USE OF SPOT AND RADAR DATA FOR FOREST INVENTORY IN SARAWAK, MALAYSIA.

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ABSTRACT:- In Sarawak, logging is a major economic activity, and concern is very high to keep this activity sustainable. To this end, forest inventory and timber volume estimation are needed by timber companies and forestry authorities (e.g. forestry ministries) for forest management. In this context, satellite remote sensing data are particularly suited, to obtain timely and accurate qualitative and quantitative information, at reasonable cost. The present project has been carried out to assess both, the complementarity and the synergy of SAR and SPOT data, to establish a forest pre-inventory and to quantitatively evaluate the potential in timber volume. Panchromatic and multispectral SPOT images were used in combination with Radarsat SAR images taken at different incidence angles, and an interferometric pair of ERS SAR images. Radar data in this case was used both to complement for missing information in the SPOT data, due to cloud cover, but also as a source of thematic information to discriminate between different forest types, in combination with the SPOT data. The degree of coherence between the two ERS images for example enables direct discrimination between bare and vegetated soils. Furthermore, the Radarsat SAR stereo pair enabled to generate a Digital Elevation Model (DEM) which was then used to geo-reference the thematic products generated in the project.

1. CONTEXT OF THE PROJECT

The Malaysian State of Sarawak in Northern Borneo still has more than 60% of its territory covered by forest. In Sarawak, logging for construction wood and paper is a major economic activity, and concern is very high to keep this activity sustainable. Borneo Pulp & Paper is a timber company based in Sarawak who has already used satellite imagery in order to assist their forest resources management activity.

It has been demonstrated in the past that the use of satellite imagery can provide the necessary information to meet the requirements of timber companies for both forest resources management, logging licences and forest certification. Spot Image has decided to investigate the possibility of adapting its offer of multi-source satellite imagery to the needs of forestry companies. To this end, a pilot study was set up by Spot Image with Spot Asia and Borneo Pulp & Paper (BP&P), a timber company based in Sarawak, in order to develop prototype information products to meet the requirements of BP&P, using multi-sensor satellite imagery.

This pilot study therefore provided an opportunity for the Spot Image Group to develop new forestry-oriented information products, as well as to demonstrate the complementarity of SPOT and Radar data in this particular application domain.

2. IDENTIFYING USER NEEDS

The first task was to identify BP&P's specific needs in terms of information products for their forestry activity. BP&P already uses a Geographic Information System (GIS) as a tool for their forest resources management activities, and have experience in the use of satellite-derived geographic information. The following information needs were identified with BP&P:
- Digital Elevation Model
- Linear networks especially rivers and logging tracks, in the form of vector data
- Forest inventory, in digital and analogue format
- Timber volume estimation (in m^3/ha.)

In the pilot study, these information products were generated over a 30km by 60km test area in Sarawak, and projected to the specific geodetic system used by BP&P.

The following data sources were used to generate the prototype information products :
- 1 Radarsat stereoscopic pair (Standard#2 and Standard#7 beam modes) - Figure 1
- 1 SPOT XS (multispectral) – Figure 2
- 1 SPOT P (panchromatic)
- 2 ERS SAR scenes acquired in tandem mode (1-day interval between acquisitions)

Multi-source data are required because of the cloud cover that may preclude the exclusive use of SPOT data. In addition, there is little chance that radar alone can be the data source to meet the user's requirements.

Spot Asia, a joint venture between Spot Image and SSC-Satellitbild, is a distributor of SPOT, ERS and RADARSAT spaceborne radar data in South-East Asia. The role of Spot Image in this project is to provide technical support to Spot Asia and to clients on radar products and applications, as well as to develop new applications of SPOT and radar data in commercial projects. Various other partner companies were involved in this pilot study, co-ordinated by Spot Image:

- PRIVATEERS N.V., of the Netherlands, responsible for most of the image processing and the production of the thematic information products.
- ISTAR, of France, responsible for generating the DEM by radargrammetric processing of the Radarsat stereo pair.
- SSC-SATELLITBILD, of Sweden, responsible for ortho-rectifying all the various source data.
- Gamma Remote Sensing, of Switzerland were responsible for the interferometric processing of the ERS SAR tandem pair in order to generate a coherence imagery product.
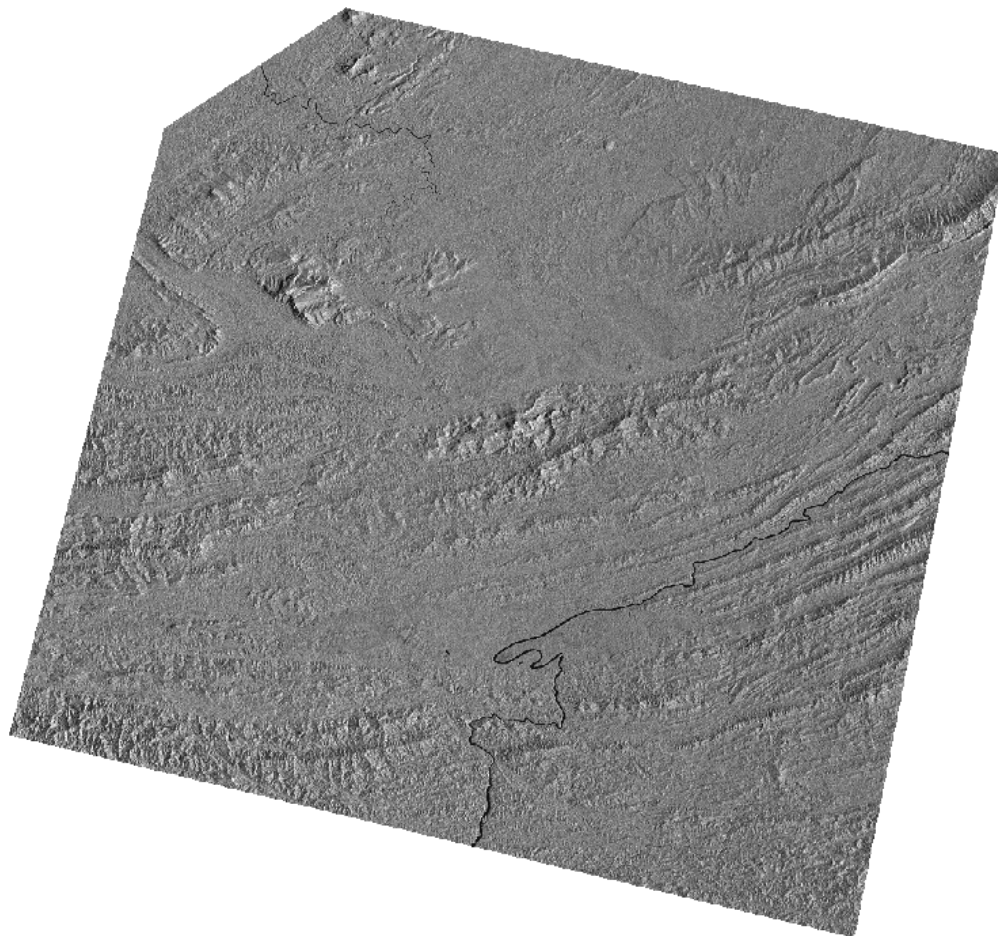

Figure 1: Orthorectified Radarsat S7 image (Processed by ISTAR). © CSA, 1996.
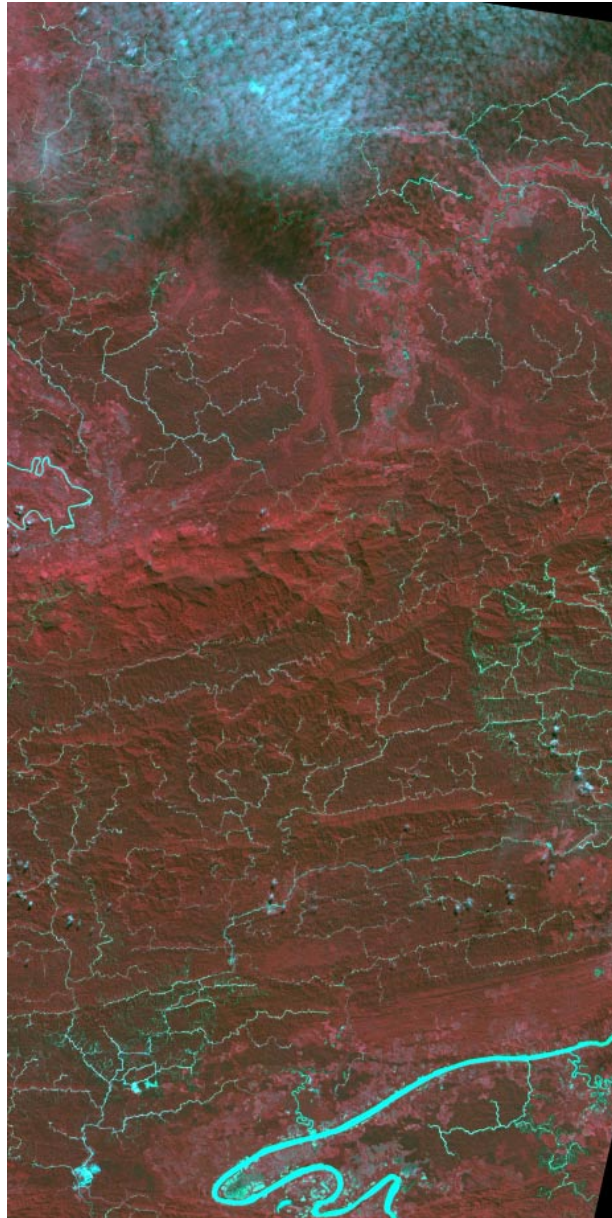
Figure 2: SPOT-XS image (scene covers 28x55 km). © CNES, 1996.

3. METHODOLOGY

3.1 Image pre-processing

Pre-processing of the various remote sensing source images was of crucial importance. Indeed, the quality of this pre-processing contributes substantially to the accuracy of the final thematic products. Complete radiometric calibration of the SAR image products is carried out, using a Bayesian adaptive speckle filter for multichannel SAR images, recently developed by PRIVATEERS NV [1].

3.2 Correction of topographic effects

French-based ISTAR generated a Digital Elevation Model by radargrammetric processing of the two RADARSAT SAR standard beam mode images acquired at different incidence angles: beams S2 and S7, forming a stereo pair [2]. Accuracy of the DEM was estimated at about 19 meters rms in altitude, using GPS ground measurements

In remote sensing images, relief is systematically displaced with regard to its true geographical location, due to the viewing geometry and this effect is particularly important in SAR images. To a lesser extent, it also affects optical

SPOT images. The DEM is therefore used to ortho-rectify and geocode the various source images used for the production of the forestry products.

Using the DEM, radiometric corrections were applied in both the SPOT and the SAR images to correct for the variations in illumination conditions with relief (SPOT), as well as for the variation of effective scattering area with local slope and orientation (SAR).

3.3 Hydrological and logging-track network extraction

Forest managers and timber industry companies need accurate knowledge of the hydrological network and of the logging-track network, such as roads and logging tracks.
Automatic extraction of the hydrological and logging-track network is performed simultaneously in at least two images, using pattern recognition techniques. Complementarity between different data sources enables to detect reciprocally missing features and to achieve complete detection.

3.4 Forest inventory

Within the cloud-free part of the SPOT-XS image, classification is performed on a set of mixed SPOT/Radarsat derived indices to exploit the thematic complementarity between SPOT-XS and SAR data. These indices, obtained through Tasseled-Cap analysis of the SPOT XS channels, and SPOT/Radarsat data fusion are designed to extract the information that is relevant to the current application.

Within the cloudy part of the SPOT-XS scene, classification is carried out using the SAR images, the degree of coherence between the two ERS images, and the SPOT-P image. These two partial classifications fit perfectly to each other and are simply merged to produce the final one (Fig. 3). In this final classification six classes are identified:
- Logging track networks, water bodies and rice fields (blue).
- Very high yield forest (dark green).
- High and medium yield cutover (medium green).
- Re-entered cutover and secondary forest (light green).
- Clearcuts and very low yield areas (grey).
- Bare soils and agricultural surfaces (orange).
Preliminary verification shows that results are fully satisfactory.

3.5 Timber volume estimation

Timber volume estimation is performed using a new technique developed and validated by PRIVATEERS N.V. which uses SAR/optical data fusion, a forest structure model, and the classification results [3], [4].
Within the cloud-covered areas of the SPOT-XS image, automatic training in the SAR images based on results obtained within the cloud free areas of the SPOT-XS image compensates for the lack of optical data.
It is worth noting that this technique requires calibration using point or stand timber volume information. In the present study, a tentative calibration has been performed, using only general mean reference values, leading to some inaccuracy in the absolute timber volume yield estimations. Nevertheless, a field trip to the area enabled us to determine that timber volume is never overestimated by more than 20%.

4. CONCLUSION

The pilot study has enabled Spot Image and Spot Asia to develop new products to better serve users in the field of forest resources management, by listening to its clients needs. Prototype products using a combination of SPOT and Radar data were obtained which provide a more complete and accurate information dataset for forest management.

Spot Asia thus helped BP&P to evolve from the simple use of raw SPOT data to the use of higher-level value-added products, that can be directly integrated in their GIS. BP&P are currently making use of these products, providing them with valuable information tailored to their operational needs.

This use, along with projects with other timber companies, will then set the requirements for the development of a new line of products dedicated to the forestry application domain. These results may also be adapted to other regions of the world.

Finally the increased flexibility and capabilities of ENVISAT satellite will make it even easier to access timely to the most appropriate data to combine optical and SAR information and extract accurate information dataset for forest management.
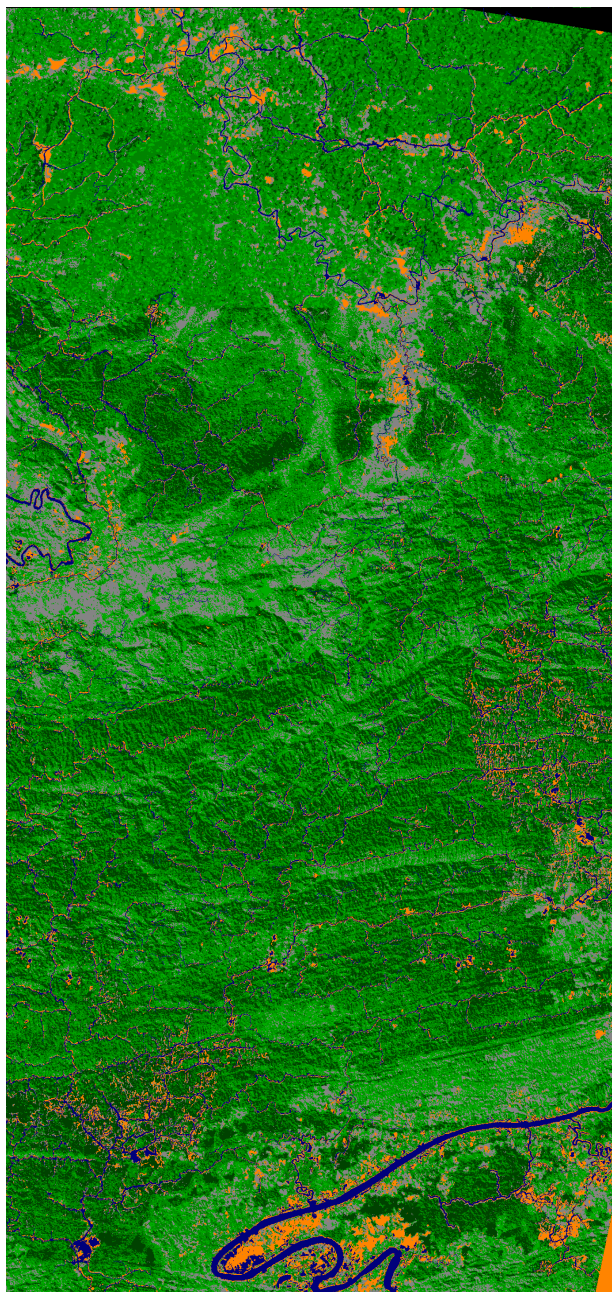

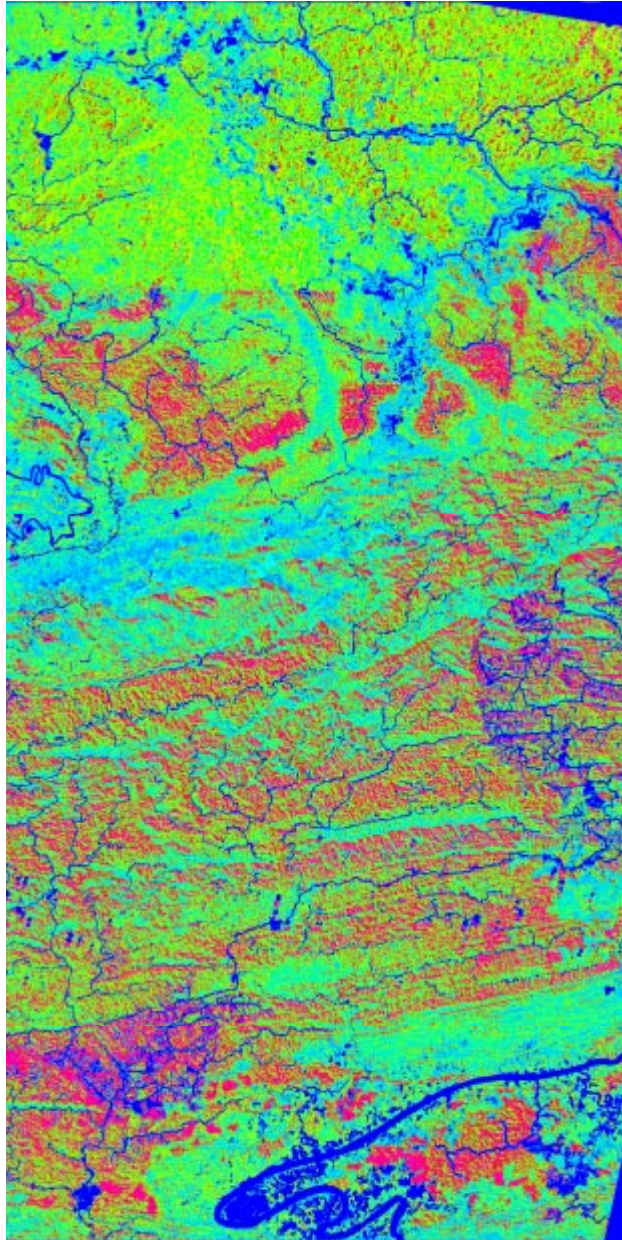Figure 3: Forest pre-inventory map (Processing by PRIVATEERS).

Figure 4: Timber volume map, in m^3/ha (processing by PRIVATEERS)

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