scale, or a given land utilization type (LUT), at the farm-field scale, represents in terms of carbon content (both in the form of above-ground biomass and in the soil as SOC or SOM), biodiversity (at the ecosystem or at the species level), actual or risk of land degradation, and actual food security, requires an accurate assessment of the current status as well as estimates of the changes in status of each of the concerns mentioned above, which could be brought about by LUC. Therefore methodological steps need to be designed and tested, that would allow for comparisons, for a given geographical area, of the current status and the potential changes in each of such concepts in order to provide rationality for decision making about LUC.

THE METHODOLOGY PROPOSED

Any methodology developed for these assessments should address the four main areas of concern, namely:

- enhancement of carbon sequestration;
- conservation of biodiversity;
- prevention of land degradation;
- food security and poverty alleviation.

The meeting point of these concerns and therefore, crucial to address the interlinkage between them is land use change (LUC). These four areas of concern could be thought of as objectives that need to be optimized simultaneously. Interventions into ecosystems, whether agro-ecosystems, forest ecosystems or any other kind of managed ecosystem, in order to optimize the objectives stated above can only be made trough LUC and the improvement of land management practices. In this sense, for any given area of the world, the methodology sets out to:

- Assess quantitatively the current situation regarding the objective in turn (i.e. determine the status quo), except in the case of related issues that are not directly in line with the project objectives, such as food security assessment and poverty alleviation, which are assessed only qualitatively and indirectly.
- Assess quantitatively the improvements that can be made in the objectives by a given potential land utilization type (including management practices) and generate scenarios consisting of land use patterns that include the potential land utilization types that optimize the objectives.
- Sets up participatory mechanisms that ensure stake-holder (farmer) participation in the selection of land use patterns for a given geographical area (i.e. a watershed or sub-watershed) and by and large serving as a forum for farmer information and participation in stating preferences values and aspirations, taking the form of an electronic round-table.
- Optimizes quantitatively the objectives through Pareto Optimality criteria incorporating stake-holder preferences and aspirations and reaches a compromise solutions, generating optimal scenarios of land-use change at both, the farm level and the watershed level.
- Provides a mechanism for upscaling and downscaling of computations and estimates.

Strategy

The strategy to tackle the four main areas of concern consists of treating them as if they were independent modules of a system, and develops the methodological concerns of each module separately and in detail. At a later stage they the assessments resulting from each module are

integrated methodology proposed here consists of four main sections or modules (one for each pillar or objective) and within each it assesses the current situation and evaluates promising alternatives creating scenarios. The sections are:

- The assessment of carbon stock and carbon sequestration potentials.
- The assessment of the status of biodiversity and its potential changes implicit in a LUC.
- The assessment of the current status of land degradation via its indicators, and the formulation of required land management practices for every suggested land utilization type that would arrest and reverse land degradation.
- The simultaneous optimization of the objectives above including constraints for food security and minimum income by means of mathematical programming models.

Description of the Methodology

The details of procedures and activities in each of the modules are provided below:

Module I. Assessment of Carbon Stock and Carbon Sequestration Potentials

This module embraces the sequence of activities and procedures for assessing and estimating the carbon stock in both above-ground biomass and below-ground (soil and biomass) and is broken down correspondingly into stages for both pools. First, the assessment of the carbon stock in the current land use pattern is carried out. Then, the generation of scenarios of potential land uses and their Carbon sequestration potentials are formulated. It is assumed that the geographic area of concern (i.e. the watershed or administrative unit) has been already identified and its boundaries delineated in a topographic base map or corresponding cartographic materials, and that the method attempts to make full use of existing FAO methodologies (e.g. AEZ, FCC, etc) tools (AEZWIN, etc.) and databases (SOTER, SDB, WOCAT, etc.). The stages are briefly described below:

1.1. Assessment of Carbon Stock in current land-use (CLU) patterns

1.1.1. Above-ground Pool

The approach to assess this pool has two components:

- Data Processing and Analysis of Existing Information
- Field measurements at benchmark sites for model calibration and "ground-truthing"

The data processing and analysis of existing information makes use of the following materials: existing remote sensing imagery, existing forest and vegetation inventories and land use (land utilization types) surveys and characterization.

The stages for this pool are all coded with "A" (for "Above-ground") as a name extension to distinguish them from the "B" ("Below-ground") procedures for easy reference. These procedures are graphically shown in their generic form in the flow chart of Figure 1, and in a more detailed manner for the aboveground pool in the flow chart of Figure 2

CLU Stage IA.

Remote Sensing Imagery Analysis, Land Cover Classification and Waveband Ratios

1.1. Image acquisition into the GIS

1.2. Image enhancement and correction

FIGURE 1
Assessment of carbon stock in current land use

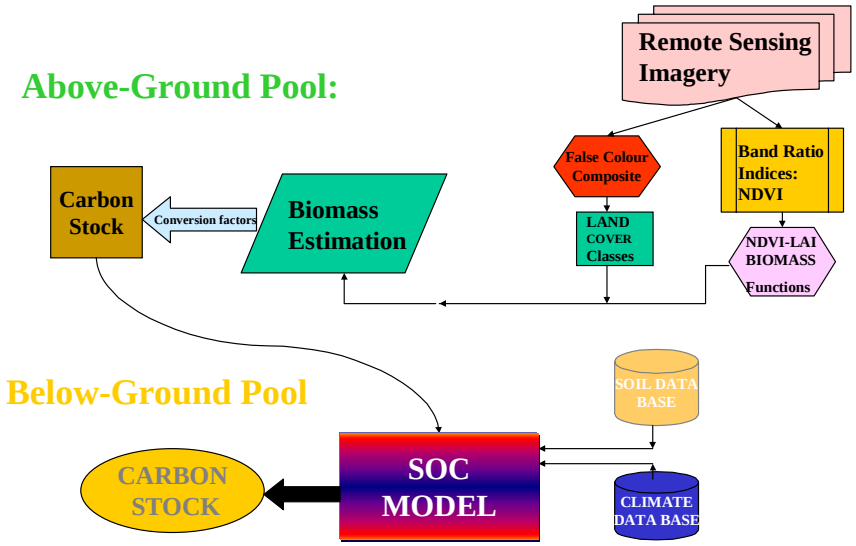
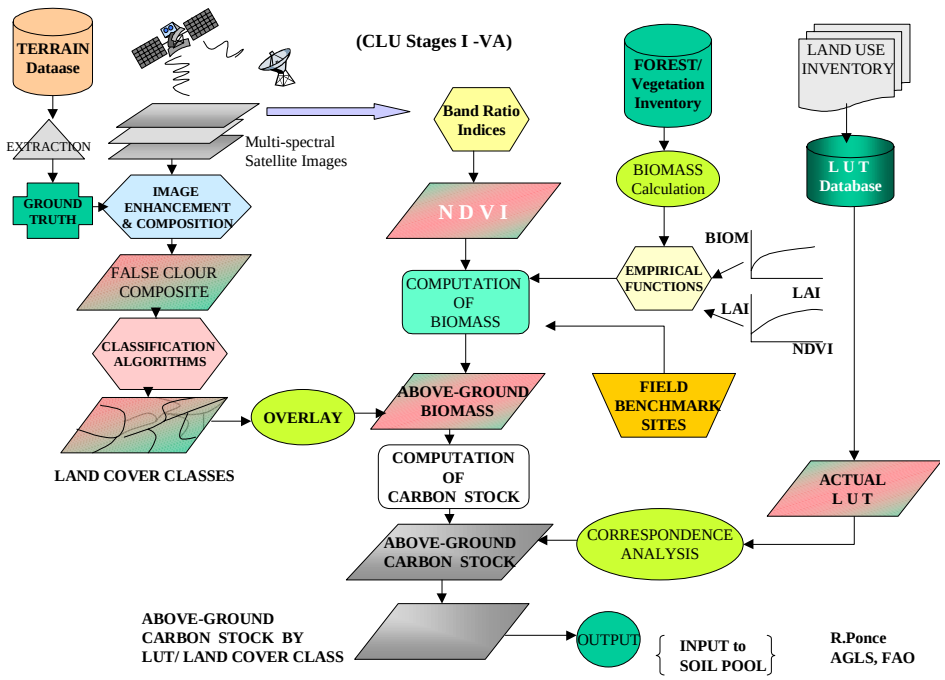


FIGURE 2
Estimation of carbon stock in above-ground pool of current land use (CLU)



1.3. False-colour composition and georeferencing
1.4. Computation of waveband ratios (i.e. NDVI, etc.)
1.5. Image classification into land-cover classes, generation of land-cover classes map

CLU Stage IIA

Field Measurements at Benchmark Sites for Parameterization of Models and Ground-truthing

2.1. Field measurements at benchmark sites

2.1.1. Measurement/observation of structural parameters: LAI, canopy/cover, H, and DBH

2.1.2. Biomass (direct measurement/estimation)

2.2. Ground-truthing of land cover classification (from 1.5)

CLU Stage IIIA

Computation of Estimates of Above-ground Biomass

3.1. Develop/research and use empirical functions of BIOMASS-LAI and LAI-NDVI

3.2. Computation of estimates of biomass from NDVI map

3.3. Adjustment of biomass estimates by forest resources inventories (FRI) data /land cover inventories data (if existent).

3.4. Overlay of land cover classes map onto biomass map and production of above-ground biomass map by land cover classes.

CLU Stage IVA.

Computation of Carbon Stock in Above-ground Biomass (First Accounting of Above-ground Pool)

4.1. Computation of estimates of above-ground carbon stock map by land cover classes through suitable conversion coefficients.

4.2. Calibration of above-ground carbon stock estimates using data from field benchmark sites.

CLU Stage VA.

Attributing Carbon Stock to Land Utilization Types (LUT) through Correspondence Analysis between Biomass/Land Cover Map and LUT Inventory Map.

5.1. Inventory of land use from field and desk surveys

5.2. Generation of map of actual land use (ALU) in terms of LUT

5.3. Correspondence analysis of land cover classes with LUT boundaries.

5.3.1. Overlay of land cover class map on LUT map

5.3.2. Adjustment of boundaries and generation of land cover/LUT map (output to biodiversity module)

5.4. Attributing carbon stock estimates to land utilization types (output to below-ground pool)

5.5. Database compilation and storage of tabular information (output to below-ground pool)

1.1.2. Below-ground Pool

The sequence of methodological steps for the assessment of this pool assumes that:

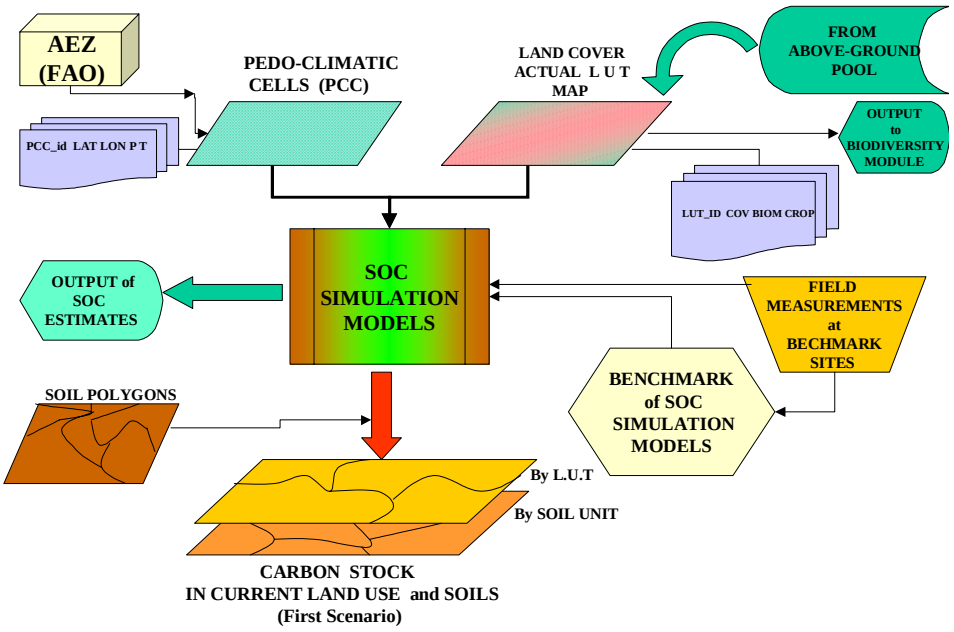
- The area has been selected
- The characterization of the area is made in terms of agro-ecological zones following the FAO approach or any other similar approach. Details of the methodological steps can be seen in Figure 3.

CLU Stage I-B

Biophysical Characterization of the Area

1.1. Definition and Mapping of agro-ecological zones (AEZ) at the scale of watershed or at a suitable scale for the study area using FAO's approach and tools.

FIGURE 3
Estimation of carbon stock in current land use and soils (below-ground pool)



CLU Stage II-B

Preparation of Soil and Climate Parameters for Soil Organic Carbon Model Parameterization

This stage requires of intensive data processing and preparation for the generation of the parameters to feed into the carbon and soil organic matter simulation models. Such steps are illustrated in Figure 4.

2.1. Soil and climatic data

- 2.1.1. Database extraction
- 2.1.2. Spatial interpolation of point-data
- 2.1.3. Creation of raster maps of soil and climate parameters

2.2. Creation of pedo-climatic cells (PCC) as spatial objects for modelling

- 2.2.1. Define spatial resolution according to scales
- 2.2.2. Creation of pedo-climatic cells (PCC) map from overlay of soil parameter layers on climatic parameter layers.
- '2.2.3. Creation of ecological cells (EC) Map from overlay of vegetation classes map (from Stage II-A, 2.2) on PCC map.

CLU Stage III-B

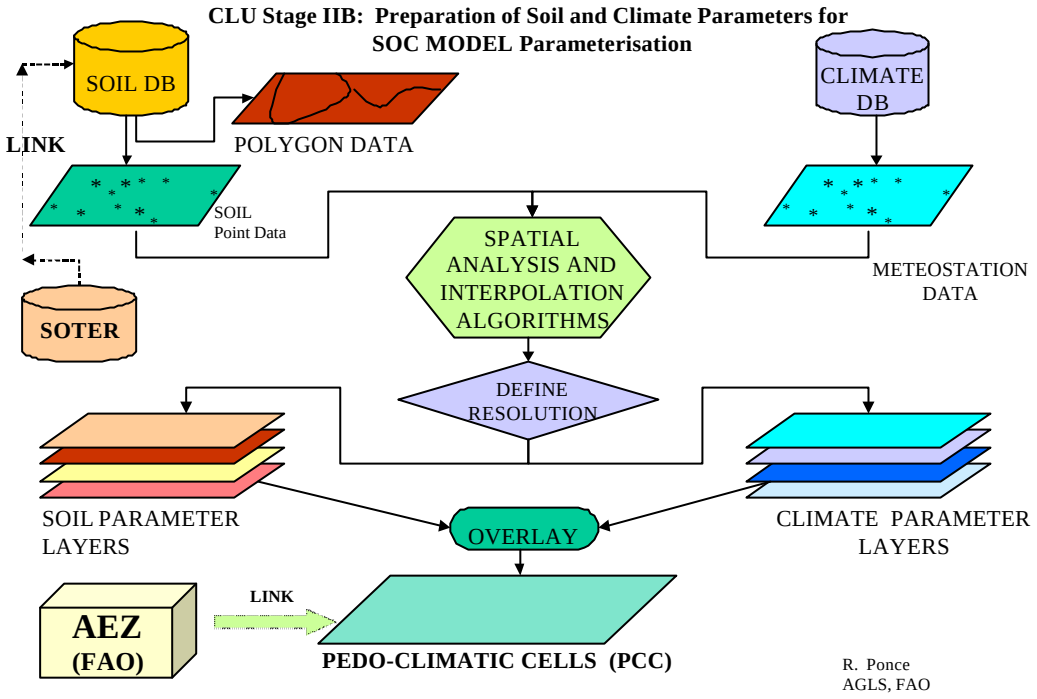
Soil Organic Carbon (SOC) Model Calibration and Benchmarking

3.1. Field measurements and sampling for selected benchmark sites (site selection and location in separate protocol)

- 3.1.1. Field sampling
- 3.1.2. Soil and below-ground biomass characterization
- 3.1.3. Aboveground characterization of sampling sites (from stage II-A)

3.2. Performing benchmarks for candidate SOC models in shortlist (likely: CENTURY, RothC, ICBM, SQUAF, other).

FIGURE 4
Assessment of carbon stock in current land use (CLU)



CLU Stage IV-B
Simulation of Soil Organic Carbon Dynamics and Estimation
4.1. Input of land-cover/above-ground contributions (From above-ground module)
4.2. Extraction of soil and climate parameters per EC/soil polygon and input into selected model and model execution.
4.3. Simulation of scenarios over time horizons and output.
4.4. Storage of scenarios into a database.

CLU Stage V-B
Generation of Carbon Sequestration Scenarios over time and space per LUT
5.1. Link of SOC simulation model output to a geographical information system (GIS)
5.2. Preparation of scenarios by LUT and by soil type/land unit from the GIS
5.3. Computation of statistics of total carbon stock by both pools.

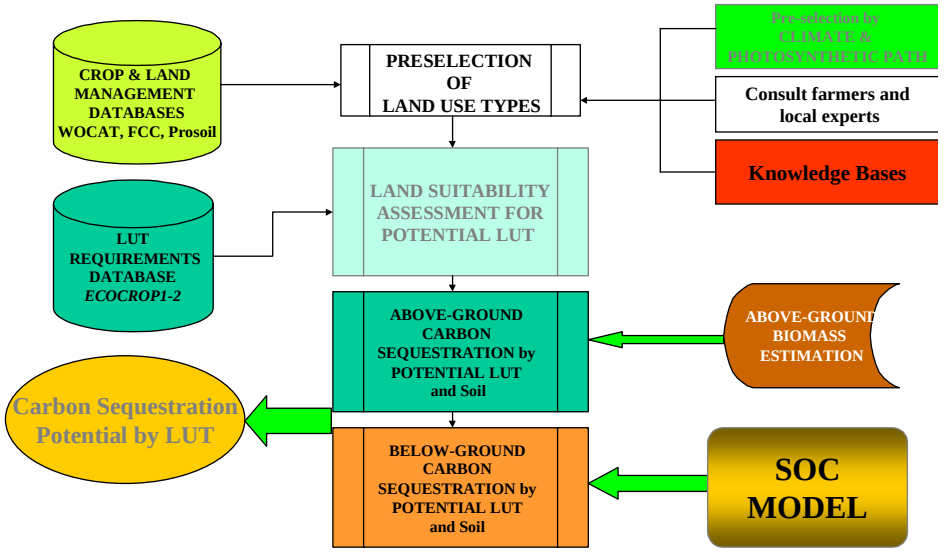
1.2. Assessment of Carbon Sequestration Potential from alternative Land Utilization Types.

The assessment of potential land utilization types (PLU) representing LUC requires of the assessment of the physical suitability of the identified Land Utilization Types for the land areas in the watershed. An exercise in land evaluation is conducted first to ensure the LUT are viable in the physical environment where they will be implemented. The assessment is made in several stages that can be grouped into three main activities, taking into consideration the above-ground (AGP) and the below-ground (BGP) pools, namely:

- Land evaluation for potential land utilization types.

- This is to ensure that proposed land utilization types are suitable for the area by meeting the bio-physical characteristics and qualities of the local environment, besides having reportedly high carbon sequestration potential.
- Estimation of above-ground carbon sequestration implicit in the potential land utilization types.
- Estimation of the below-ground carbon sequestration as SOC from simulation SOC models taking into account the contributions from above-ground represented by the potential LUT. These stages are illustrated in Figure 5.

FIGURE 5
Assessment of carbon sequestration in potential land use types



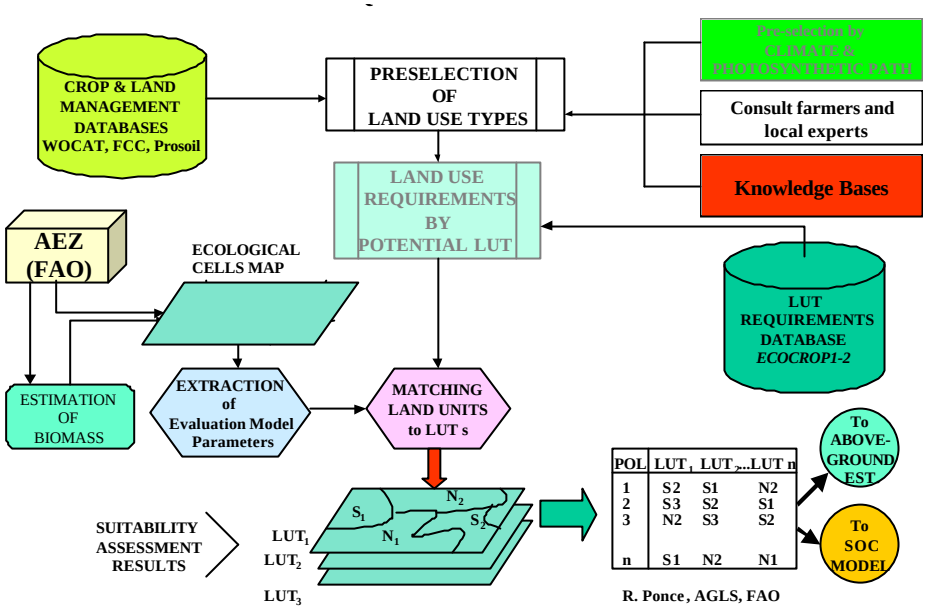
1.2.1. Land Evaluation for Potential Land Utilization Types

The procedural stages for evaluating the suitability of potential land utilization types are coded with a prefix "PLU" meaning "potential land use"; no suffixes are added to roman numerals. The stages (in Figure 6) are as follows:

PLU Stage I
Preselection of LUT by Climatic Suitability and Photosynthetic Pathway
1.1. Compilation of preliminary list of LUT by climatic suitability (temperature, radiation and soil moisture regimes)
1.2. Revision of list according to photosynthetic pathway

PLU Stage II
Literature research on LUT with maximum Carbon Sequestration Potential (CSP)
2.1 Compilation of data and short list of species with high CSP for the LUT mix.
2.2. Identification of LUTs with high CSP as per the literature and matching findings to list from PLU stage I.
2.3. Consultation with farmers and local experts regarding the LUTs. Refinement of the list

FIGURE 6
Suitability assessment of proposed land use types for carbon sequestration potential



PLU Stage III

Characterization of Potential Land Utilization Types selected in terms of infrastructural setting, socio-economic conditions, level of inputs, cropping system and land management, particularly as it pertains to soil organic matter.

3.1. LUT socio-economic and infrastructural characterization

3.2. Consultation and information extraction from current FAO databases (WOCAT, PROSOIL, FCC)

3.3. Characterization of LUT in terms of land management practices and soil organic matter (SOM).

3.4. Identification of Potential LUT requirements (consultation to ECOCROP database)

PLU Stage IV

Biophysical Characterization of the Area, Definition and Mapping of Agro-ecological Zones (AEZ) and EC Map (from CLU Stage I-B) at the scale of watershed or at a suitable scale for the study area using FAO's approach and tools.

4.1. Use of ecological cells (EC) map from CLU Stage II-B, 2.3.

4.2. Creation of ecological cells map by soil type (polygon) by overlay of soil polygons on EC map

PLU Stage V

Land Suitability Assessment of Potential Land Utilization Types.

5.1. Development of a suitability assessment model.

5.2. Extraction of soil and climate characteristics for land evaluation from PLU IV, 4.2

5.3. Land suitability assessment of potential LUT by matching LUT requirements to land qualities and characteristics for land unit or soil polygon. The stages are illustrated in Figure 6.

PLU Stage VI

Generation of Potential Land Use Scenarios (Preliminary)

The generation of land suitability scenarios involves the following steps:

6.1. Transfer of land suitability assessment ratings to the soil map or per EC map in the GIS

6.2. Generation of first suitability assessment scenarios by selecting only the LUTs with the highest two suitability ratings per each land unit/cell. One map for each potential LUT.

1.2.2. Above-ground Pool of Potential Land Utilization Types

Having determined the suitability of the proposed potential LUT, and cleared the LUT with highest suitability, the next step is to determine their C stock potential in the aboveground pool. The procedural stages here are coded with suffixes "A" for "above-ground".

PLU Stage I-A

Computation of Biomass Estimates of Potential Land Utilization Types selected

1.1. Use AEZ methodology and models for biomass computations for each potential LUT per EC

PLU Stage II-A

Computation of Potential Carbon Sequestration per LUT and Generation of Carbon Scenarios

2.1. Computation of estimates of carbon sequestration per potential LUT by using conversion factors on biomass calculations from PLU II-A, 7.1 (output to below-ground pool)

2.2. Generation of carbon sequestration scenarios by transfer of estimates to the GIS. One map of carbon sequestration per LUT for all land units/cells.

1.2.3. Below-ground Pool of Potential Land Utilization Types

For the "below-ground" pool of potential LUT, similar steps to those for the current LUT are to be followed. A "B" suffix is added to the code of the stages. These are as follows:

PLU Stage I-B

Simulation of Soil Organic Carbon Dynamics and Estimation

1.1. Input of contributions from land-cover/above-ground potential LUT (from above-ground module)

1.2. Extraction of soil and climate parameters per EC/soil polygon and input into selected model and model execution.

1.3. Simulation of scenarios over time horizons and output.

1.4. Storage of scenarios into a database.

PLU Stage II-B

Generation of Carbon Sequestration Scenarios over time and space per LUT

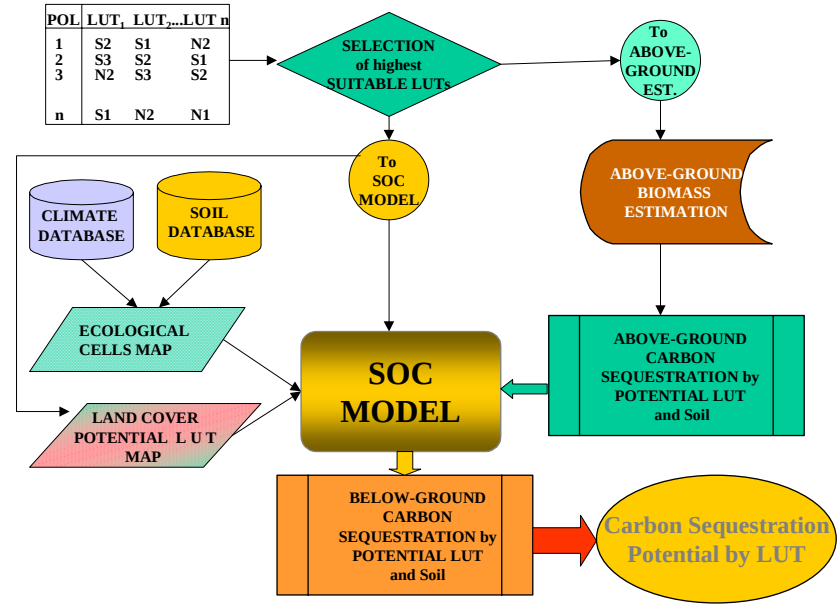
2.1. Link of SOC simulation model output to a Geographical Information System (GIS)

2.2. Preparation of scenarios by LUT and by soil type/land unit from the GIS

2.3. Computation of Statistics of total Carbon stock by both pools.

This module included all methodological stages and analytical steps to provide with estimates of carbon stock for the actual land utilization types and the carbon sequestration implicit in potential land utilization types. The procedures are illustrated in the diagram of Figure 7.

FIGURE 7
Estimation of carbon sequestration by potential land use types



1.3. Carbon Sequestration Attributable to Land-Use Changes (LUC)

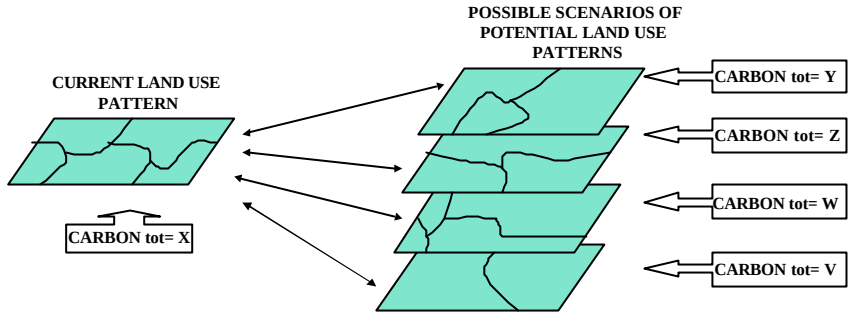
The estimates of carbon stock for the actual land utilization types and the carbon sequestration implicit in potential land utilization types have been assessed in the preceding sections. A comparison of estimates between current and potential LUT would yield the gains in carbon stock that could be attributable to land use changes. The stages to generate such scenarios are shown in Figure 8 and are described as follows:

Stage I-LUC
Tabulation of Carbon Stock Totals in Current Land Use (CLU) Pattern and in Potential Land Use (PLU) Patterns by Polygon or Cell.
1.1 Computation of total carbon stock by LUT in the CLU pattern: $C_{CLU} = \sum C_{LUTi}$
1.2 Computation of carbon sequestered by LUT in the PLU pattern: $C_{PLU} = \sum C_{PLUTi}$

Stage II-LUC
Comparison of Totals of Carbon Sequestration between CLU Pattern and PLU Pattern
2.1 Tabulation of carbon totals in CLU and PLU patterns
2.2. Computation of differences in carbon totals between CLU pattern and PLU patterns
2.3. Tabulation of differences and attribution of differences to scenarios represented by PLU patterns.

Stage III-LUC
Generation of a Catalogue of Recommended LUTs as per Carbon Sequestration by soil type and climate including management practices.
This stage intends to database and catalogue those land utilization types, which represent potential. In both suitability to the environmental conditions of the land and a substantial carbon sequestration potential.

FIGURE 8
Assessment of carbon sequestration potential from land use change



SOIL UNIT/CELL	RECOMMENDED L.U.T.s			
1	LUT_3	LUT_1	LUT_{15}	LUT_9
	C, BioD, FSI, $	C, BioD, FSI, $	C, BioD, FSI, $	C, BioD, FSI, $
2				
3				
n				

catalogue in tabular form, such as illustrated at the bottom of Figure 8 would present in a clear and concise way to decision-makers what each of the recommended LUTs represent in terms of carbon sequestration, biodiversity, food security and their associated monetary value.

It has been stated earlier in this paper that the importance of biodiversity and land degradation Assessments cannot be overemphasized. Similarly any form of indicator of food security is crucial to balanced and rational decision making by farmers and decision-makers or extensionists aiding farmers with decisions on land-use changes. However, these topics have a breath and scope such that cannot be examined in this paper and deserve separate treatment. So, for the sake of continuity in thought and ideas, it is assumed that after working out the methodological steps for the assessment of such concepts, the decision-maker can count on estimates of the three parameters. We shall proceed therefore to describe an approach to derive the economic rationality involved in each land-use pattern scenario and in a possible land-use change from a current pattern to an optimal scenario.

MULTI-OBJECTIVE AND MULTI-CRITERIA OPTIMIZATION OF LAND-USE SCENARIOS

Having determined the current status of the carbon pools implicit in present land use, the biodiversity that this holds, the current status of land degradation incurred due to past and present land use, and an indication of the actual food security situation, the scenarios of potential land-use bring with them changes in the above parameters, some of which may not be desirable. A land-use change would impose a change of different nature and intensity in each of the parameters of concern. The interplay between these four key concepts or concerns make it imperative to aim for a situation of pareto optimality between them, while attempting to implement a given land use-change scenario. In Pareto optimality, no gain is made in any of the parameters at the expense of any other parameter. This implies a bounded optimization of each parameter to a point of not affecting any of the other three, should suitable objective functions could be formulated for each one of these concerns or parameters. The main thrust of activity therefore concern the finding data

in nature and extent necessary to convert the areas of concern into objectives and to find mathematical expressions of such objectives within a framework of optimization. The problem is therefore one of multi-objective optimization and of multi-criteria decision-making. The present module deals with the process of **simultaneous optimization** of the objective functions in the project, namely:

- maximize carbon sequestration;
- maximize conservation of biodiversity;
- minimize land degradation;
- maximize food security.

Each of these objective functions should be mathematically formulated and constructed by:

- Identifying the **decision variables** (likely to be related to the area assigned to a given Land Utilization Type).
- Identifying and deriving the t**echnical coefficients of each decision variable** (by compiling pertinent socio-economic and technical information on shadow prices, marginal productivities and marginal costs) involved in the different aspects of the implementation and in the derived benefits of each LUT.
- Identifying and formulating the **sets of constraints** imposed on the objective functions by the biophysical and socio-economic environments and by the scarcity of resources. For instance, constraints regarding food security and/or biodiversity conservation could be mathematically formulated, constructed and inserted in the model at this stage.

T wo multi-objective and multi-criteria optimization approaches could be explored to support decisions on land use scenarios and land use change: FAO's AEZWIN approach (Antoine *et al.*, 1997) and a proposed approach based on the analytical hierarchy process and goal programming (Ponce-Hernandez, 1999).

Multi-objective optimization and multi-criteria analysis by the AEZWIN method (optimization based on the aspiration-reservation method)

The AEZWIN approach to decisions support possesses a powerful module for multi-objective and multi-criteria decision-making. Although its use requires detailed examination of data formats and algorithms to enter data and to obtain meaningful results, it is possible to see that this software can be used to great advantage, for in addition to the multi-criteria optimization based on the aspiration-reservation method (Antoine *et al.*, 1997), the AEZWIN tool can also provide estimates of other valuable information such as biomass for carbon stock estimation. Giving the nature of this paper we refer the reader to Antoine et al (1997) paper for a detail description of the AEZWIN tool.

Multi-objective optimization and multi-criteria analysis by participatory multi-criteria group decision-making based on the analytical hierarchy process and goal programming

The simultaneous optimization of the four objective functions following this approach would necessitate of two stages of analysis: namely

- Participatory articulation of preferences and values by the stakeholders in a land-use change plan.
- Incorporation of such preferences into a multi-objective goal programming exercise where the objectives would be optimized in sequence as indicated by the ratings on the objective functions derived by consensus from the participation of all stakeholders.

Lately, it has been shown that the analytical hierarchy process (AHP) can be extremely useful for the participatory articulation and analysis of preferences, values and views of the stake-holders in a given decision-making problem (Ponce-Hernandez, 1999). Regarding land-use changes with carbon sequestration, biodiversity, land degradation and food security in mind, the AHP can allow the setting up of a participatory process (i.e. a form of electronic round table) where the stakeholders could rate scenarios based not only on the total dollar value implicit in the total carbon sequestered in each scenario or even in each land utilization type, but also on the implications for food security, biodiversity and land degradation associated to each scenario. These ratings of preferences could then be analyzed (i.e. synthesized) within the framework of the AHP and final weights derived for each alternative (i.e. objective function). It would be possible to know whether, on the whole, farmers and decision-makers, in consensus, decide that food security is first, then the earnings from carbon sequestration, or maybe the conservation of biodiversity can be optimized second, land degradation in third, after the first two, etc. The sequence will obviously change with the values, preferences and idiosyncrasies of the society in question. For an in-depth treatment of the AHP readers are referred to Saaty (1980) and to Ponce-Hernandez (1999) for recent examples of its applications in the management of natural resources.

Thus, the weights derived from consensus for a given geographical or planning area (i.e. a basin or a sub-watershed), could then be applied to decide the sequence of optimization of each individual objective function within the framework of a goal programming exercise. It is considered too early in the methodological development to have full details of the models to develop. However, as an example, Table 1 shows the formulation of an objective function that maximizes net profit (**Np**) as a function of the area (X_{LUTi}) occupied by a set of I LUTs each of which represents a part of the land use pattern in an scenario, and therefore also represents, a given amount of carbon sequestered, a given biodiversity, food security and land degradation. To these LUT will be assigned a different optimal area, and has a different shadow price or marginal productivity $\mathbf{a_i}$ to the objective **Np**. Note that food security (FS) in this example, is built in this model as a constraint, simply to illustrate another way in which multi-objective optimization can be simplified to single-objective optimization. So, the areas cropped with LUT_1 and LUT_6 combined have to be a minimum of Afs area for them to secure food based on those two staple crops represented by LUT_1 and LUT_6.

Table 1. OPTIMIZATION

Objective Function:

Maximize $\mathbf{N\,p = a_1\,X_{LUT1} + a_2\,X_{LUT2} +.....+ a_n\,X_{LUT\,n}}$

Subject to:

$$\mathbf{X_{LUT1} + X_{LUT2} +..... X_{LUT\,n} =< A\ total}$$

Food Security Constraint:

$$\mathbf{X_{LUT1} + X_{LUT6} >= A\ fs}$$

The sequential optimization of the objective functions as per the weights derived from the AHP would allow the identification of the "best" land-use scenario (i.e. area sizes of land assigned to suitable LUTs) which would provide economic rationality to any land-use change, based on criteria of food security, carbon sequestration, biodiversity conservation and land degradation.

CONCLUSION

This paper has identified and proposed a set of methodological stages and steps for the assessment of the current carbon stock, and the potential carbon sequestration implicit in potential Land Utilization Types included in a potential land use scenario. The methodological steps for the assessment of biodiversity, land degradation and the meaning of the given land use for food security have been also researched, identified and designed. However, due to the scope of this paper only methodology has been proposed in detail here for the assessment of carbon stock and carbon sequestration potentials implicit in land-use changes. Such procedures make extensive use of spatial analysis and spatial modelling tools such as GIS and Remote Sensing. Simulation modelling, particularly of Soil Organic Matter and Soil Organic Carbon would also be used extensively as part of the proposed methodology. It was not possible to suggest a given SOM/SOC simulation model. However, an early "light benchmarking" of such models by the author suggests that the models known as "CENTURY", "EPIC", "Roth-C", "ICBM", "DNDC", "CANDY" and "SQUAF" could be good candidates for detail benchmark in order to decide which is to be incorporated into the methodology proposed above.

Economic rationality for land-use change can be found after the multi-objective optimization of a multi-objective function based on the individual objective functions representing the four areas of concern, whose formulation demands detail technical knowledge and specific data. A participatory process based on the Analytical Hierarchy Process can help in identifying preferences, choices and values in regards to alternative land-use scenarios, for incorporation into a multi-objective (goal programming) optimization process, which could allow for sensitivity analysis and recursive and iterative decision- making to minimize risks.

The methodological steps proposed above although derived from a minimum of data processing and testing for this paper are technically sound and still represent a methodological synthesis derived largely from non ad hoc experiences of their applications, and would need to be tested extensively and refined before definite recommendations of its indiscriminate use can be made.

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Annex 1
Opening and closing addresses

WELCOME ADDRESS: Eric Kueneman, FAO-IFAD Programme, Office of the Assistant Director General, Agriculture Department, FAO

Distinguished participants, colleagues and friends from IFAD and FAO, I have the pleasure to speak on behalf of Dr. Sawadogo who is Assistant Director-General, Agriculture Department at FAO to welcome you on his behalf and to make a few opening remarks at this expert consultation.

The topic of prevention of land degradation and enhancement of carbon sequestration through improved crop-soil management is of great interest to FAO. Within the Agricultural Department, there is an exciting convergence of thinking around approaches of conservation farming and particularly in looking at the presentation of this approach through participatory methods with farmers, taking advantage of the recent experience of the farmer field school approach to participatory farmer interactions. We are quite excited about this potential. When I talk about conservation farming, I am referring to crop and soil management practices often including reduced tillage practices but in all cases management practices that optimize soil organic matter accumulation to enhance and stabilize crop production and we believe that the concepts and ideas emerging from this brainstorm meetings. We thank very much IFAD and Parviz Koohafkan in particular for bringing this to reality. But we think that the outputs of this meeting will help us not only for the particular project but to look at these wider issues on crop-soil management and environment.

I do not want to use much of your precious time because it is a one-day meeting but I would like to say a few words about FAO and IFAD joint programming. FAO was created at the end of the Second World War and it is the lead UN agency for technical expertise related to food security, agriculture, forestry, fisheries, rural development and sustainable management of natural resources. IFAD on the other hand was established in 1977 to assist developing countries to combat rural poverty by mobilizing and providing financial resources for agriculture and rural development projects and they focus their programmes to improve the conditions of the poorest populations in developing countries. So you can see by definition that FAO is a technical agency and IFAD is a financial institution. The opportunities for joint programming are immense and though, since the World Food Summit, the level of cooperation between FAO and IFAD has expanded drammatically, it is important to note that there have always been major interactions, especially through the Investment Centre Division of FAO which maintains a multi-disciplinary service for identifying and appraising projects suitable for FAO financing and assistance to developing countries.

FAO and IFAD are also working in concert with the World Food Programme which was created in 1963 which is also here in Rome. The three agencies are now holding regular tripartite policy meetings at the highest level to enhance the collaboration that is growing every day.

I have a large stack of papers which I once thought to give you an overview of the kind of projects that are emerging but I think you have very important things to do in a very short period

of time. However I would like you to know that from FAO's point of view we are most appreciative and encouraged by the stronger partnerships that are emerging particularly with IFAD and with the World Food Programme. This brainstorming meeting is the first activity of a new joint IFAD-FAO project, a strategic model project that is designed to contribute to the development of regional and national programmes that will have concrete actions at the farm level and the community level that will link the three international conventions, the Convention on Climate Change with its Kyoto Protocol, the Convention to Combat Desertification and the Convention on Biodiversity.

We very much appreciate you taking time from your busy schedules to share your ideas and experience with us and to which, I can assure you, we are paying close attention. Thank you.

CLOSING REMARKS: Bahman Mansuri, Deputy Assistant President, IFAD

I think our discussion is finished. I would like to make the following two suggestions for your consideration. .

- On the basis of the Verbatim which has been captured in this note, the IFAD and FAO Secretariat, in consultation with the Latin America Division, will prepare the report on the outcome and the gist of the discussion for distribution.
- The project document should be revised according to the very valuable advices that we have received. It will be distributed for comments. I request Mr Koohafkan to kindly contact the Director of the Latin America Division at IFAD and to agree on a process to reach countries and to select pilot areas. I would very much appreciate that in this process they consider Mr Per Ryden, the Managing Director of the Global Mechanism who will also be involved in this process.

Finally, with regard to the Panel of Experts, I suggest to set up a panel of three or four experts who will continue to advise this project. It would be very useful if you consider the possibility of establishing an informal network for exchange of ideas, experiences and information about the existence of data, success stories, the availability of relevant inventories, etc.

I am sure the issue of the synergy between the three Conventions would be receiving a lot of attention in the Maastricht Conference which is going to be organized by FAO and the Government of the Netherlands this year and which is going to lead to the CSD-Eight in the year 2000 within the context of the United Nations efforts.

I just wanted to add that this consultation of course will be followed up with an e-mail consultation with you and with some additional people, depending on time and availability, in order to enrich the work. We do want this to be a continuous process.

Now, I would like to thank all of you. IFAD was very privileged to have you here and your participation in this meeting. It was a very useful meeting. We benefitted a lot and I am sure there will be concrete results coming out and I hope in a similar meeting that we will be reporting to you the concrete outcome.

Annex 2
Revised project proposal

PROJECT DOCUMENT

TITLE:	**Prevention of land degradation, enhancement of carbon sequestration and biodiversity conservation through land use change and sustainable land management in Latin America and the Caribbean.**
DONOR:	IFAD/FAO
GOVERNMENTAL ORGANIZATIONS:	Ministries of Agriculture, Science, Technology and Environment in Latin American and Caribbean countries.
EXECUTING AGENCY:	FAO
PROJECT DURATION:	2 Years
STARTING DATE:	1 January 1999
BUDGET:	IFAD contribution: US $130 000 FAO contribution in kind US $ 130 000 Participating countries: contributions in kind

A. BACKGROUND

The Tropical lands in Latin America and the Caribbean region are severely affected by various forms of land degradation at different intensities, spatial and temporal scales. Increasing land degradation causes, among other effects, increased carbon emissions to the atmosphere.

Farms, grasslands, forest and savannas in Latin America have the potential to store carbon in the soil and the people have a great need for the land practices that improve soil carbon storage and productivity. Desertification and land degradation reduce soil quality, which then leads to declines in agricultural productivity. Declining soil quality occurs when soil organic carbon is reduced as the carbon moves from the soil to the atmosphere, thus exacerbating climate change. Fortunately, restoring degraded soils through improved agricultural practices reverses this process, thus increasing agricultural productivity and slowing climate change.

Successful projects on Carbon sequestration by soil and related activities in Latin America and the Caribbean must have a strong sustainable development component, such that the project tackle poverty alleviation and enhancement of food security in rural and urban areas of tropical and subtropical countries, improve the livelihood of farmers by improving agricultural productivity, reducing the risk of crop failure, providing access to better agricultural inputs, such as organic fertilizers.

Poverty alleviation and enhancement of food security has become the major thrust of FAO and IFAD activities. Particular attention is given to activities and actions aimed at reversing land degradation and carbon losses due to deforestation and inadequate land use and land management practices in these countries, all of which would enhance carbon sequestration and could be used in a trade-off with pollution of industrialised countries within the framework of implementation of the so called Clean Development Mechanism of the Kyoto Protocol.

Clearly, all of the processes resulting from anthropic interventions on the environment are strongly interconnected in many complex ways. Their understanding first, and then the formulation of interventions to combat poverty and food insecurity, through combating the degradative processes that entrench them, requires a holistic approach. Such interventions would help in reversing global negative environmental trends such as global warming resulting from greenhouse gas emissions, and in enhancing environmental quality. Scientists, national and international environmental and development agencies, governments and policy-makers have by now accumulated substantial evidence which indicates that fragmented, discipline-oriented approaches to tackle the complexity of the interconnections of such problems are bound to produce, at best, only fragmented and partial results if not failure to a greater degree. Population pressures, inadequate land use systems and land management practices causing land degradation, soil fertility loss, the onset of desertification, decreased land productivity and low food production, leading to food insecurity result in the need to search for more land, with consequent deforestation and slash-and-burn agriculture with their consequent increased in carbon gas emissions to the atmosphere. These are all phenomena that are related, interconnected, mutually dependent, and linked in one way or another to the cycle of mass rural poverty. Solutions to these problems need to address the different facets of such interconnections. There is an urgent need to reverse land degradation, carbon emissions and biodiversity losses, food insecurity and to alleviate poverty in these areas. The fundamental challenge, for each area or basin in turn, is to answer the question: what is the pattern of land use systems, in space and over time, that would simultaneously:

- Minimize Poverty
- Maximize Food Security

- Minimize Land Degradation
- Maximize Biodiversity Conservation
- Maximize Carbon Sequestration

Actions leading to the promotion of land use systems and land management practices at several spatial and temporal scales, that provide economic gains to alleviate poverty and enhance food security while providing environmental benefits, greater agro-biodiversity, improved conservation and environmental management and increased carbon sequestration, need to be identified and encouraged.

An improved approach for the integrated and sustainable use of natural resources will require a new paradigm centred on the user's role, as well as on increased effectiveness and synergy between local, internal and external forces. The present proposal puts emphasis on the synergy between the three Conventions (CCC, CCD, CBD) and on the incremental and global benefits for both sustainable development, food security and environmental protection.

B. PROJECT JUSTIFICATIONS

Globally, countries and international agencies have recognized the need to address those problems. This recognition resulted in the Convention on Climate Change (CCC) and the Kyoto protocol (December 1997), the Convention to Combat Desertification (CCD) and the Convention on Biodiversity (CBD), the World Food Summit (WFS), November 1996. In all of these initiatives, the land plays a central role. This is already recognized in UNCED Agenda 21, Chapter 14 "Sustainable Agriculture and rural Development"(SARD) which encourages integrated planning planning at watershed and landscape level to reduce soil loss and protect surface and groundwater resources and stresses the centrality of land in what is called the land cluster of Chapters (Chapter 10 "Integrated planning and management of land resources", 11 "Combatting deforestation", 12, "Combatting desertification and drought", "Mountain areas", and 15 "Conservation of biological diversity"). The Convention to Combat Desertification and the Convention on Biodiversity also emphasize the importance of Tropical lands in terms of sustaining production systems and the livelihood of poor farmers through land conservation and the enhancement of agro-biodiversity.

The major justification for this project is the development of what could be thought of as a new working paradigm. At the core of this new paradigm are the synergies among efforts under different Conventions and undertakings (CCC, CCD, CBD, WFS) addressing phenomena and problems that are intimately interconnected, but that have been formulated separately. Such paradigm is to be based on an multi-temporal and multi-scale, integrative, multi-disciplinary, participatory and holistic approach to land use and land resources management, and will allow for the development of guidelines and procedures to support country efforts at taking stock and assessing the current status of land-use and land management in relation to CCC, CCD, CBD and FS. It will also help countries to produce scenarios that would present realistic possibilities for the implementation of beneficial land use changes. These could optimize the multiple objectives of farmers, land users and other stake-holders and decision-makers.

Complementary justifications

In March 1998 the Ministers of Environment of Latin America and the Caribbean met in Peru to discuss among other subjects the significance and the opportunities offered by the Kyoto Protocol. The meeting recognized the need for projects to quantify the capacity of soil and vegetation as

carbon sinks to promote land use systems which will lead to mitigation of CO2 emissions, and to contribute to sustainable development taking into consideration national policies and priorities.

Subsequently, the Central American Environment and Development Commission (CCDA) requested FAO assistance in the preparation of a Carbon Sink Programme for the Central American region. The main objective of this programme is to strengthen regional and national capacities to define policies and strategies focused on absorbing and reducing greenhouse gas emissions for the benefit of sustainable management of the natural resources of the region.

IFAD and FAO have established a programme of collaboration on the implementation of the Convention to Combat Desertification (CCD). Within the programme AGL is supporting a number of countries in the tropics and subtropics in the preparation of National Action Programmes (NAPs) on land development and under the Convention to Combat Desertification and the Convention on Biodiversity. Currently funds provided by IFAD are used in implementing a joint programme "National Action Plan for Combatting Desertification: Integrated Natural Resources Management Plan for the Cauto River, Cuba" with financial resources provided also by the CCD. The project is in continuation of these joint IFAD-FAO activities.

Also within the framework of the CCDA request, FAO and IFAD agreed to implement a second programme on "Prevention of land degradation, enhancement of carbon sequestration and biodiversity conservation through land use change and sustainable land management in Latin America and the Caribbean" with FAO and IFAD co-funding the programme. The aim of this programme is to promote improved land use systems and land management practices which are expected to provide economic gains as well as environmental benefits to poor farmers in the Latin America and Caribbean Region. This includes greater agro-biodiversity, improved conservation and environmental management and increased carbon sequestration. It is intended to also contribute to the development of regional and national programmes by linking the Convention on Climate Change (CCC)-Kyoto Protocol, the Convention to Combat Desertification (CCD), and the Convention on Biodiversity (CBD), especially focusing on synergies among these three Conventions. Therefore, this programme has a close link with the other on-going FAO/IFAD collaborative programme on the implementation of the Convention to Combat Desertification (CCD).

C. PROJECT OBJECTIVES

The overall objective of the project is to contribute towards a set of comprehensive guidelines and procedures to support efforts by individual countries at taking stock and assessing the current status of land and land resource use and management in relation to food security and the alleviation of poverty food security and the aleviation of poverty carbon sequestration, biodiversity, and land degradation and conservation, in their jurisdictions and territories, with a view to produce alternative optimal land-use scenarios indicating realistic possibilities for implementation of land-use changes that would optimize the multiple objectives of local and other global land-users and stake-holders. In particular, the project will:

- Assess, as accurately as possible with present data and information, the qualitative and quantitative assets of the major land use systems and land management practices in Latin America and the Caribbean in terms of soil fertility and soil productivity, agro-biodiversity and carbon stock and carbon sequestration potentials.

- Establish criteria for identifying land utilization types and their land management practices with great potential for carbon sequestration in different agro-ecological and socio-economic environments and farming systems.
- Evaluate the possibilities and options for land use changes and land management practices to prevent land degradation, conserve agro-biodiversity and enhance carbon sequestration.
- Set up demonstration pilot sites in representative Ecological Zones of the Regions in order to develop monitoring and measuring protocols for soil carbon, and illustrate the economic benefit of such efforts to landowners, and the carbon benefits of such projects to potential investors.
- Prepare regional and national strategies and action plans, based on the results of the various demonstration pilot sites, linking together (for the synergetic effect and the incremental benefits), the three Conventions and their programme areas, within the legislative framework in place in the areas of operation.
- Contribute to the elaboration of a manual for soil carbon sequestration measurement.
- draft guidelines for developing policy frameworks, implementation mechanisms and support programmes for land use changes and land management practices which would prevent land degradation, conserve agro-biodiversity and enhance carbon sequestration at farm, community, national and regional level in relation to the Clean Development Mechanism (CDM).
- Design a Web Page to facilitate communications, access to project information and results, and the development of institutional and individual networks.

1. Regional objective

Propose options and experiences which optimize the complementarity among poverty alleviation, food security, sustainable development and the protection of the environment in tropical land areas, through identified suitable land use changes and enhanced land management practices, in order to maintain soil productivity, to provide economic benefits to rural populations, to conserve biological diversity and to enhance carbon sequestration. Prevention of land degradation is imbedded in IFAD's programme of poverty alleviation in Latin America. The Conventions on climate change, combating desertification, and biodiversity each provide new options to stimulate beneficial changes in the land use and management system of an aggregate of farm households. The total benefits of the individual policy interventions of the Conventions may well be greater if they are designed with a view to optimize multiple objectives in synergy: improvements in household food security and income; land and water conservation and improvement; carbon sequestration; biodiversity in its several aspects. These synergies will strengthen priorities of food security and poverty alleviation among the poorest sections of the Region.

The sites to be selected in the Latin American and Caribbean Region should be representative of the variability in ecological conditions and should allow for the transfer of experiences to other countries in Latin America and to other parts of the world on the basis of agro-ecological and socio-economic conditions.

2. Global objective

Sustainability of Earth ecosystems and the improvement of the global environment are objectives which require solidarity between developing and developed countries. The project will contribute to a better understanding of interrelations between three major environment and development issues, namely, land degradation-desertification, loss of biological diversity and carbon sequestration capabilities of major land use systems. The project will also provide information, decision support and strategy options for the use of sinks to transfer or acquire emission reduction

units and certified reductions from forestry and agricultural projects that can be used to operationalize, among others, the Articles of the Kyoto Protocol.

D. PROJECT APPROACH AND STRATEGY

The project will be based on a multi-scale, multi-temporal, multi-disciplinary, integrative, participatory and analytical approach. The implementation of the programme in the field will require the watershed as the unit for project implementation, and the adoption of an Integrated Ecosystem Management (IEM) approach which consists of a set of ecologically and stakeholder-based guiding principles, and rests on a strong and healthy partnership between research networks (science), local and national governments and institutions (policy) , NGOs and the communities or farmers groups, and the farmers themselves (implementation).

The strategy proposed is to concentrate on the appropriate agroecological zones for increased carbon sequestration in relation to land use practices and select the socio-economic zones (SEZ) where the small farmer groups will benefit most. Those SEZs are the zones with the larger incidence of poverty. Country selection would occur subsequently in agreement between FAO and IFAD Latin America Division, taking into account the typology of the areas, and the National Action Programmes to combat desertification.

The institutional setup for implementing the IFAD-FAO collaborative programme should be clearly defined. Project efforts are more likely to succeed if they build upon institutions, initiatives, organizations and farmer's groups. It should be based on partnerships with institutions at regional, sub-regional and at national level. The project should be the starting point for such partnerships and collaboration on data and information gathering. Partners should be identified who have information and can contribute to the analysis. There should also be a linkage with the strategies of the National Action Programmes to combat desertification

The project will assist Governments in Latin America and the Caribbean within the framework of their National Action Programmes (NAP), according to modalities foreseen in CCD and its regional annexes for Latin America and the Caribbean.The project will carry out 3 case studies in selected pilot sites of Latin America and the Caribbean in countries which have ratified the International Conventions on Desertification and Biodiversity and the Kyoto protocol.

The preparation of NAPs are an essential part of a long-term and dynamic strategy that focuses not only on a diagnosis of the state of the desertification processes and a campaign against it, but also on the rehabilitation, conservation and sustainable management of land and water resources leading to enhanced land productivity, reduction of greenhouse gas emissions and improved living conditions at farm and community level. The project strategy is to collaborate with institutions dealing with NAP implementation and contribute to the development of concrete field actions which would help operationalize the NAPs via the implementation of land development initiatives at pilot areas.

The project outputs will be used in preparing future Land Management Plans (LMP) to be executed together with the project beneficiaries. These plans will aim for sustainable production in the selected pilot areas and other areas with similar environmental and socio-economic conditions to allow for an increase in the productivity of forestry and farming systems, an increase in the quality of the rural environment and an increase in producers' quality of life.

The institutional capacity of a variety of active partners, including the national and local authorities, will be reinforced in order to prepare a number of policy decisions to implement the National

Action Programmes and improve the quality and efficiency of their services at community level.The project activities will be implemented in collaboration with CCAD, CCD and national institutions through Letters of Agreement.

E. BENEFICIARIES

The project identifies direct and indirect beneficiaries.

Direct: individuals, farmers, cooperatives and land users in the pilot areas (watersheds or basins), rural households and communities, local organizations and local governments, local technicians and researchers in the area, and specialists of participating organizations.

Indirect: Governments, provincial, national and regional organizations, universities and NGOs linked to the sustainable management of natural resources and to the implementation of NAPs and other programmes related to the Conventions and the Kyoto Protocol.

F. INSTITUTIONAL FRAMEWORK

Agriculture and Environment Departments of the Ministries of Agriculture, Science, Technology and Environment are the lead organizations for the establishment of the Project's institutional framework in collaboration with FAO. These Departments will co-ordinate, through the established National CCAD or CCD Secretariats and in co-ordination with the partners in the watershed management consortium (i.e. local governments, communities and universities or research institutions), the activities of any other institutions and organisations, which will take part in the case studies. The participating institutions should possess adequate experiences for developing the activities required by the IEM approach and those related to the project objectives. For the execution of these activities, the Ministries of Agriculture, Science, Technology and Environment will be authorised to sign the specific Letters of Agreements with the participating institutions according to project needs.

Relationships with other National and Sub-regional Projects

In view of the global and, at the same time, local nature of desertification, biodiversity and greenhouse gas emissions. Cooperation among countries and regions is foreseen in the Conventions, and the present project also has provisions for both inter-regional and intra-regional cooperation.

This Project will relate closely to projects in Cuba, Haiti, Jamaica, Costa Rica, Peru and the Dominican Republic, as well as to other projects sponsored by other funding agencies that are implementing the IEM approach in the selected watersheds for the pilot areas (e.g. Mexico and Ecuador). Technical Cooperation among developing countries (TCDC) and exchange visits are foreseen for the co-ordinated planning, development of common approaches and implementation of programmed activities.

Relationships with FAO normative Projects

This project is related to the various FAO normative programmes and projects dealing with SARD, in particular to AGL's ongoing or planned programmes and projects as follows:
211b1: Land resources, soil fertility and plant nutrition policies, planning and management.
211c1: Moisture conservation and fertility management in rainfed agriculture

211p1: Land and water information systems, databases and statistics
UNCED follow-up.

G. PROJECT ACTIVITIES

The project activities are as follows:

- Collection of information, review of literature and desk studies
- Selection of pilot sites in representative agro-ecological and socio-economic zones in the region.
- Establishment of demonstration sites for monitoring and measuring protocols for soil carbon, illustrating the economic benefits os such efforts to landowners, and the carbon benefits of such projects to investors.
- Delineation of areas: characterization of the environment in terms of climate, terrain, soils and socio-economic conditions.
- Inventory of major land use systems and their characteristics and dynamics in space and time.
- Realization of participatory diagnoses for the identification of problems that affect production and productivity of the current systems.
- Calculation of present carbon stock balance per land unit and per land use.
- Estimation of degradation and its effects in under the present land uses in various units.
- Potential of carbon sequestration/biodiversity conservation and food security by better land management including : (i) Conservation tillage in combination with planting of cover crops, green manure and hedgerows (ii) organic residue management (iii) water management including in-situ water conservation in the root zone (iv) soil fertility management including the use of mineral fertilizers and organic wastes, rhizobium inoculation, liming and acidity management (v) agroforestry (vi) adapting crop rotations and crop/farming systems with avoidance of bare fallow and (vii) stabilization of slopes and terraces.
- Impact analysis and optimization (modelling of scenarios) to evaluate environmental and socio-economic effects of proposed interventions.
- Identification of fields of applied research for adoption of land use and management and alternative production systems which enhance carbon sequestration.
- Realization of participatory workshops to prepare alternative land use and land management technologies that increase carbon sequestration.
- Prepare a workshop with a small group of experts to assemble materials for a draft Manual on Carbon measurement protocols that are widely circulated for comment.
- Identification of stakeholders and of relevant decision-making structures (institutional/ watershed authority/ NGOs/ communities/ farmers frameworks), in the case study areas selected in the Region.
- An extensive review and analysis of experiences and paradigms of implementation policies of programmes in the rural sector of the pilot areas in order to identify experiences and policies which have shown to be successful in materializing durable recommended changes in land use and land management to farmers and which keep with the objectives of food security and poverty alleviation. Particularly, conduct extensive institutional research on documented experiences with policy frameworks involving land resource use and management and their meaning as they affect the multi-level stake-holder structure, as they relate to farm management activities and farmer commitments and perceived benefits.
- Conduct information sessions at the various levels in the decision-making hierarchy (e.g. institutions/watershed/communities/farmers, etc.) about the structure and objectives of the project.

- Gather stakeholder information about experiences related to policy frameworks for implementation of programmes, and facilitate the articulation of farmer's concerns needs and preferences regarding food security, poverty alleviation, land use and land management, through participatory methods, under a scenario of CDM incentives. Obtain farmer's views about mechanisms and policy instruments with high potential for implementation of the CDM. Derive consensus among stake-holders.
- Carry out analysis, cataloguing and documentation of past experiences/paradigms of policy frameworks for implementation of programs. Synthesis and derivation of conclusions.
- Translation of results into a policy framework in agreement with standing government policies.
- Elaboration of a web page to facilitate access to project information, approaches, methods used and results.

H. PROJECT OUTPUTS

- Baseline data and information on land, land use, processes and time scales (including technologies and practices).
- Methods/case studies:
  Verified methods to assess (satellite and ground-based data and models) the stocks of carbon pools and the role of various land use systems as sinks of carbon.
- Strategy/policy guidance:
  Implications of expanding the use of better land management on productivity, bio-diversity, and other environmental and socio-economic activities.
- Estimates of the potential magnitude of carbon sinks - costs and benefits provided by selected improved land uses in short- and long-term.
- Capacity building and institutional reinforcement to improve co-ordination and capacity to render services so as to ensure better management and integral development of land resources.
- A field pilot project demonstration site/watershed
- Information to improve the decision-making capacity of the participating institutions and to monitor the activities of the land use programs and projects, in order to improve land use and land management.
- The knowledge and experience gained, contributing to a better understanding of the precise relationship between three important environment and development issues, namely land degradation-desertification; loss of biological diversity and carbon sequestration capabilities of major land use systems.
- Information, decision support and particularly strategy options for a policy framework for the use of sinks to transfer or acquire emission reduction and certified reductions from forestry and agricultural projects which can be used to operationalize, among others, the Articles of the Kyoto Protocol.
- A manual for carbon sequestration measurement.
- A knowledge base of paradigms and experiences of successful implementations of programmes in the field involving land use changes and land management practices at the

farm, community and watershed level in the Chosen Region and their relevant policy implications

- Materials and options for a policy framework based on tested methodological approaches for addressing multi-level concerns in the implementation of land use changes and improved land management practices in tropical areas which shall maintain soil productivity and provide economic benefits to rural populations while at the same time conserve biological diversity and the environment and also enhance carbon sequestration, necessary for the operationalization of the Clean Development Mechanism of the Kyoto Protocol.

I. PROJECT INPUTS

The following inputs are foreseen for the 3 case studies

1. **National staff supplied by the participating Institutions**	(Months/person)
National Technical Director/Professional in Land Use planning and management (3)	24
Expert in production systems(3)	24
Administrative Assistant (3)	24

2. **International Experts TCDC financed by the Project**	(Months/person)
Expert in land use modelling	2
Expert incarbon sequestration modelling	2
Expert in land management	2
Expert in agricultural, forestry and land use policy and economics	2
Total	US$ 15000

3. **Other experts and FAO human resources** (to be determined).

4. **Inputs supplied by the participating institutions**

Space for administration and operations, with furniture and office equipment.
Logistics support: maintenance of office and transportation
Materials and provisions: office consumables, tires, fuel and lubricants, and various office items
Official journeys: daily subsistence allowance of national project staff. Furniture and equipment required by the national staff, such as desks, chairs, files, etc.

5. **Official travel**

Technical support and supervision missions from FAO and IFAD Headquarters experts at a cost of US$ 15000 for two years.

6. Services and contracts

Letters of Agreement signed with national organisations for the field research and survey on land use, land management and carbon sequestration.

7. General operating costs

Under this heading are included the resources required for the maintenance and current Project costs.

Equipment operation and maintenance: US$ 5000
Reports and publications US$ 15000

8. Material

Materials required by the Project will be US$ 10000.

9. Equipment and Provisions

Under this heading the Project will assign:

US$ 10 000 for field equipment.
US$ 20 000 for computer programs and equipment to be provided to participating institutions to ensure the adequate development of all activities planned in the Project's Logical Framework.

As a result, the total cost under this heading for the two years will be US$ 30 000.

10. Training

Training workshops will cost US$ 15 000.

J. PRESENTATION OF REPORTS, EXAMINATIONS AND PROJECT EVALUATION

Reports

Semi-annual Reports

Under the Letters of Agreement the participating institutions will draw up annual work plans (calendar year) giving a detailed description of the activities to be carried out by the project during the corresponding year, including a budget revision with the necessary resources, and semi-annual progress reports.

The Project will present semi-annual reports presenting the progress of activities and comparing these results with the content of the Project document and the work plan, mentioning the difficulties encountered, and quantifiable results. Measures taken or to be taken to avoid these difficulties will also be included.

Technical Reports

Under the Letters of Agreement the participating institutions will present FAO Headquarters with the technical reports for examination, finalisation and presentation to IFAD.
Final Report

A first draft of the final report will be prepared by FAO one month before Project completion for presentation to IFAD.

This report will concisely evaluate how the project's planned activities have been carried out, how the results have been produced and how the immediate objectives and main development objective have been achieved. Recommendations derived from the Project will also be formulated for any complementary measures in the future.

Examinations

FAO, the participating institutions and IFAD will jointly examine the progress of the project every year. During these tripartite reviews the project's progress will be studied and decisions made about possible readjustments. Furthermore, a final tripartite review will be carried out which will study project achievements and decide upon possible complementary measures. The organisation, the mandate, the date and the place of the review will be decided in consultation with FAO, the participating institutions and IFAD.

In every tripartite review, an evaluation report of the project results will be presented, prepared by the responsible institutions. During project implementation, other evaluation reports of the project results may be demanded. The discussion during the final tripartite review will be based on the final project report.

Evaluation

The project will have two evaluations considering all aspects (objectives, plan, achievements, results and impacts). The first one, at mid term will be held at the end of the first year, and will aim at project readjustment and correction of deficiencies that have cropped up or were unforeseen. The second one concerns the final evaluation of the project and will be carried out during the second year. In both evaluations independent teams of FAO, the participating institutions and IFAD will be present. The mandate and the date will be decided upon jointly among FAO, the participating institutions and IFAD.

BUDGET (financed by external sources)

Personnel	US$
Regional and TCDC experts	15 000
Other experts and human resources	(t.b.d)
Others	
Official technical support	10 000
Services and contracts	50 000
General operating costs	10 000
Equipment and supplies	10,000
Training	10 000
Travel and meetings	25 000
	130,000

Budget by main activities

Activity	US $	%
- Desk study and preparation	15,000	12

- Data bases establishment	25,000	20
Visit to the selected countries, consultation with national and international institutions, field visits and workshops	35,000	26
Land use inventory, modelling, evaluation/interpretation, analysis	45,000	35
- Writing and preparation of documents	10,000	7
Total	130,000	

Annex 3
Agenda

THURSDAY, 15 APRIL 1999

08.00 - 08.45	Registration
09.00 - 09.10	Opening of the consultation (Raquel Peña Montenegro, IFAD)
09:10 - 09.20	FAO-IFAD Programme (Eric Kuenemann, FAO)
09:20 - 09:40	Food security, poverty alleviation and global environment (Parviz Koohafkan, FAO and Bahman Mansuri, IFAD)
09:40 -10:00	Coffee break

Session 1

10:00 - 10:30	Soils and Carbon Sequestration
	Global carbon pools and fluxes (Rattan Lal)
	Purposes and Modes of Carbon Sequestration (Wim Sombroek)
10:30 - 11:00	Land use, Land management and carbon sequestration
	Land use change, biodiversity and carbon sequestration in tropical forest margins (Mike Swift)
	Linking land use, land management and carbon sequestration (Anthony Young)
	Some experiences from IIASA's research related to land use and carbon sequestration (Günther Fischer)

Session 2

11.00 - 12.10 Discussion on the following four topics (20 minutes for each)
Open to the participants

1. Which kinds of pilot studies or examples of carbon sequestration by land users, and in which environments, could most rapidly provide a clear and convincing case for more general application?
2. Which kinds of data are available for the estimation of net carbon flows under various uses in different agro-ecological zones?
3. How could this information be expanded over more uses and agro-ecologies, rapidly and at limited cost?
4. Which contrasting, promising and less promising land use systems or sets of land management practices could be analysed with respect to their benefits for food security,

prevention of land degradation, carbon sequestration, improvement of soil and above-ground biodiversity, with a view to identify and quantify demonstrable benefits?

12:10 - 12:30 Conclusions from the discussions

12:30 - 13:30 Lunch break

Session 3

13:30 - 14:00 The Economics of Carbon sequestration

The global environmental benefits of land degradation control on agricultural land (Stefano Pagiola)

Assessment of carbon stock and carbon sequestration potentials (Raul Ponce Hernandez)

14:00 - 15.15 Discussion on the following five 5 topics (15 minutes for each)
Open to the participants

1. Which kinds of land management improvements are currently spreading without, or with limited specific incentives, in which countries and environments, and what are the main policy, economic and biophysical conditions that have led to the successful spread?
2. What are the main benefits perceived by the farmers that have led to the adoption of the practices?
3. What strategies could be developed to highlight and use the synergies among the objectives of the Conventions (including carbon sequestration and biodiversity conservation) and the objectives of sustainable land use and management and of household food security?
4. How could values of carbon sequestration by individual farm households be most effectively bundled into a volume of interest to the national or international actors wishing to purchase carbon emission entitlements? (considering aspects of quantity estimation and certification, power balance of land user groups versus certifying entity, bundling and negotiating entity and purchasers)
5. Which kinds of government policies would effectively internalize into the farm household part of the environmental benefits from improved land management? For which kinds of land use might, a case for biodiversity stewardship payments, be most effectively developed?

15:15 – 15:30 Coffee break

Session 4

15.30 - 17.00 Recommendation: Follow-up action and mechanisms for project implementation (Panel discussion)

The session would review the results of the preceding discussions and propose practical recommendations for implementation in the FAO-IFAD programme and the proposed project. In particular, issues of collaboration between FAO, IFAD and other institutions should be addressed. The possibility to set up a panel of experts for the follow-up of the programme should be investigated.

17:00 -17.15 Summary of the discussions and conclusions

17.15 - 17:30 Closure of the meeting

18:00 -19:00 Cocktail Party

Annex 4
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