LCLUC ST Tropical and Subtropical Agenda
UMUC Inn and Conference Center
November 19-21, 2001

Day 1 November 19th Room 1105

9:00 Welcome, objectives for the meeting, status of LCLUC within NASA, Project Reporting and Review – Garik Gutman (NASA HQ)
9:20 National and International Context – Chris Justice (UMd, College Park)
9:40 Current state of LUCC – Emilio Moran (Indiana U.)
10:00 The LCLUC contribution to LBA – Dave Skole (Michigan State U.)

10:20 – 10:45 Break

10:45 – 12:15 Results Presentations (30 mins)

- 10:45 Ron Smith (Yale)
  Landscape Changes in the Middle East: A regional assessment using remote sensing
- 11:15 Jiaguo Qi (Michigan State U.)
  GOFC Data and Information for Tropical Forest Assessment and Management
- 11:45 Robert Walker (Michigan State U.)
  Pattern to Process: Research and Applications for Understanding Multiple Interactions and Feedbacks on Land Cover Change

12:15 - 1:15 Lunch 1:15 Group Photo

1:30 – 3:30 Results Presentations

- 1:30 Ruth DeFries (UMd, College Park)
  Towards Methodologies for Global Monitoring of Forest Cover Characteristics with Coarse Resolution Data
- 2:00 Youngsinn Sohn (UMd, Baltimore)
  A Comparative Study of Forest Mapping Methods/Algorithms: Towards Optimal Solutions for Operational Global Forest Mapping/Monitoring
- 2:30 John Townshend (UMd, College Park)
  Improvements in Landsat Pathfinder methods for monitoring tropical deforestation and their extension to extra-tropical areas

3:00 – 3:30 Afternoon Tea

3:30 – 5:30 Results Presentations

- 3:30 Steve Prince (UMd, College Park)
  Inter- Annual Land Surface Variation
- 4:00 Nadine Laporte (UMd, College Park)
  An Integrated Forest Monitoring System for Central Africa
- 4:30 Paul Desanker (UVa)
  Operationalizing GOFC in the Mambo Region and Questions of Carbon
- 5:00 Bruce Chapman (NASA JPL)
  The Development of a Fine Resolution, Continental Scale Forest Monitoring System Using SAR imagery

Day 2 November 20th Room 1105
9:00 The Landsat Data Buys and CRSP – Rose Fletcher (Lockheed Martin)
9:20 Landsat Data Continuity Mission - Jim Irons (NASA GSFC)
9:40 Status of Terra – Jon Ranson (NASA GSFC)

10:00 – 10:30 Coffee break & hang posters

10:30 – 12:30 Results Presentations (30 mins)

- 10:30 Emilio Moran (Indiana U.)
  Human and Physical Dimensions of Land Use/Cover Change in Amazonia: Forest Regeneration and Landscape Structure
- 11:00 Steve Sader (U. of Maine)
  Mesoamerica Biological Corridor Project
- 11:30 Richard Bilsborrow (U. of North Carolina, Chapel Hill)
  Agricultural Colonization in the Ecuadorian Amazon: Population, Biophysical, and Geographical Factors Affecting Land Use/Land Cover Change and Landscape Structure
- 12:00 Dan Nepstad (Woods Hole Research Center)
  A Panamazonian Model of Deforestation, Logging and Forest Fire: the Amazon Scenarios Project

12:30 – 1:30 Lunch & finish hanging posters

1:30 – 3:00 Poster Session Room 1101

- Mohamed Sultan (Argonne National Laboratory)
  Assessment, Monitoring, and Modeling of LCLUC and Their Impacts on Groundwater Resources, Ecosystems, and Carbon Cycling in Saharan Africa: A Case Study, SW Egypt
- Mike Coe, et al. (U. of Wisconsin)
  Climate and Human Impacts on Water Resources in Africa
- Billie Turner, Deborah Lawrence (Clark U. & UVa)
  LCLUC-SYPR II
- David Roy (UMd, College Park)
  Burned Area Mapping in Southern Africa: Case Study Synthesis and Regional Application of MODIS Data
- Curtis Woodcock, Mutlu Ozdogon (Boston U.)
  The Effects of Agricultural Expansion on Regional Hydrology in Southeastern Turkey
- Lisa Curran (U. of Michigan)
  Influence of Humans, Climate, and Fire on Forest Ecosystems and Carbon Dynamics in Indonesian Borneo
- Trent Biggs (U. of California, Santa Barbara)
  Regional Biogeochemistry of Land Use Change in the Humid Tropics Detection and Modeling of the Aqueous Land Use Signal for Messocale Basins

- Greg Asner (U. of Colorado, Boulder)
  Land-use Impacts on Regional Biogeochemical Cycles in Sub-tropical Ecosystems
- Brian Markham, John Barker (NASA GSFC)
  Landsat Radiometric Calibration: Towards a 20-Year Record of Calibrated Thematic Mapper Class Data for Carbon Cycle Studies
- Brent McCusker (West Virginia U.)
  Vulnerability, Livelihoods, and Land Cover/Land Use Change in South Africa: Integrating Social Science and Remote Sensing Perspectives
- Chandra Giri (Columbia U.)
  Monitoring Land Use/Land Cover Change in Southeast Asia
- Andy Hansen, Ruth Defries (Montana State U., UMd, College Park)
  Land Use Change Around Protected Areas in LCLUC Sites:
  Synthesis of Rates, Consequences for Biodiversity, and Monitoring Strategies

(At the beginning of the poster session, presenters will be asked to give a brief presentation in the order above (2 min per poster) to introduce themselves & their topic)

3:00 – 3:30 Invited Presentation – Brian Turner (Australian National University)
Australia's National Multitemporal Landsat Land Cover Database for Carbon Accounting

3:30 – 5:00 Results Presentations

- 3:30 Dave Skole (Michigan State U.)
  Case Studies and Diagnostic Models of the Inter-annual Dynamics of Deforestation in Southeast Asia
- 4:00 Foster Brown (Woods Hole Research Center)
  Land-Cover/Land-Use Change and Carbon Dynamics in an Expanding Frontier in Western Amazonia: Acre, Brazil
- 4:30 Nadja Lepsch (National Institute for Research in the Amazon)
  Anthropogenic Landscape Changes and the Dynamics of Amazon Forest Biomass

Day 3 November 21st Room 1105

9:00 USGCRP Carbon and the NASA Carbon Initiative – Jim Collatz (NASA GSFC)
9:20 AVIRIS update – Rob Green (NASA JPL)
9:40 Summary of EO-1 Science Team Activities – Greg Asner (U. of Colorado)
10:00 IKONOS Status – Bill Baer (Space Imaging)

10:20 – 10:35 Break

10:35 – 12:00 Open Discussion

- Program Direction
- Results Packaging
- The LCLUC Book
- Possible Program Workshops
- LBA LCLUC Coordination
- Other Issues (TBD)

12:00 – 12:30 Wrap Up and Program Feedback Session – Chris Justice/Garik Gutman

12:30 Close of Workshop

Implementation of Global Observation of Forest Cover (GOFC) in the Boreal Forest

Meeting Sponsors

Siberian Branch of the Russian Academy of Sciences (SB RAS)
Institute of Computational Technologies of the SB RAS (ICT SB RAS)
NASA
International START Secretariat.

Executive Summary

This workshop was the third in a series of regional and thematic implementation planning and coordination meetings for the Global Observation of Forest Cover (GOFC) project. GOFC is a pilot project of the Committee on Earth Observation Satellites (CEOS) aimed at strengthening operational provision and use of satellite data for forest monitoring. The GOFC project falls within the Carbon Theme being prepared for the Integrated Global Observation Strategy (IGOS) Partnership by the FAO and Global Terrestrial Observing System. The workshop was designed to bring together representative data users from high northern latitude (boreal) regions to assist in the design of the implementation of GOFC and to discuss the potential role of regional networks.

High northern latitude forests are important to GOFC from a variety of perspectives. First, the boreal forest region can be divided into two distinct regions. The northern part of the boreal forest is a region where a significant portion of the landscape is underlain by permafrost, which lowers the overall net primary production of the forests and at the same time results in low rates of decomposition and the build-up of significant levels of dead organic and extremely high levels of terrestrial carbon storage. In addition, the dominant disturbances in this region are from natural causes – fires and insects/diseases. In contrast, the southern part region represents the transition zone between temperate and boreal forest, and contains a large amount of timber resources that will subjected to increasing harvesting pressures as demand for wood and fiber products increases and available supplies are depleted elsewhere. Second, the boreal forest region has experienced significant climate warming over the past three decades and is in the region where some of the highest levels of warming in the future are projected. Given that two of the primary disturbance mechanisms in this region (fire and insect damage) are positively correlated with temperature, damage to the forest resources from fire and insect invasions is expected to continue to increase in the future. And third, the ecosystems found in the boreal forest region represent one of the largest terrestrial reservoirs for carbon, and are thought to be presently serving as a net sink of atmospheric carbon. However, increased disturbance (both natural and anthropogenic) combined with climate warming will certainly alter the role of the ecosystems of this region in the carbon cycle. For all the above reasons, development of a system that can aid in the systematic monitoring of key forest cover characteristics in the boreal region, and make this information widely available to a broad array of users is needed.

The workshop was organized into a series of oral presentations followed by breakout groups organized by region (North America, Fenno-Scandia and Western Europe, and Eastern Eurasia). The presentations and detailed information regarding the workshop can be found at www.gofc.org/gofc.

The focus of the presentations and breakout sessions were to address the six objectives defined for the meeting. The objectives for the meetings as well as the conclusions and recommendations from the breakout sessions are as follows:

Objective 1 - Summarize the key information requirements for the different regions of the boreal forest.

Conclusion - While it appears that the scientific community and satellite-data user communities are well represented within GOFC, steps need to be taken to encourage participation of resource managers and policy makers at all levels of government (e.g., national and sub-national), private industry, and representatives of civil society. The workshop participants were able to broadly define the information requirements for the boreal forest region, but it was strongly felt the workshop did not have a balanced representation from the perspectives of many different constituents, regions, or disciplines.

Recommendation - GOFC needs to interact with the broader user community to develop a real consensus for information requirements

Objective 2 - Define how satellite remote sensing data can fulfill the information requirements defined for the boreal forest region.

Conclusion - Given the large participation by information providers at this workshop, a large number of satellite products were reviewed, many of which were specifically being developed for the boreal forest region.

Objective 3 - Identify existing satellite products that fulfill key information requirements.

Conclusion – A variety of data products have been or are being generated for the boreal forest region, primarily coarse resolution products derived from AVHRR and ATSR. These products are of two types: land-cover maps and active fire maps. These products can be divided into two categories: (a) global products and regional products. The regional products have a high degree of validation, while the global products have yet to be thoroughly evaluated.

Recommendation – There is a need to conduct validation of the global information products being generated from existing satellite systems. In particular, the utility of global active fire products derived from AVHRR and ATSR for accurately depicting fire activity needs to be assessed.

Objective 4 - Identify potential future GOFC products.

Conclusions – A number of additional data products that could be developed for the boreal forest region were discussed. These products can be divided into three broad categories: (a) Land Cover; (b) Fire Mapping and Monitoring; and (c) Biophysical Parameters. It was concluded that a number of additional products developed from new satellite systems such as MODIS, VEG-A, and Landsat 7 were of particular interest to the GOFC boreal forest community.

Recommendation: Future GOFC meetings on the boreal forest should review and evaluate the utility of new satellite information products, including: (a) land cover maps derived from MODIS and VEG-A; (b) land-cover change maps; and (c) regional and global-scale maps of biophysical parameters such as net primary production and the temperature status of vegetation;

Recommendation: A particularly important information need for the boreal forest region is high-resolution information on land cover over the past three decades. While the satellite data exists to create such products for North America and the west Eurasia, high resolution data sets for eastern Eurasia currently do not exist. GOFC needs to give high priority for creation of time series (once per decade) high-resolution, data set for this region.

Objective 5 - Define requirements for the information networks needed to distribute GOFC products to the user communities.

Conclusion – The discussion of this objective was subsumed by two issues - (a) Defining the regions are required to adequately represent the boreal forest (see Objective 6); and (b) The lack of representation at the meeting by the various user groups (see Objective 1).

Objective 6 - Recommend next steps towards developing a regional network for implementation of GOFC in the boreal forest

Conclusion – It was agreed that a regional focus was needed for the boreal forest in terms of national interests, as well as different types of forests, management practices, and disturbance regimes. However, most countries that contain boreal forests also contain temperate forests as well, and the separation point between these two biomes is not easily defined in most cases. Finally, there are national interests in terms of information systems and management strategies that need to be considered in terms of regional delineations, particularly in Russia which contains > 60% of the world's boreal forests.

Recommendation - There are real issues in terms of the delineating boreal versus temperate forests and defining national interests in the GOFC mission that GOFC needs to address prior to convening the next regional workshops.

In addition to the conclusions and recommendations concerning the objectives for the meeting, one other conclusion was:

Conclusion - While it became clear during the workshop that GOFC is involved in a large number of international initiatives, the goals and role of GOFC in these were not clear to the participants.

Recommendation - The participants in this workshop second the recommendation made by the delegates of the Tropical Forest Workshop on the need to clearly define the goals of GOFC and to clarify its responsibilities in relation to other international organizations with interests in and responsibilities for forest cover.

In summary, the workshop confirmed that there is strong support within the boreal forest region for the overall goals of GOFC, and that there is significant interest in participating in GOFC, particularly in operational pilot projects focused on specific information needs that are unique to this region. The workshop participants recommend that the next steps include holding a series of regional workshops to strengthen and expand the GOFC information network and to identify and initiate a set of operational pilot projects.

1.0 Workshop Objectives

The objectives of the GOFC Boreal Forest Workshop were to:

1. To review the spatial and temporal information requirements of the broad boreal forest user community, specifically with respect to products that can potentially be derived from earth observing satellites;
2. To review the unique spatial/temporal capabilities and characteristics of the current generation of earth observing satellites;
3. To review data products which are currently being generated from satellite data for operational and research use in the boreal forest;
4. To recommend and prioritize new information products for the boreal forest that should be developed and included in GOFC;
5. To identify the information networks needed at global and regional scales to ensure easy access to GOFC information products;
6. To determine the data required to validate GOFC products (including determining the suitability of existing in situ data collection);
7. To examine the extent to which improved synergies can be achieved between in situ and satellite data for meeting user information needs; and
8. To foster the development of regional science networks for studying boreal forests.

To achieve these objectives, the meeting alternated between plenary presentations and breakout sessions, where participants were organized by different geographic regions (Scandinavia and Western Russia, Eurasia, and North America). The first set of presentations discussed background information on GOFC and straw-man information requirements for various segments of the forestry community. During the first breakout sessions, the participants prioritized information requirements specific to each region. Next, presentations were made to review the information capabilities of existing remote sensing systems and identify potential GOFC boreal forest products. During the second breakout session, the workshop participants then discussed these capabilities and potential products with respect to the information requirements for each region. Finally, presentations were made to review existing information systems and plans for new systems. During the third breakout session, the workshop participants discussed user synergies and requirements for regional information networks.

2.0 Overview Presentations

Presentations at the workshop focused on presenting participants with background information on key GOFC activities, reviews of information requirements for boreal forest regions, and existing data products and systems that could potentially contribute to a GOFC Boreal Forest Network. Table 1 summarizes the presentations made at the meeting. Some presentations (marked with an * in Table 1) were accompanied by papers that were distributed to the participants for their review. These papers are presented in Appendix Four.

Table 1. Summary of oral presentations made at the GOFC Boreal Forest Workshop.

User Information Requirements	
The Global Observation of Forest Cover (GOFC) Program	Tim Perrot, CCRS
Information Requirements for the Boreal Forest	Alexander Isaev, RAS
Information Requirements for Forest Management*	Susan Conard, USFS
Information Requirements for Fire Management*	Tim Lynham, CFS
Information Requirements for Insect and Disease Monitoring and Management	Alexander Isaev, RAS
Information Requirements for Forest Inventory and the Terrestrial Carbon Budget*	Anatoly Shvidenko, IIASA
Information Requirements for Disturbances*	Eric Kasischke, UMD
Information Requirements for Understanding the Role of the Land Surface in Climate Modeling*	Gdaly Rivin, RAS
Information Requirements for Monitoring Forest Recovery*	Don Clarke, UVA
Remote Sensing Capabilities	
Remote Sensing for Large-Scale Fire Monitoring	Eric Kasischke, UMD
Remote Sensing for Forest Cover/Forest Change Monitoring*	Sergei Bartalev, JRC/RAS
Remote Sensing for Monitoring of Forest/Surface Conditions	Donald Deering, NASA
Existing Fire Data Products	Tim Lynham, CFS
Existing Forest/Vegetation Cover Data Products	Jon Ranson, NASA
Existing *In Situ* Data Sets	Anatoly Shvidenko, IIASA
Preparation for Regional Science Networks and GOFC Requirements	
Preparation for Regional Science Networks	Garik Gutman, NASA
GOFC Testbed Requirements	Herve Jeanjean, CNES
A User's Perspective on Information Requirements	Lars Laestidius, WRI

3.0 Poster Paper Sessions

In order to review a large number of activities that have a direct bearing on establishing a viable Regional GOFC Network in the boreal forest region, several sessions where poster papers were presented were convened. A summary of these poster papers is presented in Table 2. Summaries of these papers are presented in Appendix 5.

Table 2 - List of Poster Poster Papers

Product	*Presenter*
Global Fire Monitoring Center	Goldammer (MP)
Canadian Wildland Information System	Lynham (CFS)
Fire M3	Perrott (CCRS)
Russian Fire Information Center	Avialsookhrana
Global Land Cover Facility	Townshend (UMD)
Alaska Geophysical Data Clearinghouse	Mark Shasby (USGS - invite)
TACIS – National Fire Monitoring System for Russia	Belyaev – Avial.
World Fire Web	JRC
Automation and Information Processing?	Rabinovich
JERS Boreal Mosaic	McDonald (JPL)
Disturbance Mapping	Kharuk (KSU)
Forest Biomass Mapping	Krankina (OSU)
Forest Inventory and Land Cover Products	Shvidenko (IIASA)
Land Cover and Biophysical Parameters	Latifovic (CCRS)
REALM Boreal Product	Gutman (NASA)
Global Forest AVHRR Cover Product	DeFries/Janetos (UMD/WRI)
MODIS Product	Kimble/Townshend
Russian Forest Cover	Achard/Bartalev (JRC)
Global Forest Watch – Russian Forest Cover	Tarakanova (WRI)
Russian Active Fire Products	RFS
Canadian Fire Products Derived from AVHRR Imagery	Perrott (CCRS)
Russian Fire Products	Sukhinin/Conard (RAS/USFS)
Land Cover Mapping using Radar Imagery	Ranson (GSFC)
Boreal Forest Water Cycle in Siberian Cryolithic Zone: Main Features and Network of Experimental Stations and State Network on Observation of Water Cycle Elements	Georgiadi (RAS)
Russian Fire Scar Map	Minko (RAS)
North American Large Fire Data Base	Stocks/French/Kasischke
Alaska Forest Cover Mapping	Winterberger
Alaskan Fire Scar Products	Kasischke/French
Scatterometer/Radar Data Products	McDonald (JPL)
ERS Forest Cover Products	Schmulnus (DLR)
Insect Damage Mapping	Isaev (RAS)

4.0 Breakout Group Deliberations

The boreal forest is commonly used to describe the coniferous and mixed coniferous/deciduous forests high northern latitude regions, generally north of 45° to 50° N latitude. This region coincides with the discontinuous permafrost region, so many boreal forest types are found on cold, poorly drained sites, resulting in low levels of aboveground biomass (relative to temperate and tropical forest) and deep layers of organic soils. Because of these characteristics, there is little pressure to exploit true boreal forests for their timber resources, but this biome is extremely important in terrestrial carbon cycle studies because of the large sink present in organic soils. Another process that is unique to the boreal region is the fact that fire and insect infestations are the primary disturbance processes that influence large regions of the landscape every year.

A challenge facing GOFC in developing systems to monitor the boreal forest is the fact that there is no clear delineating boundary between the boreal and temperate forest region. In transitional regions, there is much discussion concerning the factors that can be used to classify a forest as being either temperate or boreal. In addition, most countries that contain boreal forests also contain temperate forests as well, including Canada, Russia, China, Finland and Sweden. The fact that the southern boreal forest transitions into the northern temperate forests raises issues concerning management of forest resources for harvesting wood and fiber that are not a driving issue in many regions of the boreal forest.

Finally, there are large differences in terms of satellite and Web-based spatial information resources that can be used to monitor the boreal forest region. In North America and Fenno-Scandinavia, these resources have been extensively developed and to a large extent are readily available to those requiring information. In the Eurasian portion of the boreal forest (which includes Siberia, the Far East, Mongolia, and northern China), satellite-based technologies are only now being exploited to provide information products. While fire monitoring and mapping projects are well under-way for this region, other satellite-based information products are much needed.

Because of these distinct differences between different regions of the boreal forest, three separate regional break-out groups were formed: (1) Scandinavia and Western Russia; (2) Eurasia; and (3) North America. The deliberations of each one of these groups is presented in this section.

This meeting was organized in a very different fashion than the previous GOFC meeting on the Tropics. First, the boreal forest encompasses a much smaller number of countries that the tropics. Greater than 90% of the boreal forest is found in just two countries – Canada and Russia. Second, in the tropics, there have been many pathfinder projects whose purpose was to systematically gather and archive extensive satellite data sets specifically to monitor fire, patterns of deforestation, and patterns of reforestation. These projects served to facilitate the development of networks of data users within the different regions where projects were carried out, and provided a framework to develop the GOFC tropical meeting around. While some projects have been developed for North America, no equivalent satellite pathfinder projects existed for Russia. Thus, the GOFC Boreal Forest Workshop represented the first opportunity for this community to communicate in a systematic fashion.

All of these considerations lead to the formulation of the agenda used for this meeting. The agenda was designed to allow the attendees to address the objectives for this meeting by addressing each of the following topic areas:

1. Review the relevant boreal forest information requirements from a user's perspective
2. Review and prioritize the relevant information requirements from a regional perspective
3. Review the needs for in situ data for validation of satellite information products
4. Review priorities for operational data products
5. Review requirements and strategies for regional information networks

4.1 Scandinavia/Western Russia (*Co-Chairs: Frédéric Achard, Tuomas Häme, Olga Krankina)*

In terms of completely defining the information requirements for this region, it was noted that representatives from governmental agencies at national or local levels, as well as forest managers or forest industry were missing from this meeting. These users need to be included in future GOFC regional meetings in order to develop a more complete set of user requirements. Although some information needs are the same for different categories of users, the need to be more specific by category of users was strongly expressed.

It was noted that the educational component of GOFC was extremely important from the standpoint of more clearly defining user requirements. In many cases, potential users do not clearly understand the potential applications of remote sensing information, and therefore need to be informed of this potential.

The boreal part of Europe (Scandinavia) is characterized by an intensive forest management. In that respect the western part of Russia is more similar to Scandinavia compared to Siberia, because the logging activities are more intensive and the fire regime is more strictly controlled. It has been also mentioned that the permafrost regime of western Russia is also very different from the permafrost regime of Siberia.

A user's perspective common to Western Russia and Scandinavia is the need to: (a) to provide more detailed information at finer spatial scales; and (b) to emphasize change-monitoring approaches using satellite imagery. However, the user community in Western Russia is sufficiently different from the Scandinavian user community leading to different requirements in terms of resolution of information. Medium resolution satellite data (e.g., 25 m) might prove satisfactory in Western Russia when aerial photographs (1 m resolution) are needed in Scandinavia.

The *in situ* data for validation of satellite data products was considered as a first priority. Relative to other parts of boreal zone the data resources available for validation in Western Russia and Scandinavia are extensive; however, certain field measurements may be very limited. To improve the current situation a first task would be to identify what *in situ* data are available for validation. A second task would be to facilitate accessibility of to such *in situ* data.

For this region, detailed forestry data exist but are not freely available. In particular for Finland, Sweden and Russia, the 'original' inventory data produced at local level are generally not available. Only 'summary' data created at sub-regional administrative district, i.e. at very coarse resolution equivalent are available. It was recommended to develop meta-data at regional

level and to geo-reference such existing data or information (through the preparation of GIS databases). Institutional barriers need to be addressed.
The first premise was that information on forest cover status at regional scale is needed in order to derive better products that represent change: if good biomass map exists then one can derive better estimates of carbon losses from fire and other disturbances.

Satellite information products desired at a regional scale include: (a) Forest maps at 1:250,000 scale that include forest type and biomass; and (b) Maps of the land covered by the Kyoto protocol (afforestation, reforestation, deforestation) at 1:1,000,000 scale. Satellite information products desired at a regional scale include: (a) Stand maps at 1:10,000 scale derived from aerial photographs; and (b) More continuous monitoring (at annual sampling frequencies) of disturbance and logging activities from very high-resolution remote sensing data. It has to be noticed that sometimes, even aerial photography might be not detailed enough. Foresters need 1 to 10 m resolution data for change assessment.

Finally, the following broad recommendations were made: (a) GOFC should promote test data-sets to be made available to all potential users; (b) For forest managers it will be useful to promote a test product at 20/30 m resolution with a 2/3 years frequency; and (c) All levels of processing should be retained and made available to users.

It was strongly recommended by this group that a regional workshop be convened. The focus of this workshop would be to identify current and future information needs of different user groups, discuss plans for development of a regional directory (meta-data) of existing datasets useful for validation and interpretation, and plan future interdisciplinary research and education/exchange activities. It was recommended that this workshop be convened in St. Petersburg in the summer 2001 and be hosted by INENCO.

Candidate GOFC projects for this region include:

A. Generation of a status map database
B. Production of maps of differences in land-use (land cover) patterns in Scandinavia and Russia connected with differences in history and economy of Russia and Fennoscandia.
C. Maps of the differences in disturbance (change) patterns in Scandinavia and Russia in past, present and future
D. Test the ability of sensors to detect stand thinning activities and selective cuts. This is known to be a major challenge for remote sensing, however this is a major forest management activity and disturbance type in the region. Poor detection of this type of timber harvest can be a problem for many users (i.e. mapping intensively thinned or selectively cut stands as ‘virgin forest’).
E. Enhancing existing data products with additional ground data, e.g. monitoring change in the timing of seasonal changes in vegetation as an indicator of changing climate.

4.2 Eastern Eurasia (Siberia/Far East) - *Co-Chairs: Sergei Bartalev, Susan Conard, Vacheslav Kharuk, and Peter Schlesinger*

It was noted by this group that the eastern Eurasian boreal forest not only includes Siberia and the Russian Far East, but Mongolia and the northern portion of China as well. Future discussions of GOFC information needs and projects for this region need to include representatives from these regions. Furthermore, the group noted that only a few of the members represented actual information users. In particular, representatives of government agencies at the national level were not in attendance, leading to the recommendations that steps be taken to ensure their participation in later meetings as the GOFC process continues.

The first important question for this group was to identify what differentiates eastern from western Eurasia. The key factors for eastern Eurasia are remoteness and poor access to most of the territory; this is a corollary to the low population density outside of the few large urban centers. This leads to two conclusions: (a) GOFC needs to promote the establishment of a network of on ground test (validation) sites, because work on the ground is expensive and difficult; and (b) GOFC needs to emphasize use of multiple scales and types of remote sensing to supplement widely-spaced ground sites and to develop a set of well-validated remote sensing methods. While such an approach had been developed for the Sputnik project, it needs to be adapted to modern satellite technology.

It is important to recognize also that there are many types of users of data besides managers, such as the global change research community, policy makers, and conservation groups. Interests and needs of these various groups may differ.

An important step for GOFC is to work with forest managers and other users to identify and define the problems that can benefit from the types of data available through remote sensing and from integration of remote sensing data with other spatial databases. Identification of potential products useful to users is a process that involves two-way communication. For example, while forest managers in the Federal Forest Service have already defined many of their data requirements, the identification of needs is often based to some extent on the perception of what is available or feasible. So, while GOFC should look to the user community for input on information needs, GOFC must educate the users concerning the potential of remotely sensed data to provide useful information efficiently, economically, and accurately

While it is common knowledge that the forest community has good sources of static information, dynamic data is also required. For example the seasonal dynamics of leaves, impacts of stress, development of insect and disease infestations, fire and logging activities, manmade hazards, and other anthropogenic impacts on forests are readily reflected in changes in spectral characteristics. These are all important indicators of forest dynamics, forest health, and susceptibility to disturbance. It is critically important to emphasize dynamic data requirements in any discussion of data needs—and remote sensing has unique capabilities to meet these needs.

In summary, the group identified the following preliminary list of priority information needs for the region:

1. Ownership, land use, logging concession boundaries, forest protection zones
2. Inventory information such as homogeneity, density, growing stock, species composition, stand structure
3. Landscapes types, vegetation distribution
4. Forest and vegetation type (including non-forest types--swamp, steppe, tundra, etc.), LAI, albedo
5. Factors related to meteorological and climate observations
6. Other types of data needed for biogeochemical modeling
7. Forest vigor/health (pollution, insects/disease, biological stress)
8. Dynamics of forest areas, bog/forest, forest/tundra, and forest/steppe ecotones, trends of forest invading tundra zone, including information on species regeneration and forest productivity
9. Wildfire information, including: (a) Burned areas and timing/seasonality; (b) Type and severity of wildfires (ground fire, low-moderate severity surface fire, canopy fire); (c)

Fuels information (including fuel characteristics and type and age of vegetation burned); and (d) Pyrological factors (fuels/fire danger).

10. Detection of different types of disturbance, for example--logged or burned, insect and disease infestations, steppe vs. agriculture
11. Wildlife data, including: (a) relations between forest biomass and animal populations; (b) animal density, wildlife habitat, vegetation mosaics; and (c) hunting association grounds.
12. Permafrost, including: (a) type of permafrost; (b) and depth of seasonal melting layer.
13. Hydrogeological functions, including: (a) surface water and groundwater; (b) soil parameters; and (c) drainage networks
14. Terrain features including relief and slope.

A matrix was developed to relate data needs and scales to potential sources of information and assessing the appropriateness of various remote sensing products for meeting these needs (See Appendix 3). The group defined several categories of products: carbon cycling or stocks (carbon), disturbance, fire, GIS, land use and land cover change (LULC), wildlife, and general physical or land cover characteristics (blank in this table). For each of these, specific information requirements were listed. A determination was made as to whether information could be obtained "directly" through classification/validation of satellite data, or "indirectly" through some form of analysis, modeling, or mathematical correlation of satellite data with, for example, forest inventory data from satellite sources. Some types of data were classified as "basic", meaning that they were foundation data for many purposes. For each information requirement, an assessment was then made of the usefulness of various satellite platforms or sensors at providing the necessary information at local to global scales.

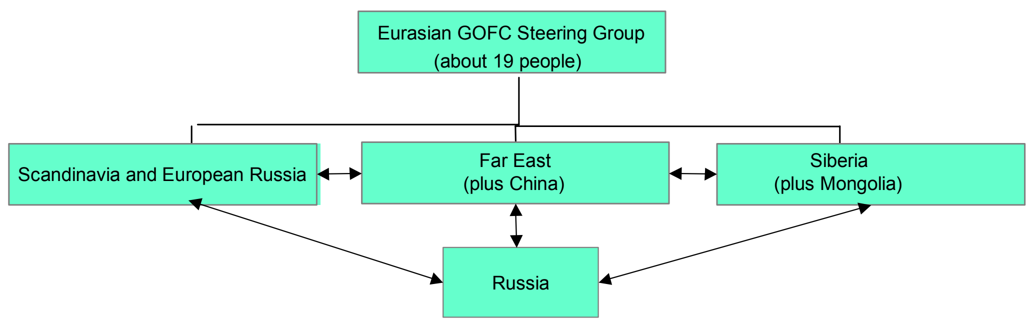
Considerable and spirited discussions were held within this group as to how to best to structure future GOFC activities in Russia, and resulted in a set of recommendations. These recommendations are summarized in Figure 1. The overall concept is to establish a Eurasian network for GOFC but to break it up into three regional working groups that reflect areas where management problems and forest cover types are most similar. The Russia box in Figure 1 represents the necessary coordination of all groups within Russian federal agencies with responsibility for land management, space observation, etc. in recognition that management of all such activities in Russia is highly centralized and that certain types of agreements and understandings would be common to all groups.

The Eurasian Steering Group is envisioned as a coordination group, with about 19 people on it. This group would include representatives from the regional groups, whose membership would include: (a) Russian Federal Forest Service and other governmental representatives; (b) Representatives from other boreal countries in this region and elsewhere; (c) Coordinators of the regional groups; (d) representatives of major RAS Institutes in European Russia, Siberia, Far East; (e) representatives of major science projects; and (f) civil society representatives.

The three regional groups would do most of the actual coordination and information exchange at a project level. They would include: (a) Researchers from regional institutes; (b) International cooperators; (c) Forestry and other management cooperators; (d) Forestry committee representatives; (e) Ecology committee representatives; (f) Civil society organization representatives.

It is envisioned that the Siberia and Far East groups would initially meet together and would only divide as the number of participants increased and once coordination between the two groups was ensured. It is recommended that the first regional workshop be held sometime in 2001.

Figure 1. Eurasian Network



4.3 North America - *Co-Chairs: Kathleen Bergen and Tim Lynham*

A number of data product generation relevant to GOFC are ongoing in North America. The USDA Forest Service has supported the development of complete Landsat-level land cover for the USA. This was required to make the Forest Inventory Assessment (FIA) more robust and more economical. In Canada, there is no national Landsat land cover product; however, there is a digital-land cover product developed from AVHRR imagery. Meanwhile, the Canadian Space Agency (CSA), the Canadian Forest Service (CFS), and the Canada Centre for Remote Sensing (CCRS) are cooperating to build a Canada-wide digital land-cover map based on Landsat. Land-cover maps serve as the building blocks for many other products such as forest monitoring and change detection.

Although wildfire monitoring and mapping is the key focus of this GOFC boreal forest change initiative, GOFC recognizes the importance of monitoring other forest conditions such as the insect outbreaks, pathogen attacks, and other stressors (e.g., drought). For wildfires, mapping and monitoring are a higher priority than detection. There are area burned databases nearing completion for Alaska and Canada.

Some of the main biophysical parameters and processes that are needed include biomass, carbon, trace gas (including methane), phenology, and moisture levels related to soils and vegetation. Users employ models that make use of inputs that are available to them and are eager to incorporate new products when available. User needs are being driven by international agreements (Kyoto Protocol, Montreal Process, Helsinki Accord, ITTO, and the United Nations Environmental Program) for quantifying and monitoring forest sustainability. In all cases these agreements are predicated on a set of criteria and indicators (see Table 1 in Appendix 3).

A large number of data product generation activities are underway being carried out by a number of groups in Canada and Alaska that are directly related to the goal specified by GOFC. These products are summarized in Table 3 in Appendix 3.

Specific conclusions and recommendations made by this regional working group include:

1. Global-change science needs coarse to moderate resolution satellite data.
2. Management increasingly desires higher resolution (10-30 m data while moving towards 1-5 m data) and GOFC must be prepared to implement higher resolution data.
3. Hyperspectral sensors will provide data on large numbers of spectral bands, dealing with complex land eco-systems that can be imaged and accurately classified. GOFC needs to be able to advise on the applicability of such data.
4. Information on land structure and moisture content should be enhanced by the use of SAR, scatterometers, and lidar.
5. Sensor fussion may be required at the pixel, feature, and decision level.
6. The integration of remote sensing and field data must be included in project development and execution.
7. There is a continuing role for education and outreach related to remote sensing applications.
8. Strategically, there is potential for monitoring general forest condition using multi-stage monitoring and sampling (e.g., AVHRR could form the basis for depicting normal conditions, along with the use of higher resolution data to zero in on specific management issues.

5.0 Recommendations Towards the Implementation of the GOFC Boreal Forest Component

Based on a review of the deliberations and reports of all three regional working groups, a common set of conclusions and recommendations emerged with respect to the objectives defined for this workshop. These conclusions and recommendations are summarized below:

Objective 1 - Summarize the key information requirements for the different regions of the boreal forest.

Conclusion - While it appears that the scientific community and satellite-data user communities are well represented within GOFC, steps need to be taken to encourage participation of resource managers and policy makers at all levels of government (e.g., national and sub-national), private industry, and representatives of civil society. The workshop participants were able to broadly define the information requirements for the boreal forest region, but it was strongly felt the workshop did not have a balanced representation from the perspectives of many different constituents, regions, or disciplines.

Recommendation - GOFC needs to interact with the broader user community to develop a real consensus for information requirements

Objective 2 - Define how satellite remote sensing data can fulfill the information requirements defined for the boreal forest region.

Conclusion - Given the large participation by information providers at this workshop, a large number of satellite products were reviewed, many of which were specifically being developed for the boreal forest region.

Objective 3 - Identify existing satellite products that fulfill key information requirements.

Conclusion – A variety of data products have been or are being generated for the boreal forest region, primarily coarse resolution products derived from AVHRR and ATSR. These products are of two types: land-cover maps and active fire maps. These products can be divided into two categories: (a) global products and regional products. The regional products have a high degree of validation, while the global products have yet to be thoroughly evaluated.

Recommendation – There is a need to conduct validation of the global information products being generated from existing satellite systems. In particular, the utility of global active fire products derived from AVHRR and ATSR for accurately depicting fire activity needs to be assessed.

Objective 4 - Identify potential future GOFC products.

Conclusions – A number of additional data products that could be developed for the boreal forest region were discussed. These products can be divided into three broad categories: (a) Land Cover; (b) Fire Mapping and Monitoring; and (c) Biophysical Parameters. It was concluded that a number of additional products developed from new satellite systems such as MODIS, VEG-A, and Landsat 7 were of particular interest to the GOFC boreal forest community.

Recommendation: Future GOFC meetings on the boreal forest should review and evaluate the utility of new satellite information products, including: (a) land cover maps derived from MODIS and VEG-A; (b) land-cover change maps; and (c) regional and global-scale maps of biophysical parameters such as net primary production and the temperature status of vegetation;

Recommendation: A particularly important information need for the boreal forest region is high-resolution information on land cover over the past three decades. While the satellite data exists to create such products for North America and the west Eurasia, high resolution data sets for eastern Eurasia currently do not exist. GOFC needs to give high priority for creation of time series (once per decade) high-resolution, data set for this region.

Objective 5 - Define requirements for the information networks needed to distribute GOFC products to the user communities.

Conclusion – The discussion of this objective was subsumed by two issues - (a) Defining the regions are required to adequately represent the boreal forest (see Objective 6); and (b) The lack of representation at the meeting by the various user groups (see Objective 1).

Objective 6 - Recommend next steps towards developing a regional network for implementation of GOFC in the boreal forest

Conclusion – It was agreed that a regional focus was needed for the boreal forest in terms of national interests, as well as different types of forests, management practices, and disturbance regimes. However, most countries that contain boreal forests also contain temperate forests as well, and the separation point between these two biomes is not easily defined in most cases. Finally, there are national interests in terms of information systems and management strategies that need to be considered in terms of regional delineations, particularly in Russia which contains > 60% of the world's boreal forests.

Recommendation - There are real issues in terms of the delineating boreal versus temperate forests and defining national interests in the GOFC mission that GOFC needs to address prior to convening the next regional workshops.

In addition to the conclusions and recommendations concerning the objectives for the meeting, one other conclusion was:

Conclusion - While it became clear during the workshop that GOFC is involved in a large number of international initiatives, the goals and role of GOFC in these were not clear to the participants.

Recommendation - The participants in this workshop second the recommendation made by the delegates of the Tropical Forest Workshop on the need to clearly define the goals of GOFC and to clarify its responsibilities in relation to other international organizations with interests in and responsibilities for forest cover.

In summary, the workshop confirmed that there is strong support within the boreal forest region for the overall goals of GOFC, and that there is significant interest in participating in GOFC, particularly in operational pilot projects focused on specific information needs that are unique to this region. The workshop participants recommend that the next steps include holding a series of regional workshops to strengthen and expand the GOFC information network and to identify and initiate a set of operational pilot projects.

APPENDIX ONE – MEETING PARTICIPANTS

Program Committee

F. Achard, JRC
S. Bartalev, RAS Moscow IIF
S. Conard, USDA/USFS
A. Georgiadi, RAS Inst. Geography
J.G. Goldammer, Max Planck Institute
G. Gutman, NASA/HQ (Co-Chairman)
A. Janetos, WRI
E. Kasischke, UMD (Co-Chairman)
O. Krankina, OSU
T. Lynham, CFS
T. Perrott, GOFC/CCRS (Executive Secretary)
Y. Shokin, SB RAS
A. Shvidenko, IIASA
E. Vaganov, RAS Krasnoyarsk IF

Local Organizing Committee

Novosibirsk:
Y.I. Shokin, ICT SB RAS (Chairman)
G.S. Rivin, ICT SB RAS (vice-chairman)
V.A. Detushev, ICT SB RAS
E.G. Klimova, ICT SB RAS
V.N. Kopilov, Hydrometeoservice
K.P. Koutcenogii, ICKC SB RAS
Y.L. Molorodov, ICT SB RAS
V.A. Proskuryakov, SB RAS
E.A. Rabinovich, NGTU
V.I. Zinenko, Hydrometeoservice

Krasnoyarsk:
G.A. Ivanova, IF SB RAS
A.I. Sukhinin, IF SB RAS

Appendix 2 – Workshop Agenda

Day 1 – 28 August 2000

Defining GOFC Information Requirements for the Boreal Forest

0800 - Welcome and Meeting Overview *(Session Chair – Rivin)*
0800 – Opening of Session (Gutman)
0815 – Welcome to Novosbirsk (Shokin)
0830 – Workshop Overview – (Kasischke)

0850 - Plenary Session 1 – GOFC Overview *(Session Chair – Kasischke)*
0850 – The Global Observation of Forest Cover (GOFC) Program (Perrott)
0920 – Information Requirements for the Boreal Forest (Isaev)

0950 – Break

1020 – Plenary Session 2 – Information Requirements – Forest Resource Management *(Session Chair – Vagonov)*

1020 – Forest Resource Management (Presenter – Conard)
1050 – Fire Management (Presenter – Lynham)
1120 – Insect/Disease Monitoring/Management (Presenter – Isaev)

1200 – Lunch

1400 – Plenary Session 3 – Information Requirements – Research (Session Chair – Krankina)

1400 – Forest Inventory and Terrestrial Carbon Budget (Presenter – Shvidenko)
1425 – Disturbances (Presenter – Kasischke)
1450 – The Role of the Land Surface in Climate Modeling (Presenter – Rivin)
1515 – Forest Recovery (Presenter – Clark)

1540 – Breakout Session 1 – Review of Information Requirements

1800 – Meeting Adjourn for the Day

1900 – Banquet

Day 2 – 29 August 2000

Linking User Requirements with Satellite Capabilities

0830 – Breakout Session 1 Reports

1000 – Plenary Session 4 – Remote Sensing Capabilities *(Session Chair – Kharuk)*

1000 - Large Scale Fire Monitoring (Presenter – Kasischke)
1025 - Forest Cover/Change Mapping (Presenter – Bartalev)
1050 - Monitoring of Forest/Surface Conditions (Presenter – Deering)

1115 – Poster Session I – Data Products

1230 – Lunch

1400 – Plenary Session 5 – Existing Data Products *(Session Chair – Perrott)*

1400 – Fire Data Products (Presenter – Lynham)
1425 – Forest/Vegetation Cover (Presenter – Ranson)
1450 – In Situ Data Sets (Presenter – Shvidenko)

1515 – Breakout Session 2 – Matching Data Products with User Requirements

1800 – Adjourn

1830 – Reception

Day 3 – 30 August 2000

Local Tours Organized by Host Committee

Day 4 – 31 August 2000

Connecting Information with Users – Archiving and Networking Requirements

0830 – Reports on Breakout Session 2

1000 – Plenary Session 6 – Preparation for Regional Science Networks and GOFC Requirements *(Session Chair – Gutman)*

1000 – Preparation for Region Science Networks (Presenter – Gutman)
1015 – GOFC Testbed Requirements (Presenter – Jeanjean)
1035 – Review of Information Systems and Networks (Presenter – Laestidius)

1100 – Poster Session 2 – Information Systems and Networks

1215 – Lunch

1400 – Breakout Session 3 – User Synergy and Requirements and Strategies for Regional Information Networks

1700 – Adjourn

1900 – Banquet

Day 5 – 1 September 2000

Meeting Wrap Up

0830 – Reports on Breakout Session 3

1000 – Open Discussion on Conclusions and Recommendations *(Session Chairs – Kasischke and Gutman)*

1200 – Lunch

1400 – Meeting Adjournment

Appendix Three – Reports from the Breakout Groups

1. Breakout Group Deliberations - Scandinavia/Western Russia

Co-Chairs: Frédéric Achard, Joint Research Center, EU
Tuomas Häme, VTT, Finland
Olga Krankina, Oregon State University, USA

Participants in the group discussions:
Hervé JeanJean, CNES, France
Kira Kobak, State Hydrological Institute, St. Petersburg
Lars Laestadius, WRI, Washington
Evgenii Loupian, Space Research Institute, Moscow
Natalia Malysheva, All Russian Scientific and Information Center, Moscow
Gennady V. Menzhulin, INENCO Center, St. Petersburg
Rudolf Treyfeld, North-Western State Forest Management Enterprise, St. Petersburg
Xiangming Xiao, New Hampshire University, USA

Deliberations of Breakout Session 1: Review of Information Requirements

The first breakout session was focusing on two main questions and issues:

- Do the strawman papers include all the relevant information requirements from a user's perspective?
- Do the strawman papers include all the relevant information requirements from a regional perspective? What are the priorities from a regional perspective?

Review of the relevant information requirements from a user's perspective

It was first noticed that several groups of users are represented in the group but some are not here. The constituent groups, which were represented, are:

- scientific community in particular carbon assessment scientists
- few remote sensing method developers
- regional forest inventory service of Western Russia
- international NGO (WRI)

Representatives from governmental agencies at national or local levels, as well as forest managers or forest industry were missing (from both Western Russia and Northern Europe). As it was noticed that the lists of 'real' users were missing in the strawman papers, the first recommendation was to add such kind of list of potential users in each strawman paper.

In most strawman papers, the requirements have been presented from a certain point of view (in general 'administrative') but it was noticed that the same requirements could be easily re-adapted to satisfy other user groups. Although some needs are common for different users, the need to be more specific by category of users was strongly expressed. Two examples were highlighted to illustrate that need:

- Different institutional user levels need different scale or resolution of information to answer needs from national planning to local forest management.

- For the NGOs in general, specific requirements are to get information about the ecological status of the forest (related to biodiversity, carbon monitoring, habitat, etc.) and to get access to information in a quick, accurate and cost-efficient manner.
-

Following these considerations, the second recommendation of the group was to ask the strawman papers' authors to provide more specific requirements by category of users.

Another important and somehow surprising point which was made during the session, is that sometimes the final user does not know his/her own requirements in terms of information because he/she does not know the available technology. That seems to be particularly true for the forest industry companies. This is a good illustration of the need and the usefulness of a better dialogue between users and information providers. But it was immediately noticed that one of the goals of the GOFC is to properly develop such dialogue, so no further recommendation was issued from this point.

Finally it was felt that it is more difficult to define the requirements by discipline (such as forest cover status, forest changes, environmental impacts) in comparison to the user's approach.

Review and prioritize the relevant information requirements from a regional perspective

The boreal part of Europe (Scandinavia) is characterized by an intensive forest management. In that respect the western part of Russia is more similar to Scandinavia compared to Siberia, because the logging activities are more intensive and the fire regime is more strictly controlled. It has been also mentioned that the permafrost regime of western Russia is also very different from the permafrost regime of Siberia.

A common user's aspect between Western Russia and Scandinavia is that there is a need to emphasize the change-monitoring activities and to provide more detailed information (finer scale). But the user community in Western Russia is 'quite' different from the user community in Scandinavian countries leading probably to different requirements in terms of resolution of information. Medium resolution satellite data might be satisfying in Western Russia when aerial photographs would be needed in Scandinavia.

Taking into account that although western Russia is closer to Scandinavia than Siberia, there are differences, in particular in the forest management practices, two priorities can be highlighted:

- a more detailed level of attention (scale) has to be given to this region
- industrial users (including loggers) have to be considered with more attention

The need of a GOFC sub-regional workshop and the idea of the creation of regional center were also mentioned.

Deliberations of Breakout Session 2 - Matching Data Products with User Requirements at Regional Scales

The second breakout session was focusing on two questions:
- Have the information products been validated to the extent necessary?
- What are the highest priorities in terms of operational data products from a regional perspective?

Need for in situ data for validation

The *in situ* data for validation was considered as a first priority. Relative to other parts of boreal zone the data resources available for validation in Western Russia and Scandinavia are extensive, however certain field measurements may be very limited. For example it was mentioned that not enough data exist and are available for validation of the NPP maps. To improve the current situation a first task would be to identify what *in situ* data are available for validation. A second task would be to facilitate accessibility of to such *in situ* data.

For this region, detailed forestry data exist but are not freely available. In particular for Finland, Sweden and Russia, the 'original' inventory data produced at local level are generally not available. Only 'summary' data created at sub-regional administrative district, i.e. at very coarse resolution equivalent are available. The example of the forest inventory service of western Russia was given. In the forest inventory services of western Russia data exist at stand level (> 70,000,000 stands) with up to 200 variables collected at regular time periods (from continuous surveys). But these stand-level data are not geo-referenced.

It was recommended to develop meta-data at regional level and to geo-reference such existing data or information (through the preparation of GIS databases). Institutional barriers need to be addressed. The issue of accepting model outputs as 'data' was discussed but left unresolved.

Priorities for operational data products

The first premise was that information on forest cover status at regional scale is needed in order to derive better products that represent change: if good biomass map exists then one can derive better estimates of carbon losses from fire and other disturbances.

Products of interest at regional scale:
- Regional map of Scandinavia and western Russia map at 1:1,000,000 or 1:500,000 scales. The 1km resolution data might not be accurate enough for such purpose.
- Forest maps at 1:250,000 scale with the following main parameters: location, types, biomass, which may be derived from RESURS MSK data (150 m), MODIS (250 m), JERS 100m mosaic, ...
- Maps of land areas, which are covered by the Kyoto protocol (afforestation, reforestation, deforestation) at 1:1,000,000 scale.

Products of interest at local scale:
- For forest inventory services: stand maps at 1:10,000 scale derived from aerial photo

- More continuous monitoring of disturbance and logging activities from very high-resolution remote sensing data. It has to be noticed that sometimes, even aerial photography might be not detailed enough. Foresters need 1 to 10 m resolution data for change assessment .

The time frequency requirement for intensive monitoring by forestry community is a yearly period, however to ensure that quality scenes are available the actual frequent has to be much higher. The requirements in that regard are higher in our region because of short vegetative period and frequent presence of clouds during it. The optimal month is August, but that can be complemented by other periods. In addition, continuity of observations is important for monitoring change at the time scale of several decades. This may be an argument for making new sensors compatible with the old ones to facilitate the detection of change in vegetation cover. It is also important to maintain and to make accessible the archives of remotely sensed data so that changes over the period of many years could be detected. In addition, data used for image interpretation may be as valuable or more valuable than the final product. For example field plot measurements used to interpret the remotely sensed data, could also be made available to test global vegetation/biomass models.

It was also mentioned that today no space system (such as IKONOS) has the capabilities to replace aerial photography for many applications.

As forest fires are more controlled in this region, maps of fire scars are not a priority product here.

The group made the following recommendations for this breakout session:

- GOFC should promote test data-sets to be made available to all potential users
- for forest managers it will be useful to promote a test product at 20/30 m resolution with a 2/3 years frequency
- all levels of processing should be retained and made available to users

Deliberations of Breakout Session 3: Requirements and Strategies for Regional Information Networks

Requirements for Regional Networks

A. Rationales for the network:
1. Production of independent information
2. Opportunities to combine data and information from many sources (governmental, scientific organizations, NGO)
3. To serve as catalyst in the developing new applications for remotely sensed data, including disciplines that did not traditionally use remotely sensed information (i.e. certain social sciences, phenologists)
4. To establish and maintain dialogue between information users and providers

B. Interdisciplinary approach needed (the need to involve social sciences, NGO, forest management and forest industry, decision makers at regional/sub-regional level)

C. Participants of the network can be people who are not necessarily from the region but who are interested in the region

D. It was not clear to the group if the network should be the network of people or a network of organizations. It was stressed that while different user groups have their own agendas it is important to maintain the objectivity of information. Scientific interest in using information should be required.

Products, Near Term Goals

A. Collection and compilation of information about existing datasets, with possible enhancement (geo-referencing, upgrading, quality control). Making this information available on the Internet can facilitate its use and help identify critical information gaps
B. Status maps are needed before more sophisticated products can be derived (equivalent mapping scale 1:1,000,000 to 1:500 000)
C. Continuously up-datable database that makes it possible to derive disturbance information whenever needed
D. Exploration of methodologies to combine data and products from different sensors
E. Advanced methods for data and information dissemination (through the Internet)

Recommendations

Convene a regional workshop to assess current use of remote sensing, identify future needs of different user groups, discuss plans for development of a regional directory (meta-data) of existing datasets useful for validation and interpretation, plan future interdisciplinary research and education/exchange activities (St. Petersburg, summer 2001, hosted by INENCO).

Candidate Projects

A. Status map database
B. Differences in land-use (land cover) patterns in Scandinavia and Russia connected with differences in history and economy of Russia and Fennoscandia. The impact of these differences on biodiversity, carbon cycling, hydrology, patterns of population distribution can be assessed. These themes can be of interest for EU.
C. Differences in disturbance (change) patterns in Scandinavia and Russia in past, present and future
D. Test the ability of sensors to detect stand thinning activities and selective cuts. This is known to be a major challenge for remote sensing, however this is a major forest management activity and disturbance type in the region. Poor detection of this type of timber harvest can be a problem for many users (i.e. mapping intensively thinned or selectively cut stands as ‘virgin forest’).
E. Enhancing existing data products with additional ground data, e.g. monitoring change in the timing of seasonal changes in vegetation as an indicator of changing climate

F. Providing good information technology. At some locations in Russia (e.g. INENCO) such network already exists, but in many other locations it is underdeveloped. Lack of access to information is a major obstacle for many users.

G. Potential collaborations that would lead to production of new GOFC data sets or validation of existing data sets include representatives of all user groups. Collaborators who are better prepared by past experience include government agencies (especially those managing natural resources), research organizations, and academia.

Conclusions

1. Validation/interpretation of remotely sensed products with *in situ* data is a major general need.

2. Data for validation/interpretation exists in the region and is quite extensive. Facilitating access to it involves identification of useful datasets, their enhancement by geo-referencing, and creating meta-databases. In addition, for some datasets and potential collaborators obtaining formal security clearance is a pre-condition for participation.

3. Maintaining a dialogue with users is essential, many users being also the suppliers of data for validation. However, many potential users are unaware of remote sensing capabilities and cannot formulate their own requirements. Outreach effort can significantly expand the user community.

4. The creation of a regional network could be used to meet some of the needs stated in conclusions 1-3. A Russo-Nordic network would be useful, but countries outside Russia may prefer to work through the EU.

5. A regional workshop is needed to plan and to coordinate future efforts in order to compile information on *in situ* data resources available in the region, to formulate regional user needs, and to identify research priorities (proposed to be held in St. Petersburg in summer 2001 hosted by INENCO).

6. The region-specific thematic focus is change detection with emphasis on human impact.

2. Breakout Group Deliberations - Siberia/Russian Far East

Co-Chairs: Sergei Bartalev (IFI, Moscow, Russia and JRC, Italy)
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Vyacheslav Kharuk (SB RAS, Sukachev Forest Research Institute, Krasnoyarsk, Russia)
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Shvidenko, A. (IIASA, Vienna, Austria)
Solovyev V.
Sukhikh V. (IFI, Moscow)
Sukhinin A. (SB RAS, Sukachev Forest Research Institute, Krasnoyarsk, Russia)
Xiangming X. (University of New Hampshire, USA)

Breakout Session 1 - Review of Information Requirements

Question 1 – What are the information requirements for meeting forest management and research needs for spatial data in Siberia and the Far East?

General discussion: Perhaps the first important question is to identify what differentiates Siberia and Far East from other boreal forest regions in Eurasia. The key factors here are remoteness and poor access to most of the territory; this is a corollary to the low population density outside of the few large urban centers. This leads to two conclusions: (a) We need to carefully establish a network of on ground test (validation) sites, because work on the ground is expensive and difficult. (b) We need to emphasize use of multiple scales and types of remote sensing to supplement widely spaced ground sites and to develop a set of well-validated remote sensing methods. It was noted that there was formerly such an approach with Sputnik project, but it needs to be adapted to modern satellite technology.

After some discussion, it was decided that the best use of time, rather than analysis of holes in papers presented in the plenary session, was to develop a preliminary proposed list of the detailed requirements for information in terms of the specific disciplines and types of users. This was the focus of the rest of the discussion. The group frequently expressed concerns that only a few of the participants represented the user community and that representatives of government agencies at national level were missing; these led to recommendations to ensure their participation in later meetings as the GOFC process continues.

Data or mapping products may be global, regional, or local; there are several gaps that need to be breached. The purpose of every type of map product must be specified, relative to objectives, and applied uses. A focus on user needs is critical or products may not be used. Maps should be based on a fundamental idea; when we speak about forest mapping, we must answer the question of which particular parameters need to be mapped, and at what resolution. Output must be related to the information available for validation or for compiling the map. For example, an accuracy of 10-12% for certain parameters may not be feasible for Russia or W. Europe. Information requirements must contain a general idea and an approach to attain the idea. The objective of a map must be stated before deciding on the best approaches to obtaining the information. Using sensors with different resolution, we can meet multiple needs.

One of the key issues is to identify the specific requirements of managers. An important step is to work with managers to identify and define the problems that can benefit from the types of data available through remote sensing and from integration of remote sensing data with other spatial databases. It is also important to identify both existing spatial databases and existing sources of potential validation data (e.g. forest inventory). Many of these information requirements have existed for a long time, and for 20 years people have been trying to get information from satellites, but there has been little connection between management community and the remote sensing community, and only a small part of the available data are being used right now. People will pay for what they actually need, and that is why the GOFC aim is to bring together the users and providers. Our trouble is that the user percentage among us at this meeting is only 10%.

Identification of potential products useful to users is a process that involves two-way communication. For example, while forest managers in the Federal Forest Service have already defined many of their data requirements, the identification of needs is often based to some extent on the perception of what is available or feasible. So, while we should look to the users for input on needs, we also must educate the users concerning the potential of remotely sensed data to provide useful information efficiently, economically, and accurately. In some cases this may mean offering potential users a choice of available options (e.g., different resolutions, degrees or types of classification) as well as an evaluation of the potential costs and benefits of specific types of spatial information. We should go further and suggest what is needed in the future for users, and then show that it is possible and useful. Illustrative products can help to persuade managers or policy makers of potential usefulness of the data. For example, several regional demonstration projects on fire monitoring and mapping using remote sensing were well-received by western US fire managers during the summer 2000 fire season; one result has been growing support for development of operational products. There is a general need to add a GOFC educational component to develop a broader user community for remotely sensed forest data. We also need better approaches for getting the information to users when it is available.

It is also important to recognize that we will not be able to provide all possible products (e.g. all resolutions at all scales from local to global). For example, we may be able to do precise regional mapping of certain parameters for forests in China, but we probably cannot do that for all of the global products. We must determine the minimum resolution necessary to meet a specific goal. Mapping today is often less a technical or scientific problem than an economic problem, relative to available financial resources and the costs of carrying out the work. For example, there is a marked lack of remote-sensing information in Russia. At least part of this is financially based. The Resurs satellites have not been producing data, and although there is a wealth of experience in aerial remote sensing in Russia, there has been no money for that either. Improved access to Landsat TM 7 data satellite would be extremely useful.

It is important to recognize also that there are many types of users of data besides managers, such as the global change research community, policy makers, and conservation groups. Interests and needs of these various groups may differ.

An example of users the forestry community may not often think of is the energy industry. In the area of oil and gas production in W. Siberia, the major problem is where to locate the future enterprises to minimize possible impacts to environment by operating these facilities. Before making decisions about making decisions about make oil/gas, we must get the corresponding information on the region, prepared in form of maps with supporting information. Data are required on all components of the environment: relief, soils, climate, wildlife, and with information on particular shifts quantified. These data then must be matched with operational requirements for these technological activities, to select the approaches that are most optimal from both economic and environmental perspectives. Not a single map is obtained without remote sensing data, space data are used everywhere to make comprehensive evaluations about geomorphological structure.

While it is common knowledge that we have good sources of static information, dynamic data is also required. For example the seasonal dynamics of leaves, impacts of stress, development of insect and disease infestations, fire and logging activities, manmade hazards, and other anthropogenic impacts on forests are readily reflected in changes in spectral characteristics. These are all important indicators of forest dynamics, forest health, and susceptibility to disturbance. It is critically important to emphasize dynamic data requirements in any discussion of data needs—and remote sensing has unique capabilities to meet these needs.

Biophysical data requirements as they are typically presented are too general and lack specificity. The forest is a multi-level structure. We can't get vertical structure of tree stands from most types of remote sensing, but can we get ground and soil data? We would like to make these requirements more precise and specific. There are groups processing and using operational data, seasonal and annual data. We have all meteorological data, but we have no online information about biosphere, and it is necessary. For example, to monitor and manage fire or insect outbreaks is impossible without remote sensing. We must define the exact correlation between space-based, aerial, and ground measurements. There are momentous tasks for using fire data to quantify and predict fire behavior. When we talk about the need for online information on our biosphere, we must decide the time scale, and determine when daily (or more frequent) data are needed and when seasonal and longer-term scales are sufficient.

The group identified the following preliminary list of priority information needs for the region:

Ownership, land use, logging concession boundaries, forest protection zones

Inventory information such as homogeneity, density, growing stock, species composition, stand structure

Landscapes, vegetation distribution

Forest type, LAI, albedo, changes in these parameters (Also need to include non-forest types--swamp, steppe, tundra, etc.)

Factors related to meteorological and climate observations

Other types of data needed for biogeochemical modeling

Forest vigor/health (pollution, insects/disease, biological stress)

Dynamics of forest areas, bog/forest, forest/tundra, and forest/steppe ecotones, trends of forest invading tundra zone.

- Species regeneration
- Forest productivity

Wildfire information, including:

- Burned areas and timing/seasonality;
- Type and severity of wildfires (ground fire, low-moderate severity surface fire, canopy fire),
- Fuels information (including fuel characteristics and type and age of vegetation burned)
- Pyrological factors (fuels/fire danger)

Detection of different types of disturbance, for example--logged or burned, insect and disease infestations, steppe vs. agriculture

Wildlife data

- Relations between forest carbon and animals,
- Animal density, wildlife habitat, vegetation mosaics,
- Hunting association grounds,

Permafrost

- Type of permafrost
- Depth of seasonal melting layer

Hydrogeological functions.

- Surface water and groundwater;
- Soil parameters.
- Drainage networks

Terrain features including relief, slope

It was noted that for all of these areas it is critical to determine the scale most appropriate to the specific process or data need.

A summary of some of the opinions or concerns expressed during the initial dialog follow:

1. We have partly misaddressed the problem, because we don't know the specific requirements of managers. We should identify the problems and then how to solve them.

2. The information requirements of the users at the different (usually national, regional, and local) levels needed to be broached and specified much more clearly in terms of the desired information, scale, spatial resolution, regional extent, etc. Need to classify the users to further clarify the issue.

3. Not only scientific and technical issues, but also economical aspects (such as cost, available resources, etc.) have to be defined and harmonized with users' requirements

4. GOFC needs to focus not only on forest information but also on the physical environment (such as terrain and soil data, hydrology, climate data), on information required as inputs to modeling biogeochemical cycles, and on data on non-forest types.

5. Many types of dynamic data are required for forest management. This is a strength of remote sensing.

6. We shouldn't overestimate the potential assistance of the user and should offer the user a choice (the map scale, legend, content, and approx. cost and etc.). We should go further and suggest what is needed in the future for users, and then show that it is possible and useful.

7. Need to add an educational component to GOFC to create new users for these data. Getting the information to users was not discussed here in any detail, but needs to be!

8. A recommendation for future GOFC meetings is to narrow the scope and get the information (e.g. from overview papers) out ahead of time.

Breakout Session 1/2—Matching Data Products with User Requirements at a Regional Scale

This breakout session focused on developing a matrix relating data needs and scales to potential sources of information and assessing the appropriateness of various tools for meeting these needs. This is summarized in the accompanying matrix (Table 1). The group defined several main categories of products: carbon cycling or stocks (carbon), disturbance, fire, GIS, land use and land cover change (LULC), wildlife, and general physical or land cover characteristics (blank in this table). For each of these, specific information requirements were listed. Then a general categorization was made as to whether information could be obtained "directly" through classification/validation of satellite data, or "indirectly" through some form of analysis, modeling, or mathematical correlation of satellite data with, for example, forest inventory data from satellite sources. Some types of data were classified as "basic", meaning that they were foundation data for many purposes. For each information requirement, an assessment was then made by the group of the usefulness of various satellite platforms or sensors at providing the necessary information at local to global scales. The group freely acknowledged that this is a preliminary attempt and that the resulting table was limited by the combined knowledge of the group members about specific systems.

Table 1. Appropriateness of various satellite platforms for meeting specific types of spatial data needs for forest management and monitoring in Siberia and the Far East

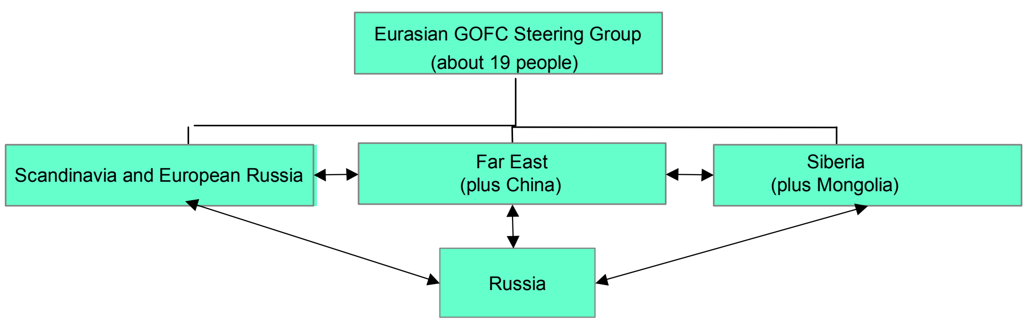
Sib/FarEast	Info Requirements vs. Data Products		1km		20m	1km	160m	30m	~10m	140m		250m	170m			1km
Category	**Info Requirements**	**Type**	**AVHRR**	**TOVS**	**SPOT**	**SPOTVEG**	**RESURS**	**LANDSAT**	**DISP**	**Okean/Meteor**	**SeaStar**	**Terra**	**IRS-Wifs**	**SAR**	**SIR-C**	**DMSP**
Carbon	C Sequestration by Vegetation Type/NBP	indirect	g3,r3		r3l3	g3r3	r1l1	r3l4		r2		g3r3	r2	r2l3		
Carbon	Carbon stock	basic	g2r2		r2l2	g2r2	r1l1	r3l4	r2l2	r1		g3r2	r1	g2r2	r2	
Carbon	NPP	indirect	g3		r3l3	g3r3	r1l1	r3l4		r1		g3r3	r1	g4r4		
Carbon	Reforestation of Clearcuts	direct	g2r2		r3l3	g1r3	r2	r3l2	r2l2	r1		g2r2	r1	g3r3	r2	
Carbon	Stock of Mortmass	indirect	g2r2		r2l2	g1r3	r2	r2	r2l3	r1		g2r1	r1	g1r2l2	r2l3	
Carbon	Stock of phytomass (by levels of forest vegetation)	direct	g2		r3l3	g2r2	r2	r2l2	r2l3	r1		g2r2		g2r2l3	r3l4	
Disturbance	Biological stress	direct	g2r2		r3l3	g2r2	r1	r3l3	r1l1			g3r3	r1		r1	
Disturbance	Forest vigor/health (pollution, insects/disease,nuclear)	direct	r2g2		r3l3	g3r3	r1	r4	r1l1			g3r3	r2		r1	
Fire	Area of wildfires (active fires)	direct			r2l2	g2r2	r2	r2				g3r3	r2			g2r2
Fire	Burnt area	direct	r3g3		r4l4	g4r3	r4	r4l4				g4r4		l3	r1l3	
Fire	Fire type (canopy, ground, underground)	indirect	g1r2		r1l1	g1r1	r2	r2	r1l1			g3r3	r2			
Fire	Cloud types	direct	g1		r2	g1	r1	r2	r1			g3r3	r2			
Fire	Current Moisture of Fuel Material	direct										g2r2		r3l3		
Fire	Damage assessment post-fire	indirect	g2r2		r3l4	g2r2	r1	r3l3	r2l2			g3r3	r2	r1	r2	
Fire	Fire behavior (intensity in 3 levels)	direct	g1r2									r4				
Fire	Fire location (point)	direct	g2r3		r3l3	g2l2	r1	r3l3	r3l3			g3r2	r2			g2r2
Fire	Lightning locations and Parameters	nonRS														
Fire	Pirological factors (fuel loading)	indirect			r3l3			r2l2								
Fire	Pirological factors (fuel types)	indirect			r2l2			r3l2				r1				
Fire	Emissions	indirect			r3l3	g2r2		r3l3				g4r4				
Fire	Smoke detection	direct	g3r3		r1l1	g3r3	r1	r1l1				g4r4				
Fire	Wind Direction/speed near active fire	direct		g3r3												
GIS	Forest protection	nonRS														
GIS	Hunting associations	nonRS														
GIS	Ownership, land use, logging concession boundaries	nonRS														
Human Impacts	Anthropogenic Impacts on Forests	indirect			r3l3	g3r3	r2	r3l3	r2l2			g3r3		g2r2	g2r2	
Human Impacts	Logging	direct	r2g2		r4l4		r3	r4l4	r3l3			g3r3		r3l3	l3	
LULC	Changes (landuse landcover)	direct			r3l3	g2r2	r3	r3l3	r2l2			g3r3		g1r1	g1r1	
Wildlife	Wildlife/Density/Habitat	indirect	g1r1		r2l2	g1r1	r1	r2l2	r2l2	r1		g2r2				
	Albedo	basic	g4r3		r3l3	g4r3	r4	r3l3				g4r4				
	Climate	indirect	g4r3													
	Drainage networks	direct			r3l4		r2	r3l1	r3l4							
	Ecosystem Diversity assessment	indirect	gr		r2l	gr	r2	r2l								
	Forest age	indirect			r2l2			r2l2	r2l3					g1r1l2		
	Forest density	direct	g2r2		r3l3	g2r2	r2	r3l3	r3l3			g2r1		r1l3		
	Wood Stock	indirect			r2l2	g1r1	r1l1	r2l2	r3l3			g2r2		g2r2l3		
	Forest non-forest map (including forest ecotone)	basic	g3r3		r4l4	g4r4	r4	r4l4	r3l3	r4	g4r4	g4r4l1		l2r3	r3	
	Forest type	basic	g2r2		r4l3	g3r3	r3l1	r4l4	r2l1	r3l1	g4r4	g4r3l1				
	Frontier forests	basic			r3l3		r1l1	r3l3	r3l4			r2l2				
	Groundwater	direct												g1r1		
	LAI	indirect			r3l3	g2r2	r1	r3l3	l1							
	Landscapes (including relief/geomorphology)	indirect										g4r4		g4r4l4	g4r4	
	Meteorological	direct														
	Permafrost (including seasonal melt layer depth)	indirect												g1r1		
	Phenology	direct	g2r3		r4	g3r3	r3	r4				g4r3				
	Snowcover dynamics	direct	g4r4		r4	g4r4	r2	r4				g4r4				
	Soil parameters	indirect	g1r1		r1	g1r1	r1	r1						g1r1		
	Surface water	direct	g2r2		r3	g2r2	r2	r3						g2r2		
	Vegetation map	basic	g2r2		r4l3	g3r3	r3l1	r4l4	r2l1	r3l1	g4r4	g3r3l1		r3l3	r3l3	
	Wetland areas	direct	g2r2		r2	g2	r1	r3				g3r3		g2r2l3	l3	

Explanation of codes: g=global; r=regional; l=local; 1-4 rank appropriateness of products for particular applications, from 1 (most appropriate) to 4 (least appropriate). Satellites not discussed because of lack of familiarity included: Meteosat and GOMSS.

Breakout Session 3—User Synergy and Requirements for Regional Information Networks

This group focused on discussion of how best to structure future GOFC activities in Russia. Discussion was quite heated, but ultimately the group agreed on a set of recommendations. These recommendations are summarized in Figure 1 and are discussed further below. The general concept was to establish a Eurasian network for GOFC but to break it up into three regional working groups that reflect areas where management problems and forest cover types are most similar. The Russia box represents the necessary coordination of all groups with Russian federal agencies with responsibility for land management, space observation, etc. in recognition that management of all such activities in Russia is highly centralized and that certain types of agreements and understandings would be common to all groups.

Figure 1. Eurasian Network



1) The Eurasian Steering Group is envisioned as a coordination group, with about 19 people on it. This group would include representatives from the regional groups. Members might include:

- RFFS and other governmental reps
- Representatives from other boreal countries (including North America Steering Group)
- Coordinators of regional groups*
- Representatives of Major RAN Institutes in European Russia, Siberia, Far East*
- Representatives of major science projects*
- Civil society representative
- Preliminary group established before regional meetings (about 12 participants)

*final reps may be recommended by regional groups

2) The three regional groups would do most of the actual coordination and information exchange at a project level. They would include:

- Researchers from regional institutes
- International cooperators
- Forestry and other management cooperators
- Forestry committee representatives
- Ecology committee representatives
- Civil society organizations

It is envisioned that the Siberia and Far East groups would initially meet together and would only divide as the number of participants increased and once coordination between the two groups was ensured.

Proposed Meetings:

A preliminary steering group meeting is proposed to review inputs on priorities and make general recommendations. The regional groups would then meet to consider recommendations and discuss regional projects and coordination. Once regional groups were operational, they would recommend additions/changes to steering committee to ensure adequate regional representation.

Information needed:

- Nominees for Steering Committee
- List of current products; where is validation needed?
- Suggestions of potential participants (not at current meeting)
- Contact list information
- Send information to GOFC for forwarding to Steering committee

International Agreements needed:

- Steering committee reps contact Russian gov't agencies re GOFC/ cooperation needs
- Develop bilateral MOU's between cooperating countries concerning mutual work with geographic data

Information Systems

- Evaluate needs for data exchange capabilities
- Develop strategy to enable free sharing of resources; data storage and access
- Consider equipment and communication links needed (e.g. many sites have no high-speed internet access)
- Evaluate capabilities and use of existing receiving stations

Proposed Scheduling

- Steering committee nominations, lists of potential participants and contact information to GOFC – 1 October
- Send info on current projects, priorities for GOFC products, etc. to GOFC --1 November
- Preliminary Steering Committee established– 1 December
- Steering Committee develops recommendations for priorities and regional organizers—1 February
- First regional meetings—late Spring 2001

3. Breakout Group Deliberations - North American Boreal Forest Region

Co-Chairs: Kathleen Bergen (UM)
Tim Lynham (CFS)
Participants in the group discussions:
Don Clark (UVA)
Eric Kasischke (UMD)
Rasim Latifovic (CCRS)
Kyle McDonald (JPL)
Tim Perrot (CCRS)

Introduction

This report discusses the characteristics of the global observation of forest cover in the boreal forest, with an emphasis on North America. Monitoring forest cover is broken down into observations of land cover and land cover change, disturbance due to wildfires, and biophysical processes. The global monitoring of boreal forests includes the use of data collected from remote sensing platforms whose forest-cover information is dependent on sensor type, spatial resolution, temporal resolution, and spectral resolution of the systems being used.

Users (constituents) requiring this information include carbon budget scientists, managers at local and regional levels, and policy makers mostly at the national level. To effectively use remote sensing-derived information for scientific, management and policy purposes will require direct involvement of the forest management agencies that can integrate traditional field methods with recent remote sensing methods. Outreach and training will be required for the forest managers on an ongoing basis.

Characteristics of the Boreal Forest

The boreal forests have lower biomass relative to tropical forests and lower species diversity, especially at the tree level. The effect of fire (and other disturbances) is longer-lived because disturbance can result in changes in dominant species for long periods of time (i.e., 20 years to several hundred years).

Permafrost (in the north) and large expanses of wetlands are characteristic of these forests. The strong seasonal climate patterns in the boreal forest (that includes freezing and thawing) controls growth, senescence, and patterns of decomposition. The boreal forest has had a lower rate of land conversion because of because of lower population densities, and it is often treated like a frontier forest. There is, however, increasing pressure to exploit the vast timber and mineral supplies that exist in this region.

Conditions common to the boreal forest affect data acquisition from remote sensing platforms. Cloud cover often limits sensors that operate in the visible and infrared spectrum, and low sun illumination is common due to the northern position of the boreal forest. However, there is a higher repeat coverage for most satellite sensors at northern latitudes, partially offsetting the loss of data due to the higher probability of cloud.

Characteristics of the North American Boreal Forest

The North American boreal forest has several features that distinguish it from other boreal forests. It has been glaciated more often and more severely than the European boreal forest, resulting in shallower soils (except in peatlants) and a large number of lakes. In addition, wildfires are high-intensity crown fires that are stand replacing because North American boreal forests are denser than European boreal forests.

The North American boreal forest has two well-defined boundary zones. These are the southern grasslands in the center of the continent and the western coastal rainforest that is separated from the boreal forest by a cordillera called the Rocky Mountains.

The North American boreal forest falls under the jurisdiction of two countries (Canada and the USA) and includes twelve different management agencies. In the USA there is the state of Alaska and in Canada there are three territorial and eight provincial governments responsible for forest management. This often results in different policy directives. Most communities in the boreal forest depend more on resource extraction than on manufacturing. Thus, in many areas, the forest is a primary socio-economic driver, providing opportunities for employment as well as recreation. Many areas are protected from resource exploitation as parks and wildlife refuges.

Characteristics of a GOFC Boreal Information Network in North America

A North American boreal GOFC information network should be developed in the context of other GOFC programs in other regions of the world. Although nations will develop national-scale land-information products, it must be remembered that ecosystems transcend political boundaries. For example, Alaska and the upper Great Lakes states are coordinating some efforts with Canada. The Canadian national soil carbon database covers Alaska as well. There is a strong argument for compatibility of land cover classifications between Canada and the U.S.

The amount and number of data types and information requirements makes it imperative that GOFC develop an efficient metadata network. The Open GIS consortium is one model for integrating data that is independent of software and hardware. The systems must be flexible enough to capitalize on advances in sensor technology, modeling, and computing.

All GOFC participants must recognize that in addition to the resources, ideas, and products that are developed by the public and private sectors, we must now recognize the contribution of the "civil society." This includes groups such the World Resources Institute (WRI). They are equipped to utilize remote sensing data and GIS and report independently from government and industry groups. Linking with such efforts should be a high priority for GOFC.

Breakout Session 1 – Review of GOFC User Information Requirements

What are the users' requirements in the areas of land cover and land cover change, disturbance monitoring, and biophysical processes within the North American boreal forest region? The USDA Forest Service has supported the development of complete Landsat-level land cover for the USA. This was required to make the Forest Inventory Assessment (FIA) more robust and more economical. In Canada, there is no national Landsat land cover product; however, there is a digital-land cover product developed from AVHRR imagery. Meanwhile, the Canadian Space Agency (CSA), the Canadian Forest Service (CFS), and the Canada Centre for Remote Sensing (CCRS) are cooperating to build a Canada-wide digital land cover based on Landsat. Land-cover maps serve as the building blocks for many other products such as forest monitoring and change detection.

Although wildfire monitoring and mapping is the key focus of this GOFC boreal forest change initiative, GOFC recognizes the importance of monitoring other forest conditions such as the insect outbreaks, pathogen attacks, and other stressors (e.g., drought). For wildfires, mapping and monitoring are a higher priority than detection. There are area burned databases nearing completion for Alaska and Canada.

Some of the main biophysical parameters and processes that are needed include biomass, carbon, trace gas (including methane), phenology, and moisture levels related to soils and vegetation. Users employ models that make use of inputs that are available to them and are eager to incorporate new products when available. User needs are being driven by international agreements (Kyoto Protocol, Montreal Process, Helsinki Accord, ITTO, and the United Nations Environmental Program) for quantifying and monitoring forest sustainability. In all cases these agreements are predicated on a set of criteria[1] and indicators[2] (Table 1).

Table 2. Examples of Indicators required by an agency, a national process, or an international agreement.

USDA Forest Service	FIM	Montreal Process
wildfire location and size	Land area by cover class	fragmentation by forest type
fuel load	Area of forest land	growing stock volume
vegetation species	volume of trees by forest type	annual depletions
vegetation moisture content	biomass by forest type or ownership	area affected by insect, disease, fire, flood, etc.
threatened and endangered species	crown dieback	total forest biomass and carbon by forest type and age
forest cover type	crown density	contribution of forest to total carbon budget
regeneration success of forest	vegetation diversity indices	
flood damage		

Break-Out Session 2 - Matching Data Products with User Requirements at Regional Scales

Land Cover and Land Cover Change Products

Land-cover change in forested areas usually focuses on changes due to fire, logging, insects and disease, land conversion, afforestation, and pollution. Coarse resolution, 1 km products (e.g., from SPOT AVHRR and SPOT VGT) provide adequate information for use in many national

[1]Criteria are the elements that are considered important for sustainable forest health and management and by which change will be measured and/or success or failure to achieve will be judged.

[2]Indicators form the basis by which criteria are measured.

and global-scale models. SPOT VGT has improved spectral resolution and geometric fidelity over AVHRR. These data present the potential for monitoring general forest conditions using multi-temporal monitoring. As an example, one could establish a baseline (normal) condition and then use follow-up data to map changes.

Moderate resolution land cover data (in the range of 250-500 m resolution) from instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) will provide data that will improve our understanding of the larger-scale, longer-term dynamics occurring in the boreal forest. MODIS has the potential and most certainly will play a vital role in the development of earth system models designed to monitor global change. A key advantage is that the MODIS program includes a strong validation plan.

High-resolution satellite data products (Landsat TM/ETM and SPOT) in the 10-30 m resolution range are more useful to managers for addressing local management needs. These imagery are often limited by cloud cover, time between repeat coverage and differences in radiometry from scenes that cover a large geographical area . Therefore they are more easily used to manage small land areas that require few frames. On the other hand these data can be used for building coverage of large areas (e.g., nationwide coverage) if the coverage can be collected and processed over a 5 to 10 year period. Fine resolution (1 to 5 m resolution) satellite imagery (IKONOS, IRS) is becoming more common with additional fine-resolution satellites planned to be operating by the end of 2001.

The Forest Inventory Assessment (FIA) project is a source of validation data for land cover initiatives in the USA. The National Forestry Inventory System (NFIS) is a national digital database that roles-up forest inventory information from all the Canadian provinces. Canada is also launching a 10-year remote sensing project called Earth Observation for Sustainable Development of Forests (EOSD) that will develop operational remote sensing systems for monitoring Canadian forests. EOSD addresses forest cover, forest cover change, and biomass in Canada and has a validation scheme that will make use of the NFIS.

Fire Products

A number of global fire mapping products have been developed, with the justification that they provide information required to assess global levels of fire activity. The World Fire Web provides an AVHRR-derived daily, global fire product that maps active fires. MODIS has the potential for mapping fires but currently there is no fire product. The Along-Track Scanning Radiometer (ATSR) is producing a global fire product that is a fire burnt scar product. Validation has shown that the ATSR fire product may be inaccurate - it may overestimate single year burnt area by including burnt areas from previous years. A systematic analyses of such data products is certainly needed. The Canadian fire product (Fire M3) uses daily AVHRR data to map hot spots across the country. At the end of the fire season, area burnt is mapped using SPOT VGT data in conjunction with the hot spot data. First, multi-date VGT data are used to map any changes, then AVHRR hot spot data are used to confirm which changes are due to fire.

To date, little or no validation of hot spot data or area burnt has been carried out for fire products. Fire M3 is carrying out a validation exercise that will use about 100 Landsat TM frames to map 197 large (i.e., greater than 200 ha) fires form 1998 and 1999.

In situ measurements on fires should be combined with remote sensing to examine the relationship between area burnt and fire severity. Meanwhile it is uncertain how projects like Fire M3 will continue or how similar fire mapping efforts can be coordinated.

Another valuable contribution that remote sensing offers is improved fuel mapping for North America. Present fuel maps are based on coarse resolution satellite data that are not detailed enough for making reliable fire behavior predictions.

Biophysical Products

Existing biophysical products include LAI, NPP, FPAR, and NDVI from the AVHRR and MODIS satellites. Information needs and the sensors that have the potential to provide satellite data related to those needs are summarized in Table 2.

Table 3. Summary of Information Needs and Data Sources

Information Needs	Data Source
LAI, FPAR, APAR, NDVI, NPP	multispectral optical, SAR
Height	polarimetric and interferometric SAR
Biomass/carbon	SAR
Crown density/closure	high resolution optical, lidar
Crown depth	interferometric SAR, lidar
Understory	Combined optical/active SAR & lidar
Texture (canopy roughness) and vertical structure	SAR
Soil moisture dynamics	SAR, scatterometers
Seasonal temperature cycles (freeze/thaw)	SAR, scatterometers
Snowpack properties	SAR
Standing and downed woody debris	? (hyperspectral)

Synthesis of Information Requirements

Terrestrial ecosystems are defined as volumetric segments of the earth that include the atmosphere, lithosphere, and biota contained within these volumes. It is useful to know the boundaries of your system, to work on the issues that affect your system, and to be aware of the work of other agencies on their systems.

We propose a paradigm for the current status of a forest ecosystem. That paradigm examines the composition (e.g., forest cover), structure (e.g., biomass, height, density), and function (e.g., carbon cycling, water cycling, nutrient cycling) of the ecosystem.

Forest ecosystems may change slowly over time due to natural ecosystem dynamics such as the aging process within a forest. In comparison, other natural changes such as wildfire, blowdown, and insect and disease infestations happen quickly. Meanwhile, human-induced activities such as logging and urbanization also cause fast, distinct changes. But changes such as increased wildfire or changes in insect and disease infestations are also being influenced by human activities. The proportion that is related to human influence is not always easy to deduce.

Status of Forest Ecosystems: Composition, Structure, and Function

MODIS and SPOT-VGT global land cover products are in production but they will have to be validated. In North America, a Landsat land cover classification is being considered for capturing the forest composition. In Canada, the EOSD project proposes to develop a land cover classification for several time frames (1990, 2000, and eventually 2010). All these efforts for land cover classification require a methodology to continuously update forest changes. In order to capture all changes, it may be necessary to include SAR imagery. The best estimates of biomass using SAR have occurred in plantations. The baseline data for validating biomass estimates will come from the NFIS in Canada and the FIA in the USA.

Estimates of above-ground living biomass will be an indicator of forest structure. Initially categorical estimates of biomass could be derived from JERS but a continuous estimate could be provided by SAR imagery. Height and density could be determined from lidar and interferometric SAR.

Measures of the how well a forest functions will be captured through measurements of NPP, APAR, LAI, and FPAR. This will require a North American network of validation sites.

Conclusions and Recommendations

- Global science needs coarse to moderate resolution satellite data.
- Management increasingly desires higher resolution (10-30 m data while moving towards 1-5 m data) and GOFC must be prepared to implement higher resolution data.
- Hyperspectral sensors will provide data on large numbers of spectral bands, dealing with complex land eco-systems that can be imaged and accurately classified. GOFC needs to be able to advise on the applicability of such data.
- Information on land structure and moisture content should be enhanced by the use of SAR, scatterometers, and lidar.
- Sensor fussion may be required at the pixel, feature, and decision level.
- The integration of remote sensing and field data must be included in project development and execution.
- There is a continuing role for education and outreach related to remote sensing applications.
- Strategically, there is potential for monitoring general forest condition using multi-stage monitoring and sampling (e.g., AVHRR could form the basis for depicting normal conditions, along with the use of higher resolution data to zero in on specific management issues.

Appendix Four – Position and Background Papers

Information Requirements for Forest Resource Management in the Boreal Zone

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Boreal forest and woodland cover about 1.2 billion ha and represent about 30 percent of the earth's forested area. Some two-thirds of these forests occur in Russia. Most of the rest is in North America (Canada and Alaska), with a lesser amount in northern Europe (primarily Scandinavia). Boreal forests have been estimated to contain from 10 to 17 percent of global carbon reserves. Because much of the broad extent of boreal forest occurs in remote regions of low population density, these forests are perhaps less intensively managed and less impacted by direct human activity such as logging than the forests of the temperate and tropical zones. Their future will be one of competing values as sources for wood products and other resources, conservation reserves, and carbon storage. Sustainable management of these forests to meet resource needs in an ecologically and environmentally sound manner will be an increasing challenge in the years ahead.

Throughout much of the boreal zone, disturbance processes such as fire and insect and disease infestations play a major role in forest dynamics. Wildfire alone burns some 10 to 15 million ha per year. In some regions, logging is also an important activity; but land conversion for development, agriculture, and other purposes has not been as widespread as in many temperate forests. Human impacts are greatest near population centers and along major transportation routes such as roads, railways, and rivers.

Global climate change models predict the largest temperature changes in the boreal forest and tundra zones. Researchers have already documented changes in arctic tree line and changing phenology over the past several decades. Models also suggest that changing climate will lead to increased seasonal fire hazard over much of the boreal zone. Stress on forests from increasing temperatures and more widespread fire is also likely to be reflected in greater frequency and extent of insect and disease outbreaks. Accurate monitoring of changes in these forests is necessary to provide a sound basis for sustainable management and for carbon accounting.

Because of their large extent and isolation from road access in many areas, the benefits of remote sensing approaches to evaluating and monitoring the dynamics of boreal forests are likely to be even greater than for temperate forests. The cost of ground-based and even aircraft sampling can be high compared to resource values. Forest inventories are often inaccurate and out of date. And accurate quantification of the extent and severity of disturbance impacts may not be available.

Specific Information Needs for Resource Management

Some of the key areas of information needs are listed below. Many of these will be discussed in more detail by speakers that follow.

Vegetation classification:
Monitoring of long and short-term changes in land use and vegetation

- Distribution and classification of vegetation types
- Occurrence and impacts of disturbance (invasive species, fire, harvesting, urbanization, etc.)
- Vegetation changes due to climate/global change (e.g. treeline changes, phenology changes, changes in productivity or structure/composition)
- Wildlife habitat

Forest Inventory:

- Stand structure, dynamics, harvesting and other changes
- Forest health monitoring (insect and disease, environmental and pollution damage or stress)
- Monitoring of some sustainability Criteria and Indicators (Montreal protocol)

Productivity and Carbon budget monitoring:

- Biomass, vegetation type and structure, impacts of disturbances
- Integration with climatic models
- Data for monitoring/compliance re international agreements (e.g. Kyoto)

Environmental impacts of disturbances:

- Emissions from wildland fires,
- Erosion and sedimentation,
- Riparian zone and hydrologic impacts
- Wildlife habitat (threatened and endangered species, game species; fisheries)

Monitoring of seasonal patterns:

- Snowpack
- Phenology
- Vegetation stress/fire hazard
- Moisture

Monitoring for emergency response:

- Fire detection and active fire monitoring
- Early detection of insect and disease, invasive species

Integration of remotely-sensed data with data and models from other sources

There is potential for much of the data discussed above to be obtained through the use of global observation systems. However, several factors need to be considered in terms of the need to integrate remote sensing data with data available from other sources. Some of the key data in natural resource management are likely to be available primarily in the form of GIS (Geographic Information Systems) databases. Some of these potential GIS layers include: roads, development (e.g. towns, campgrounds, homes, census information), rivers and lakes, terrain data, and planning information such as land use categories, use restrictions, and proposed manipulations.

For remotely-sensed data to be most useful to forest resource managers and to policy makers requires integration with predictive models, such as models of global climate change, stand dynamic simulators that model growth and succession processes, models of insect and disease population dynamics, carbon cycling, or animal population/habitat relationships. These models will often need to be developed through process-level experiments, ground observations, or understanding of basic physical processes.

A critical factor in use of remote sensing for meeting forest resource management needs is the development and implementation of appropriate ground truthing methods. To determine the accuracy of remotely-sensed data requires scaled ground-based and multi-level sampling to test and develop interpretations and models. An example of this is the use of forest inventory plots to characterize the vegetation and stand structure and development of models linking this information to characteristics that can be observed and classified from remote platforms.

Issues of scale

Natural resource data needs vary greatly in their required spatial and temporal resolution. It is critical to understand these requirements and consider them in developing systems for use of remotely-sensed data.

The required spatial resolution depends on:

- How the data will be used (locally or for national or global models or policy-making);
- The scale of the disturbance or process being monitored (e.g large wildfires may cover many thousands of hectares, while a typical harvest unit is 5 hectares to several hundred hectares; wildlife habitat mapping may require even finer scale);
- The type of measurements that are needed (general vegetation type or specific stand structure information).

Data requirements also vary in temporal frequency. Some data need updating daily or weekly; most data can be updated annually or less often. Again, this depends on how the data will be used. Predictions of fire hazard, for example, may need to be updated daily during the fire season, while maps of fuel type and fuel loading might be updated annually or less often depending on the vegetation. In some instances, it may be possible for high frequency, coarse resolution data to be used to update low frequency, higher resolution data. For example, if appropriate algorithms can be developed linking fine-scale seasonal changes in fuel moisture (e.g. adjusted for slope, vegetation composition, etc.) to 1-km resolution satellite data, fine scale maps might be updated daily without requiring data from higher-resolution platforms.

Conclusions

Accurate information on spatial distribution and temporal changes of boreal forest resources is critical for regional and national land management planning and for monitoring short term effects of disturbance and long term resource trends on regional to global scales. Adequately validated remotely-sensed data is an essential component in meeting the information needs of managers and policy makers for sustainable forest resource management in the boreal zone.

Satellite Earth Observation for Wildland Fire Management

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Background

Natural boreal and temperate forest, brush, and grassland ecosystems evolved and adapted with wildland fire as an agent of ecological change. Human development has altered many natural landscapes and placed people in direct contact with wildland fire. Wildland fires cause loss of human life and personnel property, economic upsets, and disturbances in regional and global atmospheric composition and chemistry, and climate. Wildland fire managers want to respond appropriately to wildland fires to best protect and preserve the resources at risk within the constraints of local policy objectives.

Managing wildland fire effectively depends on information that varies according to the user of the information, the characteristics of the geographic region, and the current and evolving phase of the wildland fire. For suppression planning and for prioritization of areas for surveillance, it is important to assess the wildland fire potential (risk and hazard mapping) in the most fire-prone areas. In the crisis phase, it is necessary to know the exact position of the wildland fire (detection), how it is developing and spreading (behavior), how it has progressed over time (monitoring), and how it is likely to develop into the future (behavior prediction). After suppression it may be necessary to examine the type and extent of damage and to plan for recovery actions (assessment, mapping, and rehabilitation).

In the following section, wildland fire management is divided into three different phases**:** preparedness, detection and response, and post-fire assessment. The information requirements are usually different in each phase. The biggest differences relate to the temporal and spatial resolution and accuracy of the required information.

Preparedness

The most important task in the preparedness phase of wildland fire management is to assess values at risk. Conducting risk assessment studies to identify areas with the greatest potential for protecting human lives, property, and natural resources can help authorities impose greater surveillance or restrictions on fire use in these areas. Risk assessment considers variables such as land use and land cover, wildland fire history, demography, infrastructure, and urban interface.

Remote sensing is used to derive vegetation stress variables, which are subsequently related to wildland fire occurrence. Indices are most frequently based on the estimation of live and dead vegetation moisture content, as derived from meteorological variables, some of which can be obtained from meteorological satellite data. Information on wildland fire high-risk areas is pivotal in planning for preparedness and wildland fire prevention. There are tools for mapping the risk areas, based on land cover maps, statistical wildland fire information and daily weather conditions.

Information on the actual combustible matter, especially on a global scale, is not available. Currently, the estimation of fuel moisture is based on the information from local ground weather stations. Under-canopy observations, integrated with ground measurements, are required. Improved satellite technologies and methods to generate accurate, updateable, global wildland fire fuel maps are needed. Weather models to facilitate daily and 1 to 2 day prediction of dead fuel moisture to augment or replace requirements for ground weather stations are also needed for most of the land areas of the world.

Wildland fire detection and response

Some satellite borne sensors can detect wildland fires in the visible, thermal, and mid-infrared bands. Active wildland fires can be detected by either sensing their thermal or mid-infrared signature during the day or night, or by detecting the light emitted from the wildland fires at night. The sensors must also have frequent overflights with data available in near real time.

The spectral, spatial, and temporal resolutions of current satellite platforms do not adequately meet the need for real-time detection of wildland fires. However, detection of large wildland fires in remote areas, such as Alaska and the tropical forest belts, has been successful using Earth observation.

Existing satellite sensors with wildland fire detection capabilities are underutilized. They include NOAA-GOES, NOAA-AVHRR, and DMSP-OLS. We believe that technology for generating and distributing daily wildland fire products on regional to global scales from these systems is feasible. This would provide an extremely valuable service for both wildland fire management and prevention.

Local fire mapping for strategic support and suppression response is the highest priority data product required, as it is needed to save human lives and natural and manmade resources. For global monitoring of wildland fires, where the detection time is not so crucial, the main requirement is to have good access to the data flow from several information sources. Geostationary and polar-orbiting weather satellites are currently used successfully for mapping and monitoring of wildland fire on a large scale. An operational system for the timely distribution of high-resolution geospatial products displaying fire location and intensity is needed by organizations responsible for wildland fire suppression.

Post-fire assessment

The most important post-crisis activity in wildland fire management is the assessment of the burned area and protection of watersheds and critical resources. Although remote sensing has already proven its usefulness in this activity, very few authorities utilize space-borne data operationally in assessment of wildland fire damage. With space-borne remote sensing, the wildland fire damage or the extent of burned area is determined by the single-date or multi-temporal analysis of the images

Burned area assessment frequently requires acquisition of data from several different sources. Smoke and clouds often obscure the ground for extended periods following large wildland fires. Impediments to supporting the user with this information may be the high cost or slow access to the data streams. When developing new applications, these difficulties present a major hindrance.

Wildland fire scars and burning of biomass are often studied locally. In some regions, the existing satellites cannot provide good timely coverage. For a global understanding of the scale and impact of biomass burning, there must be an operational worldwide system to determine the area burned and the fuel type for assessing the amount of carbon released.

In addition to the requirement for prescribed fire decision support on smoke management and air quality monitoring, there is need for broad area monitoring of trans boundary smoke movement to help determine its impact on human health and safety. Smoke causes reduced visibility, closing airports and creating hazards to air, ground, and sea transportation. Better information on the impact of smoke on lower atmospheric chemistry and potential changes in global climate is also required.

Other Considerations

Currently, wildland fire management requires the use of data from satellites, which were not designed for wildland fire monitoring. The investment in the currently developed applications will be at risk if the currently used data sources are discontinued. Recognizing that there is currently no satellite system dedicated to wildland fire management, the requirements are dependent on the data from several satellite data sources. When commercial data is used, the cumulative price of and access to data becomes a major hurdle in developing the most useful applications. In the event of a crisis situation, several satellites might have to be co-scheduled (tasked) in order to get proper satellite coverage of the area of interest.

In addition to the above recommendations, there is a need for regional expertise in remote sensing to provide an overall organizational framework of leadership and direction in coordinating international fire prevention and in training, monitoring, suppression, and assessment efforts. The Committee on Earth Observation Satellites (CEOS) could be instrumental in improving remote sensing capabilities and expertise in wildland fire management and should initiate discussion with international organizations to address these activities.

Information Requirements for Monitoring Disturbances in the Boreal Forest

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The world's boreal forests are subjected to disturbance from a number of sources, both human and natural. Information on the extent and severity of these disturbances are required by a wide range of users, including those from the private and public sectors interested in a wide range of scientific and management oriented uses.

The types of disturbance that occur in the boreal forest include tree damage and mortality from:

(a) fire (both natural and human);
(b) insects and pathogens;
(c) climatic events such as winds, snow and ice;
(d) acid deposition; and
(e) logging and land clearing.

Some may argue that a sixth category of disturbance needs to be considered: (f) drought. However, unless drought extends over several growing seasons, it rarely results in permanent damage or mortality over broad areas. However, at regional scales extensive drought makes forests more susceptible to damage from insects and pathogens or fires.

Disturbances are an extremely important process in the boreal forest, and are highly variable year-to-year. This is particularly true about those disturbances that are dependent on climate, e.g., fire, insects and pathogens, and damage from wind, snow and ice. Because of this dependence, the annual level of disturbance in the boreal forest is not constant. In any case, the current levels of disturbance that are known include: fire – 2 to 15 million ha yr^{-1} (average 8 to 10 million ha yr^{-1}); insects and pathogens – 2 to 6 million ha yr^{-1} (average 3 million ha yr^{-1}); acid deposition – approximately 2 million ha yr^{-1}; and logging and land clearing: approximately 2 million ha yr^{-1}.

Regardless of the category of disturbance, the same types of information disturbance are required:

(a) Location of the disturbance – where is the disturbance occurring.
(b) Size of the disturbance –how large of an area did the disturbance cover, or better yet, the geographic boundary of a disturbance
(c) Characteristics of the vegetation being disturbed – what is the species composition of the forest stand being disturbed? what are the sizes of the trees being disturbed? what are the soil characteristics of the area being disturbed?
(d) Timing of the disturbance – for a particular disturbance event, when did the disturbance start and when did it stop? what is the rate of disturbance?

(e) Severity, or quantification of the level of disturbance in terms of 1) how much biomass is consumed, extracted or converted and 2) the extent of ecosystem conversion through mortality or repalcement. Each type of disturbance has it's own unique set of characteristics. In particular, the following types of questions are asked: What proportion of the dominant vegetation was killed or removed? What is the scale (area) of stand replacement? What proportion of the canopy was damaged? Will the species compositon and structure change after the disturbance? How much biomass (or carbon) was lost from the system? How much organic soil or mineral soil was lost from the system?

(f) Interactions between disturbances. In many instances, one type of disturbance is related to another. For example, in land clearing activities, fire is often used to remove unwanted or excess slash from the fires. Fires with the cut region often are the source of ignition for adjacent regions. In many instances, invasion by insects and diseases follows other types of disturbances, including damage from ice, wind, and snow, acid deposition, and fire. Fire is known to occur in stands that have been damaged by insects and pathogens. In these cases, the most important questions are: What is the combined severity of the related disturbances? How much greater is the probability of occurrance of each secondary disturbance given that the primary disturbance has occurred?

These information requirements pertain to the 1) assessment of disturbances that have already occurred, 2) predicting disturbance, and 3) modeling disturbance under alternative climate and management scenarios. While satellite systems are critical for assessing the extent and general characteristics of disturbance, ground-based assessment and modeling are needed to: (1) validate the satellite observations (e.g., assess the type, severity and extent of the disturbance); and (2) develop analytical and predictive models which exploit the remotely sensing information.

It is important to recognize that disturbances in the boreal forest occur at a wide range over a wide range of spatial and temporal scales. For example, fires can destroy very large areas of the boreal forest (single fire events in the boreal forest typically are > 10,000 ha (100 km^2) in size and can range to greater than 1,000,000 ha (1000 km^2). Destruction of forested lands from fires occurs at these large scales occurs during a single growing season (e.g., within several months). In contrast, deforestation activities occur at much smaller scales. While several million hectares of boreal forest can be cut during a single year, the scale of the areas being cut is typically limited to the forest stand level (e.g, tens to hundreds of hectares). Finally, while the damage from acid deposition can occur over a very broad region (e.g., several million ha), the damage from a single year is typically difficult to discern – the effects of acid deposition typically only manifest themselves after several years.

Damage to forest canopies from disturbances results in unique signatures that are easily detectable by satellite systems operating over a wide range of the electromagnetic spectrum. Numerous examples of these capabilities will be presented the latter sessions of this workshop.

The Role of the Land Surface in Climate Modeling

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Introduction

As time scales of climate prediction extend beyond decades and centuries, components of climate system such as terrestrial vegetation becomes increasingly important. Global climate simulations have been shown to be sensitive to changes in the land surface conditions.

Example. The impact of a 5% increase in continental albedo is a reduction in precipitation of between 5% - 20%. But in nature albedo depends on the vegetation, which in turn depends on the soil moisture.

In the nature the various fluxes between the climate system components (atmosphere, ocean, the terrestrial biosphere, the cryosphere, etc.) are usually very close to being balanced when averaged over periods of one to several decades. In before industrial period the uptake of CO_2 by photosynthesis was exactly balanced by its released through decay of plants and soil matter but there can be small imbalances from year to year due to the natural climate variation.

Humans are affecting the operation of climate processes and therefore the natural balance of the climate system through persistent regional to global scale changes in the composition of the atmosphere and in the conditions of the land surface. Over the last century, there have been alarming changes in climate - changes that have had major impacts on the boreal forest. These impacts are consistent with those caused by burning fossil fuels, and that continued change could cause severe and irreversible forest damage. Because of human-caused emissions, levels of carbon dioxide in the atmosphere are growing rapidly. Climate is expected to change dramatically in high latitude countries like Canada and Russia, putting enormous stress on our forests and wildlife. Scientific estimates suggest that 50- 90% of the Earth's boreal forest could be destroyed by climate change over the next few decades. This would release billions of tons of carbon into the atmosphere and speed up the rate of climate change.

Example. Dr. Michael Apps (head of the Canadian Forest Service's climate change research program) in "Retrospective assessment of carbon flows in Canadian boreal forests" , 1996, concluded that**:**

Over the last 20 years, the Canadian boreal forest has lost almost a fifth of its biomass (18%) because of a huge increase in forest fires and insect outbreaks.

The area of forest disturbed more than doubled during the last 20 years.

Total disturbances averaged 3.9 million hectares per year between 1970 and 1990.

This huge increase in disturbances has converted one of the word's largest carbon "sinks" into a significant carbon source. I can't overstress the importance of this point. Between 1920 and 1979, the Canadian boreal forest absorbed, on average, 147 Tg (million tons) of carbon per year.

This more than counterbalanced Canada's emissions of fossil fuels during the same time period.However, in the last decade, the forest released 57 Tg of carbon on average, adding to Canada's emissions from fossil fuels.

Modeling of the Processes in the Boreal Area

Forests are important part of the global carbon cycle and regional/global hydrology cycle. Concentration of the atmospheric CO_2 and land water balance are related, so that a change in the concentration CO_2, as possible climatic variation, will affect the water balance of the land covered by forests. The direct effect of a CO_2 increase will be very significant for photosynthesis and stomatal resistance. Change in the atmosphere circulation will affect forests more than other vegetation types because of their large aerodynamic roughness. It is well known surprising results from BOREAS project that boreal lowland soils behave like semi – impermeable layer. In terms of the water and energy balance the boreal ecosystem behaves like an arid area. This is because even though the moss layer is wet for most of the summer, the soil and climate conditions lead to low photosynthesis rates, which in turn lead to low evapo-transpiration rate. Much of the precipitation penetrates through the moss and sand to the underlying semi – impermeable layer and runs off. The incoming solar radiation is intercepted by vegetation canopies which control transpiration water flow, rather than by moist soil covered by moss. As the result much of the available surface energy is dissipated as sensible heat, which leads to the development of the deep boundary layer. This partitioning of the surface energy fluxes should have a significant impact on the design of the parameterization schemes of the land surface processes using in climate model. The new understanding of controls on regional evaporation rate is relevant to the question of whether the boreal is the sink or source of carbon. This question remain yet unresolved. The updating of carbon by conifer, the component of the boreal forests, is limited in the spring by permafrost (the dynamics of permafrost influences the vegetation structure, permafrost is warming in many high latitude), and in summer by high temperatures and dry air. In the fall, conifers have the largest carbon assimilation of the season.

A lot of land-surface models have been developed for using within general circulation model to provide surface – atmosphere exchanges of energy, moisture, and momentum and biochemical fluxes on short time scale to adequately represent the coupling to boundary layer processes. The need to realistically simulate these exchanges, especially over long timescale, is the most obvious reason for including a comprehensive land surface model into general circulation model.

Climate Models

The international Atmospheric Model Intercomparison Project (AMIP) is being carried out Program for Climate Model Diagnosis and Intercomparison with support from the U.S Department of Energy. This project call for the simulation of the decade 1979-1988 by all atmospheric general circulation models using the observed monthly-averaged distributions of sea-surface temperature and sea ice, and standardized values of the solar constant and atmospheric CO_2 concentration.

Preliminary analysis of the monthly-mean output from 30 atmospheric general circulation models participating in AMIP shows that they generally simulate the observed large-scale seasonal mean climate reasonably well, although there is a notable spread among the model's results, especially in the case of high - latitude sea - level pressure, tropical precipitation and cloudness.

One of the "good" models is General circulation atmospheric model (GCM/INM-RAS) which has been developed by staff of the Institute Numerical Mathematics RAS and documented in *V. Alexeev , E. Volodin, V. Galin, V. Dymnikov and V. Lykossov, 1998*. This model is finite-difference model at 4x5 degree horizontal resolution. There are 21 level in the vertical are defined on σ - surface in the troposphere and in stratosphere with top at about 2 mbar and with higher resolution near the surface.

Land surface processes model *(V. Krupchatnikoff 1998, V. Krupchatnikoff et al. 1999)* coupled to GCM/INM-RAS and is based on the works by *G. Bonan (1995, 1996) and Sellers et al. (1996)*. Required surface data for each land grid cell derived from *Olson et al. (1983), Webb et al. (1993) and Cogly (1991)* and over-laid onto the NCAR CCM 5^0 x 4^0 –grid.. This model is able to predict terrestrial photosynthesis and respiration flux of CO2.

Simulations with the coupled land surface – atmosphere model showed that CO2 fluxes can be successfully added to the land surface model to simulate annual cycle of the CO2 surface fluxes. The geographic patterns of seasonal net CO_2 fluxes are qualitatively similar to other models *(Bonan, 1996; Randall et al., 1996)*.

The natural and antropogeneous sources and its modifications define a qualitative and quantitative state of air pollutions. The environmental change prognosis consists of the correct description of air pollutions transport, the realization of computational experiment for obtaining the expert estimations with the help of meteorological data observation and ejections in atmosphere, finding and evaluation the influence area for given region.

Usually the solution of this problem is based on the direct simulation with help of the transport equation as part of general circulation model. This method needs many numerical experiments especially for the evaluation of the contribution of the different industry regions. More better using for this aim the more effective technique of adjoint equations based on the G.I.Marchuk method *(Marchuk, 1992; Rivin G.S., Voronina P.V., 1998; Rivin G.S., Voronina P.V., 2000)* together with finding backward traces *(Klimova E.G., Rivin G.S., 2000)*.

The main problem with this coupled model is the **poor simulation in the Siberian and Northern America,** where photosynthesis is too low.

Summary and Discussion

To evaluate potential temporal and spatial patterns of change in the distribution of vegetation structure in response to climate change dynamic boreal vegetation models must be developed.

The dynamic boreal vegetation models must be coupled with Climate Model in order to simulate this response of boreal ecosystem to climate change by using different scenarious. Important component of the Climate Model is land surface model which depend on

- seasonally and inter-annually varying vegetation cover;
- leaf-stem densities;
- map of different types of vegetation;
- leaf morphologies.

These types of vegetation may change over decades – centuries, according to their interactions with climate system.

To validate of the land surface parameterization schemes it's necessary to define

- the global time-varying fields of the fraction of photo synthetically active radiation absorbed by green canopy from NDVI;
- total leaf area index LAI to calculate the carbon assimilation rate.

We need to use satellite data, which can provide us with consistent global world's vegetation:

- fraction of photo synthetically active radiation (NDVI);
- albedo from spectral reflectance;
- roughness;
- canopy resistance.

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Information Requirements for Monitoring Forest Recovery Following Disturbance in the Boreal Forest

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The global boreal forest zone represents nearly 17% of the terrestrial surface, approximately 15 million square kilometers and disturbances such as fire and insect outbreaks play an integral role in shaping both the structure and function of all circumpolar boreal forests. Effective monitoring and assessment of boreal regions impels one to investigate both historical and present-day disturbances. Related to disturbance is the omnipresent issue of scale, both spatial and temporal, and this must also be dealt with when monitoring and assessing terrestrial ecosystem responses to change. The vast territory and often remote geography of the boreal forest make direct assessment of land use change impacts and their associated consequences difficult to monitor directly. Furthermore, temporal patterns of disturbance and recovery are generally considered in terms of decades and centuries and these scales are problematic when forest monitoring is carried out on much shorter time scales. All these considerations emphasize the need to couple remote sensing technologies with numeric modeling as a primary method for integrated ecosystem analysis and prediction.

A better understanding of the linkages between observed patterns and their associated processes would certainly enhance the monitoring of present-day forests, but more importantly would help with predictions about future forests. For example one might consider how observed patterns of forest recovery are related to the collective assortment of post-disturbance processes, such as re-invasion, establishment, growth and competition. Forest succession models can be used in this case to evaluate the different re-establishment processes and when coupled with remotely-sensed data, can provide realistic projections of future forest cover. Furthermore, by using input drivers such as altered climate and disturbance conditions, a forest succession model coupled with forest cover data could provide important predictive information within the context of forest monitoring.

The approach to couple remotely sensed data with forest succession models is one means to address the issue of long-term monitoring of forest cover. However, concomitant with this approach is the need to properly identify and gather a variety of sources of information (e.g. data). The information requirements to address the issues raised above involves collating information sources that span a broad temporal and spatial range. For example, forest recovery can be viewed as a lengthy process (relevant to the observer) however it is comprised of a variety of events that can be either rapid (seed dispersal, herbaceous vegetation invasion etc.) or slow (decay of pre-disturbance materials like CWD etc.). Additionally, it is often necessary to decide *a priori* on the spatial extent of area of interest since ecological characteristics can be relevant over a wide scale from the community to the landscape and to the region. For example, in the context of fire disturbance, tree mortality and susceptibility to fire may be critical variables across a several scales since a larch dominated landscape might have very different mortality as compared to a forest dominated by other species. In the case of insect disturbances, these events are highly spatial and can show landscape-level responses to forest composition, yet extend over vast forest regions. With this in mind, the information requirements of post-disturbance forest recovery will assuredly span far across time and space scales.

Within the context of the forest monitoring approach described here, the information requirements can be broken down into a table as a means to simplify this for discussion.

Information Type	Variable (Unit)
Disturbance	
Fire	size (ha), frequency (years), severity (depth of burn, DOB), mortality (% death/area), serotinous species (extent)
Insect	Species affected, extent (area), frequency (years), mortality (% death/area), rate of spread (area/year)
Human (e.g. clearing)	size (area), frequency (years), mortality (% death/ha), % removal of forest cover (e.g. partial vs. complete)
Vegetation	
General Forest Inventory	biomass (weight/area), productivity (weight C/area/year), density (ind./area), basal area (area/area), composition (size class, age class, tree height), regeneration success (% species/area) most silvicultural or forest inventory data, preferably in electronic format.
Ecological Classification	Predominant cover type (%/area), herbaceous cover, shrubaceous cover, bryophyte cover
Site Classification	Surficial Deposit (e.g. type, permafrost, drainage, major nutrient status), elevation (e.g. DEM), aspect, slope
Climate	
Regional-scale	Precipitation, temperature , solar radiation, cloud cover, snow/ice damage, regional anomalies
Local-scale	Cold air ponding, local anomalies

Much of the data requirements listed here might be found in certain references (e.g. the book, "A Systems Analysis of the Global Boreal Forest"), however more regional information and more site specific data would be very beneficial. For instance, having specific data from sites that represent the range of major forest cover types over the boreal forest would be very beneficial to help calibrate our modeling activities. One such region could be forests that are underlain by permafrost and are dominated by larch forests. A key requirement of this data is that it could be compiled into a series of map layers that are connected spatially. Existing data archives are frequently disjoint and it is sometimes difficult to organize data in a way that is consistent.

Several examples of the rationale for needing the information listed above are detailed here. Insect outbreaks have important consequences over large spatial and temporal scales and sometimes their effects over large landscapes are not intuitive. For example, regions of the eastern boreal forest of Canada can be heavily affected by spruce budworm outbreaks. Over heterogeneous landscapes where the predominate forest cover is deciduous forest, the smaller patches of coniferous forest (such as balsam fir) are often passed over by the budworm as it spreads over the landscape. These patches are in turn very important seed reservoirs over the landscape as a whole. The role of fire is also a very important process for boreal forests and information about fire severity (heat pulse downwards) and fire intensity (heat pulse upwards) are often confused and aspects of both these variables needs to be better quantified. An important consequence of differing effects of fire severity and intensity are that they are often necessary to explain both the short term forest recovery following fire and the long-term success of a forest to adequately regenerate to antecedent conditions. The interaction between several of these information sources, such as fire and climate, are also very important areas that need consideration. One example of the interaction between fire and climate is the general assumption that increasing mean annual temperatures over the boreal forest would likely cause an increase in fire activity. Historic climate/fire reconstructions have suggested that periods of cool climate is associated with an increase in fire activity due to drier conditions, whereas, climatic warming can be associated with wetter climatic conditions thereby decreasing fire activity. It is clear from these examples that not only is there an increase in the need for ecological data, but that an increased understanding of the mechanisms and interactions of these data sources is also relevant.

Information Requirements for Forest Inventory and Terrestrial Carbon Budget

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1. Traditional resource specific forest inventory and monitoring systems (FIMS), utilized in a majority of temperate and boreal countries, satisfied major information requirements of forest management fairly well for the last several decades. These requirements were based on three major interconnected goals 1) the provision of aggregated information on forest resources to national (federal) and regional state and forest management bodies; this information forms the basis of national forest policy, as well as the basis for the establishment of middle- and long-term programs for forest sector development; 2) the creation of reliable and relevant monitoring system for estimation the condition and dynamics of forests, in particular for territories with a rapid changes of forests; and 3) the provision of information at the operational level - for practical forest management. To some extent, these three goals correspond to both the three major operational (spatial) levels of forest management (national, regional, local) and to three major structural parts of the national forest inventory systems: national inventory, monitoring, and forest management (resource) inventory.

2. The transition to the sustainable forest management paradigm [SFMP, defined as "…managing forest resources and associated lands to meet the social, economic, ecological, cultural and spiritual needs of present and future generations" (FSC, 1996)] have dramatically changed the basic philosophy and information needs which should be addressed in current or future FIMS. None of countries of the northern hemisphere has an inventory system which can completely satisfy the SFMP. The most common shortcomings of existing FIMSs are poor integration of components and inability to address properly all criteria and indicators of the SFMP. To provide support for SFM the inventory system has to assume new and complex tasks : 1) integrated estimation of impacts of actual and potential human activities on forest ecosystems (particularly land use change, harvest, fire suppression, soil contamination, and air pollution) interacting with such stresses as insects or climate change, and how those influence current and future forest ecosystem productivity, health and biodiversity; 2) quantification of the multifunctional role of forests, including resource, social and ecological values, with an evident emphasis on the latter as a major driving force of forest management at the operational and regional levels; 3) spatial modeling of the environmentally protecting and landscape forming roles of forests, and following the necessity to monitor impact of forests outside of areas actually covered by forests; and 4) information needs for quantitative estimation of impact of forests on major global bio-geo-chemical cycles (in particular, the impact of forests on the global carbon budget in connection with problems which have arisen in the post Kyoto world). In addition, national FIMS have to meet international obligations (global and supranational information requirements), mostly stemming from the 1992 UN Conference on Environment and Development Agreements (UNCED Rio Declaration, Agenda 21, Forestry Principles), as well as the Conventions resulting from UNCED (Convention on Biodiversity, Convention on

Climate Change and Convention on Desertification), and from UN FAO periodic assessment such as Forest Resource Assessment (FRA-2000 as the latest) or World Agriculture Assessment. Finally, FIMS can and should significantly contribute to other important international activities and processes related to forests, e.g. those initiated by IPF/IFF, the World Commission of Forests and Sustainable Development, or global observing system and initiatives as GTOS, GCOS or GOFC. Impact of world forest management globalization on information requirements is an evident inherent feature of current FIMS development, at least at national and regional levels.

3. In essence, the FIMS should be presented as an integrated system which would be able to combine in a relevant way primary on-ground and remote sensing measurements, different data collection, image acquisition, processing, up-dating, information transmission, etc., including modeling procedures which would base on quantifying spatial regularities of actual landscapes. It would finally be able to reach the above goals as informational and methodological background of a decent consequence: data-information-decision-support system-implementation, taking into account inevitable operational constraints, such as timeliness, cost and affordability, accessibility and uncertainty, frequency, recentness and continuity, although institutional, legislative and political restrictions could be equally or even more important (*cf.* ideas of the Multipurpose Resource Inventory, Lund 1998, or the Forest Assessment and Monitoring Environment concept, de Gier *et al*. 1999, or basic principles of a project of future FIMS for Russia, Malysheva *et al.*, 2000). In an ideal form, the FIMS should be a forest oriented sub-system of an Integrated Land Information System in which term *land* is used according to the FAO definition (1981). Such a system is eventually designated to provide information support for sustainable development/management of natural landscapes and land resources as a whole.

4. In order to structure information requirements, the following aspects seem to be relevant as the basic prerequisites: 1) multi-functionality of forests and the holistic essence of the SFMP define the needs of system integrity and comprehensiveness of information; it leads to relevancy of an appropriate combination of terrestrial surveys, remote sensing observations and different particular/auxiliary information sources; 2) needs for both (connected) attributive and spatial data are of the same importance and priorities for all levels and goals of FIMS; thus, GIS technologies should be considered as a major tool of information processing; 3) different groups of users as well as three basic levels (local, landscape and national) have (at least, partially) significantly different information requirements. [The term *basic* is used for the designation of the objects for which specified information is required, i.e., the latter cannot be received by integration or disintegration of information collected for other levels]; 4) for all levels and for all functions considered, the information required refers to both "state" and "change" indicators; it defines the crucial role of both remote sensing applications and reliable regional models of forest dynamics; 5) operational monitoring requires information which would by relevantly distributed in time depending upon disturbance types (e.g., for forest fire monitoring, information is required on: state of fire hazard (accumulation of fire fuels, monitoring of weather conditions, etc.), fire detection; operative data for fire suppression; and estimation of fire damage (direct and indirect); 6) information needs are dynamic due to social and political changes, and as a compromise of user requirements, technical developments and economic possibilities; 7) uniformity of

definitions and standardization of methods for data collection and analysis is of paramount importance , in particular, if supranational and global information requirements should to be covered; 8) necessarily improvements of information supply have to be implemented in a complimentary way, without impeding actual information flows; and 9) orientation to user-friendly technologies is an obligatory information requirement of FIMS.

5. The overall structure, thematic priorities, relevant and accessible sources, scale, frequency, recentness, accuracy, etc., of FIMS information required are defined by two major driving forces. *First,* by specifics of major user groups (actors). These groups could be classified in different ways (e.g., on institutional basis-governmental, non-governmental, etc.; based on operational scale (level) -from local to worldwide; by types on inventory needed, etc.). Evidently, these groups act under political, economical, social, intellectual and technical constraints, different for different groups and countries. *Second,* by definitions and comprehensiveness of classification of forest functions [Sheingauz (1988) in his, probably one of the most comprehensive classifications indicated about 80 major forest functions] to be sustained with respect to criteria and indicators of the SFM. An absolute majority of all well recognized international and national systems of criteria of the SFMP are practically identical, while the indicators are usually oriented to existing information and do not present any complete systems which would satisfy the SFMP, and are often presented by weak and truncated sets. In addition, we do not know any (at least, official) recommendations in what way the use of the indicators (which have a different character of interactions-from synergetic to exclusive) should be properly operationalized. Thus, information requirements considered have to be addressed to perspective systems of the indicators, while national forest management bodies have to develop information strategy for the SFMP urgently.

6. Combining the indicators in thematic groups as well as priority for different user groups are (sometimes significantly) different and depend upon the operational level of FIMS. The minimal list of the groups include: 1) general landscape description; 2) land and forest cover; 3) functional distribution of forests (forest functions' allocation), i.e. prioritization of one or ranking of several major functions; 4) forest types; 5) naturalness of land/forest cover, i.e., conversion, modification and transformation of land cover with a special emphasis to transformation and degradation of forests; 6) productivity (growing stock, phytomass by fractions, gross and net growth, Net Primary/Ecosystem Production, etc.); 7) biodiversity; 8) human-induced and natural disturbances (for the boreal zone, mostly fire, harvest, insect outbreaks, industrial pressure); 9) forest health; 10) forest products; 11) major bio-geo-chemical cycles, in particular carbon budget; 12) socioeconomic parameters; 13) land tenure; 14) indigenous (forest landscape dependent) communities; 15) site parameters; 16) stand parameters (*cf.* de Gier *et al.,* 1999; Shvidenko, 2000). Some attempts to enumerate the number of the relevant primary indicators reported about 200. For instance, USDA Forest Service Resource Inventory (1990) recommended 173 indicators approximately evenly distributed in 9 thematic groups (nevertheless, some criteria of the SFM were not completely covered); a project of indicators suggested to cover the Russian criteria of SFM amounts 176 primary indicators (Shvidenko, 2000). Practically all the above mentioned themes are required at all levels, but priorities are significantly different. As a rough aggregation, it could be concluded that the increase of the level reinforces the needs of multi-purpose forest management on the contrary to the single-function approach.

7. The recent history (after the 1992 Rio Conference and, in particular, the 1997 Kyoto Protocol) replaced the forest carbon budget (considered in two interconnected approaches - partial and full carbon accounting) from science to national and international policy and economic. Needs of the terrestrial (with a special emphases to forest) full carbon accounting (FCA) generate a number of specific information requirements which should be included in a holistic way into those of FIMS. These requirements are defined by the following major peculiarities of the FCA (cf. Nilsson *et al*., 2000): 1) the terrestrial carbon budget is a *dynamic non-linear stochastic fuzzy process* dependent on inter-seasonal variability of climate, connected peculiarities of disturbance regimes, and previous history of forests and forest management; 2) the basic scientific goal (and, simultaneously, one of the crucial user requirements) of the TCB is *minimizing the uncertainties*; for fuzzy systems, it leads to a principle of *available information maximum use*, and from the information point of view to the use as much as possible diversity of independent sources; 3) the TCB requires information on previous dynamics of forest and forest land-use (up to 200 years for the north of the boreal zone); 4) many indicators which are crucially important have never been measured; 5) the Kyoto Protocol requires a scientifically solid, verifiable and transparent carbon budget; it means that a) the problem of *uncertainty* of information becomes a crucial feature of the TCA, and b) information required (as well as all assumptions, models and calculation schemes) should be appropriate for the use in an explicit algorithmic form; and 6) a number of indicators which have not been of major importance, or even have not been measured in previous FIMS, become of the equal significance with major resource and ecological indicators. Indicators of which uncertainties are generated a bottle-neck with respect to monitor the FTCB at levels which would satisfy the incentives of the Kyoto Protocol form the following groups (*cf.* Shvidenko *et al*., 1996; Isaev, Korovin 1998; Krankina *et al.,* 1998; Nilsson *et al*., 2000): 1) permanent monitoring of bioproductivity of forests expressed in terms of gross growth, net growth, mortality and Net Primary Production; 2) monitoring of disturbances including their distribution, severity, rate of ecosystem transformation, and post disturbance effect; 3) evaluation of the dynamics of dead organic matter in forest ecosystems (detritus, litter) and soil organic matter; and 4) quantitative evaluation of succession dynamics, in particular at pioneer and initial stages after stand replacing disturbances.

8. Requirements to the accuracy of information have been changing. This problem has at least two extremely important aspects. *First,* establishment of relevant limits of accuracy for major indicators is a relatively trivial task only at the operational level, e.g., accuracy of growing stock estimation for commercial harvest has an explicit economic background and rather simple calculations. Commonly, there is an evident need to develop an economic theory of required accuracy of FIMS indicators which would be workable in the framework of the SFMP. *Second,* the general philosophy and science of the problem becomes different. Usual applications of the classical statistical analysis in terms of *precision* and *bias* are well understood and widely used, but this approach is applicable only to some partial events and steps (collected data, as a rule, does not satisfy the scientific requirements of the classical statistical analysis, e.g. due to absence of statistical design of measurements, lack of robustness of estimation procedures to the nature, way of acquisition and amount of initial data, the insufficient background of up-scaling procedures, etc.). Taking into account the

fuzzy character of an absolute majority of problems considered (the carbon accounting is a typical example), uncertainty of information and results should be considered in the system way and on a more appropriate basis, e.g., as a function of random and systematic errors with the (sometimes significant) use of *a priori* (personal) probabilities. Such a "fuzzy" estimate could be defined as a "summarized error" (Nilsson *et al*., 2000). Under rather common conditions, such an approach in a framework of the modified formal sensitivity analysis (e.g., Kendall and Stuart, 1966) can give satisfactory results.

9. All the above considerations are based on some "averaging" of information requirements, while national peculiarities can be significant. We consider some aspects of the current situation in Russia as a country under dramatic political, social and economic transitions reinforced by the deep societal crises. Russia has practically the exclusive state ownership of forest. During the Soviet era, Russia had the well developed FIMS. All requirements to forest inventory in Russia for many previous decades have been defined only by bodies of state forest management at the federal level. Current transitions have been significantly changing users groups and their interests. Major user groups in Russia currently include: 1) at the local level (spatial scales from 1:1,000 to 1:50,000)-(state) managers and professionals of forest enterprises and environment protection bodies, and private firms of forest industry; 2) regional level (scales from 50,000 to 1000000)-regional bodies of state forest management and environment protection, regional forest inventory and planning enterprises, regional offices of *Avialesookhrana*, regional governments, universities and NGOs, big industrial companies; 3) federal and supranational levels (scales from 1:1 Mio to 1:10 Mio)-the Federal Forest Service of Russia, other federal ministries, *Avialesookhrana,* universities, NGOs. Russia has an officially approved criteria and indicators of the SFM (1998). Current understanding of information requirements (cf., e.g., Giryaev, 1998; Strakhov *et al.*, 2000) leads to following major conclusions. 1) A basic part of the current Russian FIMS, the Forest Inventory and Planning (FIP-*lesoustroistvo*), should be transformed to a form of the continuos FIP. It assumed the significant increase of precision of initial measurements (e.g., the accepted error of estimation of growing stock for a separate stand should be ≤ 10%, confidential probability 0.95), and corresponding technologies of primary measurements have to be implemented. 2) The GIS approach is considered as an only acceptable information technology. Taking into account huge dimensions of Russian forests, insufficient development of information infrastructure totally and, in particular, in the forest sector, a number of other negative circumstances, any relevant development of the cartographical part of GIS requires availability of consequent and long period strategy with the two complimentary directions-bottom-up and top-down. 3) Systems of annual updating of information have to be developed. 4) A special sub-system of national inventory should be created. 5) Sub-systems of monitoring (including M of forest resources, forest pathology M, forest fire protection M, M of pollution, M of carbon budget) should be significantly improved. 6) New forms of property increase requirements to details and accuracy of information. Providing the relevant system integrity of a future FIMS is considered simultaneously as the crucial prerequisite of any success and the biggest problem. There is a particular problem of prevention of deliberative falsification of forest information due to shadow economic and black market in the forest sector. The common opinion is that the only multi-sensor concept of remote sensing applications (including aerial photography, LANDSAT TM, SPOT XS, other existing and perspective satellite platforms and sensors)

combined with appropriate systems of ground measurements and modeling could satisfy information requirements of a future FIMS and support the revitalization of the Russian forest sector, and eventually its transition to sustainable development.

Forest Cover/Change Mapping

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Introduction

This review paper was prepared with contributions of a few participants to the workshop and scientists working in this field. The paper is intended to present an overview of new types of data and information products for the boreal forest that can be generated from satellite remote sensing systems.

Forest Cover/Change Mapping using optical data

Boreal forest mapping using optical coarse spatial resolution satellite imagery

Boreal forest mapping of Europe using NOAA / AVHRR data

The EURO-Landscape project of the JRC has focussed on the development of mapping methods for forested area, other wooded land, and, in some cases, main species groupings. NOAA-AVHRR data have been used to produce a prototype small-scale pan-European forest probability map (Kennedy *et. al.* 1999). In this study, a mosaic of single date NOAA-AVHRR data was used in which the original data were calibrated using reference data, taken from the CORINE Land Cover classification. The forest probability was defined to be an estimate of the forested area within single pixels. When compared with statistical data derived from EUROSTAT and the UN-FAO/ECE –TBFRA database, the forest area derived from the probability database for twelve countries of the EU-15 was found to be underestimated by 4.2%, and 0.2% respectively.

The European Forest Institute, together with VTT Automation carried out a second study in which statistical data have been used to 'pseudo-calibrate' the probability map. This has resulted in a product in which the spatial distribution (proportion) of the forested area (divided into coniferous, deciduous and mixed woodland) is estimated on a per-pixel basis.

Use of advance radiation transfer models to characterize forest cover in Northern Europe from VEGETATION -P products

Advanced radiation transfer models can simulate the reflectance of the coupled surface and atmosphere system. They have been used by JRC (Widlowski et al. 2000) to generate look-up tables of simulated remote sensing measurements at the top of the atmosphere, for typical conditions of forest cover and atmospheric composition found in northern Europe. These simulations, were evaluated against actual observations under identical viewing and illumination geometries, available for the blue, red and near-infrared spectral bands of the VEGETATION instrument (from P products), to retrieve the most likely of the pre-defined solutions to the inverse problem. The accumulation of results over 20 days in June 1999 permitted the establishment of maps, showing the likelihood of identifying various forest types, their corresponding structural characteristics as well as the associated atmospheric optical depth at the day of retrieval.

Mapping the forest cover of Russia with SPOT4/VEGETATION – S10 products

A new vegetation map of Russia at continental scale is under preparation in the framework of the Sib-TREES project (JRC-IFI initiative). This map will be based on the analysis of 10-days mosaic data (S10 products) from the SPOT4 / VEGETATION sensor. The method for analysis of satellite imagery is taking into account the spectral, temporal and angular properties of the ToA reflectances for the main forest and other land cover categories along a full vegetative season (April to November 1999). The procedure is including the following steps:

- Detection of cloudy and snowy pixels;
- Production of seasonally optimized mosaics (spring/summer/autumn): the duration of snow-free period and the NDVI temporal behavior are used to define transitions;
- Production of spectral indices using the MRPV bi-directional reflectance model: these indices are independent from Sun-Earth-satellite geometry conditions;
- Unsupervised classification and labeling into the main forest ecosystems and land cover categories. Ancillary GIS layers are used during this step.

A first version of this new Russian forest map is expected to be ready by the end 2000. Validation would be carried out in 2001 from available recent forest inventories.

"Global Land Cover 2000" Initiative

In the framework of the VEGA 2000 initiative launched by CNES, the JRC has launched the GLC 2000 initiative which is focused on the delivery of the global land cover map. Global daily S-1 products for the full year 2000 will be used for analysis and production of a global land cover map by the end of 2001 in collaboration with a network of partners. Commitment has already been made by U.S.G.S. for the Northern America continent. There is need for research to develop the most appropriate methodologies and product.

Boreal forest cover assessment using medium spatial resolution optical data

Boreal forest mapping of Europe using IRS-WiFS data

In the framework of the FMERS project the possibility of the forest cover mapping in the Europe was demonstrated (Tuomas Hame at al., 1999). The target classes were forest, other wooded land, and the main tree species groups. Seventeen IRS-WiFS images from 1997 were used to compile two reflectance image mosaics. An unsupervised classification of the mosaic was performed using a geographic stratification. The clusters from the unsupervised classification were labeled to target classes using their spectral reflectance values and other available information. The best results were achieved in forest / non forest discrimination, and the most difficult category was the mixed forests. The comparison with the NUTS II level statistics showed that satellite data with a resolution of 200 meters can be used for forest mapping up to equivalent mapping scales 1:500,000 or possibly up to 1:250,000.

Assessment of RESURS/MSU-SK data for boreal forest mapping and monitoring

Capabilities of RESURS 150 m resolution data to map boreal forests at regional level have been investigated by IFI (SibTREES project). One test area in the Krasnoyarsk region has been selected as representative of the various conditions of Taiga forests in Central Siberia.

First the spectral properties of the main forest categories (including different spatial and age structure) have been characterized. Then hierarchical supervised and unsupervised classifications were tested. The following thematic maps can be obtained:

- forested and non-forested areas;
- main forested and non-forested land categories;
- dominant forest species groups (light coniferous/dark coniferous/broadleaf forest) ;
- forest age groups within dominant species classes (young/grown-up forests).

The evaluation of these products was made by comparison to national forest inventory data. The average accuracy of the forest/non-forest, main land categories classification, dominant forest species groups and forest age groups classifications is about 88%, 65%, 77% and 74% respectively.

Mapping frontier forest of Russia using RESURS/MSU-SK data

In cooperation with the ScanEx Center in Moscow, the World Resources Institute is developing a forest condition map of the Russian Federation at a scale of 1:1 million in the framework its Global Forest Watch initiative (WRI, 2000).

This map is based on the medium resolution (150 m) images obtained by MSU-SK instrument on board of the Russian satellites "Resurs – O1" using neural network analysis methodology. The map will show blocks of frontier forest greater than 100,000 hectares, as well as infrastructure and some other aspects of forest development. The map will be validated in the field during the summer of 2000, reviewed, and made available in 2001.

Boreal forest mapping using fine spatial resolution radar data (ERS/SAR, JERS/SAR); **SIBERIA Project**

Partners in the project are: DLR for geometry, CESBIO for information content, SCEOS for preprocessing and classification, CEH for accuracy assessment, UWS for computational issues, Satellus for map production, IIASA for ground data.

Within the SIBERIA project an extensive data set has been build including satellite and ground-truth data acquisition. A large range of processing methods were developed including interferometric processing, radiometric and interferometric calibration, DEM generation and incidence angle correction, ERS-JERS co-registration, classification development and accuracy assessment, and map construction based on a total of over 1400 satellite radar scenes.

The methodological objectives were to analyze the available radar data with the help of ground data provided by Russian foresters, in order to:

- define the forest information carried by the radar data
- provide efficient and effective methods to extract that spatial information.

The methods had to meet several conditions:

- to be automatic because of the large amount of data (550 ERS / 890 JERS scenes)
- to be adaptive because of changes in image properties between scenes

- to be consistent for scene-independence and continuity between overlapping scenes
- results have to be validated.

ERS SAR Tandem (1997), ERS-2 SAR PRI (1998) and JERS SAR (1998) were processed using DLR-DFD and GAMMA processors. Calibration methods for the ERS data were evaluated as well as the impact of topography on the radar images. The following products will be delivered: forest cover maps and radar image maps (160 map sheets); DEM for 50% of the area.

Global Boreal Forest Mapping (GRFM) Project

The Global Boreal Forest Mapping Project (GBFM) is an effort led by the Earth Observation Research Center (EORC) of NASDA in cooperation with, among others, NASA's Jet Propulsion Laboratory (JPL), NASA's Alaska SAR Facility (ASF), the Space Applications Institute of the JRC, the Swedish Space Corporation (SSC), the German Space Agency (DLR), and the University of California, Santa Barbara (UCSB).

The GRFM project aims to produce spatially and temporally contiguous SAR data sets over the boreal belt on the Earth by use of the JERS-1 L-band, through generation of semi-continental, 100 m resolution, image mosaics.

The GBFM project was initiated in 1997 and through a dedicated data acquisition policy by NASDA, data acquisitions could be completed over the three geographical regions (Siberia, Northern Europe, Canada and Alaska) before the JERS-1 satellite was taken out of operation in 1998. Image mosaicking and thematic analysis initiated in 1999. All data will be provided free of charge to the international science community for research and educational purposes.

North America

The primary goal is the production of continental scale wintertime and summertime SAR mosaics of the North American boreal forest for distribution to the science community (McDonald et al., 2000). As part of this effort, JERS-1 imagery has been collected over much of Alaska and Canada during the 1997-98 winter and 1998 summer seasons. To complete the mosaics, these data are augmented with data collected during previous years.

Eurasia

The JRC is developing a focused approach to look at the use of the GBFM 100 m resolution radar mosaics in combination with other optical sensors (such as LANDSAT 7 ETM+ and SPOT4 / VEGETATION) for mapping the inundated forests and for biomass and soil/vegetation water content estimation. The JRC will generate a pyramid of 100m resolution radiometric and texture products and will compile a georeferenced mosaic of the Eurasian region. The JRC is conducting investigations to adapt the mosaicking , geolocation and calibration processing chains that were formerly used successfully for the GRFM Africa mosaic.

ERS SAR tandem data will be used in combination with the GBFM mosaics to derive DEM and additional thematic information over the Ob river basin (window adjacent to the SIBERIA window).

Monitoring land cover and ecosystem dynamics at regional scales

JERS SAR imagery will be used to develop a landscape segmentation map, which will be coupled with landscape freeze/thaw dynamics derived from temporally dense spaceborne scatterometer data (McDonald et al., 2000). Integration of an ecosystem model with the remote sensing-derived products will allow improved quantification of carbon flux dynamics on regional and continental scales. The project will involve two main steps:

First a regional landscape classification will be made with data from the GBFM North American Component, providing information about distribution of woodlands, positions of tree line, current forest biomass, distribution of wetlands, and extent of major river courses. Comparisons across several years will provide additional baseline information about short-term landscape change.

Second landscape processes were monitored with Spaceborne Scatterometer (NSCAT) over Alaska during the 1997 spring thaw. In boreal regions, temporal change in backscatter is correlated with thaw processes. By examining the backscatter change relative to wintertime frozen conditions, the monitoring of the springtime thaw processes is possible across broad landscape regions. *In situ* observations of vegetation component and snow pack temperatures and meteorological parameters have been correlated with NSCAT backscatter to verify sensitivity to freeze/thaw state transitions.

Disturbance Mapping using Radar Imagery

The objective of this study (Ranson et al., 2000) is to develop procedures for detailed assessment of forest disturbances in Siberia by the combined use of high resolution satellite data (e.g., TM, Radarsat). Because of smoke and clouds radar offers a consistently clear view of fire scars, however when available Landsat-7 may provide better classification ability.

SAR classification can be improved with use of texture measures and reduction of effects of topography. Techniques such as radiometric correction with DEMs and SAR channel ratios were shown to work well in the test area (Western Sayani in Krasnoyark region). Better DEMs or multichannel radars are needed to use these techniques for global forest assessments.

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