GLOBAL FOREST RESOURCES ASSESSMENT 2000 FOR NORTH AMERICA: A Proposal To The North America Forest Commission For The Remote Sensing Component

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OBJECTIVE

The global Forest Resources Assessment 2000 (FRA 2000) is designed to measure certain indicators of forest sustainability at the spatial scales of continents and broad eco-floristic zones, which span multiple nations. FRA 2000 is covered by the mandate of the United Nations, and is conducted in cooperation with numerous national and international institutions.

Among the most important indicators of sustainability are estimates of the area and composition of forest land (e.g., the state in year 2000); the rates of change among different categories of forest and land cover (e.g., the changes between 1990 and 2000); and trends in these changes over time (e.g., the annual rates of change from 1980 to 1990 compared to the rates of change from 1990 to 2000). Biomass and carbon fluxes are other indicators that will be estimated in FRA 2000.

FRA 2000 uses a scientific sample of high-resolution satellite data to produce estimates for these indicators of sustainability. These estimates are feasible using globally consistent methods, measurement dates, and classification system. Remotely sensed indicators complement existing data from national institutions. However, use of remotely sensed indicators avoids incompatibilities among existing data from different nations and regions of the world. These incompatibilities confound multi-national assessments and weaken the scientific input into policy decisions.

The purpose of this paper is to propose a technical approach to FRA 2000 for consideration by the North America Forest Commission. This remote sensing approach is consistent with plans for FRA 2000 by the European Commission for Eurasia, and the Food and Agricultural Organization of the United Nations for tropical forests in 90 developing nations in South America, Asia and Africa.

BACKGROUND

FRA 2000 has been formulated in accordance with the United Nations Conference On Environment and Development (UNCED) in Rio de Janeiro, Brazil, 1992, Agenda 21, Chapter 11, Programme D under the heading “Basis for Action.” Chapter 11 describes the present situation of forest resources assessments as follows:

> “Assessment and periodical evaluations are essential components of long term planning, for evaluating effects, quantitatively and qualitatively, and for rectifying inadequacies. This mechanism is, however, one of the often neglected aspects of forest resource management, conservation and development. In many cases, even the basic information related to the area and type of forests, existing potential and volume of harvest, etc. is lacking.”

To address these concerns, the United Nations Committee on Forestry designed a comprehensive Forest Resources Assessment program which has four separate objectives. The fourth objective is:

> "Remote sensing survey. Includes actions aimed at surveying forest resources state and change at global, regional and sub-regional levels using remote sensing and statistical sampling."

Experts in forest resources from member countries of the United Nations, international and national organizations, non-governmental organizations and individuals contributed to planning FRA 2000. The international forestry community provided important recommendations through a number of meetings, culminating with the "Expert Consultation on Global Forest Resources Assessment 2000" (Kotka III) held in Kotka, Finland in 1996. Kotka III recommended expanding the FRA 1990 survey of tropical forests into the temperate and boreal regions to ensure comprehensive and consistent information on forest-related change processes throughout the world. An FRA 2000 strategic plan was developed, which provides the overall conceptual framework for the assessment. In February 1997, the Fourth Session of the UN Intergovernmental Panel on Forests (IPF IV) expressed strong support for FRA 2000, the Kotka III recommendations and FAO's role as facilitator for the execution of FRA 2000. In March 1997, the United Nations' Committee on Forestry endorsed Forest Resources Assessment as one of highest priorities for the FAO Forestry Department.

Many nations have excellent inventory and monitoring systems available for their forest lands. FRA 2000 will gather available information from national institutions, which will be presented in a public database. However, multi-national assessments based on available information are confounded by national differences among classification schemes, measurement methods, timeliness, intensity, and completeness of national forest surveys. In addition to existing national data, FRA 2000 will use globally consistent methods based on remote sensing.

Global land cover can be mapped with low-resolution satellite data (e.g., AVHRR). However, AVHRR data can not discriminate between many types of forest and land cover, and are not well suited for change detection. High-resolution satellite data (e.g., Landsat, IRS, SPOT) can distinguish between more detailed categories of land cover, and can better detect changes in land cover. However, there is no funding available to interpret the thousands of high-resolution satellite scenes that cover each continent. As a compromise, a scientifically valid statistical sample of high-resolution scenes (e.g., 10% sample by area) can efficiently estimate the results that would be obtained with the full set of satellite scenes. Cost-effectiveness can be improved by intensifying the sample of satellite scenes within strata that have high priority for assessments or fast rates of change (i.e., "hot-spots"), and decreasing the sampling intensity in geographic areas with lower priority. In addition, some results from interpretation of high-resolution satellite data can be predicted from low-resolution satellite data, such as AVHRR and MODIS. These predictions can approximate the results that would have been obtained from 100% of the high-resolution satellite scenes. This improves monitoring through use of multiple sensor systems.

SUCCESSFUL USE OF REMOTE SENSING FOR GLOBAL ASSESSMENTS

Successful use of high-resolution remote sensing for global assessments requires:

- methods that are understandable and credible to policy makers, scientists, and concerned individuals;
- consistent classification schemes and nomenclature for land and forest cover and other indicators of sustainable forests, which are:
    - relevant to evaluations of forest sustainability,
    - widely accepted in the international community,
    - compatible among the boreal, temperate, and tropical regions,
    - feasible with the selected measurement methods;
- equitable and complete coverage of all lands regardless of land tenure;
- consistent techniques for measuring land cover and other indicators of sustainable forests, including changes over time;
- consistent time periods over which status, changes and trends are measured;
- estimates of net changes and the individual components of this change (i.e., transition or change matrices), which require repeated observations of the same landscape segments over time;
- information that leads to better understanding of the causes of changes, including associations between specific landscapes and socio-economic data for each landscape;
- methods that can cover entire eco-floristic zones that span sub-continental regions and the globe;
- methods that can be feasibly applied by any nation at a reasonable cost;
- results that have known precision and can be feasibly verified by any reviewer or auditor.

Success also requires efficient methods that can adapt to regional differences, while meeting the requirements above. This flexibility includes:

- classification of landscapes that are fine-grained mosaics of several categories in the global classification system (e.g., “fragmented forest” or “managed forest”, in which landscapes contain numerous and intermingled patches of closed forest, open forest, and regenerating forest, where the patches are smaller than the minimum map unit);
- associated objectives of national institutions (e.g., estimates of different indicators of forest sustainability, such as protection status).

The supposition is that achievement of these criteria requires high-resolution satellite data; there are insufficient resources to interpret the 2171 Landsat scenes that cover North America[1]; and a statistically rigorous sample of scenes can provide statistically valid results with negligible bias and sufficient precision for input to assessments, periodic evaluations, long term planning, quantitative evaluation of effects, and rectifying inadequacies. Given these suppositions, a sample of high-resolution satellite data requires flexibility for:

[1] Includes Greenland, Central America, and Caribbean Islands

- variable sampling intensities for precisely delineated geographic areas (i.e., strata), and unbiased statistical methods, to accommodate:
    - different diversities of landscapes at very broad scales,
    - different levels of funding and cost of remotely sensed imagery and interpretation,
    - different assessment priorities, including the potential to cover 100% of certain sub-regions (e.g., “hot spots” of change, or transition areas between Eco-floristic zones that might be most sensitive to changing climates);
- variable sizes of sample landscapes (i.e., sample satellite scenes) to accommodate:
    - different diversities of landscapes at local scales,
    - different levels of funding and cost of remotely sensed imagery and interpretation,
    - swath widths of different high-resolution satellites;

The Food and Agricultural Organization of the United Nations (1996) used a simple monitoring system for the global tropics as part of the 1990 Forest Resources Assessment (FRA 1990). This system meets the above requirements with remote sensing. The monitoring system uses photo-interpretation of high-resolution satellite data to reliably classify nine categories of land cover: closed forest, open forest, long fallow, fragmented forest, short fallow, tree plantations, shrubs, water, and other land cover. The cost was reduced by taking a 10% sample of the 1173 Landsat satellite scenes that entirely cover the forested landscapes in the tropical zone, which is distributed over 90 countries. The statistically valid probability sample assures that the estimates are unbiased by design. Each satellite scene is covered by 2 images acquired over a 10-year period, which provides direct observations of the components of change among each of the nine categories of land cover. Each sample scene can be independently interpreted to evaluate the reliability of the results.

FRA 2000 INFORMATION PRODUCTS FROM REMOTE SENSING

The products based on the FRA 2000 remote sensing survey include:

- estimates of deforestation and afforestation trends and change processes for the periods 1980-1990 and 1990-2000 at regional, ecological and global level;
- assessment of the ecological impact of deforestation and support to policy making and scientific environmental studies through the estimation of:
    - biomass fluxes associated to the processes of change
    - forest fragmentation
    - presence/absence of forest conservation measures

Example of Results for FRA 2000

FAO conducted a pilot study for one Landsat scene that covers the Olympic Peninsula in the State of Washington, USA[1]. Three dates of imagery (1974, 1986, and 1993) for this single scene where photointerpreted using standard FRA 2000 methods, which are described in more detail starting on page 14. This pilot study provides an example of the expected results for each sampling unit and sample estimates for broader scales (e.g., continents and broad eco-floristic zones). Transition matrices (Table 1) provide all class-to-class changes observed over the two time periods, from which trend information (Graph 1) and deforestation rates (Table 2) are derived. The transition matrices are also input to the Biomass Flux Diagrams (Figure 1) that describe the processes of change as a function of area change percentage and relative estimated biomass gradients.

Table 1:

Transition Matrices and Trends for Area of each Land Cover Class

Olympic Peninsula, WA. USA

	Date	MX periods (years)		
Date antique image(s)	12-Sep-74		Path/row	
Date historic image	01-Ago-86	12	Path/row	47/27
Date recent image	25-Feb-93	6.5	Path/row	47/27

(Area in '000 hectares) — Classes of HISTORIC image (1986)

ANTIQUE image (1974)	Total	Closed Forest	Open Forest	Long Rotation	Short Rotation	Fragm. Forest	Shrub/ Regrowth	Other Land Cover	Water	Manmade Woody Veg.
Closed Forest	**1157.6**	961.2		34.4	32.4	49.6	32.8	46.0	1.2	
Open Forest										
Long Rotation	**37.6**	3.2		34.4						
Short Rotation	**65.2**	11.6		4.4	45.2	2.0	2.0			
Fragm.Forest	**145.2**	17.2		0.8	1.6	116.4	2.0	7.2		
Shrubs/Regrowth	**66.8**	38.4		0.8	0.4	1.6	25.2	0.4		
Other Land Cover	**124.0**	37.2		0.4	1.2	1.6	3.2	80.4		
Water	**456.8**	0.8							456.0	
Manmade W.Veg										
Total HISTORIC (1986)--	**2053.2**	**1069.6**		**75.2**	**80.8**	**171.2**	**65.2**	**134.0**	**457.2**	
RECENT image (1993)	Total									
Closed Forest	**952.4**	924.0		1.2	4.4	3.6	12.0	7.2		
Open Forest										
Long Rotation	**86.8**	13.2		73.6						
Short Rotation	**80.4**	4.8			75.6					
Fragm.Forest	**198.4**	29.2				166.0	2.0	1.2		
Shrubs/Regrowth	**71.2**	19.2			0.8	0.4	48.0	2.8		
Other Land Cover	**206.4**	78.8		0.4		1.2	3.2	122.8		
Water	**457.6**	0.4							457.2	
Manmade W.Veg										
	2053.2									

[1] Appendix 2 describes a pilot test of the FRA 2000 procedures for two other Landsat scenes in the USA; however, Appendix 2 does not include examples of data products.

Graph 1:

Changes and Trends in Area for each Main Type of Land Cover

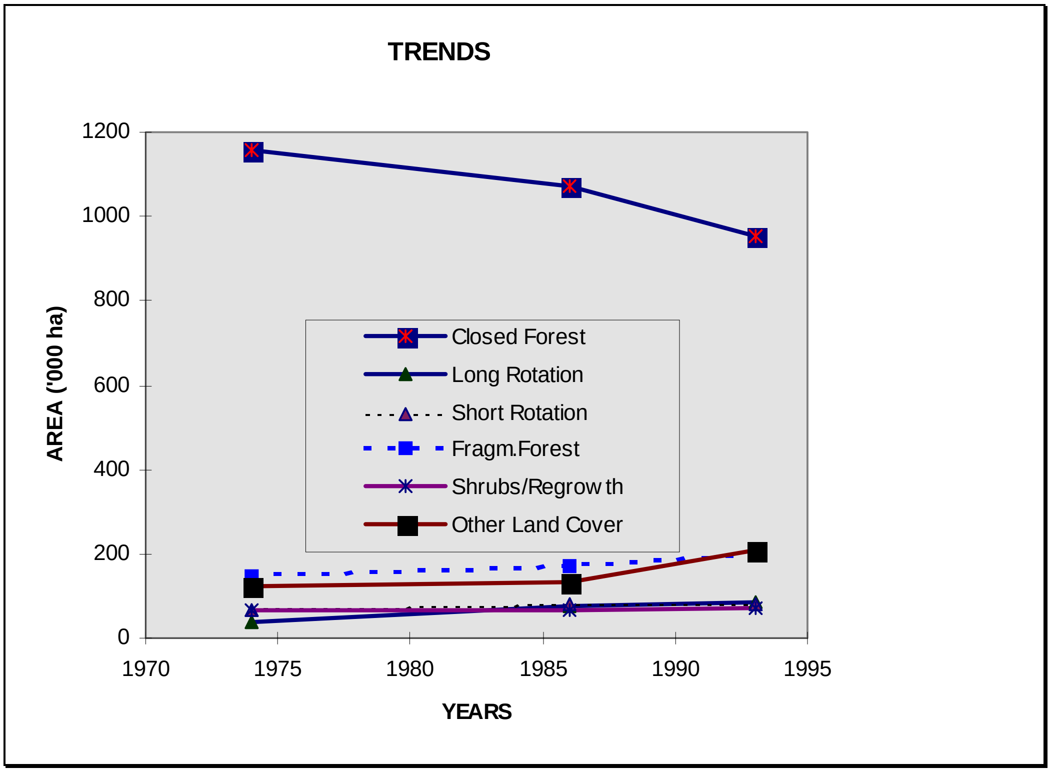


Table 2[1]:

Total Forest Area And Deforestation Rates

	forest fraction	1974		1986		1993	
		class area	actual forest	class area	actual forest	class area	actual forest
Closed Forest	1	1157.6	1157.6	1069.6	1069.6	952.4	952.4
Open Forest	1						
Long Rotation	0.8	37.6	30.08	75.2	60.16	86.8	69.44
Short Rotation	0.6	65.2	39.12	80.8	48.48	80.4	48.24
Fragm.Forest	0.33	145.2	47.916	171.2	56.496	198.4	65.472
Manmade W.Veg	1						
Total Forest			**1274.716**		**1234.736**		**1135.552**

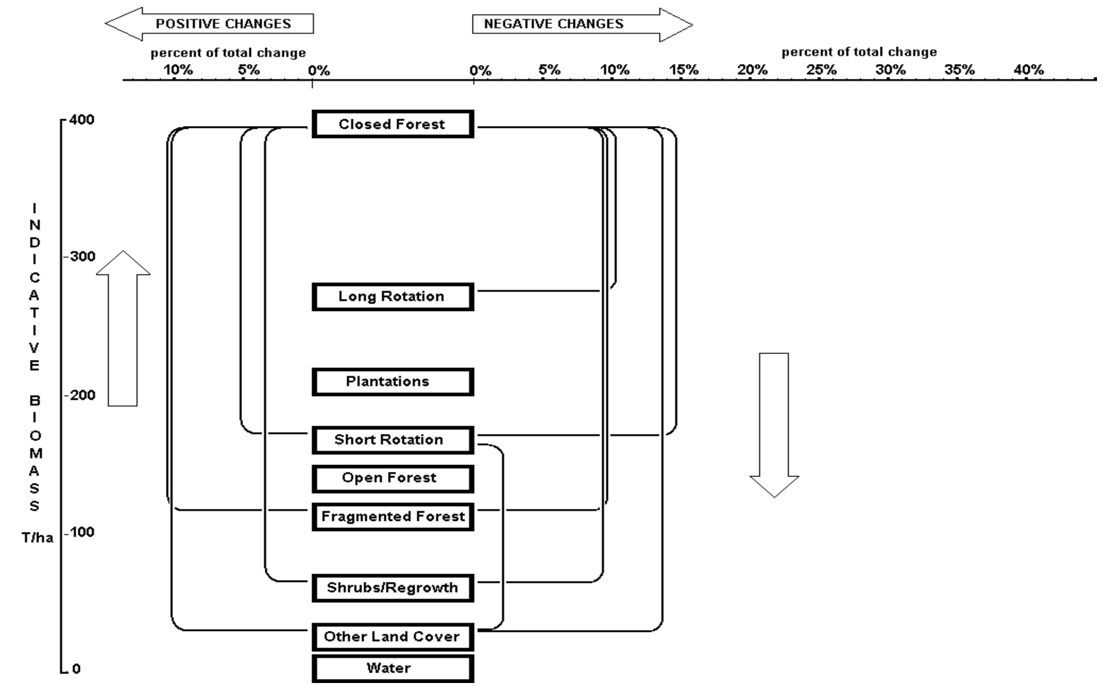
Forest Change	**74 - 86**
Tot area	-40.0
Annual area	-3.3
Annual compound rate %	-0.27

[1] ***Open forest*** was not present in this area and the class ***man-made woody vegetation*** (plantations) could not be separated in this study and is included into the classes ***closed forest*** and ***short*** / ***long rotation***. The forest fraction used to estimate an area of actual forest within the composite classes is tentative only.

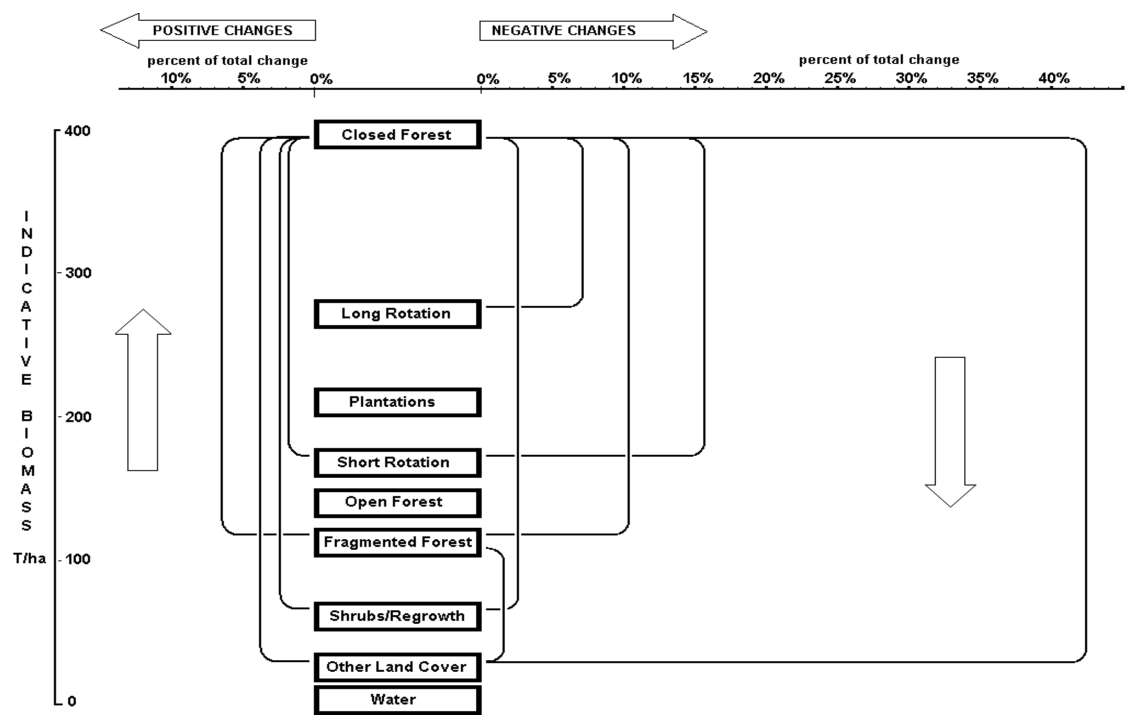
Figure 1

Biomass Flux Diagrams

Period 1974 - 1986



Period 1986 - 1993



The biomass flux diagrams[1] in Figure 1 help describe the processes of change in land cover and understand the differences between the two time periods for this relatively small landscape.

- The diagram for 1973 to 1986 shows a very dynamic but fairly stable situation, where negative and positive transitions are almost equal. However, the closed forest cleared in this region is mainly old growth, and the regenerated closed forest is far less rich in biomass.
- The diagram for 1986 to 1993 is quite different. The transitions in land cover are dominated by the conversion of closed forest to other land, primarily agricultural lands. This single type of change represents over 40 percent of the total area changed. The transitions back to closed forest are almost negligible, accounting for less than four percent of the total change. The overall situation for this particular landscape appears unsustainable.

This pilot study is not representative of changes in North America. The site was selected in a landscape that has rapid change; the purpose was to test the FRA 2000 methodology and refine the classification system and nomenclature. For broad-scale assessments, the results from a sample of many landscapes will be averaged to infer the status, changes and trends for broad regions.

In addition to statistical results, the time-series of interpretations for sample scenes can be input into a Geographic Information System (GIS) and combined with geographic themes for land ownership, management priorities, administrative designations, ecological conditions, conservation status, etc. This provides opportunities to quantify other indicators of sustainability and better understand the processes of change in specific landscapes.

PROPOSAL FOR FRA 2000 IN NORTH AMERICA

This paper presents an adaptation of the FRA 1990 methods to the temperate and boreal zones of the United States, and a proposal to use compatible methods in Canada and Mexico. The methods were developed in partnership with the Joint Research Centre of the European Commission in Ispra Italy, and the Food and Agricultural Organization of the United Nations in Rome, Italy. These methods are intended for consistent coverage of the tropical, temperate, and boreal forests of the world for FRA 2000.

[1] The biomass gradients are tentative and should be considered only as an approximate indicator.

Modifications Made To The FRA 1990 Methodology

The following modifications were made to the FRA 1990 methodology.

- The FRA 2000 will use three dates of remotely sensed imagery (nominally years 2000, 1990, 1980) to assess trends in change processes.
- The sampling frame is based on the Icosahedral Snyder Equal Area (ISEA) discrete global grid, which:
  - provides a simple systematic sample of points that assures unbiased and even spatial coverage;
  - is hierarchical so that sampling intensity can be changed within contiguous regions or strata (e.g., increased intensity in “hot spots”, or decreased in regions with little or no forest cover) while maintaining the simple systematic sample;
  - is not linked to a single satellite sensor, such as the Landsat World Reference System);
  - uses hexagonal cells that exhaustively tessellate the globe with compact areas that are equal in size, shape and number of edges;
  - is a standard proposed for global modeling and indexing images from many different satellite sensors
- The primary sampling unit is a point on the ISEA global grid, which accommodates different sizes of high-resolution satellite scenes, from different dates and different sensors.
- Strata are imposed to accommodate small satellite scenes in homogeneous landscapes, and large satellite scenes in heterogeneous landscapes.

Classification system for land cover

Globally consistent classification and nomenclature is one of the unique justifications for the remote sensing component in FRA 2000. The following proposal for the temperate and boreal regions originates with the nomenclature applied in tropical regions during the FRA 1990 (Appendix 1). Then, proposals are made that modify the classification system for application in the boreal and temperate areas. The proposals are based on a pilot study by Rudi Drigo and Alessandro Baccini for the Olympic Peninsula, Washington, USA (WRS2 Path 47 Row 27). Details of the proposed classification system appear in Appendix 1.

The FRA 1990 classification system for tropical land cover will be applied to the FRA 2000 remote sensing survey. The description of the FRA 1990 tropical land cover classification system, as reported in FAO Forestry Paper130, is summarized in Appendix 1.

<u>Proposed Interpretation Key For Temperate And Boreal North America</u>

```
(total image[1])
     visible --- No --- OTHER NON INTERPRETED
          |                  |
          |           outside image/ --- No – snow over -- no -- clouds, cloud -- no -- MOUNTAIN
         Yes           sub-region             vegetation                 shadow              SHADDOW
          |                  |                      |                      |
          |                  |                     yes                    yes
          |                  |                      |                      |
          |                  |                SNOW COVER             CLOUDS, CLOUD
          |                  |                                           SHADOWS
          |                  |
          |                 Yes ------------ OUTSIDE STUDY AREA
          |
         land ---------- No-----WATER
          |
         Yes
          |
 woody vegetation cover >10% -- No -- OTHER LAND COVER
          |                           |
          |                 rocks, snow -------- No ------ OTHER LAND COVER
         Yes                          |
          |                           |
          |                          Yes -------------------- SNOWCAPS, ROCKY AREAS
          |
natural[2] --------- No --MAN-MADE WOODY VEG.COVER
          |                            |
          |               forestry purpose-- -- No --------AGRICULTURAL PLANTATION
         Yes                           |
          |                            |
          |                          Yes ---------------------FORESTRY PLANTATIONS
          |
     height > 5 m ------ No --- LOW WOODY VEGETATION
          |                            |
          |                    stable -------- Yes -------SHRUBS
         Yes                           |
          |                            |
          |                           No -------------------REGROWTH
          |
continuous---Yes-- crown cover >40% -- No - OPEN CANOPY FOREST  (cc 10-40%)
          |                     |
|                    Yes --  CLOSED CANOPY FOREST (cc >40%)
          |                             |
          |                   crown cover >70% ---- No --- DENSE FOREST (cc 40-70%)
         No                             |
          |                             |
          |                            Yes ------------------ DENSE FOREST (cc >70%)
|
     Composite Land Cover Classes  (formed by elements below minimum mapping unit)
|
     presence of regrowth ----No- FRAGMENTED
          |                            |
          |                forest fraction >40% ---- Yes ------FOREST FRA CTION 40 - 70%
         Yes                           |
          |                            |
          |                           No --------------------FOREST FRA CTION 10 - 40%
          |
managed forest ---- cleared area >20% ------- Yes ------ SHORT ROTATION
                                      |
                                      |
                                     No ------------------- LONG ROTATION
```

[1] **Main level classes are bolded**

[2] In most temperate/boreal regions the distinction natural/man-made is difficult if not impossible, in view of the long history of forest management where mixed regeneration techniques have been applied. It is likely that this distinction will discriminate only a fraction of planted areas, belonging to clearly distinguishable types, such as agricultural plantations or known isolated forestry plantations.

Grouping Of Land Cover Classes Into Land Cover Categories		
	Land Cover Categories	*Land Cover Classes*
FOREST (natural and man-made)	**Continuous Forest**	Closed Forest Open Forest
	Composite Forest	Long rotation managed forest Short rotation managed forest Fragmented Forest (for > 40%) Fragmented Forest (for < 40%)
NON-FOREST	**Other Wooded Land**	Shrubs Regrowth
	Non-Wooded Areas	Other Land Cover Water
MAN-MADE WOODY VEGETATION		Plantations (forest and agricultural)

The consistent use of the four composite classes as well as plantations must be evaluated. It is probably difficult to maintain the two levels *SHORT* and *LONG ROTATION*. It is probably easier and more reliable to keep the two levels of *FRAGMENTED FOREST* with forest fraction above and below 40%.

These composite classes will require regular verification of the proportions of their elementary components, in order to allow a reliable estimates of actual forest area as well as to ensure a consistent judgment from the part of the interpreter. This can be done by overlaying a fine dot grid (spacing 1-2 mm) to the composite class polygons and counting of the constituting elements.

Optional Classification Criteria

The United Nations has facilitated dialog on practical classification systems for assessments of land cover and change in the tropical, boreal and temperate zones of the world (The Finnish Forest Research Institute 1997). This included the following elements that could be optionally included in the classification nomenclature:

- Inland water
- Available or not available for wood production
- Publicly owned / privately owned
- Protection status
- Temporarily deforested (clearcuts, burnt)
- Mountain meadows
- Urban development and expansion of small towns into the countryside
- Geologic processes and climate change (landslides, glaciers, tundra and permafrost)

- Retired pasture

Other classification categories and systems could be added in addition to the globally consistent system used for FRA 2000.

Interdependent Interpretation Procedures for Satellite Imagery

Hardcopy Photographic Images

Globally consistent interpretation of remotely sensed data, with a compatible classification system and nomenclature, is the primary justification for the FRA 2000 remote sensing survey. Flexibility to adapt the remote sensing methodology to regional situations needs to be balanced with the need for global consistency and compatibility.

The most difficult interpretation problem is distinction between real and spurious changes, especially where the changes in land cover are small and/or indistinct. With annual deforestation rates ranging between 0.5 and 1 percent, the changes in forest cover are relatively small and often poorly distinguishable even over a ten-year span. When the objective is detailed analysis of class-to-class transition rates, it is essential the approach assures the highest level of consistency between historical and recent observations. Therefore, interpretations based on one image are verified with the second image, and weak evidence from one image is confirmed with the other image.

In principle, this analysis could be carried out through automated digital classification as well as through visual interpretation. In practice, the automated approach is confounded by variations due to haze and shadows, or seasonal variations in vegetation appearance. In addition, the classification system includes fine-grained mosaics or mixtures of categories that represent broad landscapes which are difficult to classify with automated approaches. The advantages of being able to compare the two data sources and effect continuous relative adjustments made the visual approach the most suitable method of operational pan-tropical survey in FRA 2000. Moreover, it was the most appropriate approach in terms of cost-effectiveness and timeliness. The same advantages might exist in the temperate and boreal regions.

Subjectivity is unavoidable in visual image interpretation, and is particularly strong in classes with poorly contrasted boundaries. In fact, independent interpretations of two different images covering the same area will always present differences (or variability in class delineation) that do not represent real changes. This subjectivity alone, assuming that there is a high level of consistency among all other factors, might introduce sufficient "false changes" to make the monitoring results unreliable.

Three different visual interpretation procedures were tested in the FRA 1990 pan-tropical. The results are given in FAO FRA Project Paper: "Interpretation of High Resolution Satellite Data and Compilation of Results for Forest Cover State and Change Assessment; Test Site: Zaire" (R. Drigo, 1991) The outcome was an operational methodology described in the FAO FRA report entitled "Procedure for Interpretation and Compilation of High Resolution Satellite Data for

Assessment of Forest Cover State and Change", Forest Resources Assessment 1990 Project (R. Drigo, 1991).

The methodology features an interdependent interpretation procedure in which two images, acquired some ten years apart, are interpreted within a single process. Each boundary is based on both images, thus minimizing subjectivity in class delineation between the two images.

The interdependent interpretation procedure, shown in Figure 1, can be summarized as follows:

1 The 1990 image, here called Image 1, is interpreted on a transparent overlay (Overlay 1), which is placed on top of the image.

2 The 1980 image (Image 2) is then inserted between Image 1 and Overlay 1. A new overlay (Overlay 2) is placed and fixed on top of Overlay 1.

3 The interpretation of Image 2 is carried out on Overlay 2 with continuous reference to Overlay 1, as follows:

 3.1 When the class boundary of Overlay 1 fits Image 2 it means that there are no changes and the same line is repeated over Overlay 2.

 3.2 When the line of Overlay 1 does not fit Image 2 it means that there is a difference (not necessarily in land cover); the two images are therefore compared directly. Two outcomes are possible:

  3.2.1 The line on Overlay 1 was wrong; there are no real changes in land cover. Overlay 1 is therefore corrected and the same line is drawn on Overlay 2.

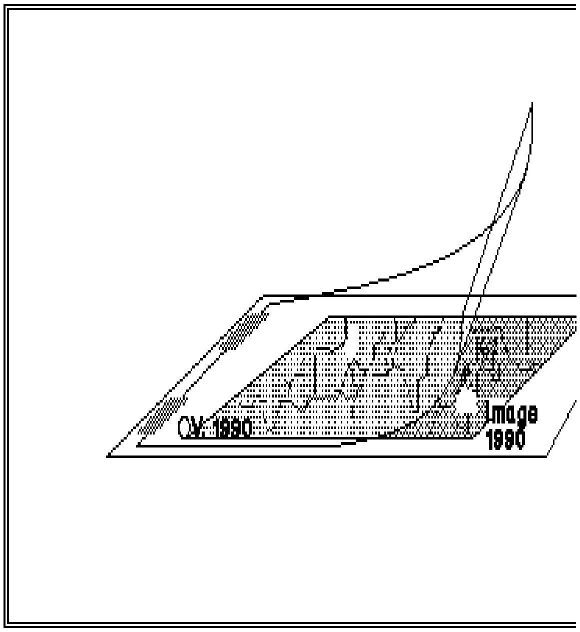
  3.2.2 There is a real change in land cover. A new class boundary is drawn on Overlay2 according to the features of Image 2.

.

Figure 1 : Interdependent Interpretation Procedure

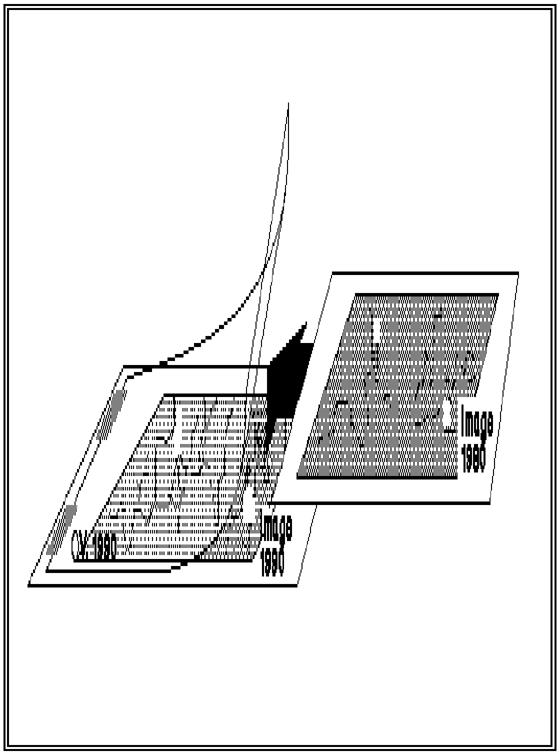
Step 1

Interpretation of 1990 image on a transparent film overlay (1990 overlay).
The interpretation includes the delineation of Land Cover Classes (black lines) and control features (green lines).



Step 2

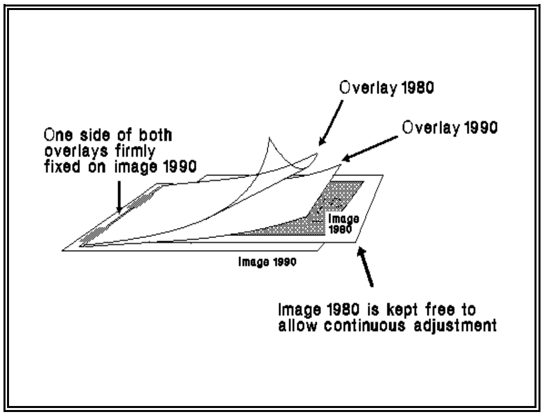
Insert 1980 image between 1990 image and 1990 overlay. Use the green control features to adjust the position of 1980 image to fit the 1990 overlay.



Step 3

Interpret 1980 image (in blue on 1980 overlay) using the delineation on the 1990 overlay as a reference.

Check and adjust constantly the position of the 1980 image with respect to the control features marked on 1990 overlay.



The interpretation is carried out on all three images with the production of three overlays, one for the recent image and one for the historical image. Steps 2 and 3 are repeated with the year 2000 image All lines correspond precisely except where a class change has been detected. The result of the interpretation process is:

- Spatial co-registration of the three overlays according to the projection of the 1990 image.
- Complete interpretation of the three images without relative subjectivity in class delineation.

Each line on each overlay is supported by the analysis of all three images for the classes that have changed as well as for those that have remained constant.

The repetition of all unchanged class boundaries may seem redundant, but it has been proved that only a thorough visual analysis permits the detection of all changes. Identifying and drawing the changes only through a visual scanning process tends to produce a systematic underestimation of changes, especially on images with highly fragmented patterns.

The continuous comparison of the three images (years 2000, 1990, and 1980) increases the consistency and reliability of both the changed and unchanged areas; often, while interpreting the second image, the need of modifying the interpretation of the first image arises, owing to new evidence. It can be concluded that, similar to the benefits of stereoscopy which increases the information content of two aerial photos taken from two different points in space, the combined "chronoscopic" use of two images taken at two points in time adds information to both images by showing the "behavior" of both land cover and satellite imaging.

An important effect of the interdependent interpretation procedure, in addition to the "thematic" co-registration of land cover classification, is the geometric co-registration of the resulting interpretation overlays. In most cases, the historical and recent (analog) images presented differing geometric corrections that produced, in spite of their common scale, considerable distortion between the images. In some cases this problem could have been avoided (cost and time constraints permitting) through digital co-registration of the satellite data.

Relative geometric distortion is a problem that, if not properly solved, could seriously affect the validity of the resulting transition matrix[1] , which requires precise spatial registration between the three dates of imagery. The 1990 image is the geometric reference, and the 1980 and 2000 overlays are matched through continuous adjustment of the images. This process is necessary in to ensure that change detection was carried out on exactly the same area, in spite of any relative distortion.

Softcopy Photo-interpretation of Digital Images

FRA 1990 used totally manual photointerpretation methods for change detection in the tropics. These same methods remain suitable for FRA 2000 (see Appendix 2). However, digitally assisted photointerpretation is a viable alternative. For this purpose, the European Environment Agency has produced sophisticated and reliable software as part of the project "Co-ordination of Information on the Environment" (CORINE). The software facilitates photo-interpretation of changes with multi-date satellite data, and is based on Windows 95. The software can export polygon boundaries as ArcInfo files.

Remote Sensing Sample Survey

Under ideal conditions, all 2171 Landsat scenes that cover North America[1] would be interpreted with the procedures and classification discussed above. The result would be a wall-to-wall map of land cover and changes in land cover in 1980, 1990 and 2000 using high-resolution remote sensing. However, an international project of this scope has never been accomplished. As a compromise, a statistically rigorous sample of Landsat scenes is used to reduce costs. This is expected to provide statistically valid results with negligible bias and sufficient precision for input to international assessments, periodic evaluations, long term planning, quantitative evaluation of effects, and rectifying inadequacies.

Sampling Frame and Sampling Units

The sampling frame is based on the Icosahedral Snyder Equal Area (ISEA) discrete global grid. The primary sampling unit is a point on the ISEA global grid. The US Environmental Protection Agency can provide GIS support for implementation. The primary justification is to build a sampling frame that is independent of any single satellite (see the section on "Modifications Made To The FRA 1990 Methodology").

Stratification

[1] The ***transition matrix***, called also ***change matrix***, records the area of each class at the two dates for which interpretation was done. Table 1 gives an example of a change matrix resulting from the interpretation of one Sampling Unit.

[1] Includes Greenland, Central America, and Caribbean Islands.

A continental-scale low-resolution map of forests will be used to define the first strata of forest lands. The preliminary proposal uses the global land cover map from the International Geosphere and Biosphere Program (IGBP), which was developed by the US Geological Survey EROS Data Center. This map is based on seasonal AVHRR 1-km data, and is available for the entire world. Strata will be defined for sampling units with

- less than 10% total forest cover in the low-resolution IGBP map
- less than 500,000-ha of land cover (i.e., coastal areas, see Table 4).

It is assumed these strata contain insignificant forest cover, and will not be sampled in order to reduce costs.

Estimation efficiency might be improved with a stratum for coastal sampling units that contain more than 500,000-ha of land cover. In the absence of this stratum, there are two ways such sampling units could be treated during statistical estimation. The probability of selection could be a function of proportion of land cover in the sampling unit. However, small changes in such units could be heavily weighted and increase sampling variance. Alternatively, entire sampling units could be used with equal weight to estimate the area of large water bodies adjacent to the coast (as defined by hexagonal units on the ISEA global grid). However, this would increase sampling variance relative to units that were entirely covered by land. Stratification can reduce this source of sampling variance.

The next level of stratification could be:

- heterogeneous landscapes
- homogenous landscapes

where heterogeneity is defined at the spatial scale of high-resolution satellite imagery (e.g., 50 to 200-km scenes). In homogeneous landscapes, a reduction in the size of the sampling unit, and a corresponding increase in sampling intensity, could improve efficiency without increasing cost. A moving window of seven contiguous hexagons (approximately 50-km^2 each) will be passed over a low-resolution AVHRR satellite map, and the variance among these seven hexagons assigned to the center hexagon. Two categories of landscape heterogeneity will be defined, and sub-continental scale regions of differing heterogeneity will be identified. Contiguous strata of these two heterogeneity categories will be defined, in which small inclusions of differing heterogeneity are eliminated. This stratification will be performed by the Joint Research Centre of the European Commission in Ispra Italy, and will be consistent with their similar efforts in Eurasia.

The final level of stratification is for sub-regions that have high priority for assessments. For example, the TREES II Project of the Joint Research Centre has identified “hot-spots” of high deforestation risk in the humid tropics. These sub-regions are typically small relative to global surveys at sub-continental scales, and they might cover 10 to 100 high-resolution satellite scenes. The intensity of sampling can be increased within these few strata, including the possibility of “wall-to-wall” coverage of the entire stratum (i.e., 100% “sampling” intensity). GIS data related to ecological and socio-economic factors will be included to enhance the understanding of these change processes in tropical regions and study the cause-effect mechanisms of main interest to policy makers. Similar strata can be formed by cooperating institutions for national assessment priorities.

For all types of stratification, strata boundaries will conform to hexagons of suitable scale in the ISEA discrete global grid.

Table 4.

Example of Landsat scenes and area[1] by sampling stratum and landcover class[2]

	Strata for Landsat scenes							
	71-100% forest	40-70% forest	10-40% forest	wood-land	1-10% forest	non-forest	land area <5000km²	**Total**
Number of Landsat scenes	427	165	234	143	149	408	645	2171
		969				1202		2171
IGBP landcover class			**Area (10^3 km²)**					
Evergreen Needleleaf Forest	2748	644	492	8	62	0	90	4044
Evergreen Broadleaf Forest	196	122	17	0	0	0	15	350
Deciduous Broadleaf Forest	958	208	72	2	17	0	7	1264
Mixed forests	1933	488	301	29	23	0	32	2806
Closed shrublands	123	147	334	195	120	32	49	1000
Open shrublands	64	172	649	87	840	354	130	2296
Woodlands	68	150	355	603	9	13	52	1250
Savannas	8	13	49	0	0	0	2	72
Grassland	72	120	379	85	645	346	12	1659
Permanent wetlands	25	42	73	90	48	74	15	367
Croplands	155	253	550	37	377	441	39	1852
Urban and Built-up	21	13	16	3	14	4	5	76
Cropland natural vegetation mosaic	138	231	323	24	447	343	12	1518
Snow and ice	2	4	56	24	21	1316	479	1902
Barren Sparsely Vegetated	9	21	63	338	53	1061	437	1982
Total area (10^3 km²)	6520	2628	3729	1525	2676	3984	1376	22439

Systematic Sample of Satellite Scenes

This section presents an example of a sample of Landsat scenes for North America. The Joint Research Centre of the European Commission is comparing 180x180km and 60x60km sampling units for FRA2000 in Eurasia and North America. The results are expected before the NAFC meeting in Salt Lake City, July7-10, 1998.

[1] 1,000's of km²

[2] low-resolution IGBP landcover map from seasonal AVHRR data

Example of map for sample of Landsat scenes in North America

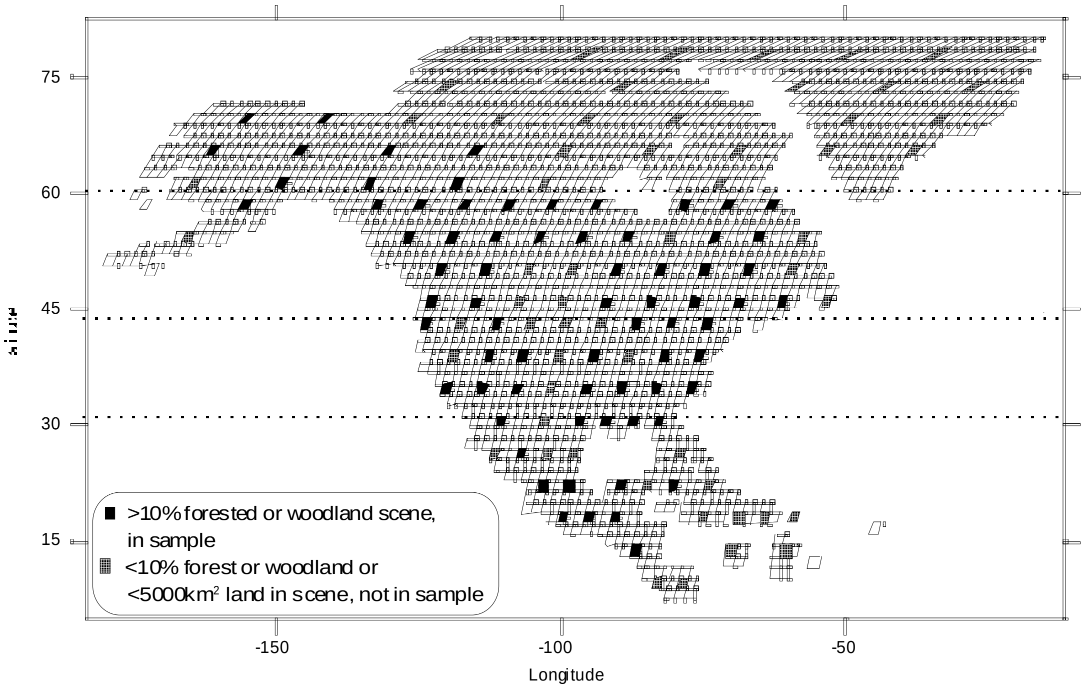


Table 3.

Example of number of sample Landsat scenes for each nation

Nation	Single-nation scenes	Multi-national scenes[1]	Additional Woodland scenes	Total number of scenes
Belize	0	0.5	0	0.5
Canada	**26**	**1.5**	**3**	**30.5**
Costa Rica	1	0	0	1
Cuba	1	0	0	1
Dominican Republic	1	0	0	1
El Salvador	0	0.5	0	0.5
Guatemala	0	0.5	0	0.5
Honduras	0	0.5	0	0.5
Mexico	**6**	**0.5**	**0**	**6.5**
Nicaragua	0	0.5	0	0.5
United States	**23**	**1.5**	**1**	**25.5**
Total	58	6	4	68[1]

[1] Half scenes are on border of two nations. For example, 3 scenes in the sample cover the border between Canada and the USA.

Estimated workload for each sampling unit

As discussed above the core element of the methodology is the interdependent interpretation of three-date images for each sample scene. The final output expected for each unit consists of transition matrices (two sequential matrices) and a set of digital maps displaying land cover classes at three dates.

Three different procedures might be followed, which depend basically on the format of satellite data available or procured, i.e. analog or digital, and, in case of digital data, on whether the interdependent interpretation is done on hardcopies or on softcopies. During the FRA 1990 survey the analog-hardcopy approach was followed, for several logistic and economic reasons. It is likely that in future surveys a mixture of approaches will be followed based on similar considerations. It is important that whichever approach is adopted the minimum mapping unit and other scale-dependent features are maintained constant and referred to scale 1:250,000.

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[1] There are 969 scenes in the sampled strata (see Table 4, strata: 71-100% forest, 41-70% forest, 10-40% forest, woodland). FRA2000 specifies a 10% sample by area. The total sample size is 68, rather than 969/10, because there is considerable overlap between adjacent satellite scenes at higher latitudes.

The main steps and estimated relative workloads involved in each approach are described below:

	Work elements	Person/ days	Remarks
1	Analog - hardcopies		
1.1	Acquisition of analog data (system corrected films)		Cost is ~50-60% of digital data
1.2	printing of hardcopies at scale 1:250,000		Approx. 70 US$ / copy
1.3	Visual interdependent interpretation on hard copies (three dates). Relative distortion is corrected during interpretation.	15	With 3 person/days more, matrices and simple raster maps can be produced using dot grids.
1.4	Digitizing of interpretation results (scanning and vectorizing)	10	
2	Digital - hardcopies		
2.1	Acquisition of digital row data		Cost is higher than analog data
2.2.1	processing for radiometric and geometric co-registration	4 ?	1600 $/3 dates (EDC)
2.2.2	production of films		450 $/3 dates (EDC)
2.2.3	printing of hardcopies at scale 1:250,000		Approx. 70 US$ / copy
2.3	Visual interdependent interpretation on hard copies (three dates)	15	With 3 person/days more, matrices and simple raster maps can be produced using dot grids.
2.4	Digitizing of interpretation results (scanning and vectorizing)	10	
3	Digital - softcopies		
3.1	Acquisition of digital row data		Cost is higher than analog data
3.2.	processing for radiometric and geometric co-registration	4 ?	1600 $/3 dates (EDC)
3.3	Visual interdependent interpretation on softcopies, i.e. interpretation on screen (three dates) which produces also digital maps.	20	Main limitation represented by screen size that limit overview

Program and Administration

The North America Forest Monitoring study, in the framework of FAO FRA 2000 Program, will require the following operational structure:

FAO Coordination
This is a part time function provided by FAO and shared across other regions. This will mainly focus on technical coordination to ensure consistency of methods and compatibility of results among the various regions of the world.

NAFC Coordination
Coordination by the North America Forest Commission will require one (full time?) person to carry out operational management and coordination among Canada, Mexico and the USA. This will include:

- finalization of classification system and nomenclature consistent with FRA 2000 in tropics (FAO, Rome) and other temperate and boreal regions (e.g., European Commission, Joint Research Centre, Ispra, Italy)
- selection and procurement of satellite images;
- organization of image production (digital processing and co-registration and/or printing of analog data);
- organization of image interpretation work through institutional cooperation agreements or contracts and, as part of the same arrangements or separately, organization of digital map production;
- organization of North America workshops:
    - one at the beginning of the project, to provide technical training on the standard methodology to all regional cooperators/contractors,
    - and one at the end of the project to discuss survey results, draw conclusions on thematic and operational aspect and formulate recommendations.

Some coordination activities might be requested from national contacts in Canada, Mexico and USA, but it is important to maintain regional and global consistency.

National Coordination
This should be located within the national institutions in Canada, Mexico and USA that are involved in the study and should provide (part time) logistic and administrative assistance to the NAFC coordinator.

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Mr. Alessandro Baccini contributed considerable time to the photointerpretation of the Olypmic peninsula in the State of Washington, USA; the results are discussed on pages 7 to 11. Mr. Jerry D. Greer and Mr. Frederick P. Weber contributed considerable time in the evaluation of the FRA photointerpretation methods and classification nomenclature using Landsat scenes in the States of Missouri and New Hampshire, USA; the results are reported on page 13 and in Appendix 2 starting on page 32. Mr. Douglas Kneeland encouraged development of this prosposal and provided institutional coordination and financial assistance through the USDA Forest Service International Program. Mr. Jean Meyer-Roux, Deputy Director of the Space Applications Institute in the Joint Research Centre of the European Commission, provided leadership in application of FRA 2000 for Europe and Russia and coordination with North America, and Dr. Javier Gallego of the Joint Research Centre contributed considerable statistical expertise. Dr. Anthony R. Olsen and Dr. Denis White from the US Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis OR, contributed statistical advice and considerable geographic information support for the Icosahedral Snyder Equal Area discrete global grid. Mr. Gyde Lund and Mr. James Space provided valuable advice and encouragement. The USDA Forest Service, Forest Inventory and Analysis Program, contributed the time of Dr. Czaplewski, and the Food and Agricultural Organization, Forest Resources Assessment Project contributed the time of Mr. Drigo. Finally, Dr. K. D. Singh from the Forest Resources Assessment Project has long provided the vision and motivation for the remote sensing component of FRA 2000, without which this proposal would be impossible.

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APPENDIX 1. CLASSIFICATION SYSTEM AND NOMENCLATURE FOR FRA 2000; A PROPOSAL FOR THE TEMPORATE AND BOREAL AREAS.

This section contains two sub-sections. The first sub-section describes the classification system used for tropical forests in FRA 1990. The second section (page 32) describes proposed adaptations to this nomenclature for the temperate and boreal forests in FRA 2000. This Appendix supports presentation of the nomenclature in the main body of this proposal (page 11).

Tropical Land Cover Classification

The FRA 1990 classification system for the tropical zone was designed to segregate different types of woody vegetation cover using photo-interpretation of high resolution satellite. The classification has three main characteristics:

- a hierarchical structure to permit the unambiguous aggregation of the classes at each level to the next level or levels.
- a simple dichotomy at each level, based on criteria usually detectable on high-resolution satellite image, or readily inferred, to facilitate the interpreter's decision at that level and about whether it would be possible to proceed to the next lower (more detailed) level.
- the inclusion of all the classes of interest to the assessment of state, change and trends in forest cover in a form obtainable from high-resolution satellite images.

The classification system is composed of three main parts. These parts are progressively followed during the interpretation of the multi-date satellite images.

Classification levels

The classification has been divided into two levels: Main Classes and the Additional Classes. The Main Classes (10 in total) identify the minimum common standard for Sub-regional, Regional and Global reporting of results. The Additional Classes represent further subdivisions of the Main Classes. These Additional Classes will be used only where their delineation is considered reliable. Different categories in the Main Classes can not be grouped together.

The decision to use Additional or Main level of classification will be documented for each class of each image on the Sampling Unit Description - ID Form and respected throughout the interpretation of that image. This means that the Additional Classes and their parent Main Class can never coexist on the same interpretation overlay.

Preliminary Image Interpretation Classes

Each high-resolution satellite image is divided into three main classes:

- *LAND*
- *WATER*
- *OTHER NON-INTERPRETED*

LAND includes all the remaining part of the image. This class is subsequently divided according to the presence or absence of (significant) *WOODY VEGETATION COVER*. 10 % is here used as the lower cover limit. The remaining land area falls under the class *OTHER LAND COVER*.

WATER includes sea and major inland water bodies. Minor water bodies and river courses are not separated but are included in the broad class "other land cover".

OTHER NON-INTERPRETED includes all portions of the image that are outside the study area (parts of image that fall outside the region or sub-region of interest) or that cannot be reliably interpreted due to presence of burnt grass (in woodland areas), clouds or dense atmospheric haze and shadows. Under the main class are found the additional classes *BURNT WOODLAND, CLOUDS-CLOUDS SHADOWS, MOUNTAIN SHADOWS and OUTSIDE STUDY AREA.*

The additional class *BURNT WOODLAND* refers to those areas where the recurrent fires destroy only (or mainly) the grass layer present under the tree cover. In these areas the black patches left by the crossing of fire would not represent a loss of woody vegetation but rather "hide" the area and prevent the interpretation. In other conditions, where the fires are known to destroy the forest completely or to follow the clearing of the forest, the class to be used for burnt areas is "Other land cover", to indicate the loss of woody vegetation cover. Therefore, it is important to classify the burnt areas with maximum care, taking into account the types of forest and land use of the area of study. The class *WOODY VEGETATION COVER* is then further divided according to its origin into *NATURAL* and *MAN-MADE*. This division, which is based on characters that are partly physiognomic and partly contextual, is dictated by the need to separate, as far as possible, these two broad categories for separate analysis and monitoring studies. Their separation will no doubt be approximate in some cases, especially when dryland plantations are intermixed with natural vegetation and when there is little background information available. An attempt of separation is, in all cases, considered important.

The *MAN-MADE WOODY VEGETATION* cover type includes a wide range of vegetation and land use types. The important distinction that needs to be made is between forest plantations and agricultural wooded areas.

FOREST PLANTATIONS will be delineated within the class Man-made Woody Vegetation Cover as visible on the high-resolution satellite image and with the support of auxiliary data. Plantation area is needed as broad statistical input without the need for detailed description like species composition, age, etc.

The remaining part of the class Man-made Vegetation Cover after the separation of Forest Plantations will be constituted by *AGRICULTURAL PLANTATIONS* and homestead gardens. This class will include, without further separation, all formations such as tea gardens, oil-palm, coconut, rubber plantations, etc. and the homestead mixture of trees and shrubs.

It is normally difficult to separate forest plantations from agricultural plantation based only on the spectral signature or the texture of the forest cover. It is therefore necessary to make a contextual interpretation with strong support of all available auxiliary information, for example plantation and landuse maps.

Classification of Natural Woody Vegetation Cover

The word "cover" is used deliberately to avoid confusion with vegetation types or formations, which have floristic connotations. This is because they are not of primary importance for a global assessment; the concern is less with local management than with estimates of global forest cover and its dynamics of biomass for global modelling and implications for species diversity, etc. Equally relevant is the fact that for a survey based on satellite data with, at this stage, very restricted scope for rigorous accuracy assessment, interpretation of floristic aspects would be of low and unequal reliability.

The classification therefore distinguishes types of woody vegetation cover primarily on the physiognomic characteristics - density or crown cover, spatial distribution - which are those most readily observed on high-resolution satellite image.

Height is used for the distinction between *FOREST* (trees) and *SHRUBS*, which constitutes the first dichotomy of the classification. While the need to differentiate between tree and shrub formations is obviously important, in practice these two categories are not always readily distinguished on satellite data. More than height, which cannot be accurately perceived on the high-resolution satellite image used for the study, spectral signature and background data on local ecology guide the distinction between these two classes.

The *CONTINUOUS - FRAGMENTED* dichotomy under *FOREST* refers to the spatial distribution of the class *FOREST* and other classes. Whenever the forest units can be individually delineated and therefore separated from the surrounding classes they will belong to the *CONTINUOUS* class.

Where the forest units are intimately intermixed with other cover types to a level that they cannot be individually separated, then the mixture of the two (or more) cover types will be classified as *FRAGMENTED* and subsequently divided according to the estimated proportions of the forest type within the class.

Quantitative criteria

Quantitative classification criteria for use with the interpretation of high-resolution satellite image can only be indicative as neither height nor crown cover can be seen or measured directly. For this reason, also, limits are set as: 10-40% and 40-70%, for example, rather than 10-40% and 41-70%.

The lower limit of 10% woody vegetation cover for '*FOREST*' and related formations is that adopted for the periodic FAO forest assessments and is in conformity with the UNESCO International Classification of Vegetation. Except in a few special cases, it is unlikely that 10% crown cover is detectable on high-resolution satellite images. The detectable lower limit for this will vary with the type of woody vegetation and with the nature and condition of the associated ground cover.

The threshold of 5 m in height to differentiate trees and shrubs is also that adopted for the periodic FAO forest assessments. On high-resolution satellite image it is usually possible to distinguish between a tall tree canopy and cover which consists of much shorter woody vegetation, especially when these occur with close spatial relation. However, the reliability of this distinction is variable and it should be confirmed from other sources whenever possible.

The 40% crown cover threshold corresponds to the lower limit for woodland in the UNESCO and other classifications with the purpose to distinguish the latter from the so-called mixed formations of grassland with trees - tree savanna, cerrado etc. In the present study the same crown cover threshold is used to separate open canopy and closed canopy forests.

The class *CONTINUOUS* is divided into the two main interpretation classes *OPEN FOREST* and *CLOSED CANOPY FOREST* based on crown cover; 10 - 40% and 40 - 100% respectively.

The very broad range of 40-100% crown cover has been further divided, arbitrarily, into two additional classes *DENSE FOREST (Crown cover 40-70%)* and *DENSE FOREST (Crown cover 70-100%).* The 70% threshold has been introduced to account for a wider range of situations in which the division between closed and open forest with a 40% crown cover threshold is not meaningful; tropical rain forest with 60% crown cover may well be a disturbed, degraded formation, while in a drier Eco-floristic zone the same crown cover may well represent a stable undisturbed formation.

For the class *FRAGMENTED* forest (mosaic of forest and shrubs or other land cover) the limits have been set to correspond to those of open canopy forest, *FOREST FRA CTION 40-70%*, and Dense forest (c.c. 40 - 70%), *FOREST FRA CTION 40-70%*, to facilitate the aggregation of classes of forest cover. For the class shrubs the threshold has been set arbitrarily at 40% crown cover (for consistency with the other limits used) to yield additional information when it can be interpreted from the satellite data.

Agricultural Impact

Agricultural impact within continuous forest areas can be detected on high-resolution satellite image by the presence of small cultivated patches (below the delineation limit) surrounded by equally small patches of natural vegetation at various stages of regrowth and areas of mature, more or less disturbed forest. This structure commonly indicates the on-going practice of shifting cultivation.

From a strictly physiognomic point of view such a forest area would still maintain all the characters of 'continuous forest' with a certain crown cover; although degraded, the forest affected by shifting cultivation could maintain, in some cases, the same crown cover as the surrounding unaffected forest.

However, in spite of this, it is important that such situations are detected and monitored in view of the important role that these practices play in the degradation process of the natural resources.

The objective of the interpretation in this case is to outline the portions of forest that appear to be affected by shifting cultivation as forest with *AGRICULTURAL IMPACT*. In practice this would mean to outline, as a sort of mosaic class, the areas under actual cultivation (cleared) and the areas at various stages of regrowth that represent the areas cultivated and subsequently abandoned in a more or less recent past.

An attempt is also made to further divide the class Agricultural Impact two additional classes, named *SHORT FALLOW* and *LONG FALLOW*, on the basis of the estimated intensity of the agricultural practices.

An area with Agricultural Impact-Present can be divided using a visual estimation of the proportion of the cropping area as follows:

$$\text{Cropping area} * 100 / (\text{Cropping} + \text{Fallow area})$$

The area for which the resulting ratio is estimated as equal or over 33 (over 1/3 of the area) is classified as Short Fallow, and the area for which the ratio is estimated as less than 33 (less than 1/3 of the area) is classified as Long Fallow.

Modifications Of Tropical Categories For The Temperate And Boreal Areas

Homogeneous land cover classes

The *SHRUB CATEGORY* used in the tropical assessment is replaced by the class *LOW WOODY VEGETATION*. This new class includes the old class *SHRUBS* (without the distinction between sparse shrubs and dense shrubs), as well as a new subclass *REGROWTH*. This new subclass *REGROWTH* was derived in order to classify those areas cleared but with new vegetation with a height less than 5 meters which for the shape, the context and the class of vegetation in proximity (very often *CLOSED FOREST*) would leave one to believe that it is not shrubs but a regenerating area (natural or planted). Unfortunately, the diffusion of regular shapes and the use of natural-indigenous species make it difficult to distinguish plantation from natural vegetation.

Under the classes at the main level *OTHER NON INTERPRETED*, the sub class *SNOW COVER* was added. This was done in order to classify those areas below the tree line that because of snow cover were impossible to correctly identify.
At the same time the sub class *BURNT WOODLAND* was deleted.

Composite land cover classes

Recall that composite land cover classes are composed by elements below minimum mapping unit. They represent fine-grained landscapes that are mosaics or mixtures of different types of land cover.

The absence of shifting cultivation in the temperate and boreal zones resulted in the elimination of the classes *SHORT FALLOW* and *LONG FALLOW***.**

However, the presence of small contiguous units of closed forest, *REGROWTH* and clearings justified the introduction of a new group, called "*MANAGED FOREST*". The presence of regrowth phases is essential to distinguish this group from the class *FRAGMENTED FOREST*. From this group two main classes were identified: *SHORT ROTATION* and *LONG ROTATION*, defined as follows:

- If the cleared area is greater than 20% of the total, then it is classified as *SHORT ROTATION*.
- If the cleared area is less than or equal to 20% then it is classified as *LONG ROTATION*.

The table below shows a first tentative definition of the categories of change resulting from transition among the land cover categories defined above.

Preliminary key to change matrix analysis.

Interpretation classes at date 1 (1980)			*Interpretation classes at date 2 (1990)*									
COVER CATEGORIES			**Forest**				**Non-Forest**					**Man-made Woody Veg.**
			Continuous Forest		**Managed Forest**		**Frag-mented forest**	**Low woody Vegetation**		**Non-Wooded**		
		Cover Classes	**closed forest**	**open forest**	**long rotation**	**short rotation**		**re-growth**	**shrubs**	**other land cover**	**water**	**planta-tions[1]**
Forest	**Continuous Forest**	**closed forest**	-	Deg	Deg?	Deg?	2/3Def	Def	Def	Def	Def	Re/Cap
		open forest	Am	-	Deg?	Deg?	2/3Def	Def	Def	Def	Def	Re/Ib
	Managed Forest	**long rotation**	Am?	Am?		Deg?	part Def	Def	Def	Def	Def	
		short rotation	Am?	Am?	Am?	-	part Def	Def	Def	Def	Def	Re/Ib
	Fragmented	**forest**	2/3Af	2/3Af	part Af	part Af	-	1/3Def	1/3Def	1/3Def	1/3Def	2/3Af/Ib
Non-Forest	**Low woody Vegetation**	**regrowth**	Af	Af	Af	Af	1/3Af	-	Db	Db	Db	Af/Ib
		shrubs	Af	Af	Af	Af	1/3Af	Ib	-	Db	Db	Af/Ib
	Non-Wooded	**other land cover**	Af	Af	Af	Af	1/3Af	Ib	Ib	-	-	Af/Ib
		water	Af	Af	Af	Af	1/3Af	Ib	Ib	-	-	Af/Ib
Man-made Woody V.		**plantations[1]**	-	Deg	Deg	Deg	2/3Def/Db	Def/Db	Def/Db	Def/Db	Def/Db	-

Change categories:

Def	=	**Deforestation** of Continuous Natural Forest (from forest classes to non-forest classes)
2/3Def	=	**Fragmentation** of Continuous Natural Forest (partial deforestation, or loss of 2/3 of the actual forest)
1/3Def	=	**Deforestation** of Fragmented Forest (the actual forest loss of is estimated at 1/3 of the total area)
Deg	=	**Degradation** (decrease of density or increase of disturbance in forest classes)
Db	=	**Decrease** of non-forest woody **biomass**
Ib	=	**Increase** of non-forest woody **biomass**
Am	=	**Amelioration** (increase of density or decrease of disturbance in forest classes)
Af	=	**Afforestation** (from non-forest classes to forest classes or forest plantation)
1/3Af	=	**Partial afforestation** (from non-forest to fragmented forest)
2/3Af	=	**Partial afforestation** (from fragmented forest to Continuous Natural Forest)
Re	=	**Reforestation** (from forest classes to forest plantation)
Cap	=	**Conversion** (from closed forest to agricultural plantation)

[1] The class plantations includes both agricultural and forestry plantations for which different change categories apply. In view of this consideration, statistics related to transitions involving the class plantations have been accounted for as a separate category.

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APPENDIX 2: FRA 2000 PILOT TEST OF PHOTOINTERPRETATION IN USA

ASSESSING CHANGE IN LARGE SCALE FOREST AREA BY VISUALLY INTERPRETING LANDSAT IMAGES[1]

Draft manuscript for presentation at the international IUFRO Conference Integrated Tools for Natural Resources Inventories in the 21st Century

June 8, 1998

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ABSTRACT

As part of the Forest Resources Assessment 1990, the Food and Agriculture Organization of the United Nations, visually interpreted a stratified random sample of 117 Landsat scenes to estimate global status and change in tropical forest area. 1980 and 1990 images were interpreted by a group of widely experienced technical people in many different tropical countries. The project demonstrated that visual interpretation could reliably quantify broad scale changes in tropical forest cover and that the procedure was cost effective, timely, and statistically sound. In 1997, we used the same methodology to interpret and compare Landsat images from two different dates at two sites in the United States to evaluate its use in northern boreal and temperate forests. We found that the techniques do work in temperate forests and with care can be applied to determining changes over vast areas in northern latitude forests. Here we review the purpose of our pilot test, methodology used, discuss our findings, and review our recommendations. We specifically look at and review the applicability of the classes of vegetation cover used in the tropical assessment and find that for the most part, they do apply to northern latitudes. We review problems experienced in our effort and present recommendations to preventing these in the future.

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INTRODUCTION

Background; FRA 1990

As part of the Forest Resources Assessment in 1990 (FRA 1990), the Food and Agriculture Organization (FAO) of the United Nations, Rome, coordinated an effort to visually interpret a stratified random sample of 117 Landsat scenes in developing countries. The objective was to estimate the global status of and change in tropical forest area (FAO 1996, Brown and Czaplewski, 1997). Images from 1980 and 1990 were interpreted and compared by a group of widely experienced technical people in many different tropical countries. They quantified areas for nine land cover classes, inclusive of four forest classes and five non-forest classes, and the class-to-class changes between 1980 and 1990 in form of transition matrices. The results and methods are fully presented in FAO 1996.

The task of assessing the global extent and condition of forest cover is formidable. However, FRA 1990 demonstrated that the visual interpretation of digital satellite data could reliably quantify broad scale changes in tropical forest cover and that the procedure was cost effective, timely, and statistically sound.

Background; FRA 2000

The United Nations will coordinate the Forest Resources Assessment 2000 (FRA 2000). This effort will describe the global status of forest resources for the year 2000 and to quantify changes over the last 20 years or, since 1980. Two main approaches will be followed to achieve this goal; 1) an assessment based on existing national information, complemented by 2) an assessment based on new multi-date satellite data in the framework of a global survey design. The United Nations ECE/FAO in Geneva has the responsibility for collection of existing information and assessment of forest trends in industrialized countries (Davis, 1997). The FAO in Rome has the responsibility for assessing forest area state, change and trends in developing countries, following both approaches, and for producing the global synthesis.

FRA 2000 has been formulated in accordance with the 1992 United Nations Conference On Environment and Development (UNCED) in Rio de Janeiro, Brazil, Agenda 21, Chapter 11, Programme D under the heading “Basis for Action.” Chapter 11 describes the present situation of forest resources assessments as follows:

> “Assessment and periodical evaluations are essential components of long term planning, for evaluating effects, quantitatively and qualitatively, and for rectifying inadequacies. This mechanism is, however, one of the often neglected aspects of forest resource management, conservation and development. In many cases, even the basic information related to the area and type of forests, existing potential and volume of harvest, etc. is lacking.” (Davis 1997)

To address these concerns, the United Nations' Committee on Forestry designed a comprehensive Forest Resources Assessment program which has four separate objectives. Our effort was a part of the fourth objective;

> "Remote sensing survey. Includes actions aimed at surveying forest resources state and change at global, regional and sub-regional levels using remote sensing and statistical sampling." (Davis 1997)

In 1997, Mr. Robert Davis, Officer-in-Charge, FRA 2000, FAO, Rome, sent a request to Mr. Doug Kneeland of the International Forestry Program Staff, USDA Forest Service for assistance from the Forest Service to help assess the procedures to be used in the temperate and boreal forests of the northern hemisphere. To meet this need ,Czaplewski has proposed a project under the coordination of the North America Forest Commission. The following pilot study is an initial step in that program. Czaplewski asked Greer and Weber to determine if the methodology and the land cover classification categories would be applicable to the temperate and boreal forests of the United States and to suggest changes that appeared to be needed.

Purpose of This Pilot Study

The purpose of this pilot study was to make a very preliminary determination to see if we could use photointerpretation methods on Landsat Thematic Mapper imagery to assess the trend in forest cover in temperate and boreal forests using the FRA 1990 methodology, which was designed for the tropics (FAO 1996). We tested the applicability of the FAO procedures to classify and compare images from two dates. Specifically we looked at the methodology and at the vegetative and other categories used in the classification process. We did not carry out the process to statistically evaluate or quantify any change in forest cover in the study areas. This work is a preliminary step before a formal pilot study that would systematically sample and evaluate scenes over a variety of sites in the continental United States and Alaska. That later study would be the foundation of our work on FRA 2000.

Pilot Areas Chosen for Study

Landsat imagery of an area in southeastern Missouri (central USA) and an area in northern New Hampshire and Vermont (northeastern USA) were furnished to the interpreters. These areas were chosen as representative of some of the mixes of forest vegetation, land uses and forested landscapes that would be found in the North American Temperate forests. Since we were looking at the methodology and at the applicability of classes, there was no need to select test sites at random. Therefore, readily available images of sites that were more or less on hand were used.

The first set of images cover an extensive area in the southeast quadrant of the State of Missouri. This is a predominately rural area of extensive hardwood forests with some significant inclusions of southern pine species. There are many established tracts (plantations) of southern pines. In general, the area is not heavily inhabited but there are significant and obvious transportation and utility corridors and several communities. The area is characterized by rough, rocky hills with locally steep terrain. This part of Missouri appears to be about eighty percent forested and agricultural uses are generally limited to more level areas in the flood plains. During the 1920 to 1940 era, many forested areas were cleared for family based agricultural use but the land is not highly productive and this is not currently the trend. There is limited urban development. Small towns are expanding very slowly if at all into the surrounding countryside but the rural population is not increasing at a high rate. The Mark Twain National Forest has large blocks of land but private lands are held by families in comparatively small holdings.

The second set of images cover an extensive forested area in the northeastern United States. This too is a predominately rural area of extensive forested lands in mountainous terrain. This area in the northern New Hampshire and Vermont is generally characterized as a northern hardwood-spruce forest ecoregion.

METHODS

The methodology we tested for this application is taken from the FAO publication *Forest resources assessment 1990; Survey of tropical forest cover and study of change processes* (FAO. 1996). This publication is based on the work of Rudi Drigo, Rome 1991 who developed the technical specifications for the interpretation process.

The Images

The Missouri Landsat scene prints are standard production products. Data is displayed as false color infrared representations. The images were acquired in August 1982 and August 1989. They show a large part of the Mark Twain National Forest. The scenes are located at Path 24, Row 34.

The northern New Hampshire and Vermont scenes were acquired in September 1985 and August 1996. They were produced with a mix of Landsat bands 3, 4 and 5, which resulted in an atypical overall color. This resulted in a somewhat perplexing “fire color” portrayal of the scene. In work we have supported over the previous 25 years, we have become accustomed to working with the more conventional false color portrayal like the Missouri scenes. Also, there is little similarity in color display between the two dates and the two scenes are vastly dissimilar in appearance. The 1985 scene is best described as flame orange and the 1996 scene as fall aspen yellow. The scenes are located at Path--, Row --.

For each area, we had four prints each printed on 24 inch by 24 inch paper. There are two full scenes, one from the early date and one from the later date which provide a broad area reference. The other two prints are quarter scenes, one of the early date and the second of the later date. These prints are of the southeast quadrant. We interpreted only the quarter scenes.

Our interpretation of the scenes was plotted on Plotlar 2000C, clear aqueous coated film. We used fine tip black Pilot™ pens to draw the polygons and pens of a contrasting color to mark reference features for later use in the manual co-registration process. During this pilot test, we did not strictly adhere to the exact technical specifications for materials outlined in the FAO methodology. We used the prescribed minimum mapping unit which at the proper scale of imagery was described as a square 3 mm by 3 mm or, a strip a minimum of 2 mm wide for rivers and other linear features.

Delineating the Study Area

Our first step was to delineate the study area for change detection. This is the area on the later date southeast quadrant image that is fully covered by the earlier date image. Since repeat coverage by satellites do not exactly match earlier ground footprints, we identified that part of the scene which common to both. The boundary of this area was plotted on the mylar sheet firmly attached to the later date image with tape. Change detection interpretations were made only of the common area. We were not confronted with the case where two sequential early date images may be required to identify a common area of sufficient size on the later date image.

Familiarization With the Study Area

Our next step was to familiarize ourselves with the resultant study area. This included a detailed visual survey of the area to note the placement of clouds, the distribution of forests, farms and communities. The images were compared to maps of the area and other sources of information about the area that would help the interpreter understand the nature of the area. Greer had lived in that area of Missouri being studied, had attended Forestry Summer Camp there, and had worked in areas of similar vegetative cover. Weber had traveled extensively in the area covered by the northeast scene and had participated in several interpretation projects there. Other references such as Baileys Ecosystem Geography were used to relate to the rest of the temperate and boreal forests in the northern hemisphere.

Assessing Image Quality

With respect to the early date image, we assessed the relative interpretability of each land cover class. We assessed the level of reliability of its potential delineation into polygons and the likelihood of separating each from adjacent, possibly very similar classes. As Drigo has pointed out, the accuracy of the interpretation depends upon two main factors. The first factor is the overall quality of the Landsat image including relative clarity of the print, the contrast, and the nature of the original data acquired by the satellite. The second factor is the knowledge of the interpreter of the area being studied and the interpreters understanding of the pattern, proximity, texture, and color of the various land cover classes that might be found within the study area.

Classification of Woody Vegetation and Other Classes

The main classes are the minimum level of classification for the change detection part of the assessment. The additional classes are to be used for change detection only if they may be delineated reliably on both the early date and later date images.

Basically, the photo interpreter is ask to identify and classify all land cover within the common area on the later date image. The first step is to identify the main categories and delineate polygon boundaries. Next, these main classifications are subdivided into the additional classes if their identification is considered reliable. If not, the main class polygons stand on their own.

Interpretation Key

Our interpreted classification was based on the key in Annex IIb in *Forest resources assessment 1990; Survey of tropical forest cover and study of change processes* (FAO. 1996). This key is reproduced in Table 1. It is important to note that this classification scheme was developed initially for tropical areas but will be used in temperate and boreal forests to maintain global consistency. Rudi Drigo originally proposed that the temperate/boreal classification be developed on the same concept as the classification system for tropical forests to maximize consistency for global assessments. At issue is whether the classes as described are applicable to the temperate and boreal forests of developed nations and if they fit the needs of developing, non-tropical nations. The initial scheme was designed to provide classes of all types of woody vegetation that might be identified on high resolution satellite images. There is a need to maintain consistency across ecoregions so that data may be merged to provide a global perspective. These are the categories that we used in our pilot study.

An attempt to classify **man made woody vegetation cover** in contrast to natural woody vegetation cover is made because of a perceived need to analyze and monitor changes in their occurrence and impact on the local forest resource. Even though the classification process is complicated by the occurrence of poor quality plantations scattered in natural forested areas, the approximate identification of this class is deemed important in tropical areas.

Most of these classes are self descriptive but a couple require a clarifying comment. The main classes labeled **agriculture impact - short fallow** and **agriculture impact - long fallow** refer to the practice of clearing small patches of forest land for crops and the shifting pattern that results as patches are farmed, left fallow, and then revert to forest cover. In the tropics, they may be seen in digital images as a sort of mosaic of cultivated areas adjacent to others of similar size in various stages of regrowth.

Interpreting the Later Date Image

We next interpreted the later date image working within the common area we previously identified. We identified polygons and marked them on the film overlays. This was done to a level at which we felt was reliably recognizable. This is a personal judgment based on the interpreters experience, knowledge of the area, and quality of the image.

We also marked directly on the overlay the alignment of rivers, highways, power-lines and other significant features that would help later to compare the polygons to the earlier date image. When drawing in such identifying features, we periodically placed the early date image under the mylar to see how much information we would need to assure positive identification of polygons. There are so many rivers, roads and features in a developed nation that the overlay could be easily cluttered if the FAO instructions were followed to the letter and all features were identified. As a result, we did not delineate many features (especially rivers) because they were not needed for reference.

Interdependent Interpretation of the Older Image

The second step in the interpretation phase to determine changes in land cover is to interpret the early date image. We followed the Drigo procedure as outlined in *Forest Resources Assessment 1990 Project, Monitoring Methodology.* (FAO. 1996) which is the basis of the following paragraphs. Figure 1 (page 14) illustrates this procedure.

In this process, we interpreted the early date image with constant reference to our interpretation of the later date image. In this process, the later date interpreted overlay was placed over the early date image. The rivers, roads, power-lines and other features that we identified for this purpose were used to align the overlay with the early date image. Then, on top of the later date overlay, we placed a clean early date overlay. We proceeded to redraw the same class polygon boundaries where it was unquestionably clear that no change had taken place. Where the polygon boundaries did not fit, we rechecked the later date image to assure ourselves that our initial interpretation was either accurate or that we had made a mistake. Errors on the later date image overlay were corrected at that time. If the interpretation were accurate, then we delineated the new class boundary and entered the class code only on that portion of the polygon that had changed. Where no changes were found, the class code for the later date image was accepted as the correct one.

In the case of image distortion due to projection, satellite orbital position or, slight differences in scale, we moved and shifted the early date image to align obvious control points and features so that polygons could be compared. Such manual co-registering permits a quick and relatively reliable system for correcting problems without the need to digitize the entire data set into a geographic information system.

Early date images are sometimes of a poorer quality than late date images, and interpreters are reminded in the protocol to be aware of sub-classes easily identified on the later date images that will not be seen on the early date images. In cases where subclasses could be identified on later date images but not on early date images, we would classify the area to the main class only and drop all reference to the subclasses.

Field Verification

We feel it is important here to note that there was no field verification of any of our interpretations. This is not uncommon in less developed areas where transportation is not as easy or reliable or where the funding for image interpreters is marginal. We believe that the way we carried out the pilot project is similar to the way it will be done in many parts of the northern hemisphere.

CONCLUSIONS AND RECOMMENDATIONS

Limits on the Study

It is important to note that we did not carry the pilot test into any statistical analysis of our findings. Our charge was to test the methodology, evaluate the classes of land cover, and comment on anything that we found that should be considered if the process were applied to the temperate and boreal forests of the northern hemisphere. Therefore, we do not comment on any data compilation phase or on any subsequent statistical assessment process.

Image Scale Problems

We had problems with scale on the images as delivered. The scale problem on the Missouri scenes was not apparent and the interpretation part of the project progressed as planned. The image over New Hampshire and Vermont delivered much later to Weber were obviously off scale. It was only after this discovery that Greer recognized his oversight in not checking the scale of the Missouri scenes upon delivery. The scale problem on the northeast area scenes was corrected before interpretation began. Initially, the two scenes from the early date and the late date were accurately compared to insure that both were of the same scale. They were found to be almost identical in scale. The failure to check the actual scale on the Missouri scenes resulted in the use of a template of the minimum mapping unit that was smaller than desired. That template was corrected and all areas near the minimum mapping unit size were rechecked to see if they were still valid. Many were found to not be. This problem can be avoided if every scene is checked for scale upon receipt. Because we were not taking this pilot test into the statistical analysis, the omission was more inconvenient than important. For the FRA 2000 survey, each interpreter should be reminded as a part of the protocol to check and double check the image scale.

Image Color

Our experience over the last 25 years of working with a more conventional false color portrayal leads us to believe that that format is the best for vegetative interpretation. To experienced photo interpreters, odd or nonstandard color portrayals are more of a distraction that a real impairment to interpretation. However, scenes for interpretation should be supplied to the interpreter in the format and color commonly used by that person for similar photo interpretation work.

Worker Isolation

We feel it is a problem when interpreters work in relative isolation without the stimulation of others in the project. I feel that to be successful, a strong and constant network of communications should be established to share information, problems, encouragement's, status, and success. In FRA 2000, this should be recognized as many interpreters across the northern hemisphere will be somewhat isolated.

Partial Scenes and the Common Area

Drigo pointed out that the difference between Landsat 1, 2, and 3 orbits and path and row designations may create the need to use two adjacent images of the early date in order to get a sufficient common are on the later date image. We strongly recommend that when two combined Landsat 1, 2, or 3 images are required for the early date image, the area of interest should be patched in a GIS/Image processor before printing so the interpreter can concentrate on the interpretation task instead of on the technique of getting two images to match the study area as defined by the later date image.

The Interpretation Key

Specifically, the main class "Man-made woody vegetation cover" (and subclasses "Forest Plantations" and "Agricultural plantations") are not discernible on the Landsat Images that we examined. A person with a more robust knowledge of local conditions might be able to map some of these classes but there are no obvious indications on the images. "Man-made woody vegetation cover" and especially "agricultural plantations" seem to be ambiguous.

"Shrubs" is another category that is not classifiable on our images without an intimate knowledge of local conditions. We know from personal knowledge that shrub fields do occur in southeastern Missouri, specifically oak regrowth, sumac species, eastern redcedar, and other invader species on abandoned farms. Many are below the minimum classification unit but large fields do occur. It is not hard to imagine that shrub fields exist on the steep south exposures of many mountain niches in Vermont and New Hampshire, but we were not able to classify any. We have seen and have classified shrub fields on Landsat scenes of lands in Colorado, Idaho and South Dakota, but in almost every case that was supported by intense local knowledge gained from survey work in these areas..

Perhaps the least applicable classifications in the United States are those associated with "Agricultural Impact." Because of the different system of land ownership and regulation in the USA, we do not normally see either short fallow or long fallow agriculture practiced. Therefore, these classes become meaningless in the United States and will probably be useless in the rest of the developed northern hemisphere. This is probably true of boreal forest areas too. As a result, these classes were not used in our interpretation.

There is one exception to this statement about short fallow farming of which we are aware. In the tobacco producing regions of the southeast USA, it is common practice to prepare a new seedling bed for new tobacco plants each year. These are created on small plots in newly cleared forest cover. Perhaps it is only tradition but growers prefer to have a newly cleared patch of forest ground for this. These patches are below the minimum mapping unit size and never constitute (in our opinion) a significant impact on the region but they do represent short fallow system in a heavily developed part of the world.

Other non-interpreted subclasses are straight forward except for “Burnt woodland.” In some cover types, burned areas will be obvious. Any conifer cover type in either the temperate or boreal forest will probably be obvious if the burn intensity was moderate or high. Low burn intensity and some moderate intensity burned areas will not be evident and cannot be mapped. (Greer, et al, 1996) In the deciduous forests, we suspect that only high burn intensity fire areas will be obvious but even then, it may take some good local knowledge to see some burned areas. As a result, and in our opinion, we will not be able to map any burn areas to meet the definition in the publication *Forest resources assessment 1990; Survey of tropical forest cover and study of change processes.* (FAO. 1996) Code 96 is to be used only in woodland areas where recurrent fires destroy only (or mainly) the grass layer present under the tree cover. By definition, this is a low burn intensity fire and it will not show up in our forests unless the canopies are very open (i.e., crown cover 10 to 40%). We can map the “code 0” areas because they are destroyed forests and they become “Other land cover.”

We suggest that for analysts working in unfamiliar parts of the world, the single best tool for training and familiarity that can be provided is one, good aerial color or color infrared photographic stereo pair, at a relatively large scale such as 1:8000 or larger. We recognize that in most of the world, this is rarely available. However, one good high resolution, pan sharpened satellite stereo pair for each sampled scene would be a good substitute to assist and train an analyst in interpretation of Landsat scenes in unfamiliar areas of the world.

Establishing cooperative projects or at least coordinating our efforts with Canada and Mexico with regard to the sampling design could reduce overall North American costs of FRA 2000.

Focusing on forest cover alone may cause us to miss an opportunity to evaluate trends on an ecosystem basis. With biodiversity now a major concern, we may want to look at a sampling protocol that will let us monitor shifts of a variety of cover types other than just forests. For example, the extent and distribution of mountain meadows might be a critical forest statistic to monitor.

Suggestions for New Subclasses

Obviously the northern temperate and boreal forest differ greatly from the tropics. One major difference is the rapidity of development and use of wild lands where forests are converted to other uses. We suggest that subclasses should be developed to reflect the loss or gain of forest areas resulting from such urban development and sprawl, but also for other change agents like geologic processes and climate change. If we want to track specific trends, the following subcategories might be helpful.

Urban, where forests are replaced by development.

Reclaimed sea bed, as in Holland where forests may be planted.

Landslides, where in mountains significant slides can change large areas. This may be important in the Rocky Mountains, the Alps, the Himalayas, and Caucasus.

Glaciers, where forests can come and grow as glaciers advance and retreat over time.

Tundra and permafrost, where forest growth can advance with warming climate.

Ocean/sea, where rising levels encroach on land as a result of global warming and forests are destroyed.

Retired pasture, where forests are retaking pasture lands after hundreds of years of use may represent an agricultural impact which could be characterized as very long fallow

SUMMARY

We believe that generally, the methodology and classification key developed by Drigo for tropical areas can be used to assess trends in forest cover. There may be some automated procedures utilizing image processing that could be used to support the manual interpretation and classification. It also seems plausible that the work could be concentrated into the hands of a relatively few interpreters located at central processing centers.

In the United States, there are sources of important data not normally used in such projects. In the United States, national forests, most BLM districts and our national parks have special "project photography" that is not indexed anywhere. These important sources of data are usually kept in the Supervisors or District Managers offices. We also need to keep in mind that other potentially important sources of photographic data such as the Space Shuttle LFC images are available. In the near future, civilian, high resolution pan-sharpened multispectral satellite data will be available for reference.

ACKNOWLEDGMENTS

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Much of our review of the FRA 1990 material is paraphrased from the United Nations references mentioned in the body of this paper. We acknowledge those materials and their unidentified authors as deserving of credit and we are in no way attempting to take credit for their work in formulating the methodology.

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Table 1: *Sampling Unit Descriptions and Classification Codes.*

Main Classes	**Additional Classes**	**Classification Codes**	
		Main Classes	**Additional Classes**
Other Land Cover		0	
	Snowcaps, rocky area		77
Water		1	
Man Made Woody Vegetation Cover		2	
	Forest Plantations		22
	Agricultural Plantations		23
Shrubs		3	
	Sparse shrubs (crown cover 10-40%		33
	Dense shrubs (crown cover > 40%)		34
Fragmented Forest		4	
	Forest fraction 10-40%		44
	Forest fraction 40-70%		45
Open Canopy Forest (Crown cover 10-40%)		5	
Closed Canopy Forest (Crown cover >40%)		6	
	Closed forest (crown cover 40-70%)		66
	Closed forest (crown cover >70%		67
Agriculture Impact - Short Fallow		7	
Agriculture Impact - Long Fallow		8	
Other non interpreted (clouds, shadows, other)		9	
	Burnt woodland		96
	Clouds, cloud shadows		97
	Mountain shadow		98
	Outside study area		99