GOFC-GOLD GLOBAL OBSERVATION OF FOREST AND LAND COVER DYNAMICS

Summary of Products: Forest Cover Characteristics and Changes Implementation Team. Background document for the GOFC Science and Technical Board

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Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a coordinated international effort to ensure a continuous program of space-based and in situ forest and other land cover observations to better understand global change, to support international assessments and environmental treaties and to contribute to natural resources management.

GOFC-GOLD encourages countries to increase their ability to measure and track forest and land cover dynamics by promoting and supporting participation on implementation teams and in regional networks. Through these forums, data users and providers share information to improve understanding of user requirements and product quality.

GOFC-GOLD is a Panel of the Global Terrestrial Observing System (GTOS), sponsored by FAO, UNESCO, WMO, ICSU and UNEP. The GOFC-GOLD Secretariat is hosted by Canada and supported by the Canadian Space Agency and Natural Resources Canada. Other contributing agencies include NASA, ESA, START and JRC. Further information can be obtained at http://www.fao.org/gtos/gofc-gold

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1.0 INTRODUCTION

This document provides definitions and specifications for a products suite to be developed by the GOFC Forest Cover Changes and Characteristics Implementation Team (FC-IT). The product suite is aimed at both global and regional/national scales, and is focused on information needs for the *Initial Priorities* and *Early Initiatives* of the FC-IT to support three thematic foci and users:

1) global change research community with an emphasis on the global carbon cycle,
2) international policy and assessments, with a proposed emphasis on the Millennium Ecosystem Assessment, and
3) national and regional forest management users.

This document is a general overview. It is meant to lay out the important technical implementation issues, regardless of who or what organization implements the products. Moreover, it is not a final specification document. This product suite is preliminary and will be refined over the course of the next 6-12 months by the FC-IT. It is based on the GOFC design strategy and precursor efforts of the Coarse and Fine Resolution Design Teams. Full reports from these design teams can be found on the GOFC web site.

2.0 GENERAL CONSIDERATIONS

Recommended for the development of the FC-IT product suite are based on some fundamental considerations, such as:

- Products developed should be achievable, whenever possible, with current technology (i.e., using data from sensors either currently operational, or scheduled to be operating in the coming year). The approach, however, should also include definitions of optimal characteristics that may be achievable with advancements in future remote sensing systems.

- On-going product development must be practical and lead to a reasonable operational concept, implemented using existing and near-term observational systems, with a straightforward and management level of effort.

- Products should be developed using existing and near term programs, and should include proven or near-ready applications rather than new experimental approaches which require considerable research and development.

- However, research will be a necessary component in most product development strategies and will be important for the long-term development of new products; as such it should be an integral element of the work of the FC-IT.

- Product definitions and specifications should be periodically reviewed and improved so that advances in methods and source data characteristics can be incorporated to improve overall data quality.

- Validation of data products is necessary to evaluate product quality, and also to identify new research priorities.

3.0 PRODUCT LEVELS AND SUITES

A review of the individual requirements of global change, forest inventory, and policy communities reveals a striking convergence, or similarity in scope and definition. The most complex and stringent requirements are set by the forest inventory users since they have needs for detailed forest cover characteristics linked to specific in-situ data with high spatial accuracy and precision. The carbon cycle community and policy users (particularly the emissions inventory requirements) have of subset of these needs. Thus, it is possible to define a single common data bundle which satisfies a very broad range of users and at the same time focuses on the requirements for the global carbon community, forest inventory community, and the policy community.

This FC-IT will focus on development of a suite of datasets and data products with the following general hierarchy levels:

Level 1: raw fine and coarse resolution data such as ETM+, Spot, MODIS or other which are not atmospherically corrected and georeferenced by system correction only.

Level 2**:** Enhanced image datasets, which will include fine and coarse resolution image data from TM, ETM+, ALI, MODIS and VEGATATION which have been atmospherically corrected, georeferenced to earth coordinates, projected, normalized for view / sun angle effect, and mosaicked when multiple scenes needed will also be provided.

Level 3: Derived data products, which will include the results of analyses of image products. These products will be used to improve existing global land cover maps, maps of forest density, assessments of deforestation, and other information on forest cover characteristics and changes.

We believe that some users will primarily need access to the Level 1 and Level 2 datasets, such as the UN FAO Forest Resource Assessment program which routinely acquires the image data and performs its own in-house data analysis. Others, such as the forest inventory community need access to Level 3 derived data such as extant forest density and fractional cover for making forest inventory or deforestation and forest degradation assessments.

4.0 SPATIAL COVERAGE

In order to design a monitoring system capable of monitoring both high and low frequency changes in forest, we propose to establish a cross spatial and temporal resolution system, using data from multiple satellite and in-situ data sources. It consists of a data system at three temporal and spatial scales.

> ***Global:*** This coverage will focus on datasets and products with global coverage, and will rely heavily on the coarse resolution datasets. Regional subsets or regional components can be used to assemble a global product, but priority will be given to single global datasets. These will be developed mostly for Forest Cover products.
>
> ***National and Regional*****:** This scale is developed and employed for National Forest Inventory assessments and monitoring and other regional and national uses. These products will be developed mostly from fine resolution source data, while some regional products with regionally-specific classifications may also appear. These datasets will be most useful for change analysis.
>
> ***Focus Areas and Sites*****:** These focus areas serve two purposes: (1) calibration and validation of derived products, and (2) evaluation and testing of products for forest management applications.

5.0 PROCESSING

Imagery acquired must be processed so the data can be analyzed quantitatively. This includes five processing steps which are detailed in the following sections.

5.1 Georeferencing. Images will be georeferenced to a common coordinate system. To geo-reference the 30m resolution imagery and its derived products, one method might be to use ortho-rectified historical TM imagery acquired through the NASA Science Data Buy program at Stennis Space Center. The product produced for NASA by EarthSat will be a georeferenced TM data ±60m of its true coordinates. Problems of relief are greatly reduced in this dataset. The mosaicked images can be used to serve as a template for georeferencing all other 30m resolution satellite images to be acquired. It must be noted that the Landsat program is producing very good locational accuracy with system corrected algorithms using the post-pass ephemeris.

For 250m - 1km resolution imagery and derived products, we could use the VEGETATION imagery from SPOT 4 satellite as a template. Unlike the AVHRR, VEGETATION sensor has a spatial resolution of 1.1km across the entire scene. Because the sensor uses an array of detectors, each having its own instantaneous field of view, the spatial resolution across the entire image is approximately the same. The spatial accuracy of this sensor is ± 500m. Alternatively, MODIS 250 data could be used. Another alternative, but with more effort, fine resolution data could be used from the method above.

5.2 Atmospheric Corrections. Atmosphere affects optical remote sensing signals two ways. It attenuates the solar radiation reaching to the earth surface and that reflected off the earth surface to the satellite sensors. As a consequence, the signal arriving at the sensor will be weakened and the resulting image will be darker. On the other hand, the atmosphere scatters solar radiation in all directions, including the direction where satellite sensors are viewing, thus contributing significant scattered radiation toward the sensor. The result of the atmospheric contribution, often termed as path radiance, is to increase the brightness of the image, and to reduce the contrast of the earth surface features. Therefore, the atmospheric effect in satellite images must be accounted for. There are several methods which can be used to correct such effects. Sophisticated methods require precise measurements of atmospheric properties such as water vapor content and aerosol density. In tropical regions, both aerosol and water vapor content varies spatially and temporally and, therefore, deployment of instruments for atmospheric measurements appears impractical. Another way to characterize the atmospheric properties is to model the atmosphere as a layered medium, which exerts effects on incoming and reflected solar radiation (Kaufman 1989). The physical properties of the atmosphere can be modeled as a function of latitude, longitude, and day of year. The modeling approach often takes substantial computation time, and thus correction of atmospheric effects on large-scale satellite images often prevent operational uses of satellite imagery. A simplified method exists (Rahman and Dedieu, 1994) and is being used to in some labs to operationally correct the VEGETATION data. Therefore, we proposed to use the simplified method based on Rahman and Dedieu (1994) to correct satellite images.

Three practical methods have potential to use in this investigation for atmospheric correction. The first is to take advantages of already-corrected VEGETATION data. By comparing the statistical means of a large area common on both the atmospherically corrected VEGETATION image and the image to be corrected for each corresponding spectral band, an adjustment can thus be determined and used for atmospheric correction. This procedure is simple, but relies on the accuracy of the atmospheric correction for the VEGETATION image. Since only histograms need to be computed, this procedure will be computationally economic.

The second method which has potential is to use simplified atmosphere models directly such as the SMAC (Rahman and Dedieu, 1994). Compute code for SMAC can be obtained and modified to various spectral bands of other sensors. Once coded, the method will be applied routinely to correct for atmospheric effects.

A third method involves the use of pseudo invariant objects found within a scene. This technique (Chavez, 1988, Qi et al., 1999) appeared to be attractive because of its use of objects of known reflectance properties. This method first identifies at a minimum two objects that are assumed to be invariant (throughout time). Their reflectance properties are known, or can be measured. The reflectance properties of the objects and their associated raw digital numbers can be plotted and the slope and intercept can thus be obtained, which can be subsequently used to correct for atmospheric effect.

These methods can be tested within the FC-IT.

5.3 Bidirectional Normalization. Because of the large area coverage from coarse resolution sensors such as VEGETATION and MODIS, each pixel in an image will have different geometric properties in relation to the sun and the sensor. Pixels away from the center of the image will have a substantially large viewing angle, resulting in different levels of brightness due to bidirectional effects. Many numerous studies have shown that bidirectional effects can be substantial and the effect on subsequent derived products, such as vegetation indices, can be greater than 20%, larger than atmospheric effects found in most cases. Even satellite imagery which is acquired with a near-nadir angle, brightness can still vary significantly due to seasonal changes in sun elevation. Therefore, it is critical to correct such brightness difference due to solar zenith angle variations, in addition to correct for effects due to varying view angles.

Many BRDF models have been proposed (Strahler, 1994, Cabot et al., 1994, and Strahler 1997) to simulate the bidirectional reflectance distribution functions. Most of them were developed for specific vegetation canopy types. Sensitivity analysis suggests that simple empirical models perform as well as many of the sophisticated models. In order to use these models to correct remotely sensed imagery acquired at varying viewing angles, simple models such as those proposed by Roujean et al. (1992), and the Walthall (1985), could be used to normalize the effect due to difference in sun elevation and the sensor's viewing angles. For all images acquired at different dates or different time, which results differences in solar zenith angles, will be normalized to a standard solar zenith angle.

5.4 Cloud Screening. Persistent cloud appearance in some regions often masks remotely sensed imagery. This will be important for our daily dataset from optical sensors. The techniques which could be used include maximum compositing (Holben et al., 1986) and those described by others (Goward 1990, Gutman 1991, Cihlar et al., 1994, and Qi and Kerr, 1997). The former technique uses the normalized difference vegetation index (NDVI) as threshold to screen clouds. Pixels having the maximum NDVI values from multitemporal images are selected to form a new composited image.

The techniques by Qi and Kerr (1997) use combination of NDVI, viewing angles, and temperature. These techniques retain all pixels above predefined thresholds. In addition, these techniques also retain as all pixels as long as they passed through the selection process, which retain more value data. In focus areas where in-situ data are available, the latter techniques will be used while for global scales the former (Holben, 1986 and Cihlar et al., 1994) technique will be used to composite all images.

5.5 Mosaicking. Once images have gone through all processes mentioned above, they could be mosaicked to cover the product areas. Although the previous processing procedures will improve the data quality, it is expected that there still be discontinuities across joining boundaries of two images. If this occurs, it may be necessary to use an overlap area matching method to reduce the discontinuity. The outputs from this procedure would be georeferenced, atmospherically corrected, and mosaicked data of the specified spatial and temporal resolutions specified above.

6.0 FOREST COVER PRODUCTS

6.1 Global Land Cover

The land cover product should be produced every five years, with completion of the product 12-24 months following the end of the baseline period. While global land cover with 250m to 500m resolution will have the highest applications value, in the near term a 1000m resolution data set is most practical and feasible. However, it is important to recognize the long-term requirement for higher resolution global land cover products.

The level of thematic detail should be greatest for woody vegetation (i.e., trees, shrubs) and only general land cover types are necessary for the other landscapes. This means that there will be uneven categorical detail, with 40-50 classes representing woody vegetation, and approximately 5-10 additional categories representing all other cover types. A draft land cover legend is presented for discussion in the Design Strategy document on the GOFC web site.

While several training procedures and classifiers have recently been used to develop global land cover data sets (i.e., Defries, et al., 1995; Loveland, et al., submitted), there is currently no clear evidence to suggest that one approach is superior to another. The selection of a method must therefore be based on applications issues, including degree of required flexibility and tailoring of the GOFC global land cover product, frequency of updates, and implementation considerations. This should be a major activity of the FC-IT.

For this product in the early stages of development, a centralized production model, in which one organization develops the product, has advantages and offers greater chances of global consistency at a lower cost and completed in a shorter period of time. A decentralized approach is more relevant for policy applications and ecosystem assessments in which it is essential that local to regional landscape conditions are most reliably represented. The decentralized production approach is amenable to those regions where a GOFC Regional Network has been established and has capabilities. In addition, specialized regional products could be developed at the coarse resolution with a legend specifically tailored to regional requirements. With a decentralized model or for regionally specific products, it is necessary to standardize inputs, and definitions of results.

Product validation is important, and could be conducted through a global scheme coupled to high resolution acquisition scheme implemented globally, or through regional activities involving the Regional Networks.

Data sets targeted for the global land cover products include MODIS, VEGETATION, and similar sensors which would be acquired through a specific acquisition model to be developed by the FC-IT.

6.2 Global Forest Density and Percent Tree Cover

An integral part of the global land cover product is a forest canopy density product that provides estimates of percent tree canopy for each pixel. The density would be described in terms of percent forest cover within the pixel, varying from 0 in locations with no woody cover to 100 for locations with full canopy cover. The resolution of this product should be the same as that used in the global land cover product. This data set should be produced every five years, but will be needed within 3 months following the end of the baseline period so that it can be used in the global land cover classification process.

The land cover classification will provide information about forest type stratified according to threshold values for canopy closure. Additional information on forest density will allow comparison with other classification systems using alternate definitions and thresholds for canopy cover. A forest density layer will also allow the identification of locations undergoing changes in forest density that would not be detectable if only considering the land cover type. This information is required to monitor changes in canopy density and to assess the condition of forests. From the point of view of the scientific user, this information permits the modeling of carbon and other biospheric properties that would not be possible with the land cover layer alone.

Processing of the forest density layer, though requiring alternate algorithms, would be done in parallel to the generation of the land cover map with a 5 year frequency. Processing for the forest density layer would be done for those pixels classified as woody vegetation in the land cover map.

Several algorithms have been developed and applied to generate forest density maps on regional and global scales. These methods generally fall into three categories:

- Endmember linear unmixing. In this approach the proportion of vegetation types are deconvolved based on the assumption that the spectral signature is a linear combination of reflectances from the components within the pixel. Implementation of this method requires knowledge of reflectances of “pure pixels” from spectral libraries, field measurements, or high resolution data. This approach has been applied at regional and global scales (i.e., Adams et al., 1995; Bierwirth, 1990; DeFries et al., submitted; Pech et al., 1986; Quarmby et al., 1992; Settle and Drake, 1993). Recently methods have been applied to incorporate nonlinear mixtures (Foody et al., 1997) and multiple endmembers (Roberts et al., in press).

- Spectral regressions. This approach is based on empirical relationships derived from coregistration between fine resolution (e.g., Landsat TM) and coarse resolution (e.g. AVHRR) data. The empirical relationships are then extrapolated over larger regions to estimate percent forest density (DeFries et al., 1997; Iverson et al., 1989; Iverson et al., 1994; Zhu and Evans, 1992; Zhu and Evans, 1994).

- Calibration of areal estimates from spatial aggregation of classifications derived from coarse resolution data. These methods can be used to derive areal estimates of forest cover based on classification of coarse resolution data. The method adjusts the areal estimates taking into account the spatial arrangement of land covers at fine resolution (Mayaux and Lambin, 1995; Moody, 1998).

These methods have all been successfully applied. A comparison of these methods for selected area needs to be carried out by the FC-IT to determine which is the most feasible in an operational context.

The forest density product should be produced in parallel to the land cover map product. Coregistration with the fine resolution product will be needed to assure consistency in results. The post-launch MODIS product generating continuous fields of vegetation characteristics provides an additional link that might useful in the implementation of GOFC.

The forest density product requires validation to provide information on the reliability of the continuum of density values. The validation of the density product may be done using methods similar to those used for the biophysical products. The forest density validation could use high resolution data and ground studies to assure accuracy. This should be carried out for a small number of selected locations.

6.3 Global Forest Cover Change Identification

Although precise estimates of changes in forest cover and density sufficient for such analyses as deforestation assessment and fragmentation analysis needs to be developed using a suite of fine resolution methods and data, a global product would provide a high level identification of areas of significant changes. A global forest cover change product would identify on an annual basis locations where changes in forest condition are occurring. This product would be linked with the fine resolution product so that more in-depth analysis at higher resolution could be carried out for these locations. The forest cover change product would serve as a flag for detecting change in forest cover.

A separate forest cover change product is needed, as opposed to comparison of classification products, because: 1) change detection methods that do not rely on successive comparison of land cover classifications are known to be more accurate; and 2) changes in forest cover need to be detected on a more frequent basis than the five years recommended for the global land cover classification product.

The forest cover change product be generated at a spatial resolution of 250m, the resolution necessary to detect clearings and modifications of forests by human activities (Townshend and Justice, 1988). The product would be produced annually and would be compared to a baseline extent of forest cover as well as to the previous 5 years. The FC-

IT would define a standardized method for deriving this product, including source data and methodology, be established by a coordinating group and that the product be generated on a continental or regional basis by various organizations.

Many methods have been used for change detection based on satellite data. Analysis of radiometric differences between dates generally provides more accurate results than analysis of difference between classification results because the latter compounds inaccuracies in the classification products. Radiometric analysis includes band differencing, band ratioing, transformed band differencing, principal component analysis, and multispectral or multitemporal change vector analysis (Singh (1989) provides a review of these methods). A key requirement for a methodology to be operational in GOFC is that the process be automated as much as possible with realistic computing resources.

In the initial phases of GOFC, we recommend that the change detection product focus on changes in forest extent. In the future, this would be expanded to cover other types of land cover conversion such as agricultural expansion.

The forest cover change product would be strongly linked to the fine resolution products. Identification of areas undergoing change would be flagged for more in-depth analysis with finer resolution data. It will also require linkages with the land cover map and fire scar product to assure consistency. The MODIS 250m and 1km land cover change products might serve as a useful linkage for GOFC.

A strong verification process will need to be an integral component of the method. This will involve high resolution data and a sampling strategy on the ground.

6.4 Regional Land Cover

Regional datasets from coarse resolution data similar to that used for the global datasets can be produced. It is also possible, and desirable at the regional scale to produce land cover maps from fine resolution datasets. In future years, a global land cover dataset can be envisioned from fine resolution datasets but in the initial years of the FC-IT effort, these will be used for regional products.

The first regional high resolution product is a Forest Cover Characterization product, produced on a wall-to-wall basis at 30 meters every five years. This product will support the requirements for forest composition and inventory with detailed classification forests based on methods which define classes based on functional characteristics.
The products from high resolution observations take advantage of recent advances in developing functional classification of forest cover which are demonstrating the potential for classifications schemes with detailed classes. The Forest Cover Product classification scheme will be compatible with the coarse resolution classification scheme. This should permit a close linkage for calibration and validation, as well as inter-product and inter-scale compatibility. Detailed land cover products for national use can also be developed. These may have specific classifications relevant to national needs, but when ever feasible

versions of the product which can provide regional harmonized products would be desirable.

The classification scheme for this product can be elaborated further to follow the convention described in the table below in which forest types are classified based on functional and structural conventions. This proposed product is deemed both feasible and compatible with the coarse resolution team's recommendations.

Specification for the Regional Forest Cover Product

Leaf Type	Needle, broad, mixed
Leaf Longevity	Evergreen, deciduous, mixed
Canopy Cover %	>60, 40-60, 25-40, 10-25
Canopy Height	Trees > 2m, Tall shrubs 1-2m, low shrubs <1 m
Other Classes of Cover	Snow/ice, water, grassland, barren, built-up, agriculture, wetlands (orchards, plantations are optional)

This classification makes framework for a fractional forest cover product for detection of subtle changes within forests.

6.7 Regional Fractional Forest Cover and Change

Forest cover changes may be subtle, particularly those changes associated with degradation and selective logging. At the regional scale using high resolution datasets, it is possible and desirable to produce fractional forest cover datasets for assessing these kinds of changes. Degradation and impoverishment of forests by deforestation, selective logging and other factors can be indicated in biophysical properties such as leaf area index, total above ground biomass, and ability to absorb photosynthetically active radiation. These properties are also important characteristics of forest for carbon sequestration and are critically needed for modeling energy and carbon fluxes.

Forest density can be viewed as having two components: a horizontal or spatial component, and a vertical component through the canopy. We could focus our effort on two data products to specify forest density using methods of direct parameterization: (1) a new algorithm which computes fractional forest cover, and provides continuous fields rather than the heretofore traditional classes of forest extent or forest type and (2) Leaf Area Index, which will provide a vertical component of forest density. Taken together these provide a 3-dimensional characterization of the forest. Leaf Area Index would be a collaborative effort of Implementation Team on Forest Biopshyical properties.

We can use fractional cover (*fc*) as an indicator of fine scale forest density and its change. By definition, *fc* is the fraction of area occupied by trees per unit area. For mature forest, *fc* would be 100% while for clear-cut forest *fc* would be 0%. Unlike traditional classification techniques, which classify a pixel either as forest or non-forest, *fc* is a continuous variable that characterize "how much" is forest or trees. Therefore, *fc* can be applied to an entire area to quantify how much of that area is occupied by forest, or applied to a single pixel to indicate the percent area being occupied by trees. This indicator specifies "how much" an area is occupied with trees/forest, but does not indicate "where" they are. Nevertheless, *fc* is a general indicator of forest density of lateral tree distribution. It complements the leaf area index, which is a more vertical distribution of leaves or branches. In addition to being an indicator of forest density, *fc* can also be used in many cases as a forest health indicator such as forest fragmentation and as a measure of forest disturbance.

The fractional cover of forest or trees can be estimated from remotely sensed imagery using an number of techniques, including those derived from linear mixture models (LMM). One potential model assumes that a pixel is a result of contribution two components: forest and soil/liter substrate. The fractional cover of the forest is *fc* and therefore the substrate is 1 – *fc*. The resulting signal, S, as observed by a remote sensor can be expressed as $S = fc \times Sv + (1 - fc) \times Ss$, where *Sv* is the signal contribution from the forest vegetation component and Ss from the substrate. When applied in the reflectance domain (Maas, 1998), equation (1) was used to successfully estimated cotton percentage cover. When used in vegetation index domain (Zeng et al., 1999, and Qi et al., 1999), fractional green vegetation cover can be mapped at different spatial scales.

6.8 Regional Forest Change

Specific area and spatial changes in forest cover can be defined over very large regions at very fine spatial resolution. This product will be used to provide regular maps and quantitative estimates of forest loss from deforestation. This product will be a forest-non forest extent map reproduced on a wall-to-wall basis every five years. Image change detection will then be used between dates to define the specific transitions and changes: forest to non forest, and non forest to forest. In addition, forest change will be measured on an annual basis using stratified sampling between the semi-decadal complete inventories.

This product will measure and map the change in forest cover using precise image-to-image change detection methods. Unlike the Forest Cover product which will be independent classifications at different dates, this analysis will be focused on change detection. To keep the analysis simple and straightforward, the product will describe "that which is forest at t=1 and is no longer forest at t=1." The product will also report areas of non-forest which returned to forest This analysis will be conducted using change pairs 5 years apart, providing a change period of 5 years globally. The five-year period will be compatible with the 5 year period of the Forest Cover Product.

To support RAD requirements, and most of the carbon cycle requirements, an annual assessment will be completed using stratified sampling. A forest-no-forest classification is implicit in this change product, but will be compatible with the Forest Cover Product at the five-year milestones, so changes on a semi decadal basis will be resolved into forest types, while the inter-milestone stratified samples will not (but could be inferred).

It must be noted that in order to produce a forward-looking stratified sampling scheme for change detection, an initial "wall-to-wall" assessment would have to made in the first 2-3 years. This initial change would define the first stratification until another assessment is made after 5 years. Thereafter the change stratification would be derived from the previous 5 year analysis. It is also important to note that the stratification scheme would be developed in coordination with the coarse resolution team, using important indicators of change as strata (e.g. fires).

General Description of the Forest Cover Change (FCC) Product

Resolution	50 meters
Frequency of update	5 years (with initial 3 year update to support the sampling product stratification
Data sources	Mostly Landsat, with gap-filling by Spot and SAR
Mapping Units	Preserve all pixels, no filters
Coverage	wall-to-wall, in areas of forest identified by coarse resolution
Thematic classes	Forest, Non Forest
Data acquisition strategy	Landsat 7 acquisitions every year, 4 times annually, focused on areas of forest cover and rapid changes, using Spot and other optical as gap filling, with SAR for gap filling. Change pairs must be of the same sensor type .
Processing requirements	Registration to earth coordinates to $\pm$ 60 m, atmospheric correction required (coordinated with coarse resolution), change detection using image co-registration to $\pm$ 15 m precision

General Description of the Sample Forest Cover Change (FCC-s) Product

Resolution	50 meters
Frequency of update	Annually
Data sources	Mostly Landsat, with gap-filling by Spot and SAR
Mapping units	Preserve all pixels, no filters
Coverage	based on stratification sampling scheme
Thematic classes	Forest, Non Forest
Data acquisition strategy	Landsat 7 acquisitions every year, 4 times annually, focused on areas with most of the area changes, using Spot and other optical as gap filling, with SAR for gap filling. Change pairs must be of the same sensor type .
Processing requirements	Registration to earth coordinates to $\pm$ 60 m, atmospheric correction required (coordinated with coarse resolution), change detection using image co-registration to $\pm$ 15 m precision

6.9 Regional Forest Fragmentation

The high resolution analysis at the regional or national scale can provide datasets which can then be characterized using fragmentation statistics. A special product which would provide patch and edge characteristics would be developed.

7.0 PRODUCT VALIDATION, EVALUATION, AND OUTREACH THROUGH REGIONAL NETWORKS

We need to develop and refine our products through collaboration with existing and future GOFC Regional Networks. There are three levels of effort needed, as described below.

7.1 Product Definition and Algorithm Development.

Working closely between the FC-IT and the GOFC Regional Networks, the algorithms can be developed for a range of forest conditions and environments. Working from the start with the Regional Networks is deemed crucial in order that the products not be created in a "black-box," with only theoretical expertise and input. Detailed knowledge of land cover in the focus countries, possessed by the invited individuals, will prove invaluable to the early remote sensing activities.

7.2 Calibration and Validation at Field Sites.

It is important that the remote sensing products must be technically sound, and usable in practical terms. This will involve calibration, validation, and evaluation activities involving our Regional Network collaborators at specific sites. Once we have calibrated the product, it must be validated. For instance, fractional cover measures derived from satellite ought to agree closely with observed cover on the ground. Validation will follow a specific procedure in collaboration with the regional scientists and users. Acquisition of special image data, such as commercial IKONOS data, may be necessary.

7.3 Product Evaluation.

Equally important as validation, the form in which the products are presented for forestry monitoring purposes must be considered and evaluated. In some respects, evaluation will be an ongoing process given the project design, which includes the involvement of network scientists, forest management professionals, and other users from the very beginning. Thus, depending on the application or institutional capability of the administrative unit charged with forestry management and monitoring, the products could be presented in digital or map form, for jurisdictional units of various sizes, and as yearly information or averages over some time period. Our regional collaborators will be able to evaluate the presentation forms of the products, and judge those most suitable for their uses.

7.4 Operational Outreach.

Operational outreach comprises the technology transfer component of the project. Here, it will be necessary to stage workshops for potential users from individual countries as well as the international community. Another approach is to involve user agencies in regular assessment workshops or conferences.