Assessing Change in Large-Scale Forest Area by Visually Interpreting Landsat Images

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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. Images from 1980 and 1990 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 the methodology's 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, the methodology used, our findings, and 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 for preventing these in the future.

The United Nations will coordinate the Forest Resources Assessment 2000 (FRA 2000) to describe the global status of forest resources for the year 2000 and to quantify changes since 1980. Achieving this goal will require: (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 Food and Agriculture Organization (FAO) in Geneva is responsible for collecting existing information and assessing forest trends in industrialized countries (Davis 1997). The FAO in Rome is responsible for assessing forest change and trends in developing countries, using both of these assessment approaches, and for producing the global synthesis.

FRA 2000 was 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 (FRA) program that 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)

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. A FRA 2000 strategic plan was developed that provides the

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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 the highest priorities for the FAO Forestry Department.

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 proposed a project under the coordination of the North America Forest Commission. The purpose of this pilot study, an initial step in that program, was to see if we could use photo interpretation methods on Landsat Thematic Mapper imagery to assess the trend in forest cover in temperate and boreal forests using the earlier FRA 1990 methodology, which was designed for the tropics (FAO 1996). Czaplewski asked Greer and Weber to determine if the methodology and the tropical land cover classification categories would be applicable to the temperate and boreal forests of the United States and to suggest changes that might be needed.

Global land cover can be mapped with low-resolution satellite data (e.g., AVHRR). However, AVHRR data cannot 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, IKONOS) 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 percent 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 an analysis of 100 percent of the high-resolution satellite scenes. This improves monitoring through use of multiple sensor systems.

As part of the FRA in 1990, the FAO in 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 areas (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 (four forest classes and five non-forest classes) and the class-to-class changes between 1980 and 1990 in the form of transition matrices. (The results and methods are fully reviewed in FAO 1996.)

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. Our pilot study 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.

PILOT AREAS

Landsat thematic mapper imagery of an area in southeastern Missouri (central USA) and an area in northern New Hampshire and Vermont (northeastern USA) was 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 were used.

The first set of images covers an extensive area in the southeast quadrant of the State of Missouri. This is a predominately rural area of extensive hardwood forests intermixed with natural stands and plantations of southern pine. Although the area is not heavily inhabited, significant transportation and utility corridors and several communities exist. The terrain has rough, rocky hills with locally steep terrain. This part of Missouri appears to be about 80 percent forested, and agricultural uses are generally limited to more level areas in the floodplains. During the 1920 to 1940 era, many forested areas were cleared for family-based agricultural use, but much of the land is not highly productive. There is limited urban development. Small towns are expanding very slowly, if at all, into the surrounding countryside, and the rural population is not increasing at a high rate. The Mark

Twain National Forest holds large blocks of public land. Private lands are owned primarily by families in comparatively small holdings. Few significant differences are apparent between the images from the two acquisition dates. Road and utility corridor patterns are quite similar on both images.

The second set of images covers 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 northern New Hampshire and Vermont is generally characterized as a northern hardwood-spruce forest type. The test area embraces a diverse land-use pattern that is greatly influenced by mountainous terrain bisected by streams, major rivers, and large impounded water bodies. The land area of the White Mountain National Forest is a dominant unit of the area. This may account for a measure of stability with regards to change and development within the area. Compared to the Missouri scenes, there were more apparent changes in the landscape on these northeastern scenes. Many recreation homes and condominiums, many associated with large ski area developments, were constructed between the two image aquisition dates. Very little evidence of logging disturbance was observed. There was little evidence of new road construction and development of new utility corridors during the period or of significant expansion of agriculture either in the non-forested areas or as encroachment into forest land. The reversion of agricultural land to forest land and the conversion of fields to forest plantations appear to be a minor influence on land use. The most obvious change during the 1985 to 1996 period was growth and expansion of urban areas into landscapes adjacent to small towns and larger cities.

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, who developed the technical specifications for the interpretation process.

The Images

The Missouri Landsat scene prints are standard production products. The data set is displayed as a false color infrared representation. The images were acquired in August 1982 and August 1989 and 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. The scenes are located at Path 13, Row 29. The prints were produced with an unknown mix of Landsat bands 3, 4, and 5 in proportions that resulted in an atypical overall color. This resulted in a somewhat perplexing fire-like color portrayal of the scene. Also, there is little similarity in the 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. In work we have supported over the previous 25 years, we have become accustomed to working with the more conventional false color portrayal as in the Missouri scenes.

For each area, we had four prints, each measuring 61 by 61 cm (24 by 24 inches). Two full scenes, one from the early date and one from the later date, 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 by 3 mm, or a strip at least 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 does not exactly match earlier ground footprints, we identified the part of the scene that is common to both scenes. The boundary of this area was plotted on a mylar sheet firmly taped to the later date image. 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 images to note the locations of clouds and 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 the 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 sources such as *Bailey's Ecosystem Geography* (Bailey 1996) 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 interpreter's knowledge of the area being studied and an 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 identifies and classifies all land cover within the common area on the later date image. The first step is to identify the main categories and delineate primary 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 test was based on the interpretation key in Annex IIb from *Forest Resources Assessment 1990 Project Monitoring Methodology* (FAO 1991). The classification coding key, from Annex Ia, is reproduced in table 1. It is important to note that this classification scheme was developed initially for tropical areas. 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

Table 1.—*Sampling unit descriptions and classification codes for Forest Resource Assessment 1990* (FAO 1991)

Main classes	Additional classes	Classification codes: Main classes	Classification codes: Additional classes
Other land cover		0	
	Snowcaps, rocky area		77
Water		1	
Manmade 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

scheme was designed to provide classes of all types of woody vegetation that might be identified on high-resolution satellite images. These are the categories we used in our pilot study.

An attempt to classify **manmade 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 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 allowed to revert to forest cover. In the tropics, these patches 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 a difference was reliably recognizable. This is a personal judgment based on the interpreter's experience, knowledge of the area, and quality of the image.

We also marked directly on the overlay the alignment of some rivers, highways, powerlines and other 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 ensure positive identification of polygons. There are so many roads and features in a developed nation that the overlay can be easily cluttered if the FAO instructions are followed to the letter and all features are 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 1991), which is the basis of the following paragraphs. Figure 1 illustrates this procedure.

In this process, we interpreted the early date image with constant reference to our interpretation of the later date image by placing the later overlay over the early image. The rivers, roads, powerlines, 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 our interpretation was 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 later date images, and interpreters are reminded in the protocol to be aware of subclasses 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 classified the area to the main class only and dropped all reference to the subclasses.

LIMITS ON THE STUDY

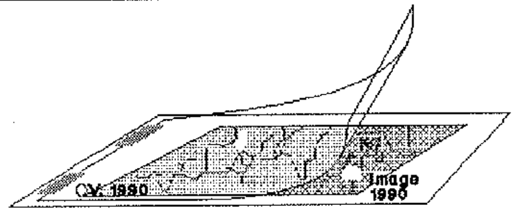
We feel it is important here to note that there was no field verification of any of our interpretations. This is not uncommon in less developed areas where transportation is not as easy or reliable or where the funding for image interpreters is marginal. We believe that the way we carried out the pilot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

It is also 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 we found that should be considered if the process is 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.

Step 1

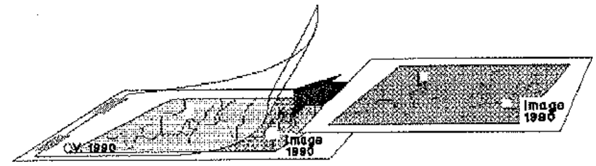
Interpretation of 1990 image on a transparent film overlay (1990 overlay).

The interpretation includes the delineation of Land Cover Classes and control features.



Step 2

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



Step 3

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

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

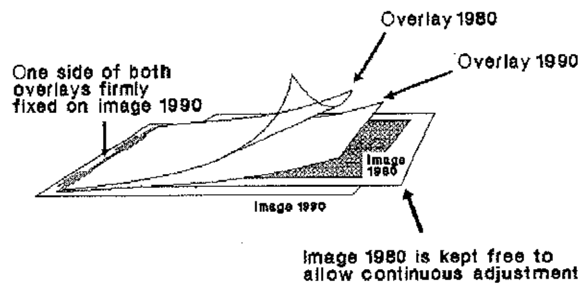


Figure 1.—*Interdependent interpretation procedure, FRA 1990 (adapted from FAO 1996).*

RESULTS AND DISCUSSION

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 images 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 Missouri scenes from the early date and the later date were accurately compared to ensure 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 the color infrared format is the best for vegetative interpretation. To experienced photo interpreters, odd or nonstandard color portrayals are usually more of a distraction than a real impairment to interpretation. However, in this case, it was very difficult to manually evaluate changes between two scenes with such wildly divergent and nontypical colors. In any case, scenes for interpretation should be supplied to the interpreter in the format and color commonly used by that person for similar photo interpretation tasks.

Worker Isolation

We feel it is a problem when interpreters work in relative isolation without the stimulation of, and interaction with, others working on the project. We feel that a strong and constant network of communications should be established to share information, problems, encouragement, status, and success. In FRA 2000, this should be recognized because many interpreters across the Northern Hemisphere may 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 to get a sufficient common area 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 "Manmade woody vegetation cover" (and subclasses "Forest Plantations" and "Agricultural plantations") are not discernible on the Landsat images we examined. Someone 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. "Manmade woody vegetation cover" and especially "agricultural plantations" seem to be ambiguous. In his review, Gyde Lund agreed. He pointed out that some of the classes are subjective and in some cases call for knowledge of the landowner's or land user's intent. This is especially true of long fallow verses short fallow. Our test certainly supports his point of view. These classification calls require information that is not available from remote sensing data.

"Shrubs" is another category that is not classifiable on our images without an intimate knowledge of local ecosystems. We know from personal experience that shrub fields do occur in southeastern Missouri, specifically oak regrowth, sumac species, eastern red cedar, and other invader species on abandoned farms. Depending upon the species, some of these shrub lands may qualify as some class of forest cover. By definition, forest cover includes lands that are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest (UN-ECE/FAO 1997). Many of these fields 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 classified shrub fields on Landsat scenes of lands in Colorado, Idaho, and South Dakota, but in almost every case that was supported by detailed 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 may be useless in the rest of the developed Northern Hemisphere. This is probably also true within boreal forest areas.

There is one exception to this statement about short-fallow farming of which we are aware. In the tobacco-producing regions of the southeastern United States, 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 a short-fallow system in a heavily developed part of the world.

Other non-interpreted subclasses are straightforward 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 reliably mapped (Greer *et al.* 1996). In deciduous forests, we suspect that only high burn intensity fire areas will be obvious, and even then, it may take some good local knowledge to map 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 Project Monitoring Methodology* (FAO 1991). 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 percent). As a result, this class that normally would be non-interpreted will be interpreted and classified as some other forest cover class. In other locations where fires have destroyed the forest, in other words, moderate to high burn intensity, we can map them as code 0 areas because they become by definition "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 where photography is not available. New multispectral space-based platforms, such as IKONOS 1 & 2, provide 1-m pan-sharpened multispectral data. The information content is comparable to a conventional 1:2,400 RF aerial photograph.

We suggest that time spent in preparing more formal and detailed interpretation keys using samples of imagery to illustrate the classes would provide more consistency of interpretation.

Suggestions for New Subclasses

Obviously the northern temperate and boreal forest differs greatly from that of 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. Subclasses for other change agents like geologic processes and climate change should also be developed. 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 go as glaciers advance and retreat over long periods of 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 destruction of forests.

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

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.

Opportunities for Cooperative Cost Reduction

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

SUMMARY

We believe that generally, the methodology and classification key developed by Drigo as reported in FAO, 1996, for tropical areas can be used to assess trends in northern boreal and temperate 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. National forests, most BLM districts, and national parks in the United States have special "project photography" that is not centrally indexed. These important sources of data, with photo index maps, are usually kept in the Supervisor's, District Manager's, or Superintendent's offices. Other potentially important sources of photographic data such as the Space Shuttle LFC images from 1984 are available. In the near future, civilian, high-resolution, pan-sharpened, multispectral satellite data will be available for reference.

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Much of our review of the FRA 1990 material is paraphrased from the United Nations references cited 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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