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Interim Report IR-00-010

Harnessing Remote Sensing to Accomplish Full Carbon Accounting: Workshop Report

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Abstract

The workshop "*Harnessing Remote Sensing to Accomplish Full Carbon Accounting*" was held on December 9-11th, 1999 at IIASA with the intention of meeting the following objectives:

1. To promote the mutual interests of the remote sensing and carbon science communities by exchanging the ideas regarding the requirements for carbon accounting and the current available products derived from remote sensing and land information systems;
2. To produce strategic recommendations on how to improve FCA at different scales with the use of remote sensing tools; and,
3. To develop a Framework to Apply Recommendations for Sub-global and National-Level Case Studies.

Although these ambitious targets were only partly met, three discussion group sessions resulted in describing:

- What is required to implement full carbon accounting;
- How remote sensing can be used to assist this implementation; and,
- How remote sensing can be used to reduce the uncertainties related to FCA.

This report summarizes the presentations, discussions and results of this workshop and outlines the next steps to be taken by IIASA.

Acknowledgments

We wish to thank the superb organization of Ms. Cynthia Festin for ensuring a successful workshop.

About the Editors

Michael Gluck has been a research scholar in the Sustainable Boreal Forest Resources Project at IIASA since 1998. Gebhard Banko was a participant in the Young Scientists Summer Program at IIASA in 1998 and received the Aurelio Peccei Scholarship for his work and returned to IIASA in 1999. Wolfgang Vrzal was a participant in the Young Scientists Summer Program at IIASA in 1999. Currently, Messrs. Banko and Vrzal are affiliated with the Institute of Surveying, Remote Sensing, and Land Information at the University of Agricultural Sciences in Vienna.

Harnessing Remote Sensing to Accomplish Full Carbon Accounting: Workshop Report

Michael Gluck, Gebhard Banko and Wolfgang Vrzal (Editors)

1. INTRODUCTION

The carbon balance has a very high profile on both national and international political agendas. IIASA has learned much from our Russian case study of full carbon accounting (FCA) based on a coupled landscape-ecosystem approach and can see that efficient remote sensing can substantially improve the carbon accounting. However, any carbon and/or remote sensing research initiative should address compatibility with goals of sustainable resource management (e.g., meeting needs of systems of criteria and indicators of sustainable forest management). This report recognizes that viewing the full carbon accounting issue as part of a more common problem should allow a broader set of goals to be reached.

FCA follows – in a consistent fashion – the full carbon-system concept. For purposes of this report, FCA is a full carbon budget that encompasses and integrates all (carbon-related) components of all terrestrial ecosystems and is applied continuously in time (past, present and future). We assume that the components can be described by adopting the concept of pools and fluxes to capture their functioning. The reservoirs may be natural or human-impacted and internally or externally linked by the exchange of carbon (as well as other matter and energy) [c.f. also Steffen *et al.* (1998) and Nilsson *et al.* (2000)].

In contrast to FCA, a partial carbon account (PCA), like that proposed by the IPCC under the Kyoto Protocol considers only human-affected portions of the terrestrial ecosystem and estimates changes in the carbon budget based only on flux-based methodologies (Jonas *et al.,* 1999).

One of the overall conclusions of IIASA's Russian case study is that to do anything justifiable with respect to the carbon budget a Full Carbon Account (FCA) has to be exercised. Furthermore, significant improvements to any carbon account can be made with the efficient use of remote sensing for the following reasons:

- Existing data lack consistent classification (specifically systems that can be directly applied to remote sensing) and definitions increasing the uncertainties of the carbon account;

- The amount of data needed for the full accounting is huge and the data collection is expensive;

- There is a substantial space and time-scaling issue connected with existing data, which creates uncertainties in the full carbon account;

- Consistency or completeness in addressing the system (see Jonas *et al.*, 1999)

- Long-term data series are required to cover several components of the full carbon account;

- There is a general lack of data describing the dynamics of disturbances efficiently; and,

- Data are limited for several important ecological processes.

Thus, there is a substantial uncertainty in the current carbon accounting, which is a major headache for policy-makers. Furthermore, even if a partial carbon account (PCA) is to be carried out (e.g., compliance with the Kyoto Protocol), it is obvious that to make a breakthrough on carbon accounting collaboration is needed between different competencies.

As a step towards this collaboration, the workshop "*Harnessing Remote Sensing to Accomplish Full Carbon Accounting*" was held with the intention of meeting the following objectives:

1. To promote the mutual interests of the remote sensing and carbon science communities by exchanging the ideas regarding the requirements for carbon accounting and the current available products derived from remote sensing and land information systems;
2. To produce strategic recommendations on how to improve FCA at different scales with the use of remote sensing tools; and,
3. To develop a Framework to Apply Recommendations for Sub-global (or continental) and National-Level Case Studies.

The format of the workshop was designed to provide as much room for facilitated discussions as possible. Because of this, formal presentations were very brief (10 minutes) and made by only some of the participants. Copies of the presentation abstracts can be found in Appendix 1.

Three group discussion sessions discussed the following topics:

1. What is required to implement FCA;
2. How to apply remote sensing to FCA; and,
3. How remote sensing can be used to reduce uncertainties in FCA?

Groups of 10 to 12 participants created short presentations summarizing their discussions and presented these to the rest of the workshop participants. A copy of the workshop agenda can be found in Appendix 2. In the following sections we have attempted to summarize the core information from the group presentations and general discussions.

2. WHAT IS REQUIRED TO IMPLEMENT FULL CARBON ACCOUNTING?

For the first group activity, participants, divided into three groups, were asked, *What is required to implement full carbon accounting?* We have summarized the discussion into the following major categories (from broad to narrow focus) that should be addressed in order to frame this implementation. These objectives were:

1. to frame the problem;
2. to understand and describe in a consistent fashion the basic processes;
3. to evaluate and apply models; and
4. to make observations and collect multi-source data.

The discussion resulted in different interpretations of FCA depending on whether it serves to answer a political, decision-making or basic scientific research question. This dimension is presented in section 2.4.

2.1. FRAMING THE PROBLEM

This objective includes identifying the *scientific* purpose of the research, the potential users of information generated and agreeing upon terms and classifications, and finally the issue of funding.

2.1.1. PURPOSE

Agreeing on the philosophy, aim, objectives and goals of FCA is paramount to implementation — however this is specific to each research activity and therefore is only noted here. Knowing why we are implementing FCA, however, was thoroughly discussed by the participants. Although IIASA's meaning of FCA in terms of the Russian Case Study (see Section 1) was used as a starting point, a consensus on an exact definition was not reached since FCA means different things depending on the spatial and temporal scale of application.

A result of preliminary discussion, which was suggested as a statement of purpose, was the question "*What information is required for science and policy makers to better understand and make recommendations for decisions concerning the terrestrial carbon cycle?*" In other words, science needs to explicitly know the uncertainties involved in understanding the terrestrial carbon cycle in order to provide recommendations to policy makers.

The participants discussed a general concept of uncertainty. Based on IIASA's FCA for Russia, an illustration of the quantifiable concepts of uncertainty was presented (Figure 1). In this example for two sets of measurements, the relative terms of accuracy and precision were provided to clarify discussion later in the workshop.

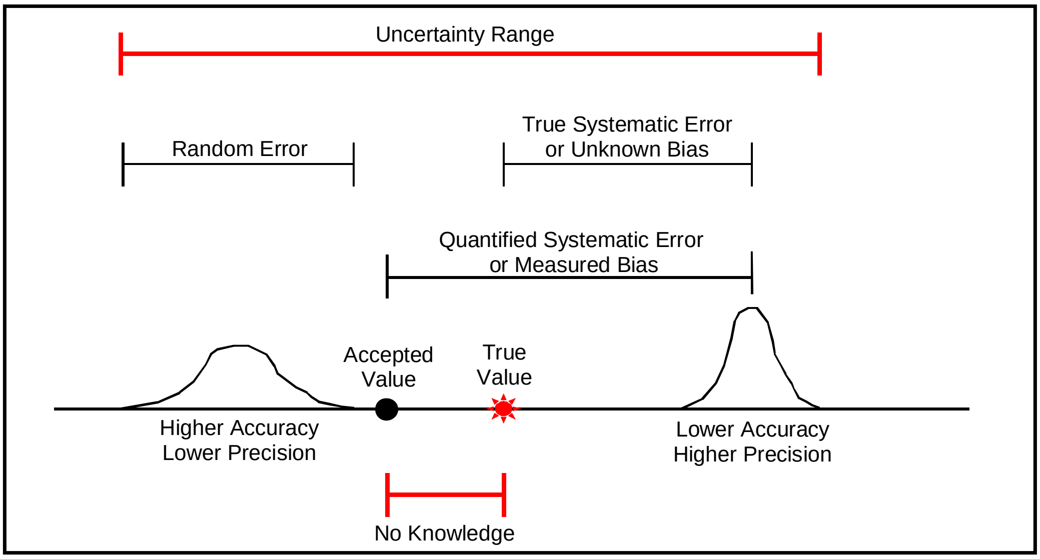

Figure 1. Concepts of uncertainty applied to two sets of measurements. (Source IIASA, 2000)

In addition, the following discussion points were raised regarding how science should deal with uncertainty:

- Do we have the adaptability or flexibility to absorb new political, technological and modeling developments?
- Are we able to deal with the different qualities of uncertainty?
- What are the acceptable levels of uncertainty scientifically and politically for verification purposes?

How participants specifically addressed ways that remote sensing can be used to deal with uncertainties in FCA is presented in Section 4.

2.1.2. USERS

Knowing for whom science is implementing FCA will assist in defining a purpose. At several times during the workshop, suggestions were made to focus on a specific user (e.g., Russia for a 10-year period) or a broader scope (e.g., Northern Hemisphere). The participants considered recommendations for a generic set of users from a broad to narrow scope: the socio-economic research community, the interaction of this community with policy makers, the previous specifically for the boreal forest, specifically for Russia and specifically for a particular region of Russia.

The Kyoto Protocol defines users on the project level. Therefore, "Kyoto-based users" would need to implement a FCA at the project (i.e., country or continent level). If the

FCA for Russia is used as an example, then this can only be accomplished using remote sensing as the information base for the account.

2.1.3 TERMS AND DEFINITIONS

The exercise of bringing together two scientific communities into a workshop setting only reinforced the need for clear and definition of terms as mathematical functions and classifications. In particular the participants indicated a need for clarification of requirements for FCA (an objective of the workshop!) from user groups, data requirements from the carbon community and priorities from both groups.

2.1.4. FUNDING (Cost effectiveness analysis)

In relation to funding, the participants posed the following research questions:

1. What are the marginal costs of a decrease in uncertainty?
2. What is the response to different management strategies keeping in mind carbon management strategies?
3. Do we need funding for the development of new sensor technologies?
4. How do we make sure that there are proper incentives for looking at C-accounting sources as well as sinks?

In addition, a relationship between the scale (spatial and temporal), acceptable uncertainty and effort of methodology application (funding) was expressed. This relationship can be visualized as a trade-off among these factors for which any research activity must position itself (Figure 2).

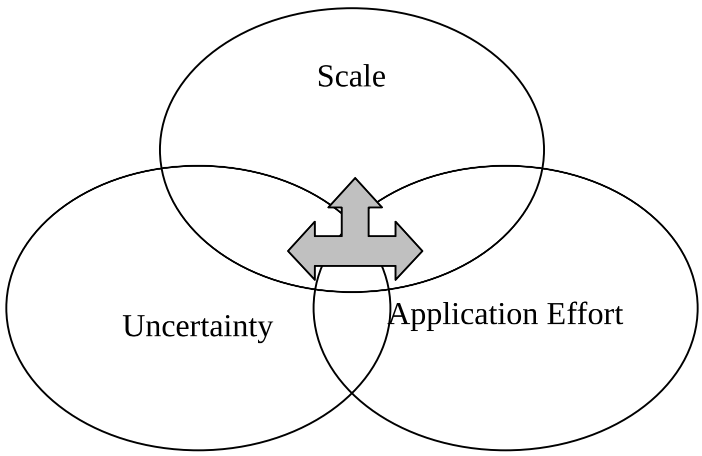

Figure 2. The trade-off among scale, uncertainty and application efforts for a hypothetical research activity.

2.2. PROCESS UNDERSTANDING

Understanding and describing processes (e.g., biophysical, socio-economic) at different scales was discussed many times during the workshop as a major objective. Participants listed this as a research prerequisite to specific methodological questions. In later sections we will discuss how specific processes were used as examples of how remote sensing can improve FCA.

2.3. METHODOLOGY

A variety of methods used in carbon accounting exist (e.g., stock-flux approaches, remote-sensing applications, flux measurements in situ, etc.). Evaluating, selecting and integrating these approaches to form an optimal methodology was identified as a research objective. We have subdivided methodology into models, observation networks and data. A more detailed discussion of methodology, system analysis of results and estimation of uncertainties followed in the second group session (see Section 3).

2.3.1. MODELS

Because models require data, one requirement is to review the data needed by models prior to starting collection of remotely sensed information. This review should evaluate technological innovations, harmonization and standardization among models and more general issues such as model assumptions and scaling.

2.3.2. OBSERVATION NETWORKS & VALIDATION

Observation networks are needed for model development and testing and validation. The participants noted that a strategic vision as how to link various existing and planned networks is required. Building on the evaluation of models to be used, these networks can be properly designed. Part of this requirement includes a review of existing networks and an analysis of missing scales of information.

2.3.3. MULTI-SOURCE DATA

Several research questions were raised regarding the use of multi-source data for FCA and these could be addressed in the following order:

1. How can existing data sets be used to get new valuable information?
2. How can we integrate all sources of data (e.g., ground, remotely sensed, historical and present-day and projected future accounting, etc.)?
3. How can remote sensing be used to up-scale or extend currently underutilized point data?

Additional considerations regarding data complexity, inherited and primary data, interpretation, standardization and access were also discussed as having importance.

2.4 SUMMARIZING WHAT IS REQUIRED TO IMPLEMENT FCA

We can summarize the relationship among the aforementioned issues in (Figure 3).

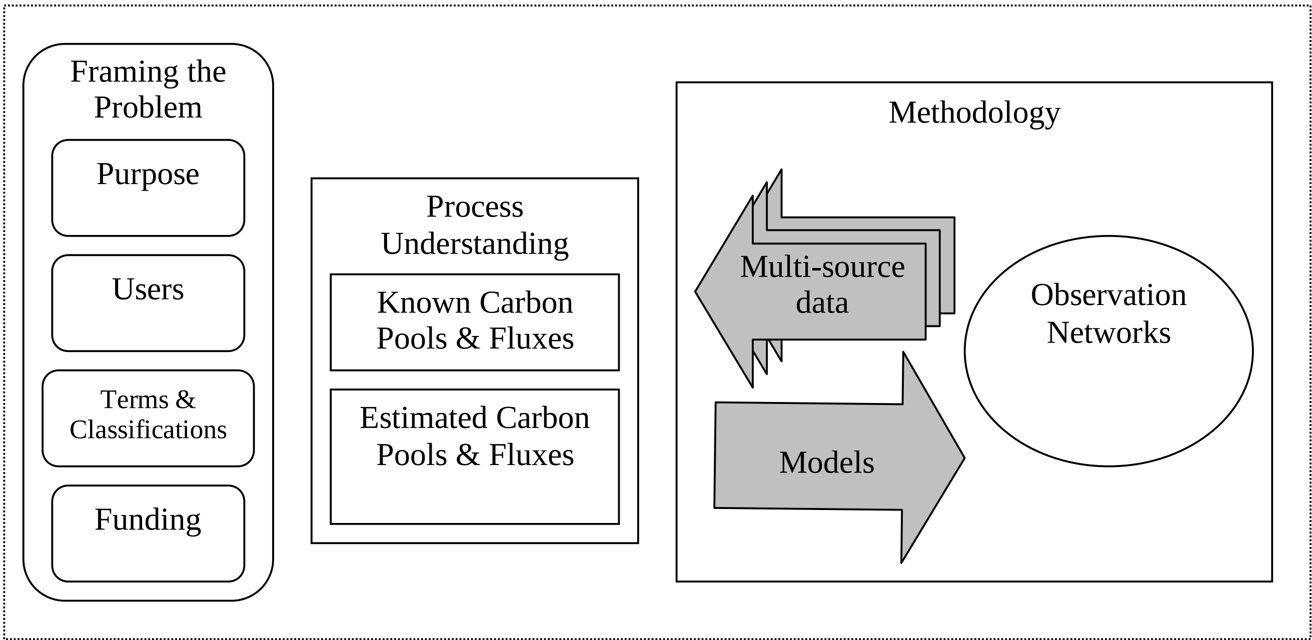

Figure 3. The relationships between requirements to implement FCA.

As mentioned earlier, different interpretations of FCA are possible depending on whether it serves to address a question from a political, decision-making or basic scientific research user group. Each of these user groups will thus have different requirements for implementing FCA (Table 1).

Table 1. User group-specific requirements for impementing FCA.

Requirement	Scientific (Remote Sensing)	Scientific (Carbon)	Decision Making
Purpose	Characterize carbon-relevant ecosystems and their dynamics	Accomplish FCA for at a sub-regional scale	Transfer scientific knowledge into policy recommendations
Terms and Definitions	Communicate data requirements and technical capabilities (accuracy and bias in measurement)	Communicate FCA requirements and scientifically acceptable levels of uncertainty	Specify political comfort levels of uncertainty
Process Understanding	Understand ecosystem dynamics and their remotely sensible characteristics	Understand carbon dynamics in terrestrial ecosystems	Describe the systems to lay-people

Requirement	Scientific (Remote Sensing)	Scientific (Carbon)	Decision Making
Models	To reduce uncertainty in characterizations of ecosystems (see section 4.1)	To reduce uncertainty in FCA.	Understanding and patience to support funding of long-term ecological research
Observation Networks	Link various existing observations in a compatible forms for exchange between user groups		
Multi-source Data	Complete acquisition coverage for multiple sensors	Create methods unifying data across spatial and temporal scales	

3. APPLYING REMOTE SENSING METHODOLOGIES

The second group exercise built upon the results of the first by asking participants, again divided into three groups, to "*identify what methodologies can be used to meet requirements of FCA*?" Discussions identified linking processes to models and models to observational data sets for various kinds of stocks and fluxes. Participants noted that priority should be placed on describing observations required to validate models and verify outputs, defining the spatial and temporal resolution of the observations listed above and addressing uncertainties (see next section). Some models were discussed as examples but a complete review of applicable models was beyond the scope of the workshop and this report.

3.1. AN OPERATION CHAIN

We can organize the operations involved in applying remote sensing to FCA into a chain that links processes that are modeled, to model-derived parameters, to remotely sensed indicators in the following categories:

- *Modeled Processes*: These are processes that must be estimated for FCA.
- *Model-derived Parameters*: These are intermediate measurement steps for estimating processes — they rely on input from remote sensing.
- *Remotely Sensible Indicators*: These are the indicators that can be directly measured using remote sensing (they may, however, require ancillary data to verify or calibrate. These parameters may be estimated for a single point in time or continuously monitored over time to determine rates of change for different processes. A variety of sensors were discussed — each applicable to a specific scale at which a process can be considered. A combination of sensors was proposed as most processes can be measured at multiple scales.

The arrangement of these categories is intentional (Figure 4). From left to right we have an order of thinking of processes to data, while right to left is the transfer of data required to drive models to help understand these processes.

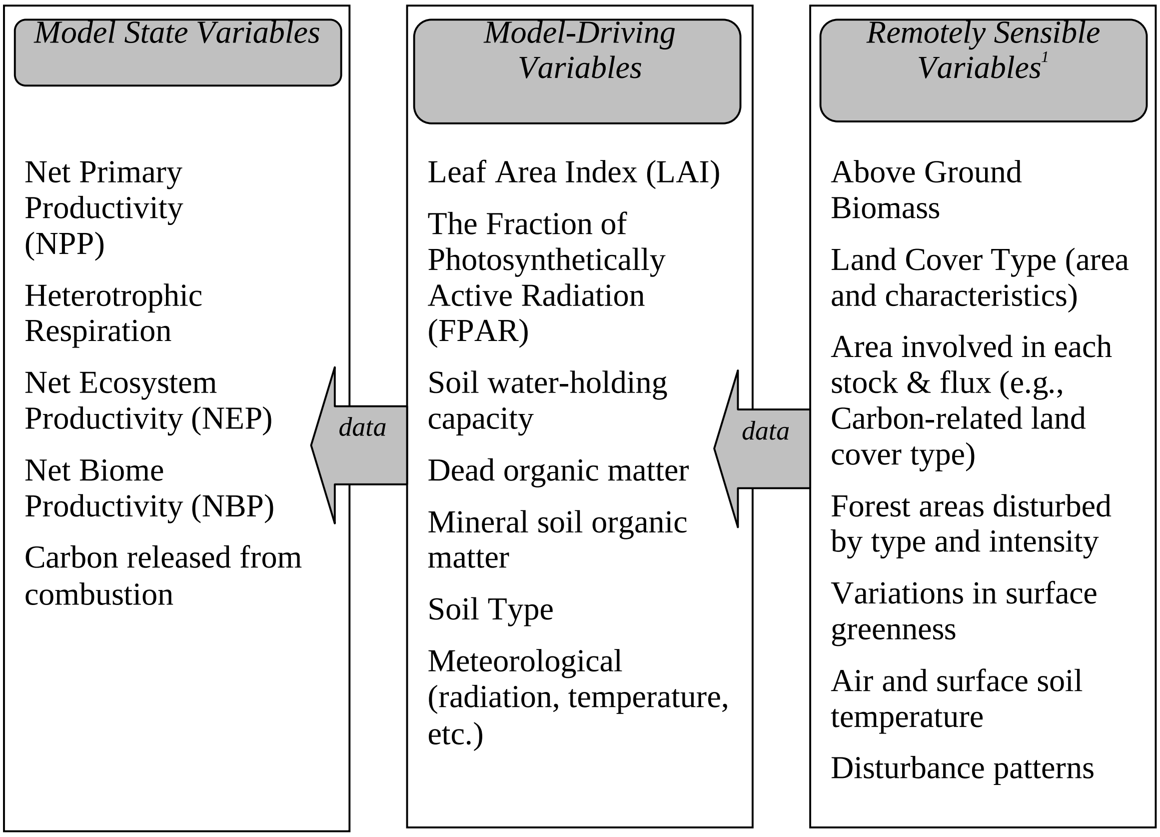

Figure 4. An operation chain for linking processes, models and remote sensing observations.

1) All existing ground reference could be incorporated into this category as an integrative land information system.

3.2 FACTORS AFFECTING THE OPERATION CHAIN

The participants identified a number of factors that influence the operation chain in Section 3.1 and should be considered when implementing remote sensing. This is not an exhaustive list of factors that should be considered, but rather a point of departure for further discussion. These factors are (in no particular order):

- climate and weather variability;
- human-induced land use changes (previous and current);
- other land cover transformation;
- natural disturbances (fires, insects, wind, etc.);
- the short-term fluctuations in current terrestrial carbon dynamics; and,
- the long-term interactions between C-cycle and ecosystems evolution/dynamics.

4. REDUCING UNCERTAINTIES

The final group activity asked the participants, divided into two groups, to explicitly describe "*How remote sensing can be used to reduce the uncertainties involved in FCA?*" Although this exercise built upon the research objectives and methodologies identified in the first two group exercises, participants reversed their thinking from the operation chain presented in Section 3.1 and considered remote sensing at the front of the chain. In this manner the focus of discussion was on how remote sensing could be used to deal with uncertainty.

4.1. UNCERTAINTY IN REMOTE SENSING

A general heuristic view of the relationship of remotely sensed information to a hypothetical model was useful in structuring the thinking of one of the groups' discussion on uncertainty (Figure 5). This illustration describes the chain from a remote sensing signal to different products that provide data to models — there is uncertainty related to every arrow. Participants were able to apply specific and general examples using remotely sensed products required to estimate carbon fluxes and stocks by viewing the chain in this manner.

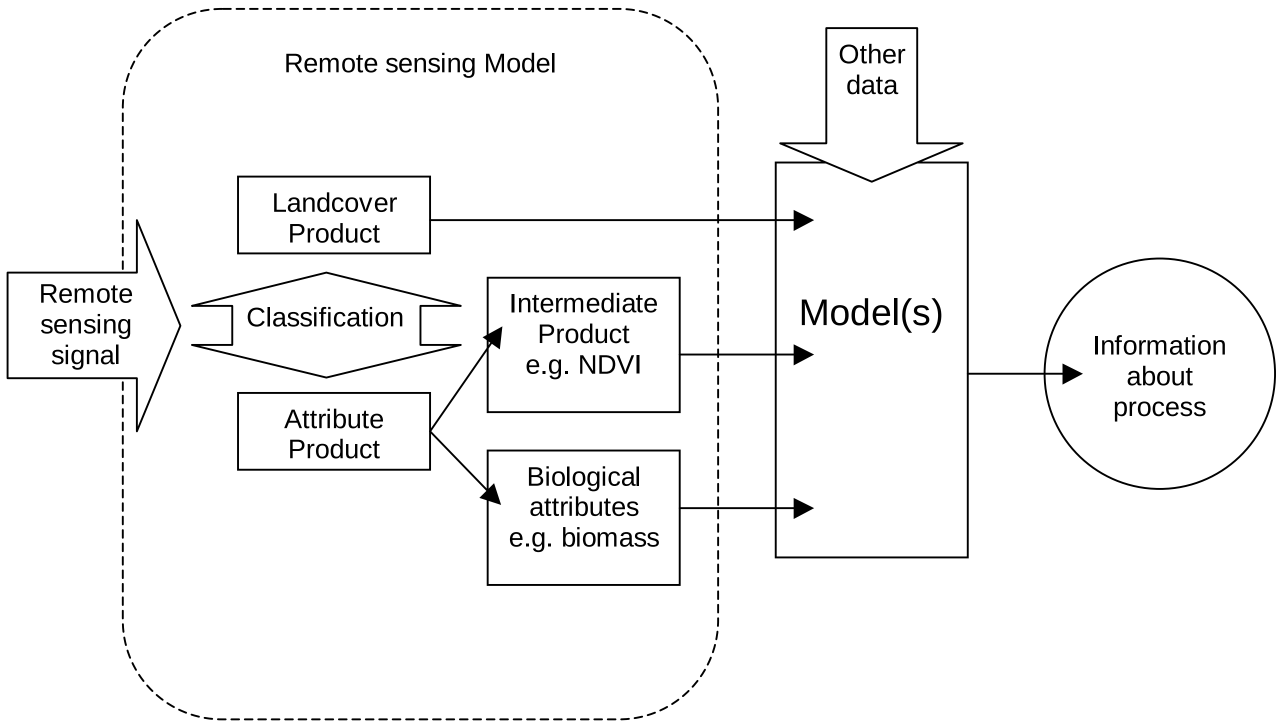

Figure 5. A general heuristic of the relationship of remotely sensed information to a hypothetical model.

4.2. CO_2 BURNING — A SPECIFIC EXAMPLE

A more specific example of calculating CO_2 emissions from biomass burning (Levine, 1994) was used to explore the concept of how remote sensing can be used to reduce uncertainty in FCA. The mass of burned biomass, M, is a key parameter in calculating the amount of CO_2 produced during biomass burning and released into the atmosphere. To calculate the mass of CO_2 produced, in units of mass of carbon, M must be multiplied by the average mass of carbon in burned biomass material (In general, 45% of biomass material is carbon by mass.) and the combustion efficiency, which is the percentage of carbon that is released in the form of CO_2 (In general, the combustion efficiency is 90%.). In this example, the participants used the formula for the mass of burned biomass:

$$M(x,y)= [A(x,y)+/-0.2A] * [B(x,y,t) +/-0.3B] * [E(x,y,t) +/-0.2E]$$

Where:

M - Mass of burned biomass

A - Area burned in a particular ecosystem

B - Average biomass material per unit area

E - Burning efficiency

In this equation, *A* is measured directly using remote sensing and thus is strongly dependent on remote sensing accuracy. *B* is currently a constant based on ground samples from ecosystems. *E* is also a constant that is process/state dependent and will have error.

Each variable in the above formula has a relative uncertainty and the group evaluated how current remote sensing technologies are used to calculate *M* and how possible future remote sensing technologies might be used to reduce uncertainty (Table 2). The best improvements for reducing the uncertainty for measuring this flux would come from improved estimates of the area. The estimation of *B* may be improved though a combination of resolving landcover using remote sensing and finer derivation of the biomass coefficient.

Table 2. How current and future remote sensing technologies can be used to reduce uncertainty.

Variable	Current Remote Sensing	Possible Remote Sensing	Uncertainty Reduction
A	High resolution satellites (damage assessed according to classification)	Finer spatial resolution with increased temporal frequency	Improved resolution *should* provide more accurate disturbance delineation

Variable	Current Remote Sensing	Possible Remote Sensing	Uncertainty Reduction
B,E	Currently a constant (only in this example -- remote sensing approaches have been used to estimate B and E (Kaisischke *et al.*, 2000)	1. Change in biomass (before and after disturbance) could be calculated using SAR, LIDAR with SAR, etc. 2. Fire spread models (usually driven by remote sensing data) 3. Direct measures	1. Check against constant that *might* reduce uncertainty. 2. Increased information *might* reduce uncertainty. 3. See 1.
M		Direct measurements of smoke plumes	Direct measurement of CO_2 levels

4.3 OTHER CARBON FLUXES

A more general approach was taken to describe how remote sensing could be used to assist in reducing the uncertainties of other fluxes. The participants did not attempt to prioritize these fluxes and a next step will be to complete this task (see Section 5).

4.3.1. SOIL CO_2 AND CH_4 RESPIRATION

Soil CO_2 and CH_4 respiration requires the estimation of the extent and condition of land use/land cover classes, in particular wetlands. Inter- and intra-seasonal variations of factors driving soil respiration and productivity need to be monitored, including soil temperature and moisture and. The participants suggested increased use of RADAR and thermal scanners in combination with RADAR and LIDAR technologies for direct measuring or modeling these variables.

4.2.2. DISTURBANCES

Disturbance information relevant for FCA includes location, extent, timing, type, intensity or severity and area with attention paid to scale, methodological consistency and operability. Proposed techniques included increased use of radar technologies and LIDAR as well as stratified random sampling with multi-scale and multi-level sensors (e.g., AVHRR, Landsat 7 and IKONOS).

4.2.3. AGRICULTURE

Agricultural issues affecting the uncertainty of FCA include production status, livestock, land-conversion effects and inventory updating. Suggested use of remote sensing for reducing uncertainty includes yield modeling, multi-stage sampling with multi-scale optical sensors and indirect measurement of crop production.

4.2.4. NET PRIMARY PRODUCTIVITY (NPP)

NPP for disturbed and undisturbed areas is estimated using models that require a suite of variables. Some variables that are required for non-disturbed areas that can be estimated using remote sensing include leaf area index (LAI), above ground biomass, surface and air temperature.

LAI is one half the total green leaf area (all sided) per unit ground surface area (Chen and Black 1992). Together with the Fraction of Photosynthetically Active Radiation (FPAR) absorbed by vegetation canopies, they are key variables in most ecosystem productivity models, and in global models of climate, hydrology, biogeochemistry and ecology. These models attempt to describe the exchange of fluxes of energy, mass (e.g., water and CO_2), and momentum between the surface and the atmosphere. LAI and FPAR products can be retrieved using models to interpret data from the Moderate Resolution Imaging Spectrometer (MODIS) and other sensors of varying resolution.

Standing biomass information can be provided using RADAR and LIDAR systems. Information from optical sensors, specifically the ratio of near infrared (760-900 nm) and red (630 to 690 nm), has been correlated foliage for crops, range lands and forests. Surface temperature also can be measured using thermal IR channels of various sensors (e.g., TM7, AVHRR, MISR, MODIS). Time-series radar data can provide information on relative soil moisture variations in disturbed regions.

5. NEXT STEPS: WHAT IS IIASA LOOKING FOR?

Our first action item is to present the results of this workshop to the carbon and remote sensing communities. We list some of these initiatives in Appendix 4, recognizing that this is a list that should be expanded as the results of this workshop are disseminated[1].

Throughout the workshop participants repeatedly said that this was too large a task to start from scratch and that IIASA should look at existing initiatives. Indeed this is a large task and IIASA believes that it should be followed up as a research task in itself. In particular, the needs and products of other initiatives should be examined and synergies identified.

5.1. WHAT IIASA CAN OFFER

To conclude, IIASA is capable of making a strong contribution to existing and/or future carbon and remote sensing research initiatives. Specifically, we can offer:

- Our experiences from our long-term involvement in Russia
- Introduction to our Russian network;
- Access to our unique database (http://www.iiasa.ac.at/Research/FOR/dbdoc/) and ground reference information (http://www.iiasa.ac.at/Research/FOR/siberia/);
- Our experiences from the existing most-detailed Full Carbon Account for Russia;

[1] In particular, we heard that IIASA should contact the hydrological and inversion modeling communities.

- Verification expertise and a systems analytical background across multiple scales (e.g., Jonas *et al.*, 1999); and,
- Hopefully, access to data through a new receiving station for Landsat 7 data in Russia.

5.2 WHAT IIASA WILL DO IN THE SHORT-TERM

In the near future, IIASA will take the following steps in order to keep momentum in this initiative:

- Disseminate this report, our report on Full Carbon Accounting of Russia, and our verification work to stakeholders in the international remote sensing and carbon communities.
- Start a dialogue with these international stakeholders in order to set priorities on issues to work with.
- Based on this priority-setting try to establish an international consortium to solve the prioritized issues.
- IIASA will continue to work on establishing a Landsat 7 receiving station in Russia.
- Finalize and evaluate the ongoing activity "SIBERIA" with respect to radar imaging and disseminate the results to the stakeholder group.

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APPENDIX 1. PRESENTATION ABSTRACTS

Siberia Forest Mapping and Monitoring

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The development of a system of forest monitoring based upon intensive use of Earth observation techniques and the establishment of a comprehensive and permanent forest information system is being initiated. The acquisition of data provided by satellite sensors offers a unique opportunity to update existing maps and to develop a monitoring system attuned to the particular conditions met in Siberian ecosystems. Emphasis will first be put on the continental and regional scales using a range of data sources compatible with the geographical extent of the territory. Low and medium resolution satellites will provide the blanket background coverage. An attempt will be made to estimate the Net Primary Productivity of the Siberian forests from time series of coarse resolution satellite imagery (such as SPOT4-VEGETATION). Existing bio-physical models will be tested and the most accurate/efficient will be selected. Field measurements of carbon fluxes (from the EUROSIBERIAN CARBONFLUX experiment) will be 'spatialised' to the level of a remote sensing satellite scene and the results will be used as input data for the models.

Mapping NPP and NEP using the Boreal Ecosystem Productivity Simulator (BEPS)

Jing M. Chen, Josef Cihlar, Jane Liu, Wenjun Chen, and Yuying Ou

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BEPS now consists of two components: one for net primary productivity (NPP) estimation and the other for net ecosystem productivity (NEP) estimation. The NPP component is developed based on Forest-BGC with several modifications. The NEP component is a combination of the Century model for soil carbon and nutrient dynamics and the Farquhar model for the canopy photosynthesis in annual time steps after a spatial and temporal scaling scheme. The major modification to the NPP model is the development of a process-based daily canopy NPP model with sunlit/shaded leaf separation after an analytical daily integration of the Farquhar model. This new model avoids problems of the original big-leaf model and has been validated using two-level CO2 tower flux data. The NEP model was developed to describe the long-term effects of disturbance (fire, insect, harvest) and non-disturbance (climate warming, CO2 concentration, N deposition) on forest carbon cycle and to simulate post-disturbance dynamics of various carbon pools in vegetation and soil. In this presentation, we will provide an overview of these models as well as Canada-wide products of leaf area index (LAI), landcover, NPP and NEP using satellite (AVHRR), 100-year climate, inventory and tower flux data. The focus of the presentation will be on NPP model development and validation.

Terrestrial Carbon Initiative: a strategy for assessing terrestrial carbon

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An accurate knowledge of the terrestrial component of the global carbon cycle has become a policy imperative for this and the forthcoming decades, both globally and for individual countries. The various global or regional activities concerned with carbon depend on accurate and objective information about the state and changes in various components of the terrestrial C cycle. Because of the many interacting factors affecting this cycle both above and below the soil surface, such information must be obtained frequently and with a high spatial resolution. To consolidate and systematize the numerous global observation activities aimed ad terrestrial carbon, there is a need to agree on the observation and modelling requirements; to achieve harmonization among the main relevant projects and activities that can contribute to a global observing 'system'; and to identify gaps and ensure their resolution.

Recently, the Global Terrestrial Observing System (GTOS) announced the launching of a Terrestrial Carbon Initiative (TCI) aimed at developing a coordinated international response to improve scientific understanding of the role of terrestrial carbon sources and sinks. The initial planning has been led by the Terrestrial Observation Panel for Climate (TOPC). In this presentation, the background and motivation leading to TCI will be elaborated upon. The concept and vision for TCI will be described, and work carried out to date as well as the plans will be reported. For successful implementation, TCI will require high degree of international collaboration among diverse scientific groups, various measurement techniques and associated models, and various national and international organizations.

Spatial Databases for the Russian Full Carbon Account

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Unique spatial databases have been developed by the Sustainable Boreal Forest Resources Project to support the Russian full carbon budget case study. These databases are based on ecosystem principles and are comprehensive in their spatial coverage for Russia. The GIS environment allows us to estimate carbon-components of individual vegetation-soil combinations and to make interesting comparisons with other carbon-related datasets. This presentation will describe the database characteristics, the integration methods used and requirements for future enhancements.

Ecosystem Modeling and Remote Sensing: Application to Carbon Accounting

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Ecosystem models are the only practical way to estimate carbon fluxes over large areas (regional to global scales). Such models must be "parameterized" with field measurements and "driven" with data representing temporally varying conditions such as weather. In most cases the parameterizations are categorical representations of species, plant functional type, or land cover class, as derived from a limited set of field measurements. These are typically insufficient to ensure the validity of the modeled fluxes across a broad range of conditions. Satellite observations can provide spatially and temporally varying data needed to drive ecosystem models. Recovery of land surface environmental variables using satellite remote sensing has advanced rapidly in recent years. It is now possible to map land surface temperature, air temperature, atmospheric humidity, and soil moisture at high resolution (1 - 64 km2) with a reasonable accuracy. Biophysical variables such as canopy light absorption and biomass can also be accurately mapped, leading to innovative methods to model and monitor photosynthesis and net primary production without recourse to land cover classification or parameterization. Results of one such model are discussed in the context of carbon accounting.

Multivariate Spatio-Temporal Clustering as a Basis for Detecting, Monitoring, and Verifying Regional and National Changes in Forest Carbon

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National and international carbon-accounting protocols will necessitate new, objective techniques for the fair and repeatable initial estimation and subsequent changes in pools of organic carbon, particularly carbon in forests. National or regional-scale carbon accounting is complicated by transformations of carbon that occur as mature forest is harvested, clear-cut, or burned, and as young forests are planted to offset these carbon debits. Changes in forest carbon storage can result from natural disturbances, ecological changes, anthropogenic forces, or sociopolitical decisions.

We have developed a technique called Multivariate Spatio-Temporal Clustering (MSTC), which can unambiguously delineate and track particular combinations of characteristics or conditions, both through time and across space, through a chronological sequence of remotely-sensed images. Characteristics can include ground-based direct measurements of ecological conditions as well as remotely-sensed spectral reflectance values. An entire time sequence of multivariate images will be processed in a single pass using a change-detection algorithm running in parallel. The proposed parallel algorithm is required for efficiency, but is portable to most parallel architectures.

Using a geographically-based multivariate clustering approach, MSTC will identify unique clusters across all maps in the sequence. The total number of clusters produced is selected by the user. A single cluster represents the same combination of conditions wherever or whenever it is found. Thus, a mix of spectral/ecological combinations representing a young, newly-planted forest can be automatically delineated and measured, as can the changes in its location and acreage through time. This tracking will allow a complete accounting of estimated total forest carbon at each point in the chronological sequence, along with estimates of the change in carbon standing stocks due to natural events, economic activities, and political policies. Carbon standing-stock will be estimated for each unique clustered combination, permitting an estimate of total forest carbon for any area at any single point in time. Although these equivalency factors will be subjective estimates based on expertise, the delineation of the unique cluster combinations will be objective, and thus have potential to be apolitical. Additional remote-sensing images can be added to the initial chronological sequence for re-analysis and accounting in future periods.

An MSTC-based carbon change-detection and accounting procedure, as a politically and economically objective and defensible tool, may offer an attractive solution to the problem of tracking regional and national-scale carbon policies.

Basic Requirements for Remote Sensing to Determine Net Atmospheric Carbon Fluxes

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This presentation is based on the IIASA Interim Report Verification Times Underlying the Kyoto Protocol: Global Benchmark Calculations (IR-99-062; available on the Internet). The presentation provides a physical background for the application of RS and other tools in accomplishing Full Carbon Accounting (FCA) and in achieving one of its important goals, the determination of net carbon fluxes into or out of the atmosphere over a range of spatial and temporal scales. Specifically, it looks at:

- FCA (in contrast to partial carbon accounting) and the underlying problems of spatial and temporal scales; and
- •concepts of favorable and unfavorable verification, which permit us to deal with uncertainties underlying carbon accounting, now and in the future.

The examination of these issues leads to basic requirements on RS to determine net carbon fluxes into or out of the atmosphere.

Biomass Burning and Global Change: The Role of Biomass Burning on Global Carbon Accounting

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The burning of living and dead biomass or vegetation for land-clearing and land-use change is a significant global source of carbon, mostly in the form of carbon dioxide, to the atmosphere. The bulk of this burning (90%) is believed to be human-initiated. In addition to being a source of carbon to the atmosphere, burning has another very significant impact on the global carbon cycle. Burning of living biomass results in the loss of a significant global carbon sink, i.e., the sequestering of carbon dioxide in the biosphere via photosynthesis.

The current state of knowledge of biomass burning as a source of atmospheric carbon will be reviewed. There are uncertainties in our understanding of the role of biomass in the global budget of carbon. Uncertainties include the total area burned and the amount carbon released into the atmosphere per unit area burned. For example, estimates of the annual area burned in the world's boreal forests range over an order of magnitude from 1.5 to 14.4 million hectares (1.5 million hectares (Seiler and Crutzen, 1980), 8.0 million hectares (Stocks, 1991), and 14.4 million hectares for the 1987 fires in Eastern Asia only (Cahoon et al., 1994)). In addition, estimates of carbon released from boreal forest fires range over an order of magnitude from 11.3 to 33.2 tons of carbon/hectare (11.3 tons of carbon/hectare (Stocks, 1991), 28.8 tons of carbon/hectare (Kasischke et al., 1995) and 33.2 tons of carbon/hectare (French et al., 1996)). Depending on which set of values are used in calculations, the carbon released into the atmosphere from boreal forest fires ranges from 16.95 million tons to 4778.08 million tons, a factor of 28 difference! The remote sensing of global fires offers an opportunity to narrow the uncertainties.

Calculations indicate biomass burning may supply as much as 3500 Tg of carbon in the form of CO2 on an annual basis (Andreae, 1991). This represents about 40% of the global production of CO2 (fossil fuel combustion plus biomass burning).

Integrating Information Across Spatial Scales

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The fluxes or levels of terrestrial carbon cannot be directly using satellite remote sensing systems, but only inferred through the use of relating surface characteristics of the vegetation/land surface to the parameters of interest. Flux processes (e.g., net primary production, soil and plant respiration, emissions from biomass burning) are typically measured at very small spatial regions or short time periods and then extrapolated over time and space using appropriate models. A number of approaches have been developed to achieve these extrapolations by directly relating the flux rates to spatial and temporal characteristics of the land surface measured using satellite remote sensing systems.

In this presentation, we will explore some the scaling issues associated in using satellite observations to estimate carbon emissions from fires in boreal forests. We will use this topic area to illustrate scaling issues associated with extrapolation of field observations to landscape, regional, sub-continental and eventually continental scales using satellite observations.

RADARSAT Data & Mobile Computer Application for Depletion Monitoring in Situ

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RADARSAT capability of imaging the Earth through clouds and in darkness is recognized as a great advantage for depletion monitoring of boreal forests. Canadian International Development Agency (CIDA) under the framework of Technical Assistance Program in collaboration with HGI company and ARICFR gives an opportunity to demonstrate the availability of geomatic technologies including GPS, GIS and RADARSAT computer analysis for Russian forestry. The objective of the ongoing pilot project in Russia is to adopt new technologies for field operations. The pilot area with depletion caused by harvesting, agriculture and settlements is located in Kosroma region that is approximately 500 kms northeast from Moscow.

Canadian partners involved RADARSAT data and mobile computer technologies into the project. Standard beam mode 7, ascending orbit RADARSAT image was acquired for pilot area on December 4, 1997. HGI company developed the special technology focused on application in forestry, agriculture and environment monitoring. This technology named Mobile Technical Office consists of mobile computer integrated with Global Positioning System (GPS) receiver and wireless communication modem.

Russian partners of the project provided digital topographic map and forest data. Combining all information sources field measurements have been conducted for recognizing forest depletion and updating forest data in Kostroma region this summer. Supervised classification of RADARSAT data became possible due to field observation and collecting the control points in situ.

The Role of Remote Sensing in FAO's Land Cover Change Assessments

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FAO has undertaken a number of national land cover and change assessments using remote sensing data, for instance for Afghanistan, Albania, Bhutan, Cambodia, Indonesia, Myanmar, and other member countries. This presentation focuses on the remote sensing component of FAO's global Forest Resources Assessment (FRA) programme, where high resolution data are being used on a sample basis to assess the present state of tropical forest cover and its changes since the late 1970'ies. 117 samples of the size of a Landsat scene (about 10% of the area of the tropical belt) have been and are being analyzed for the reference years 1980, 1990 and 2000. It is planned to increase the monitoring cycle to 5 years. The sampling design allows compilation of forest cover change statistics at regional and global level as well as an estimation of biomass fluxes associated with such changes, which could be considered as an important component for global carbon cycle modelling. The approach used for FRA can be easily extended to include also other land cover types. The statistical component of FRA collects and analyses statistical data available from national forest inventories for the entire globe.

Article 3.3 of the Kyoto Protocol: Information needs for afforestation, reforestation, and deforestation

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The Kyoto Protocol establishes in Article 3.3 that carbon stock changes during the 2008-2012 commitment period resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation (ARD), shall be used to meet the emission reduction commitments established by the Protocol. The Intergovernmental Panel on Climate Change (IPCC) has been asked to prepare a special report on land-use change and forestry in the Kyoto Protocol. One of the tasks is to provide information that can aid policymakers in implementing Article 3.3. Issues to be clarified include: - which definitions should be used for terms like forest, afforestation, reforestation, deforestation or direct human-induced? - which carbon accounting rules should be employed? - what are the data needs to implement Article 3.3, and how can these data be obtained? - how much carbon mitigation can be achieved through these activities at various scales (stands, landscapes, regions, global) and what is the amount of credits and debits that are likely to be generated under Article 3.3 of the Kyoto Protocol? Chapter 4 of this IPCC special report combines definitions into so-called "definitional scenarios" which are sets of internally consistent definitional components. The definitional scenarios describe a range of viable definitional options under the Kyoto Protocol. They are assessed with respect to criteria like: consistency with the objectives of the UNFCCC, simplicity, ease of using existing data, applicability for future commitment periods, applicability in all major regions of the world, and ability to close accounts in 2012. There is only a limited number of definitional scenarios that fulfill such key criteria. Information needs under Article 3.3 are likely to be on two issues: Area-related information to determine which lands qualify as "ARD lands" and stock-change related information. Depending on whether a wall-to-wall analysis, or a statistical approach is applied, the cost of obtaining data will differ. Except for a very simplified approach relying on default data, it is expected that the information required for implementing Article 3.3 will have to be georeferenced.

Radar Opportunities: The SIBERIA Project

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The aim of SIBERIA (SAR Imaging for Boreal Ecology and Radar Interferometry Applications) is to generate valuable information about the state of Siberian forests for dedicated Russian customers based on state-of-the-art satellite data and remote sensing techniques. More specifically, the objectives are 1) to demonstrate the capabilities of microwave remote sensing for monitoring criteria and indicators for sustainable development, and 2) for retrieving information needed for reliable estimations of economic, ecological and social roles of Russian forests under transition conditions. Direct interaction with potential customers of such information is given through the participation of IIASA and institutions from the Russian forestry sector in the project.

SIBERIA uses the advantages of dual-frequency, interferometric, and multi-temporal SAR products from the ERS and JERS missions. Thanks to a recent international effort, that ensured the systematic acquisition of ERS and JERS imagery plus ERS-Tandem images over Siberia, these data became available. The results so far suggest that the ERS coherence and the JERS amplitude are the most important parameters for forest and land cover classification. Using ERS data alone, it is in general possible to distinguish forests from burnt forests, clearcut areas, and other land cover classes, but the separation of forest classes cannot be achieved. Therefore IIASA and their Russian partners have outspoken their concern that the derived products may not be useful at an enterprise level. However, the capabilities of radar to generate reliable baseline maps are acknowledged - or on a regional scale much appreciated. Also, it remains to be investigated how much JERS SAR can contribute to the project's aims.

The Application of Remote Sensing to Modeling Boreal Forest Dynamics

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Ecological modeling is an interactive processes involving data assimilation, model/data comparison and model improvement. Current challenges (such as the potential effects of climate change, carbon dioxide enrichment, changes in nitrogen deposition and changes in spatial pattern of the boreal forest) all involve developing classes of models able to predict forest response under novel conditions. Ultimately the credibility of such models will rest on their successful testing against a wide range on environmental conditions. It is our contention that understanding boreal forest dynamics will ultimately depend on interacting a hierarchy of models at the plant process, stand and landscape level. The challenge of predicting direct and indirect carbon dioxide enhancement effects and the challenge of combining process models with models capable of simulating the structural and spatial change of forests mitigate for such a hierarchical approach. Since other presenters will discuss the process model cases, we present example simulations from models capable of projecting the effects of and changes in structural heterogeneity. These models also produce output attributes that can potentially be tested against remotely obtained data.

NBP, NEP, NPP, Plant Organic Pools and the Carbon Budget of Terrestrial Biota: System Requirements and Linkages to Remote Sensing

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Minimizing uncertainties is the major goal of current carbon budget science. The full carbon budget (FCB) is a fuzzy system, inherently stochastic by nature. Thus, any separate method cannot be estimated as "optimal", rather an integrated system of all appropriate methods should be used to meet this goal. Based on our research experience, identifying the accuracy of NBP, NEP and NPP and their interconnected indicators (phytomass, dead plant organic and soil organic pools, etc.) is the crucial prerequisite for reliably estimating summarized carbon fluxes. Remote sensing (RS) -based systems are an obligatory "additionality" of the FCB for Russian vegetation because "on-ground " determination of NBP, NEP and NPP in itself cannot satisfactorily operationalize the FCB. This presentation considers, in the framework of the Russian Carbon Case Study: •The system and accuracy requirements for estimating bioproductivity indicators at national and regional scales,• Linkages to existing and future RS systems, and Applying RS for regional hybrid models of ecosystem dynamics as a main tool for elaborating current and future carbon budgets of terrestrial ecosystems.

Land Use in the Full Carbon Account Approach

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The Kyoto Protocol states that biological sources and sinks should be used to limit or reduce the emissions of greenhouse gases. Land use (LU) change including afforestation and reforestation has been identified as a major mechanism to manipulate sources and removals to achieve this goal (UNFCCC, 1998). Conceptually, LU comprises bio-physical and socio-economic domains. This wide interpretation creates a great deal of uncertainty and makes the LU implementation hard to complete. In fact, currently there is an intensive debate on whether or not carbon in soils should be accounted.

The presentation is centered on the approach to incorporate LU into the Russian Full Carbon Account (FCA) that has been developed by the IIASA Sustainable Boreal Forest Resources Project. The examples are used to identify the necessarily "niches" for the implementation of the Remote Sensing data.

We conclude that no existing information systems can be used to address the complex and multi-discipline nature of FCA. As for many other present-day environmental problems, an appropriate solution could be based only on new advanced information system technologies that urgently need to be developed.

Remote Sensing Methods in Forest Management in Russia

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Remote sensing technology is the technical basis for Russia forest inventory and assessment. Of the 1,111 million hectares of Forest Reserve, 685 million hectares were inventoried by application of aerial photos and ground survey (this was done from 1 to 20 years ago); 330 million hectares were surveyed by application of photo statistical method using space photos with 5 - 10 m of ground resolution (this was done during 1978 - 1998); and the remaining 91 million hectares were surveyed by aerial reconnaissance from planes in the 19050's. At the end of the 1980's, 60 million ha of forest were inventoried annually, including 40 million hectares of repeatable survey. Currently, this is reduced to 30 - 35 million hectares. False color aerial photos, at 1 : 10,000 - 1 : 15,000 scales were used in the 1960's in field work and photo interpretation. Forest inventory was simplified in the 1990's and, because of economic reasons, aerial survey was conducted at scale 1 : 40,000 - 1 :60,000, with photos enlarged 2 - 4 times for forest mapping, the volume of field works was reduced, and the use of space photos ceased. All of this decreased of quality of forest inventory.

In the late 1970's, a new technology was developed for assessment and mapping all changes in forests on the basis of application of space photos with ground resolution from 5 m to 150 m, depending on the requirements of accuracy. This information provided the renovation of data on forest stock inventory. This survey was conducted on the area of 650 million hectares in 70 - 80 years. New technologies of forest surveys were developed and tested in eighties, including: inventory of forest and shrub vegetation in the desert, small scale thematic forest mapping, inventory of protective forests in the regions poor in forests, control of forest exploitation, control of forest status in the areas of oil and gas industry etc. The manual of forest protection from fires was prepared in the mid-seventies. But the main part of these methodologies were not widely used because of economic difficulties and conservatism of forest administration. The situation with application of aerial and space photos in forestry is critical in these days. These photos are used for practical purposes in small extent. Scientific investigations on this problem are conducted in minimum. But the situation is a little better in the institutes of Russian Academy of Sciences, for example, in Forest Institute of Siberian Branch, in Center on Problems of Ecology and Productivity of Forests and some others. The investigations conducted here include the application of scanning information in forestry, especially in forest management (SPOT, Landsat, AVHRR, MSU - E, MSU - SK), radar information (SIR RADARSAT, ERS, JERS) and other materials, including that obtained by national security agencies and new GIS technologies. Some other issues focus on protection of forests from fires, desertification in the arid zone, and the study of carbon cycle.

The Relationship Between Siberian Subarctic Tree-Rings And NDVI

***M.K.Hughes*[1], *F.Biondi*[2], *E.A.Vaganov*[3]**

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NDVI data are generally found to be well correlated to: a) fraction of photosynthetically active radiation (400-700nm) absorbed by green vegetation (Asrar et al, 1984); b) and time integral of NDVI which is a good predictor of biomass production (Tucker, 1980; Price, 1991) and carbon fixation (Fung et al, 1987). The report of a large-scale increase of NDVI in high latitudes is of interest: May-September NDVI increases over that decade (1981-1990) and there are changes in timing (Myneni et al, 1997). The increase in high latitude NDVI is supported by changes in carbon dioxide flux. It is hard to answer what is the significance of these changes and caused them, and is this «early greening of the North» a consequence of global warming and driven by climate because the NDVI record is so short (good records from 1981-1999 are just becoming available).

We suggest using tree-rings to support NDVI data because tree-ring width tracks early summer temperature in high latitudes well (correlation up to 0.84). The spatial-temporal analysis of relationship between tree-ring index and NDVI is a focus of study. Preliminary calculations show that mean June NDVI, for example, is significantly correlated with tree-ring width index in sites near northern timberline ($r>0.5$). Correlation between tree-ring indices and NDVI are spatially coherent over hundreds to thousands kilometers over much of Siberia. The correlation maps confirm that there is a relationship between tree-ring width index series and mean June NDVI, not only locally, but over rather large distances. The observed short-term trends in NDVI in selected territories during the last two decades are confirmed by longer variations in basal area increment of trees which is more adequate parameter of biomass accumulation in woody component of ecosystems. Increasing trend in basal area increment occurs in sites near northern timberline whereas trees in northern and middle taiga zone show decreasing trend in basal area increment during the last century. The perspectives and research objectives in application of NDVI data to annual growth variability will be discussed.

APPENDIX 2. AGENDA

Day 1. Thursday, December 9th, 1999

Time	Place	Session	Agenda Item	Speaker(s)	Topic
8:00	Bus from hotel to IIASA				
9:00	Wodak Room	Opening Plenary	Welcome	MacDonald	Welcome
9:10			Introduction	Nilsson	The Research Challenges
9:20				Gluck	General Information
9:30		Presentation Session #1. Total Information Requirements of Carbon Modeling.	Presentation	Cihlar	Terrestrial Carbon Initiative: a strategy for assessing terrestrial carbon
9:50			Presentation	Sukhikh	Remote Sensing Methods in Forest Management in Russia
10:00			Presentation	Jonas	Basic Requirements for Remote Sensing to Determine Net Atmospheric Carbon Fluxes
10:10			Presentation	Shvidenko	NBP, NEP, NPP, Plant Organic Pools and the Carbon Budget of Terrestrial Biota: System Requirements and Linkages to Remote Sensing
10:20			Presentation	Malysheva	RADARSAT Data & Mobile Computer Application for Depletion Monitoring In Situ
10:30			Question Period		
10:40	*Coffee Break*				
10:50	Wodak Room	Presentation Session #1 (con't)	Presentation	Schlamadinger	Article 3.3 of the Kyoto Protocol: Information needs for afforestation, reforestation, and deforestation
11:00			Presentation	Reichert	The Role of Remote Sensing in FAO's Land Cover Change Assessments
11:10			Presentation	Gluck	Spatial Databases for the Russian Full Carbon Account.
11:30			Question Period		
11:45	*Lunch in Schloss Restaurant (Green Coffee Room)*				
13:15	Wodak, Forestry & Raiffa Rooms	Group Activity #1. What is required to implement full carbon accounting?			
15:30	*Coffee Break*				
15:45	Wodak Room	Group Activity #1 (con't). Group Reports (30 min each)			
17:15			Wrap Up	Gluck	Logistics
17:30	Meet at Front Entrance - Bus to Heuriger at Benediktiner Hof in Gumpoldskirchen				

Agenda Day 2. Friday, December 10th, 1999

Time	Place	Session	Agenda Item	Speaker(s)	Topic
8:00	Bus from hotel to IIASA				
9:00	Wodak Room	Presentation Session #2. Capabilities of Remote Sensing to provide Information -- Integration Examples	Wake Up	Gluck	
9:10			Presentation	Vaganov	The Relationship Between Siberian Subarctic Tree-Rings And NDVI
9:30			Presentation	Achard	Siberia Forest Mapping and Monitoring
9:50			Presentation	Chen	Mapping NPP and NEP using the Boreal Ecosystem Productivity Simulator (BEPS)
10:00			Presentation	Shugart	The application of remote sensing to modeling boreal forest dynamic
10:10			Presentation	Kasischke	Integrating information across spatial scales
10:20			Question Period		
10:40	*Coffee Break*				
10:50	Wodak Room	Presentation Session #2 (con't)	Presentation	Schmullius	Radar Opportunities: The SIBERIA Project
11:00			Presentation	Goetz	Land cover mapping and ecosystem modeling
11:10			Presentation	Levine	Biomass burning & global change
11:20			Presentation	Hargrove	Multivariate Spatio-Temporal Clustering as a Basis for Detecting, Monitoring, and Verifying Regional and National Changes in Forest Carbon
11:30			Presentation	Stolbovoi & Savin	Land use in full carbon account approach
11:40			Question Period		
11:50	*Lunch in Schloss Restaurant (Green Coffee Room)*				
13:15	Wodak, Forestry & Raiffa Rooms	Group Activity #2. What methodologies can be used to meet requirements of full carbon accounting?			
15:30	*Coffee Break*				
15:45	Wodak Room	Group Activity #2 (con't). Group Reports (30 min each)			
17:15			Wrap Up	Gluck	Logistics
17:30	Front Entrance - Bus to Da Capo Restaurant in Vienna				

Agenda Day 3. Saturday, December 11th, 1999

Time	Place	Session	Agenda Item	Speaker(s)	Topic
8:00	Bus from hotel to IIASA				
9:00	TBA		wake-up	Gluck	
9:10	Wodak, Forestry & Raiffa Rooms	Plenary Session. Building a Research Activity	Work Session		
10:45	Wodak Room		Group Reports (30 min each)		
12:15	*Lunch at Laxenburgerhof*				
13:45	Wodak Room	Group Activity #3. Reducing Uncertainties			
15:45	*Coffee Break*				
16:00	Wodak Room	Closing Plenary	Closing Remarks	Entire Group	
				Nilsson	
17:30	End of Workshop—Departure to Vienna				

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APPENDIX 4: ONGOING INITATIVES

Global Observation of Forest Cover (GOFC)

Global Observation of Forest Cover (GOFC) is a new initiative of the Committee on Earth Observation Satellites (CEOS) to improve the quality and availability of satellite observations of forests and the information derived from these data. This objective will be accomplished by:

- Providing a forum for users of earth-observations to discuss their needs and for producers to respond through improvements to their programs;
- Providing regional and global datasets containing information on:
  - Location of different types of forests;
  - Major changes in forests resulting from logging, agricultural conversion, fire, and environmental stresses such as insect outbreaks and pollution;
  - Biological functioning of forests (such as the length of the growing season) which may lead to reliable estimates of the biological productivity of forests over large areas. This will help quantify the contribution forests make as absorbers and emitters of greenhouse gases.
- Promoting globally consistent data processing and interpretation methods;
- Promoting international networks for data access, data sharing, and international collaboration;
- Stimulating the production of improved products.

IGBP - Terrestrial Carbon Initiative

Recently, the Global Terrestrial Observing System (GTOS) announced the launching of a Terrestrial Carbon Initiative (TCI) aimed at developing a coordinated international response to improve scientific understanding of the role of terrestrial carbon sources and sinks. The Terrestrial Observation Panel has led the initial planning for Climate (TOPC).

IEA Bioenergy Task 25

IEA Bioenergy is an international collaborative agreement. It was set up in 1978 by the International Energy Agency (IEA) to improve cooperation and information exchange between national bioenergy research, development and demonstration (RD&D) programmes. IEA Bioenergy aims to realize the use of environmentally sound and costcompetitive bioenergy on a sustainable basis, thereby providing a substantial contribution to meeting future energy demands.

The IEA Bioenergy Task on Greenhouse Gas (GHG) Balances of Bioenergy Systems offers an opportunity to co-ordinate the work of national programmes on the ways GHG balances can be set up for a wide range of bioenergy technologies and on ways of implementing GHG mitigation strategies. The goal of Task 25 is to analyze, on a full fuel-cycle basis, all processes involved in the use of bioenergy and carbon sequestration systems with the aim of establishing overall GHG balances. For more information please see the Task website at www.joanneum.ac.at/iea-bioenergy-task25.

IPCC Special Report Land Use, Land Use Change, and Forestry

The Special Report on Land Use, Land Use Change, and Forestry has been designed to provide scientific, technical, economic, and social information on carbon sequestration activities in the land use and forestry sectors that can reduce atmospheric concentrations of greenhouse gases and assist governments operationalize Article 3.3 of the Kyoto Protocol. It will provide information relevant to assessing the potential of other human-induced additional activities as mentioned in Article 3.4 and issues associated with operationalizing this Article. It also provides information relevant to other Articles of the Kyoto Protocol. While the Special Report will primarily focus on carbon dioxide, it will address methane and nitrous oxide as appropriate. The Special report will be policy relevant, but will not be policy prescriptive.

The IPCC Special Report is being prepared in response to a request from the Subsidiary Body for Scientific and Technological Advice (SBSTA) at its Eighth Session which met in Bonn from June 2-12, 1998. The outline of the Special Report was approved by the IPCC in plenary meetings during its Fourteenth Session in Vienna from October 1-3, 1998. This outline responds to the SBSTA mandate and addresses issues raised in FCCC/SBSTA/1998/INF1.

The Special Report on Land Use, Land Use Changes, and Forestry will be approved and accepted by the Panel in plenary meetings, since it cuts across all three IPCC Working Groups and the Task Force on National Greenhouse Gas Inventories (TFI). The procedures for all preparation, review, acceptance, approval, adoption, and publication of IPCC Special reports shall apply.

The Special Report will be chaired by Dr. Robert Watson and guided by up to three "Overall Coordinating Lead Authors." Each chapter will have one or two Coordinating Lead Authors in addition to numerous Lead and Contributing Authors. There will be a Steering Committee for this Special Report comprised of the IPCC Chair, two members of the IPCC Bureau from each Working Group (one of the Co-Chairs and one Vice-Chair) and the Chair of TFI. The Steering Committee will approve the selection of Coordinating Lead Authors and Lead Authors and oversee the whole process. The Secretary of the IPCC and the Heads of the Working Group Technical Support Units will be ex-officio members of the Steering Committee.

COST Action E21

The main objective of the Action is to develop a commonly agreed carbon accounting strategoy on the contribution of the European forests in achieving the commitments taken in the Kyoto Protocol. Forest management practices, forestry products and their utilisation are included in this COST action. Indeed, interactions between natural and socio-economical systems in this matter have shown the relevance of multidisciplinary approaches.

The scientific programme for establishing the best EU methodology(ies) for assessing C-sequestration in forest ecosystems according to their management will be carried out according to the following perspectives:

- Estimation of the C-balance in forests for the calculation of greenhouse gases net emissions for the 1990 reference year, according to several methods.
- Evaluation of the forest management practices to maximise C-sequestration in forest ecosystems (e.g., afforestation, deforestation, reforestation, thinning, frequency of both natural and human-made disturbances, steady C-uptakes, management practices for conservation of C-pools, etc.)
- Studies, focused on forest matters, on a number of flexible mechanisms that may help Annex I countries to meet emission limitation and reduction targets. These are emission trading, joint imlementation among Annex I countries and the Clean Development Mechanism. Potentials of these mechanisms for European countries will be examined.

Two working groups will be active in this COST Action:

1. Inventory of sinks and sources in the perspective of net C-emission reporting. WG I will be articulated around (i) boreal and mountainous forests, (ii) temperate forests, (iii) Mediterranean forests and (iv) modeling. Standardized methods will help to report 1990 reference values for C-sequestration in forest ecosystems and thereafter changes in pools and fluxes during the commitment period 2008-2012.
2. Analysis of forest management practices. Impacts of forests on atmospheric carbon over the commtiment period will be evaluated and rules towards achieving an optimal sequestration of carbon in the managed forest ecosystems will be formulated. Carbon balance models at various scales (like CO2-FIX, GORCAM, CBM-CFS2, Dewa 1991) will help to quantify the fluxes and pools for many types of forests including their management practices. The Kyoto Protocol generated confusion around the terms "afforestation, reforestation and deforestation". WG II will also analyse the role of these activities. Finally, the significance of the so-called "Kyoto forests" will be compared to forests and forestry in general for the EU.

DOE Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems

As part of its climate change technology initiative, the U.S. Department of Energy's Office of Science in 1999 formed two centers to study carbon sequestration: one focusing on terrestrial ecosystems and the other on oceans. The centers will conduct research and help focus and coordinate research across a wide range of disciplines. The goal is to find environmentally acceptable ways of keeping atmospheric carbon dioxide from reaching concentrations that could cause unacceptable climatic changes. The DOE Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE) is led by a consortium comprising DOE's Oak Ridge, Pacific Northwest, and Argonne national laboratories. The URL for the centre is http://csite.esd.ornl.gov/Index.html

Forest Resource Assessment 2000 - Temperate and Boreal Zones

The years 1999-2000 are a decisive period in the implementation of the Temperate and Boreal Forest Resources Assessment (TBFRA-2000), which is a UN-ECE/FAO contribution to the Global FRA- 2000. The TBFRA-2000 Main Report " Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand" (industrialized temperate/boreal countries) was finalised and sent for publication as the Timber Committee study paper (SP) by December 1999. The Report presents about 500 pages of the most recent and the best possible information on the forest resources of the fifty-five TBFRA countries, covering practically all aspects and functions of the forest.

The Report includes validated national statistical data, adjusted to the TBFRA standards, graphs, tabular and textual information and analysis in the following specific thematic areas: areas of forest and other wooded land, ownership and management status, wood supply and carbon sequestration, biological diversity and environmental protection, forest condition and damage, and protective and socio-economic functions. It also includes a section with an analysis of the reliability and comparability of the TBFRA data, an Executive Summary, as well as the methodological components of the study, including the enquiry, and terms and definitions. The details of the TBFRA-2000 Report is given on a specific Timber Committee website (http://www.unece.org/trade/timber/tc-1998/3.htm).