INVENTORY OF REMOTE SENSING APPLICATIONS IN FORESTRY FOR SUSTAINABLE MANAGMENT

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ABSTRACT

To consistently and repeatedly monitor forests over large areas, it is desirable to use remote sensing data and automated image analysis techniques. Several types of remote sensing data, including Aerial photography, Optical Multispectral Scanner, Radar, Lidar (Laser) and Videographic data have been used by forest research and operational agencies to detect, identify, classify, evaluate and measure various forest cover types and their changes. Over the past decades tremendous progress has been made in demonstrating the potentials and limitations of the applications of remote sensing in forestry. Remote sensing can detect, identify, classify, evaluate and measure various forest characteristics in two ways: qualitatively and quantitatively. In a qualitative way remote sensing can classify forest cover types to: coniferous and deciduous forest, mangrove forest, swamp forest, forest plantations, etc. While the quantitative analysis can measure or estimate forest parameters (e.g., dbh, height, basal area, number of trees per unite area, timber volume and woody biomass), floristic composition, life forms, and structure. For several types of applications of remote sensing in forestry in specific regions of the world such as tropical areas, users of forest information are demanding new establishment of sensors and platforms. In order to see what kind of information we can extract from the current remote sensing sensors and platforms and how accurate is that, an inventory of all remote sensing applications in forestry is needed. This paper presents a state of the art inventory of all remote sensing applications in forestry.

1. REMOTE SENSING APPLICATIONS FOR FORESTRY

To meet the various information requirements in forest management different data sources, like field survey, aerial photography and satellite imagery is used, depending on the level of detail required and the extension of the area under study.

Before aerial photography was used for forest management purposes, information was generally obtained by means of field surveys, identifying and measuring forest types and stands. This is still by far the most accurate and detailed way of measurement, although the lack of geographical positioning systems did not allow accurate location of the forests classified. The method is, however very elaborate, time consuming and expensive, and it is nowadays used predominantly for research purposes and for intensive sustainable production purposes.

The traditional aerial photograph resulting from different film types was and still is an important remote sensing tool. Knowledge of photogrammetry and photography is essential for its proper use. For many decades the use of aerial photographic data has been accepted by many forest institutions as a tool in various forest activities, such as planning, mapping, inventory, harvesting, area determination, road lay-out, registration of declined and dead trees etc. on a local, regional or national scale.

For the purpose of consistently and repeatedly monitor forests over larger areas, it is preferable to use remote sensing data and automated image analysis techniques. Several types of remote sensing data, including aerial photography, multi-spectral scanner (MSS), radar (Radio Detection and Ranging), Lidar (Light Detection and Ranging) laser and Videography data have been used by forest agencies to detect, identify, classify, evaluate and measure various forest cover types and their changes. Over the past decades tremendous progress has been made in demonstrating the potentials and limitations for identifying and mapping various earth surface features using optical remote sensing data. For large areas, satellite imagery has been shown effective for forest classification, and consequently mapping. It is emphasised that one of the advantages of the use of remote sensing in forest survey is the relative short time in which most of the required information can be obtained.

Gradually other types of remote sensing tools were developed with which forest object properties were registered from the air or from space. The new technologies, integrating satellite imagery, analytical photogrammetry and geo-information systems (GIS) offer new possibilities, especially for general interpretation and mapping and will be a challenge for future research and application. The analogue photographic data of aerial photographs as well as the satellite scanning data can be digitized and used for multi-spectral or multi-temporal classification and corrections, geometrical or radiometrical. Scanning techniques are also applicable in airplanes.

Nowadays the products of this aerospace technology are considered to be superior to and a replacement of the "old fashioned" analogue aerial photography. However, this technology is additional and complementary to the aerial photography. Sometimes the products are used alone, but in most cases a combination with aerial photographs is applied. Also fieldwork is and remains essential when applying remote sensing techniques.

Various factors can be mentioned to explain why in managed forests the operational application of remote sensing in the estimation of a number of stand parameters, is relatively low. Foresters are in general conservative, in the beginning they were reserved in applying aerial photography and nowadays other remote sensing techniques are not embraced whole-heartily. There is a hesitation to take risks when departing from traditional data sources. Lack of knowledge of access to data of the specialized technology is and other reason for the limited application.

Overview of remote sensing application opportunities for forest management

Type/sub-type	Application	Scale/Resolu	Frequency	Cost	Limitation
Aerial photography					
- Panchromatic	+++	++	++	--	--
- True Color	+++	++	++	---	--
- Color Infrared	+++	++	++	---	--
- B&W Infrared	++	++	++	---	--
Scanning: Air					
- MSS	+++	++	++	-	--
- Hyperspectral	+++	++	++	--	--
Scanning: Space	++	+	+	-	-
Radar: Air	++	++	++	--	--
Radar: Space	+	+	+	-	--(current satellits)
Lidar/laser: Air	+	++	++	--	--
Videography: Air	+	++	++	--	--

The full version of the findings of this study can be seen on and downloaded from the following web site:

http://www.itc.nl/forestry/URS/

An assessment has been made of the use for mapping (qualitative) and measuring (quantitative) with 75% accuracy of various sensor systems for different purposes in forest management.

The results of this assessment are presented and have been used for the evaluation against the information requirements as summarised in the previous page. For the purpose of this evaluation an assessment was also made of the current and future satellite sensor systems and finally an assessment of the use of ground receiving stations and the use of Internet for improvement of the accessibility.

2. REMOTE SENSING SYSTEMS

The applications of the following remote sensing systems in forestry were reviewed.

1. Photographic (Air)
2. Scanning (Air & Space)
3. Radar (Air & Space)
4. Lidar (Laser) (Air)
5. Videography (Air)

3. REMOTE SENSING APPLICATIONS IN FORESTRY

The following applications of the above systems were found with at least 75% accuracy:

3.1 Applications of Aerial Photography in Forestry

a) Mapping (qualitative): accuracy 75% and more

Forest cover types
Identify individual species
Species composition
Forest fire detection
Forest fire hazard
Detecting forest trees health (vigor and stress)
forest trees diseases and insects infestation
forest trees under air, soil and water pollution
Assessment of wind damage and other sever climatic condition
Detecting deforestation and forest degradation
Forest monitoring:
some of the above
logging activities
reforestation and afforestation
Timber harvesting planning
Forest roads planning
Forest inventory
Forest management
Assessing slope failure and soil erosion
Assessing and managing forest recreation resources
Assessing and managing wildlife habitat

b) Measurements and estimation (quantitative): with minimum accuracy of 75%

Forest cover area measurement
Number of trees
Tree height measurement
Crown cover measurement

Crown closure measurement
Crown diameter measurement
DBH estimation
Age estimation
Site estimation
Timber volume estimation
Thinning volume estimation
Basal area estimation
Annual Growth estimation
Basal area growth estimation
Biomass estimation
Stand size
Dead, declined trees

3.2 Applications of Aircraft and Satellite Scanning Sensor System (MSS) in Forestry

a) Mapping (qualitative): with minimum accuracy of 75%

Forest cover types
Identify individual species
Forest fire detection
Forest fire hazard
Detecting forest trees health (vigor and stress)
forest trees diseases and insects infestation
forest trees under air, soil and water pollution
Assessment of wind damage and other sever climatic condition
Detecting deforestation and forest degradation
Forest monitoring:
some of the above
logging activities
reforestation and afforestation
Timber harvesting planning
Forest roads planning
Assessing slope failure and soil erosion
Assessing and managing forest recreation resources
Assessing and managing wildlife habitat

b) Measurements and estimation (quantitative): with minimum accuracy of 75%

Forest cover area measurement
Tree height estimation
Crown cover estimation
DBH estimation
Age estimation
Timber volume estimation
Basal area estimation
Biomass estimation

3.3 Applications of Aircraft and Satellite Radar System in Forestry

a) Mapping (qualitative): with minimum accuracy of 75%

Forest cover types
Forest species level mapping
Mapping flooded forest
Detecting deforestation and forest degradation
Monitoring logging activities
Detecting forest roads
Mapping burned forest

b) Measurements and estimation (quantitative): with minimum accuracy of 75%

Forest cover area measurement
Tree height estimation
Crown cover estimation
DBH estimation
Number of trees per unit area (density)
Age estimation
Timber volume estimation
Basal area estimation
Biomass estimation

3.4 Applications of Lidar (Laser) System in Forestry: with minimum accuracy of 75%

Tree height estimation.
Forest cover types determination.
Forest trees species differentiation.
Crown cover or canopy density estimation.
Forest stands volume estimation.
Forest stands woody biomass estimation.
Forest trees water stress detection.
Forest trees nutrient deficiency

3.5 Applications of Aerial Videography in Forestry: with minimum accuracy of 75%

Forest cover types determination.
Forest trees species differentiation.
Crown cover or canopy density estimation.
Detecting forest trees health (vigor and stress)
forest trees diseases and insects infestation
Mapping forest trees spatial distribution