Section Summary

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Remote sensing is an important data source for monitoring the change of forest cover, in terms of both total removal of forest cover (deforestation), and change of canopy cover, structure and forest ecosystem services that result in forest degradation. In the context of Intergovernmental Panel on Climate Change (IPCC), forest degradation monitoring requires information regarding the degree of forest disturbance that results in a reduction in carbon stock within a specific time interval. Currently, remote sensing data does not directly provide readily available information on how much carbon has been released from a disturbed forest. In this regard, the integration between remote sensing data and field/ground based measurement is key. While many types of remote sensing can detect total loss of forest cover (deforestation), it is more challenging but still feasible for remote sensing data to detect changes in the extent of remaining forests that have been disturbed. Advanced techniques for analyzing remote sensing data are able to roughly estimate the area of disturbance; however it should be equipped with sufficient field verification. Field data is needed to provide estimates about how much biomass or carbon has been removed per unit area of the disturbance.

An agreement on the main direct drivers of forest degradation is of vital need for use of remote sensing data. Consensus on the main direct drivers will lead to a general understanding of the scale and intensity of disturbances that can be detected by the selected remote sensing data. In general, forest degradation is the effect of forest logging activities, either selective planned logging or illegal logging. Currently, remote sensing can detect forest degradation through indicators such as canopy disturbance and infrastructure development (forest roads, logging roads logging decks, etc.). However, the ability of remote sensing data to detect the above indicators depends on the spatial and spectral resolution. Higher resolution data (e.g., LiDAR) provides more detailed information but also has higher costs for data acquisition, data processing, and data management. Lower resolution data (e.g., Landsat) provides a less sensitive measure of forest change, but is more readily obtained and repeated. The availability and repeatability of remote sensing data has implications in the tropics for obtaining cloud-free images and detecting, degradation with rapid post-disturbance canopy recovery. These strengths and weaknesses should be taken into consideration to select appropriate remote sensing data for the application.

Setting the objectives of monitoring is a key for setting an efficient system; and a general understanding of forest degradation drivers will assist in determining these objectives. Once monitoring objectives are determined, it is possible to assess monitoring options based on desired precision and financial considerations. In terms of financial considerations, very high spatial and spectral remote sensing data combined with

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advanced processing techniques should only be introduced for specific areas of interest and may not be favorable for wall to wall mapping at a national scale. Further, the availability of required hardware, software and capacity human resources are also important considerations.

Main challenges

General challenges of using remote sensing data for monitoring forest degradation in the tropics:
- Persistent clouds and haze in tropical areas lead to difficulties in acquiring cloud-free remote sensing data needed to fulfill monitoring objectives.
- Data continuity is a big challenge in establishing a credible forest resource monitoring system. A sufficient monitoring system must be supported by the use of remote sensing data that ensure data continuity and availability.
- Data analysis repeatability is another consideration. The techniques for analyzing the data must be implementable, replicable and must allow for the use of alternative data instead of selected remote sensing data when necessary.
- Steep terrain and forest seasonality in certain areas require specific methodologies (e.g., more image processing procedures and more field verification).
- Determining at what point high-resolution remote sensing data sets and advanced techniques need to be applied, and how to link those results with wall-to-wall interpreted maps derived from lower resolution data sources.
- A comprehensive package of human resource technical requirements, hardware and software is very important for developing a credible monitoring system, thus continued capacity building/strengthening are required to get optimal results.

More specific challenges:
- Clearly defining the causes of forest degradation in the area of interest is paramount. Lack of understanding about the local causes of forest degradation can result in activities that may not contribute to the monitoring objective.
- Dynamic change of forest cover as a result of fast crown recovery after disturbance in the tropics is another key issue. Appropriate spatio-temporal data sets need to be used to capture dynamic forest cover changes.
- Complex forest structure and composition in tropical forests are sometimes difficult to analyze with remote sensing data; for example vegetation indices, such as Leaf Area Index, will saturate after a value of 4-6 m^2/m^2 in tropical forests.
- Mismatched time of data acquisition and field data collection is a classic problem, especially in developing countries where budgets for field surveys are often inadequate. It is important to complete and process ground based field measurements that temporally coincide with remotely sensed data acquisition. Mismatches in time between the field measurements and remote sensing data sets lead to errors in analysis.
- Ability to detect single/individual tree removal by selective logging is another key issue, and likely requires high spatial resolution data. For this, there is a need to obtain imagery that is spatially and spectrally able to detect individual tree crowns, and temporally close in time to the logging activity.

Promising opportunities/approaches

- Roughly define the main driver(s) of forest degradation in the area of interest and select appropriate indicators that can be used for deriving information from remote sensing data (e.g., change in canopy cover).
- In general, select basic/simple classes for forest extent (e.g. dividing area of 'forest remaining forest') into two main classes, such as primary undisturbed forest and degraded forest. Segregating different degrees of degradation can be accomplished when appropriate high-resolution spatial data and sufficient field validation are available.
- Develop and apply a low cost policy to provide high spatial resolution data set, including simple procedures for data pre-processing.
- Develop and apply methods using high spatial resolution data and advanced techniques (e.g. the method applied for Guyana) for analyzing a specific area of interest. This is necessary to test the method (or other possible methods) in different areas, especially areas with steep terrain and deciduous forest types.
- Apply timely field/ground data measurement in order to support forest inventory programs and validate remote sensing results. The field measurements should focus on providing information on forest disturbance and potential carbon released.
- Hybrid approach of using a per-pixel classification method and a GIS-based fragmentation method to map degraded forest (e.g. the method applied for Sumatera-Indonesia) can be applied to developing national wall-to-wall coverages.