K&C Science Report – Phase 1
Tropical Forest and Wetlands Mapping, Case Study Borneo

Science Team member name
Dirk Hoekman Wageningen University, Dept. of Environmental Sciences,
Droevendaalsesteeg 4, 6708 PB Wageningen, The Netherlands, email: dirk.hoekman@wur.nl

Name of collaborators
Marcela Quiñones and Martin Vissers
SarVision, Agrobusiness Park 10, 6708 PW, Wageningen, The Netherlands, email: vissers@sarvision.nl

Abstract—**The production of spatially detailed maps of (very) large areas, and time series of these maps, requires dedicated processing approaches. This paper introduces finite mixture modelling and Markov Random Field classification as a tool for production and mosaicing of detailed thematic maps. Results are shown for a multi-temporal classification of the entire island of Borneo for the year 2007 using 50 m resolution PALSAR FBS an FBD strip data. First results indicate that more than 20 classes of forest and land cover can be distinguished well, even though strips have been collected over a 46-day cycle of observation.**

Validation of the Borneo map is still ongoing using large ground data sets and other reference sets spread over Borneo. It is pursued to develop legends in compliance with LCCS and IPCC guidelines. These results may be of key interest to develop REDD projects for the humid tropics.

Maps created for the Central Kalimantan prototype area indicate good results for LULC mapping, flood frequency mapping and peat swamp hydrology may be obtained. These maps are already used by local organisations.

Index Terms—**ALOS PALSAR, K&C Initiative, Tropical Forest**

I. INTRODUCTION

Significance of tropical rain forests

Deforestation and degradation of tropical rain forests is continuing and currently may occur faster than ever before. It threatens the livelihoods of millions of people depending on the forests, and threatens biodiversity conservation, carbon storage capacity, and other important functions these forests provide.

Environmental awareness and consumer demand for more socially responsible products from tropical forest areas increased in recent years. As a result, all biofuel for the European market for example should be produced in compliance with forthcoming EC regulations on greenhouse gas emission reduction. This will prohibit conversion of tropical forest to biomass plantations.

Moreover, agreements are negotiated under the UN Framework Convention on Climate Change (UNFCCC) to compensate tropical nations for reduced emissions from deforestation and forest degradation (REDD).

The availability of credible and regularly updated spatial information on forest and land use/cover change will be a precondition for successful implementation of initiatives such as mentioned above. In cloudy tropical forest areas new radar satellite imaging techniques will play a key role as one of the most objective methods to measure forest, land cover, biomass and hydrological changes.

Information needs

Ongoing consultation with potential user organisations indicates that satellite observations are needed, as area change is typically dynamic and covers large geographic areas. It is the only objective approach to support reduced deforestation and sustainable biomass production projects in developing countries, providing proof that deforestation rates have decreased and that plantations have been developed inside or outside forest areas.

The following satellite based information maps are required:

- Land use/cover
- Land use/cover change (including deforestation and degradation)

Emerging international guidelines require that these maps are made available at multiple time intervals using a transparent and consistent methodology. Spatial resolution in the order of 10-100 m is sufficient.

High attention and expectation for the inclusion of forest degradation in payment agreements for reducing emissions from deforestation and forest degradation requires new approaches for mapping crown canopy structure of (tropical) forests at high spatial detail. To monitor forest degradation (canopy openings) details smaller than 20m should be clearly visible requiring a spatial resolution of less than 5m; 1-2 m would be ideal. Permanent clouds are making optical satellite imagery useless; again the use of radar satellite imagery is needed (Figure 1).

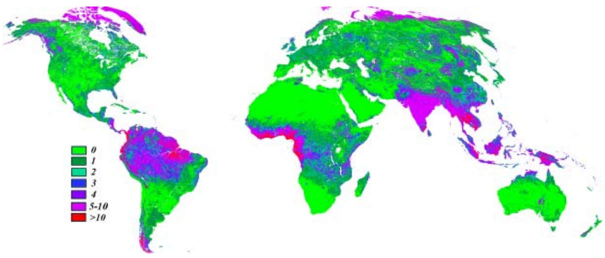


Figure 1. Persistent cloud cover prevents optical remote sensing monitoring of the world's tropical rain forest areas. The colour code shows the estimated number of months per year LANDSAT fails to deliver useful images (Source: [2]).

II. PALSAR STRIP DATA HANDLING AND MOSAICING

The production of a high resolution continental scale map requires the use of a very large number of (radar) images. Within K&C this problem is mitigated by using strip data, which have the same swath width as standard PALSAR radar images (i.e. 70 km, for Fine Beam data), but may span the entire area of interest (up to several thousands of km). For a complete coverage of the entire area of interest many strips may be needed. Borneo, for example, requires 22 of such strips (Figure 2). Often a single coverage will not suffice to meet the required information needs. For forest and land cover mapping in tropical rain forest areas it is advantageous to combine wet and dry season observations, and to combine HH and HV polarisation. For monitoring tropical forest cover change repetitive yearly observation is needed. Very dynamic areas, notably wetlands and agricultural areas, may require even more observations per year to fulfill specific information needs.

Figure 2. Three strips of radar data projected over Borneo and displayed in Google Earth.

For our work in Insular SE Asia and PNG systematic observations were used for modes summarised in Table 1. The selected cycles are shown in Table 2. To be able to produce a 2007 forest and land cover map of Borneo, for example, all the strips collected during the ascending passes of cycle 9 (FBS mode) and cycle 13 (FBD mode) should be used. For technical reasons which are not discussed here, it is not always possible to collect radar data for every pass of the satellite over the area of interest. The success rate in some areas of the world may even drop below 80%. Consequently, most mosaics cannot be created with strips collected within one cycle of systematic observation. In such a case replacement data may be available from a preceding or following cycle. For example, when strips are missing from the FBS cycle 9 these can be replaced from the FBS cycle 8 acquisitions.

Table 1. PALSAR default observation modes

Polarization	Incidence range	Swath width	Resolution (4 looks)
(FBS) HH	36.6°~40.9°	70 km	10 m
(FBD) HH+HV	36.6°~40.9°	70 km	20 m
ScanSAR (HH)	18.0°~43.0°	361 km	~100 m

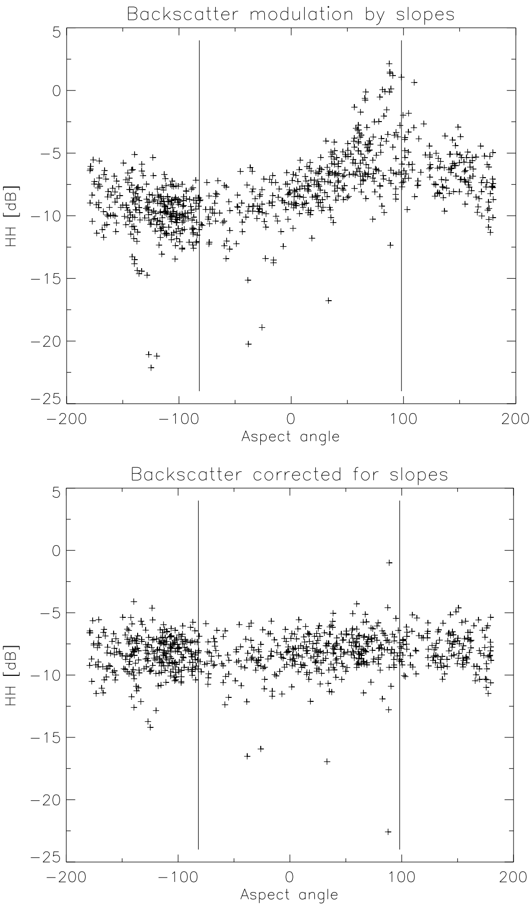
Table 2. Selected cycles for this study

Default mode	Polarisation	Cycles 2007	Cycles 2008
FBS	HH	9	17
FBD	HH+HV	13	21
ScanSAR	HH	7-16	

The time structure within one cycle is such that the time elapsed between observations of adjacent strips is 17 days or 29 days. This can be explained as follows. Starting East and moving West adjacent strips make jumps of 17 days. For example when RSP412 is the first strip acquired, the adjacent strip RSP413 is collected 17 days later and strip RSP414 34 days later. The next strip RSP415 is collected 3x17 = 51 days later, but this is in the next cycle. To remain in the same cycle 46 days can be subtracted and a jump of 5 days with respect to the first strip RSP412 remains, which is -29 days with respect to the previous strip. For the Borneo mosaic of 2007 4 (out of 22) replacement strips have been collected from cycles 12 and 14 for FBD mode and 3 (out of 22) from cycles 17 and 18 (one year later!) for FBS mode.

The time laps are an inherent feature of any mosaic and these have to be dealt with carefully within classification procedures.

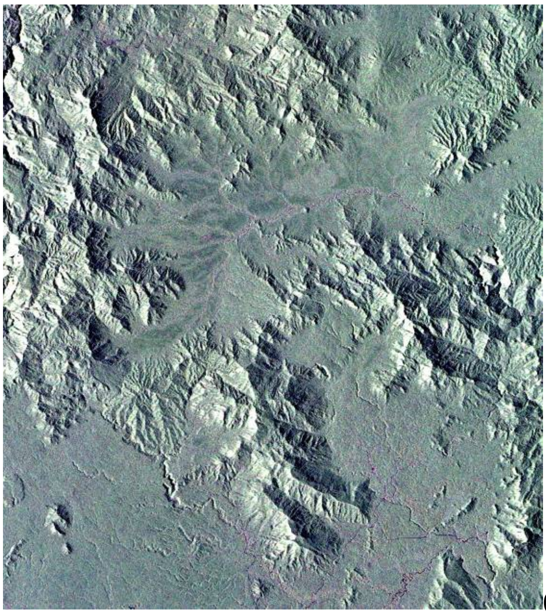
Backscatter of terrain is modulated by the surface geometry of hills and mountains. This modulation is a function of slope steepness, slope orientation and the scattering mechanism of the terrain. Results for an area in central Borneo which is almost completely covered by dense forest are shown in the Figures 3 and 4. In Figure 5 the entire mosaic, which is a multi-temporal aggregate of FBS and FBD data, is shown.



(a)

(b)

Figure 3. Slope correction for all pixels in a small test area in a mountainous section of central Borneo; (a) backscatter (gamma in dB) as function of slope aspect; (b) idem, after correction (Note: the vertical lines present the radar orientation angles).



(a)

(b)

Figure 4. (a) PALSAR FBS/FBD aggregate for an area (~42x46km) typical for the mountainous forested terrain in the centre of Borneo; (b) idem, relief corrected. Some effects of overlay and shadow remain visible and are masked after classification. ALOS K&C © *JAXA/METI*

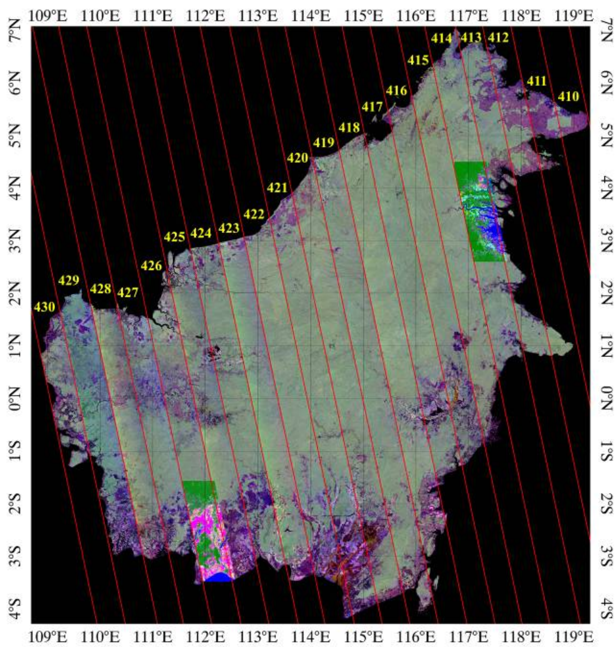


Figure 5. FBS/FDB mosaics of Borneo after radiometric balancing and slope correction. The RSP strips and two patches of classified data are superimposed. ALOS K&C © *JAXA/METI*

III. CLASSIFICATION METHODOLOGY

Several approaches for continental scale mapping (and monitoring) have been tested. The most promising and by far the most accurate approach is based on (unsupervised) mixture modelling followed by Markov Random Field (MRF) classification. The approach has been tested very successfully on agricultural areas [3, 4, 5]. The approach is ideal for the complex and heterogeneous landscapes encountered in the tropics, where ground truth is often very limited or missing.

In mixture modelling the feature space is assumed to be a superposition of a certain number of clusters, each cluster having a certain pre-defined type of distribution, and pixels belong to one or more clusters. The model can be made for any number of pre-defined clusters. In case ground truth is available the optimum number of clusters can be found by trial-and-error and clusters, or aggregates of clusters, can be labelled with a class name. An example is given in Figures 6 for a polarimetric PALSAR image.

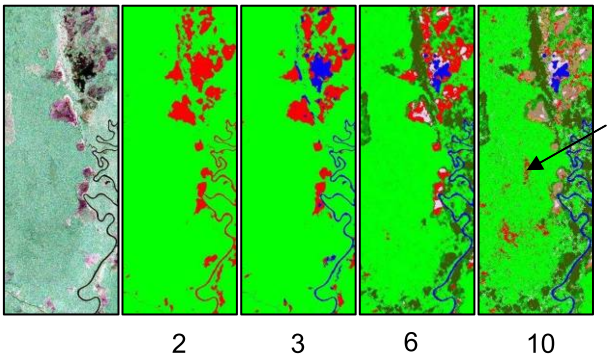


Figure 6. Mixture modelling followed by Markov Random Field classification of a small part of a polarimetric image over Central Kalimantan. Models of increasing complexity reveal a hierarchy of classes. For example, model 2 shows forest non-forest, model 3 adds the class water, while in model 10 re-generating forests can be distinguished (black arrow). Note that model 2 has 43 parameters, increasing to 219 parameters for model 10 and that the model number equals the number of clusters g. ALOS K&C © *JAXA/METI*

In case the complexity of the terrain is not well-known the optimum number of clusters can be computed from the so-called Bayesian Information Criterion (BIC). Figures 7a and 7b show the value of BIC as a function of the number of clusters g for a (complex) disturbed peat swamp forest terrain and an almost undisturbed mountain forest area, respectively. The results indicate, for the peat swamp area, that many clusters are needed to describe the information content of the image appropriately. Consequently, when ground truth is available many different classes could be distinguished. For the mountain forest area the result indicates that at least several classes (i.e. forest types) can be distinguished. *It should be noted that the latter classes may not be present in the peat swamp area, and vice versa.*

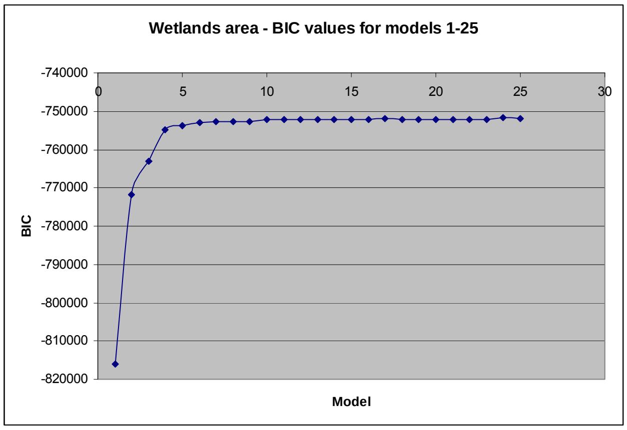


Figure 7a. BIC as a function of mixture model number g for a complex disturbed peat swamp area in Central Kalimantan (2007 FBS-FBD composite). The result indicates at least 25 clusters are needed to describe feature space.

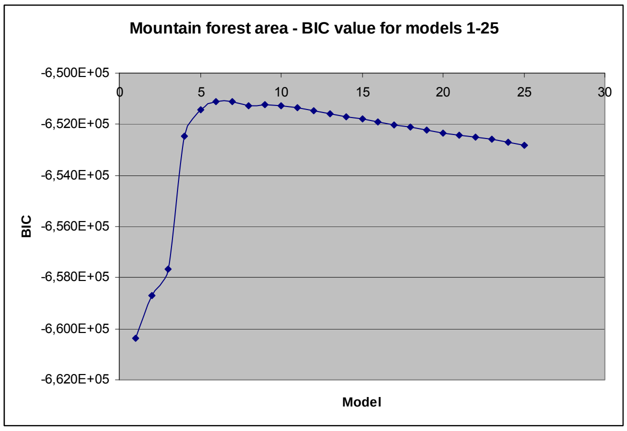


Figure7b. BIC as a function of mixture model number g for a typical undisturbed forest area in the heart of Borneo (2007 FBS-FBD composite). The result indicates that ~7 clusters are sufficient to describe feature space.

IV. MAP FRAGMENTS OF FOREST AND LAND COVER

A first series of map fragments for Borneo have been produced according the methodology introduced in Sections 2 and 3. This involves the following steps:

1. Selection of strip data and, when necessary, replacement data;
2. Radiometric balancing, orthorectification and relief correction;
3. Cluster analysis in key ecological, deforestation and agricultural regions;
4. Selection of key clusters for the description of the entire Borneo data set;
5. Aggregation of key clusters into broad classes;
6. Classification and outlier analysis;
7. Evaluation of results and legend using reference data;
8. Optionally, refinements follow by (iteratively) repeating steps 3-7.

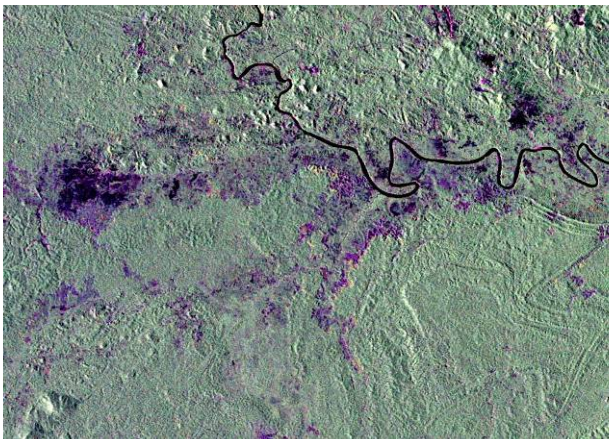
A first iteration of cluster analysis in 14 key areas yielded the following tentative legend (Table 3). It comprises classes typical for wetland areas, namely the mangroves and the peat swamps, several typical dry land forest areas, and other more general broad classes. The latter includes the class “other land cover types or mixed”.

The “class other land cover types or mixed” contains either (1) very fragmented small areas of mixed cover type which can not be classified well because of the abundance of mixed pixels, or (2) it contains an area for which an adequate representative cluster has not been selected yet. Since such an area can be detected, as a result of the outlier analysis, and the unknown area can be identified on the basis of appropriate reference data, the legend can be extended in the next iteration.

Table 3. Draft legend Borneo

Wetland areas
Mangrove 1 (Nipah)
Mangrove 2
Peat swamp less dense
Peat swamp low pole
Burnt (peat) forest and bare
Burnt shrubs and bare
Forest and forest on peat/heath
Dry land forest areas
Forest - Lower biomass and/or degraded
Forest - Higher Biomass
Deforestation types
Global types
Riverine-riperian and swamp forest
Shrub land
Shrub land – other types
Bare
Tree plantations and Palm oil
Dry land agriculture
Sawah
Water
Other land cover types / mixed
No data (radar shadow and layover)

Selected results are shown in Figures 8-10.



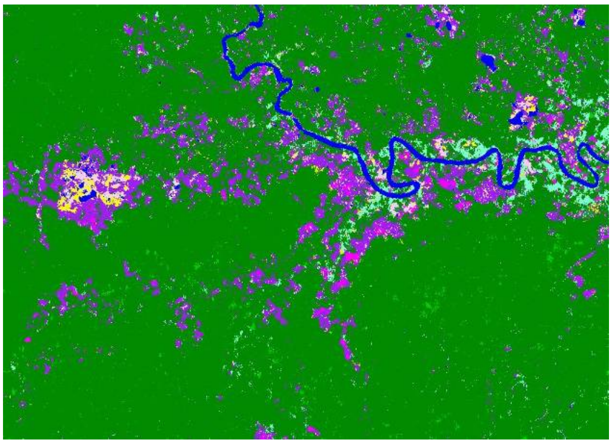
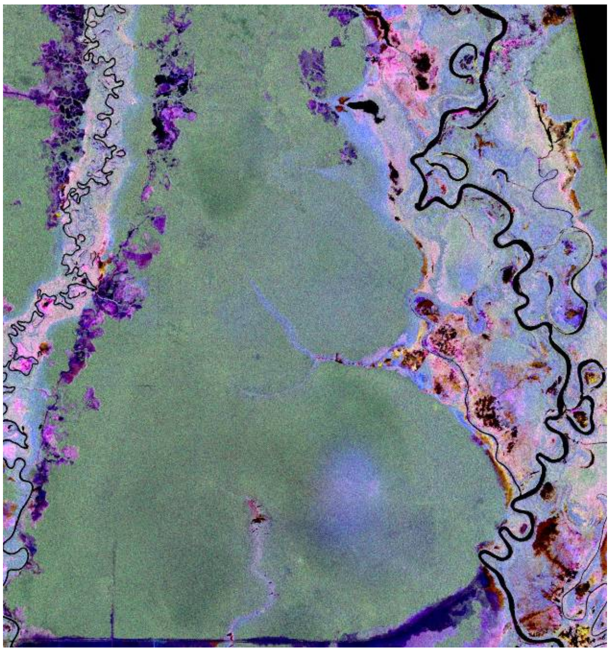


Figure 8. (a) PALSAR mosaic for an area (~43x31km) typical for deforestation in hilly/mountainous forested terrain in Borneo; (b) idem, classification. ALOS K&C © *JAXA/METI*



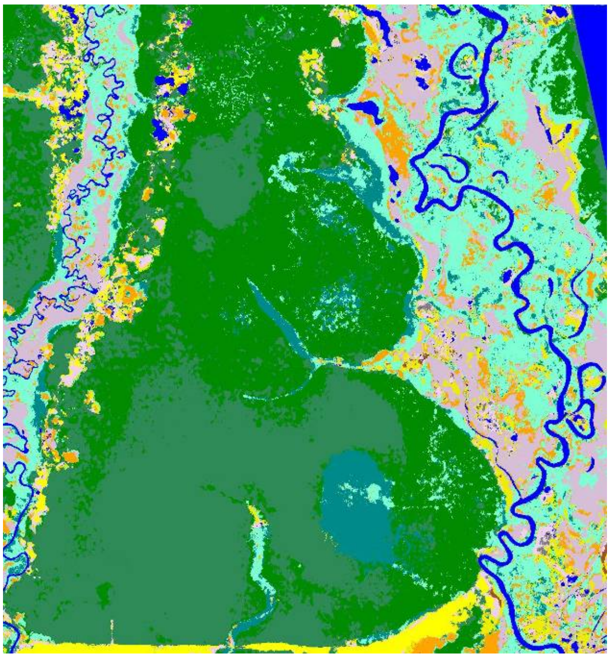
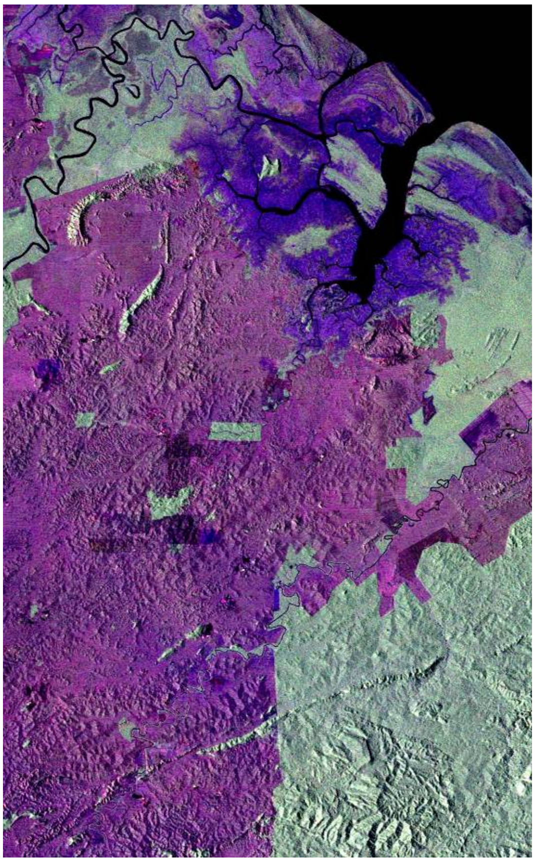


Figure 9. (a) PALSAR mosaic for the Mawas area in Central Kalimantan (~58x62km), which is typical for a (fairly) undisturbed peat swamp forest ecosystem; (b) idem, classification. ALOS K&C © *JAXA/METI*



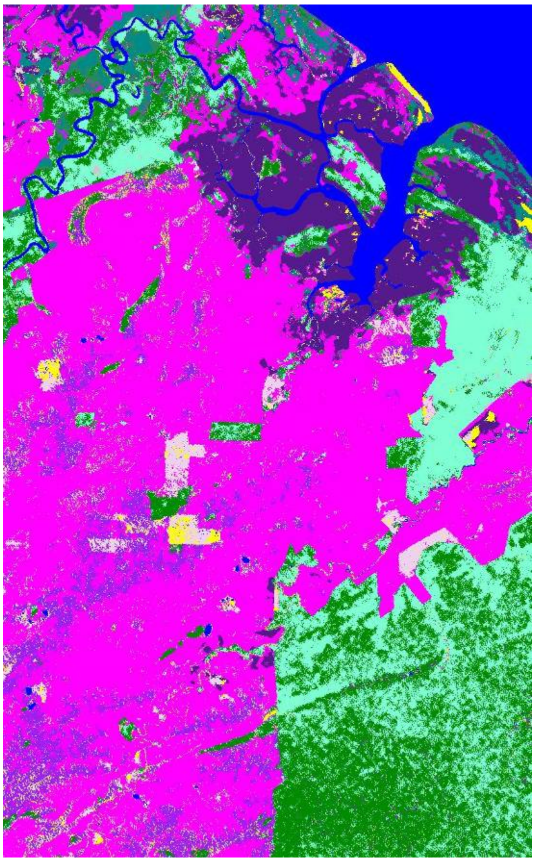


Figure 10. (a) PALSAR mosaic showing an old oil palm plantation development area and mangroves (Nipah) in Sabah (~58x32km); (b) idem, classification. ALOS K&C © *JAXA/METI*

V. FIELD DATA AND VALIDATION

For K&C dedicated data collection campaigns have been made (1) to collect extensive ground truth and reference data over Borneo in the framework of a systematic validation study funded by the Netherlands government; (2) to collect ground water level data in wetland areas to calibrate PALSAR for flooding fraction and ground water level [6, 7]. An accuracy assessment will be made for the Borneo map, as well as for each individual class of this map [8]. Guidelines provided by GOFC-GOLD [9] and GlobCover 2006 [10] for global mapping will be followed as much as possible. These state, for example, that the creation of an international expert network is the key element of the validation process [10]. This is also pursued within this project. An extensive partnership network of local end users in Insular SE Asia is already in place.

Within K&C it is pursued to produce maps to support UN conventions and development of REDD projects. Hence, two types of legend are under consideration: (1) using IPCC classes and (2) using the FAO LCCS system.
For validation the following reference data sets have been collected:

- Landsat
- MODIS 2007 (year aggregate)
- Ministry of Forestry classification, 2005

- NRM classification, 1997
- GlobCover, 2006
- Selected validation data set (samples)

Because of rapid changes in vast areas many of the reference data, even those of the Ministry of Forestry, are already outdated. This forms a major complication in the validation process. Nevertheless, the first results (presented as maps during the conference) are promising.

VI. MAPS OF PROTOTYPE AREA

It is intended to produce high resolution continental scale maps according methodologies and validation procedures introduced in Chapter 3 and Chapter 5, respectively, as the final K&C products. For development and evaluation purposes, however, several tentative products have been made at regional and local scale. These have been presented as K&C mid-term products (or posters), and will be briefly summarised in this section.

(A) LULC map Central Kalimantan

The main product development area of this project is in Central Kalimantan. In this area the intended methodology based on mixture modelling and Markov Random Field classification has been tested first. Use was made of the FBD mosaic produced by the K&C mosaicing theme, and a Scansar (WB1 HH) image of the wet season. Relief correction is not necessary since the terrain (a wetland area) is flat. An accurate forest and land use/cover map with more than 20 classes resulted (Figure 11).

This map is currently used for spatial planning in the Ex Mega Rice Project area (EMRP) by the provincial government of the Central Kalimantan, and has replaced older maps based on LANDSAT. The information is applied, among others, for ecological restoration and conservation of wild orangutan populations. Dedicated ground truth collection and evaluation based on reference data (Table 4) reveals an accuracy of at least 84%. In [11] full details on the production and accuracy assessment are reported.

Table 4. Reference data used for evaluation of the prototype area land use / land cover map of the Ex Mega Rice Project area in Central Kalimantan.

Reference data
• LANDSAT-7 ETM: Path row 118-062. 2000-07-16
• MODIS Tree cover percentage, University of Maryland / SDSU MODIS VCF 2005.
• Fire hotspot data. Database NASA/ University of Maryland MODIS, ESA/ESRIN AATSR, January 2004 – June 2007
• Other LULC maps:
• Ministry of Forestry Peta Penuputan Lahan Provinsi Kalimantan Tengah 2003
• Ministry of Forestry / BAPPEDA Peta Kawasan Vegetasi 2003
• Bakosurtanal Liputan Lahan 1:250,000 LULC map 2003EU

(B) Flood frequency map Central Kalimantan

There is a large demand for inventory and physical characterization of peat swamp forests in South-East Asia in support of hydrological modelling, management, protection and restoration. The current loss of peat swamp forest causes enormous emissions of CO_2 at the global level.

The need for such data is particularly high in the main product development area of this project, in Central Kalimantan, where the Mega-Rice Project was located. For the Central-Kalimantan prototype area a series of flood event maps have been produced for the period November 2006 until December 2007 (Figure 12). Use is made of systematic and frequent observation by PALSAR radar (Table 5) and the previously produced LULC map (see above). The approach is based on land cover dependant backscatter fluctuation caused by flooding or peat soil ground water level change. In [12] full details on the production and accuracy assessment are reported.

Table 5. Input data used for the production of the Central-Kalimantan flood frequency map.

ALOS PALSAR ScanSAR HH (WB1); EOC standard product Level 1.5;		
11-11-2006	27-12-2006	11-02-2007
29-03-2007	14-05-2007	14-08-2007
29-09-2007	14-11-2007	30-12-2007

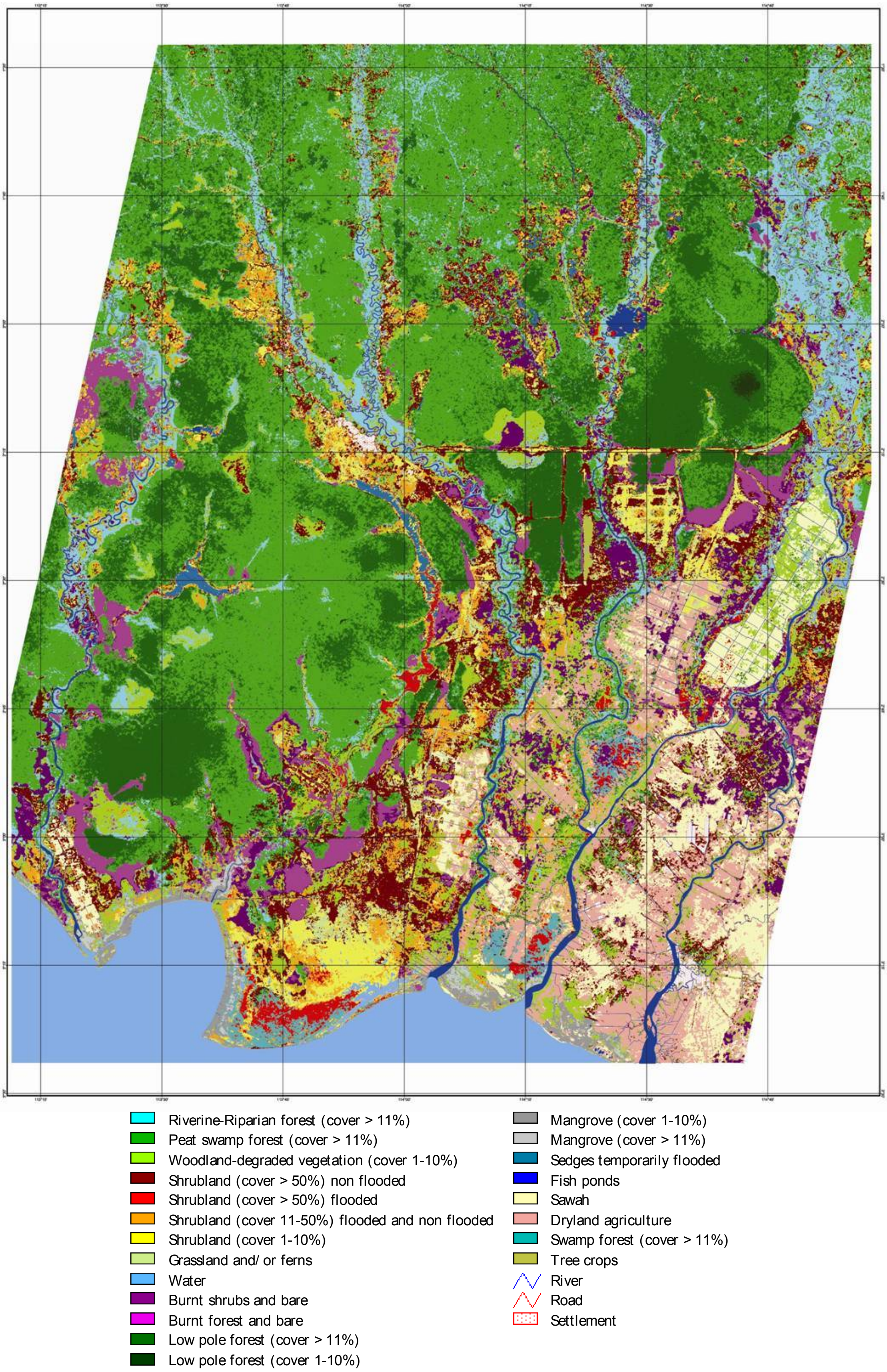


Figure 11. Map of forest and land use/cover 2007 of the main product development area (the EMRP project area and Sebangau) in Central Kalimantan based on FBD and WB1 HH data (K&C mid-term product 1).

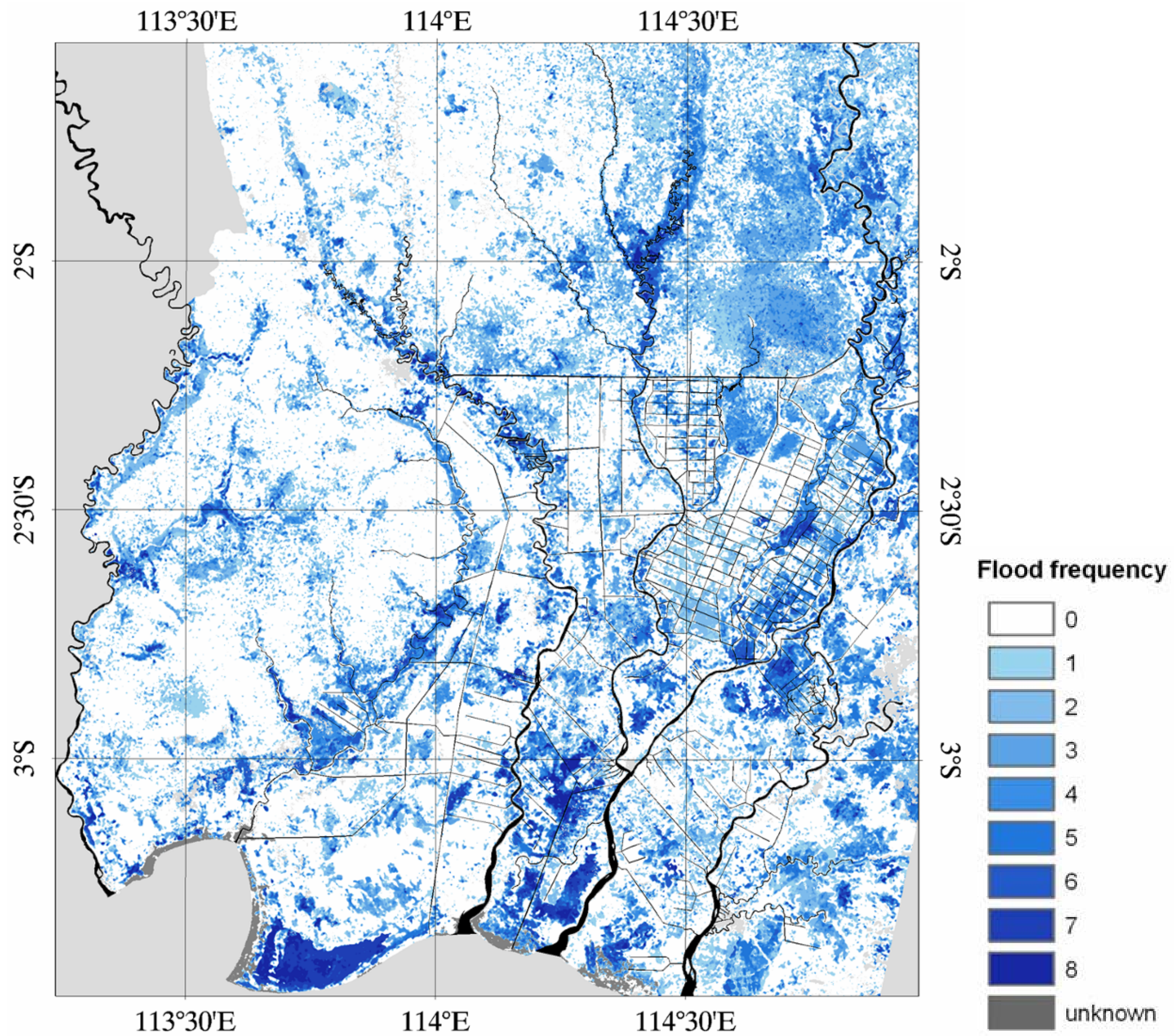


Figure 12 Map of flooding frequency in 2007 of the main product development area (the EMRP project area and Sebangau) in Central Kalimantan based on 9 PALSAR WB1 HH images (K&C mid-term product 2).

VII. FIRST RESULTS PEAT SWAMP HYDROLOGY

To study peat swamp hydrology, ecology and radar wave interaction in a systematic way a dedicated research station has been established in the Mawas peat swamp forest conservation area, which is located some 80 km east of Palangkaraya, in the province Central Kalimantan. The main feature is a research bridge, 23 km in length, crossing an entire peat dome. Instruments placed along this bridge automatically measure rainfall and water level every hour. In December 2004, an airborne radar survey (the ESA INDREX-2 campaign) was carried out along this bridge to test a variety of advanced imaging radar techniques [13], [14]. The intention is to collect field data over an extended period (i.e. 10 years) to develop hydrological modelling, examine relationships between hydrological, soil and vegetation characteristics, study carbon sequestration and to relate biomass and water (flooding) levels to L-band radar observations of the ALOS PALSAR instrument [6], [7].

(A) Hydrological characterisation

Peat domes are formed in ombrogenous peat swamp areas, which are purely rain-fed and, consequently, nutrient poor. Vegetation types are located in concentric zones, with the 'poorer' forest types located towards the centre of the dome. To characterize the hydrology of such a dome, where water is flowing from the top in the centre towards the edges, the water level variation along the flow is monitored. An example result for one of the instruments along the bridge is shown in Figure 13.

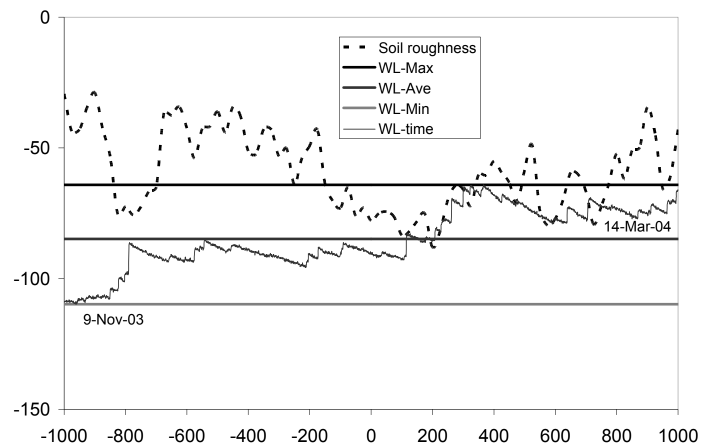
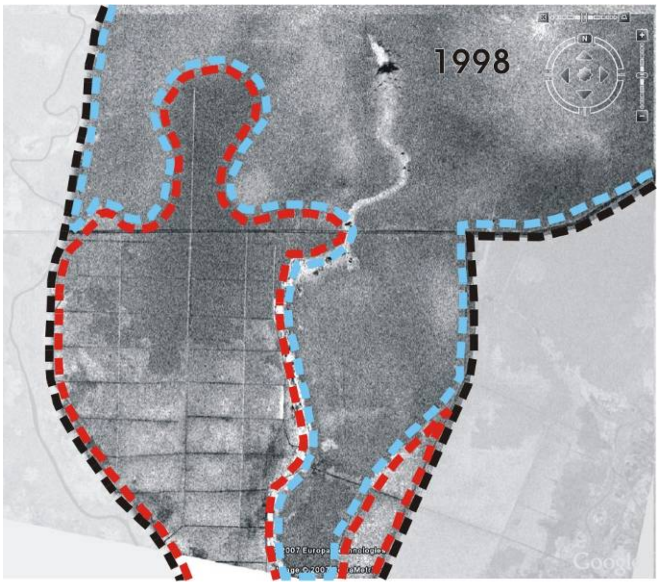


Figure 13. Water table variation WL-time (solid curve) and peat soil surface roughness (dashed curve). The vertical axis shows water level and soil surface height (both in cm). The horizontal axis shows horizontal distance (in cm) along the soil surface roughness profile (i.e. from -1000 to 1000 cm) as well as time (i.e. from 9-Nov-03 to 14 Mar-04). The position of the water table measurement is at the centre of this profile. These measurements are made every hour. The results for the period 9 Nov2003 until 14 March 2004 are shown (also along the horizontal axis). The three horizontal lines show the maximum (WL-Max), average WL-Ave) and minimum (WL-Min) water level. The percentage terrain flooding, thus, can be deduced from the combined roughness and water table measurements.

(B) Mawas ALOS PALSAR observation example

In the JERS-1 image of January 1998 (dry period) shown in Figure 14 the area demarcated by the red line is an area within the Mawas area suffering from excess drought. In the PALSAR image of 9 November 2006 (dry period) this area has decreased above the main east-west canal because of the construction of dams in the canal going North (canal Neraka). In the area south of the main east-west canal a large network of canals is still present and the continued drainage has worsened the situation. Note the very low radar backscatter (intense black) caused by very dry bare peat areas and the bright white area, which is a strongly degraded open forest with fire damage. The areas demarcated in blue are hydrologically intact, allowing forests previously damaged to regenerate.



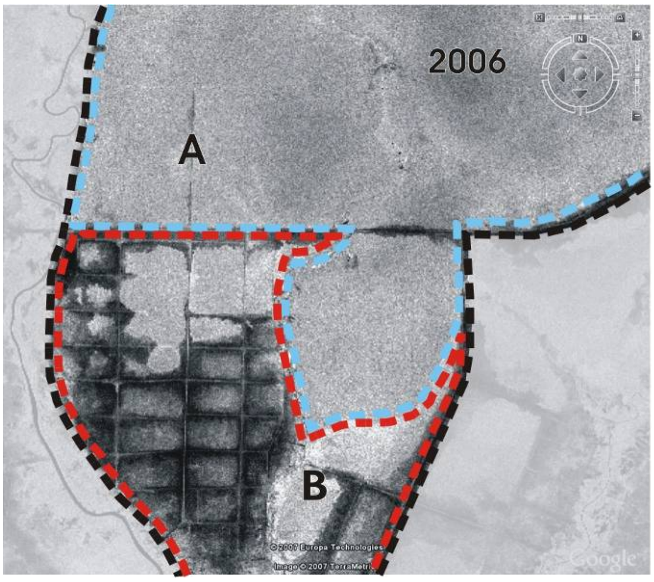


Figure 14. Peat swamp degradation (B) and restoration (A) in the Mawas area between 1998 (JERS-1) (left) and 2006 (PALSAR) (right). The red area is degraded, the blue area is intact or regenerating.

VIII. DISCUSSION AND CONCLUSIONS

The demonstrated methodology for continental wide mapping of forest and land cover at high resolution yields very promising results, and is generally applicable. These results are especially relevant for the humid tropical rain forest areas where other (optical) techniques have a poor performance because of persistent cloud cover. For monitoring, or the development of future REDD projects, radar observation seems to be irreplaceable.

The tentative legend shown already contains six forest types which have typical biomass ranges, and which can be mapped fairly accurate. Since more classes can be differentiated (on the continental scale) than initially foreseen, more validation effort is required. The (ongoing) validation study likely may reveal that more types of deforestation, tree plantations and shrubs can be differentiated.

First validation results show good agreement with the maps of the Ministry of Forestry which are based on visual interpretation of Landsat, but in general are outdated. The PALSAR maps would be perfect to improve GlobCover [10] in tropical rain forest areas with persistent cloud cover.

Maps of the Central Kalimantan prototype area indicate high accuracy for LULC mapping (over 84% for 20 classes), flood frequency mapping and peat swamp hydrology may be obtained. These maps are already used by local organisations.

It is expected that more characteristics of agricultural and peat forest areas can be obtained when the PALSAR ScanSAR cycles are included in the classification (or parameter retrieval) procedures. These features are mainly related to cropping cycles, hydrological/seasonal cycles and flooding events.

The work will be continued within the extension (phase 2) of the JAXA Kyoto & Carbon Initiative.

IX. ACKNOWLEDGEMENTS

This work has been undertaken in part within the framework of the JAXA Kyoto & Carbon Initiative. ALOS PALSAR data have been provided by JAXA EORC. The (ongoing) validation study of the Borneo map is coordinated by the Netherlands Agency for Aerospace Programmes (NIVR) and funded by the Netherlands Government, Ministry of Housing, Spatial Planning and the Environment.

REFERENCES

[1] A. Rosenqvist, M. Shimada, R. Lucas, J. Lowry, P. Paillou, B. Chapman [eds.], "The ALOS Kyoto & Carbon Initiative, Science Plan (v.3.1)," JAXA EORC, March, 2008. [Online] Available: http://www.eorc.jaxa.jp/ALOS/kyoto/KC-Science-Plan_v3.1.pdf

[2] Friedl in: M. Hansen, M. Herold, R. Ridder, and C. Schmullius, Land cover recommendations, Global Vegetation Monitoring Workshop, Missoula, August 2006.

[3] Hoekman, D.H., T. Tran, and M.A.M. Vissers, 2007a, Unsupervised full-polarimetric segmentation for evaluation of backscatter mechanisms of agricultural crops, *Proc. of POLinSAR 2007 Workshop*, ESA SP-644, 22-26 Jan 2007, Frascati , Italy (CD-ROM).

[4] Hoekman, D.H., T. Tranh, and M.A.M. Vissers, 2007b, Unsupervised full-polarimetric segmentation of agricultural crops at the DEMMIN test site, AGRISAR and EAGLE Campaigns Final Workshop, 15-16 October 2007, ESTEC, Noordwijk, The Netherlands (CD-ROM).

[5] Tran, N.T., R. Wehrens, D.H. Hoekman, and L.M.C. Buydens, 2005, Initialization of Markov Random Field Clustering of Large Remote Sensing Images, *IEEE Transactions on Geoscience and Remote Sensing*, Vol.43, No.8, August 2005, pp.1912-1919.

[6] Hoekman, D.H., 2007, Satellite radar observation of tropical peat swamp forest as a tool for hydrological modelling and environmental protection. *Aquatic Conservation: Marine and Freshwater Ecosystems*. Special edition title "Satellite-based radar – developing tools for wetlands management", Vol.17, pp.265-275.

[7] Hoekman, D.H., and M.A.M. Vissers, 2007, ALOS PALSAR radar observation of tropical peat swamp forest as a monitoring tool for environmental protection and restoration, Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, 23-27 July 2007, Barcelona, Spain (CD-ROM).

[8] Foody, G.M., 2008, Harshness in image classification accuracy assessment, International Journal of Remote Sensing, Vol.29:11, pp.3137-3158.

[9] GOFC-GOLD, 2006, Report 25; Global Land Cover Validation: Recommendations for Evaluation and Accuracy Assessment of Global Land Cover Maps, A. Strahler *et al*., March 2006.

[10] GLOBCOVER, 2008, Products Description and Validation Report, P. Bicheron *et al*., December 2008;

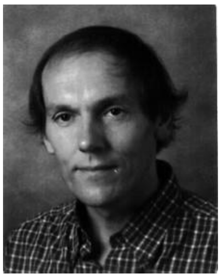
ftp://uranus.esrin.esa.int/pub/globcover_v2/regional/

[11] SarVision, 2008a, Mid-2007 Revised Land use/cover map, Ex-Mega Rice Project area and Sebangau, Central Kalimantan, Final Version, SarVision report, 28 May 2008, Wageningen, The Netherlands, 43 pages.

[12] SarVision, 2008b, Flood analysis, Ex-Mega Rice Project area and Sebangau, Central Kalimantan, SarVision report, 23 May 2008, Wageningen, The Netherlands, 30 pages.

[13] Hajnsek, I., F.Kugler, K. Papathanassiou, R. Scheiber, R.Horn, A. Moreira, D.H. Hoekman, M. Davidson, and E.P.W. Attema, 2005, INDREX 2 – Indonesian airborne radar experiment campaign over tropical forest in L- and P-band, POLinSAR 2-nd Int. Workshop on Applications of Polarimetry and Polarimetric Interferometry, ESA-ESRIN, Frascati, Italy, 17-21 January 2005, *ESA report SP-586* on CD-ROM

[14] Hajnsek, I, and D.H. Hoekman, 2006, Final Report, INDREX II – Indonesian Radar Experiment Campaign over Tropical Forest in L- and P-band, Version 1, 14 June 2006; ESA Contract RFQ/3-11077/04/NL/CB; Report ESA, DLR and Wageningen University; 142 pages.



Dirk H. Hoekman received his M.Sc. degree E.E. from Delft University of Technology, Dept. of Electrical Engineering, The Netherlands in 1981 and his Ph.D. degree from Wageningen University, The Netherlands in 1990. He is employed at Wageningen University since 1981 where he currently holds the position of Associate Professor in remote sensing with main interests in the physical aspects of remote sensing, microwave remote sensing and applications of remote sensing in forestry, agriculture, (agro-)hydrology, climate studies and environmental change. He was scientific co-ordinator for the ESA/INPE Amazonian expedition (1986) and the ESA/JRC AGRISCATT campaign (1987-1989); co-ordinating investigator for the international test site Flevoland for the JRC/ESA MAESTRO-1 campaign (1989-1991); for tropical rain forest sites in Colombia and Guyana, including ESA's SAREX-92 campaign (1992-1993) and NASA's South-American AIRSAR Deployment (1993); scientific co-ordinator for the EC programme TREES'94 ERS-1; and co-ordinating investigator for tropical rain forest sites in Indonesia, including NASA's PACRIM-2 campaign (2000) and ESA's INDREX-1 and -2 campaigns (1996, 2004). He is currently co-ordinating research programmes to support the realisation of operational wide-area radar monitoring systems for sustainable forest management and UN REDD; and exploring the scientific use of ALOS PALSAR for tropical peat swamp forest hydrology and forest cover change monitoring in Indonesia and the Amazon in the framework of the JAXA Kyoto&Carbon Initiative.

Marcela J. Quiñones received the B.Sc. degree in biology from Los Andes University, Bogotá, Colombia in 1987, the M.Sc. degree in Remote Sensing and GIS for forestry applications in 1995 from the International Institute for Aerospace Survey (ITC), Enschede, The Netherlands and the PhD degree in Environmental Sciences at Wageningen University in 2002. Now she is a researcher at SarVision working on the application of remote sensing data for the Amazon region. She has been involved mainly in research projects for resource management, ecology and land use planning in the Colombian Amazon. Her main interest is the establishment of operational accurate remote sensing monitoring systems in the Amazon region for studies of ecosystem dynamics, deforestation and fire detection.

Martin A.M. Vissers is an agricultural engineer from Wageningen University (WU), The Netherlands, graduated in Land and Water Management, 1987. He specialized in remote sensing data handling and archiving, image processing, software development, field work and radar remote sensing techniques. He was involved in many scientific remote sensing campaigns. In 1995 he founded his company "Vissers DataManagement", a small business dedicated to digital image processing, data-handling and remote sensing field campaigns. He executed several contracts for ESA-ESTEC, Wageningen University and other institutes and companies in the field of remote sensing. Since April 2000 he is managing director of SarVision BV, a company he co-founded. Beside responsible for management he executed several major contracts for ESA-ESTEC, WWF, VROM, CKPP and he was involved in several remote sensing campaigns (fieldwork as well as data processing).