APPLICATION OF POLSAR FOR TROPICAL TIMBER PLANTATION IN INDONESIA

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ABSTRACT

This paper reports the result of the study in the AOE-869 test site by exploring ASAR/APP dual polarization (VV, VH) image. The result is very promising, as it could differentiate clearly two land cover types : forest timber plantation and oil palm plantation. Although they play an important role for the monitoring of deforestation, these land covers were difficult to be differentiated in high resolution optical imageries (Landsat, SPOT,ASTER),. This ability is also required to monitor leakage in the project area for CDM A/R purpose of the Kyoto Protocol. ESA policy for the provision of free PolSAR PRO analysis software has given a concrete multiplier effect for the future potential market of polarimetric SAR data, especially in the developing countries.

1 INTRODUCTION.

The analysis of polarimetric SAR data in the developing country is largely depend on : (1) the access to the polarimetric SAR imageries, and (2) the availability of the analysis tools. In Indonesia, the first fully polarimetric spaceborne SAR data was available from SIR-C (1994), while for airborne SAR data were available from AIRSAR PacRim (2000) and Indonesia's Radar Experiment INDREX-II (2004) [2]. The first partially polarimetric spaceborne SAR data was available in Indonesia from Envisat ASAR (2003) through Envisat AOE-869.

The availability of open source and freeware PolSAR PRO software [11] provided by ESA allows the first attempt to analyze locally of these available polarimetric imageries. Since all of these polarimetric imageries are from different areas and not in the same well planned test site, this first analysis has to be prioritized to the Envisat AOE-869 test site in Sumatera island.

As most of SAR studies for tropical forest were concentrated on natural forest, this study was implemented in different approach, by concentrating on plantation forest. Detection and differentiation of forest plantation and estate plantation is difficult in high resolution optical imageries (Landsat, SPOT, ASTER). The availability of medium resolution ASAR/Envisat partially polarimetric data is expected to solve this problem at a relatively low cost approach. Ability to detect the plantation will allow to monitor the culprit of deforestation in an objective way.

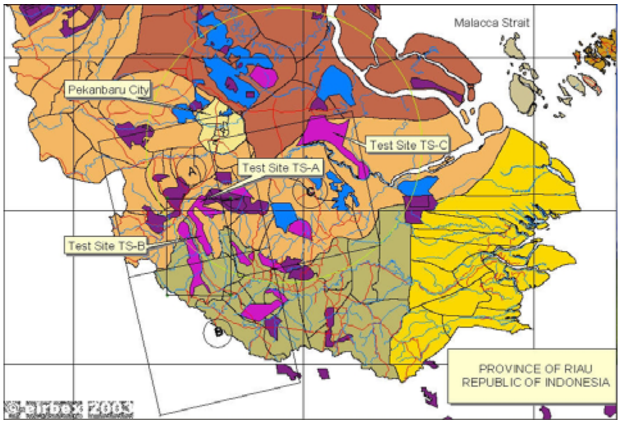
The objective of this study are : (1) to explore the first polarimetric application in the tropical plantation forest condition, (2) to analyse the derived biomass parameters in relation to the Kyoto Protocol (CDM A/R) requirements, (3) to utilize the result to educate potential user for future SAR market, and (4) to provide feed back to ESA for future polarimetric spaceborne SAR missions.

2 DATA AND METHOD

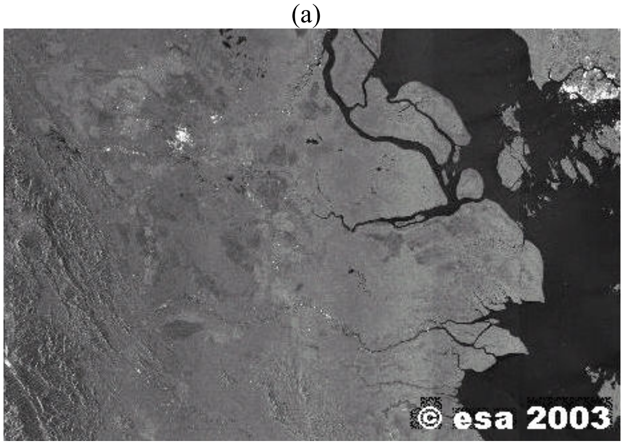
2.1 Test Sites

The location of the AOE-869's test sites is in the Province of Riau, Indonesia, in the eastern region of Central Sumatera, near Pekanbaru (0.52N 101.47E) [12]. The area can be found also in [3] displayed as ASAR/WSM color RGB in page 19. This Province is selected because of its land use is very dynamic, and deforestation has become an important issue to be monitored. This study is intended to explore the application of low cost, medium and low resolution ASAR imageries (AP and WS Mode) for the monitoring of deforestation factors.

In this study all of the timber plantation test sites are selected under close cooperation with PT Riaupulp. Fig. 1(a) provides the details of the three test sites. The appearance of the test sites and its surrounding area as displayed in the quick look of ASAR Wide Swath (WS) strip lines image of 31 December 2002, is given in Fig. 1(b). Test site TS-C which is *Acacia crasicarpa* plantation in the peat soil recorded in ASAR partial polarization image (AP Mode) is the target of this study. The previous study on single polarimetric ASAR/IMP imageries in test site TS-A was reported in [12].



(a)



(b)

Fig. 1. Location of the tropical plantation forest (blue, pink and purple) in the Province of Riau, Indonesia (a). The three selected test sites are marked with code TS-A, TS-B, and TS-C; The appearance of the area in the quick look ASAR WS image is provided (b). City of Singapore is located in the top right of the image.

2.2 Study Approach

Timber plantation for pulp (*Acacia mangium* and *Acacia crasicarpa*) in Indonesia has seven years rotation cycle. The plantation operation is managed in different level of land management unit : Sector, Estate, Compartment and Stand. Stand is the smallest management unit, with the same species and age. Under the existing plantation management practice, field data is collected in different age of timber plantation [1] : (1) Mid-Term Inventory (MRI) is collected at three years old, (2) Pre-Harvest Inventory (PHI) at six years old, and (3) Bench Mark Operation (BMO) at logging operation (seven years old) is implemented for selected and limited Compartment to reconcile the actual harvesting yield data with the inventory model yield prediction.

Based on the above plantation management practice, and the limitation of image quota for AOE-869, the study was implemented with the following 3-steps approach :

1. **Step-1** : Exploration was first done on ASAR/APP, IS-2, VV-VH Polarization, to examine what polarization was suitable for plantation detection (ETM-Landsat was used for comparison).
2. **Step-2** : The suitable polarization was then applied for ASAR/WSM single polarization imagery to explore the performance of detection ability in the low resolution and wide coverage ASAR image. The intention was to reduce the monitoring cost by using this type of ASAR/WSM imagery.
3. **Step-3** : Further polarization analysis was implemented on ASAR/APP imagery, by using ESA provided PolSAR PRO open source and freeware software. This exploration was intended to see the result of PolSAR analysis in the selected plantation type

2.3 Imagery and Data Sets

All of field data sets for test site TS-C were provided by PT Riaupulp in the confidential basis. As the area was on the early stage, most of the data contained planting operation status. The two types of forest plantation inventory data is expected on 2004 for MRI and 2007 for PHI. GPS direct data collections were made as necessary during the study, in addition to archive data provided by PT Riaupulp.

Based on the field data, land preparation of the TS-C test site was completed. The site is in first rotation and the first planting date was 2001. The first ASAR/APP (IS-2, VV-VH Pol, Ascending) imagery was recorded on 10 July 2003. It could be used for monitoring of 2001 and 2002 plant growth condition, and 2003 planting operation status (planted, on-going logging operation and harvested ready area of the natural forest). Landsat-ETM archive image (1999) was used as a comparison between medium resolution ASAR/APP image and high resolution optical image. The last image was ASAR/WSM (VV, Ascending) was recorded on 16 December 2003 to test the performance of detection ability at low resolution, wide area coverage. The next ASAR/AP image is scheduled for PHI in 2007, with the intention to compare with ALOS/PALSAR image if available.

3. RESULTS

Compared to test site TS-A which planting date was started in 1997 [12], the TS-C planting date was started in 2001. Both test sites were in their first rotation, but TS-C was in early stage. As the concecquences, the recorded 2003 ASAR/APP image could not be used for MRI purpose, except for the ability to detect and to differentiate age and planting operation status in partial polarization imagery. It is expected that he next ASAR image acquisition of 2007 will provide the first record for PHI application.

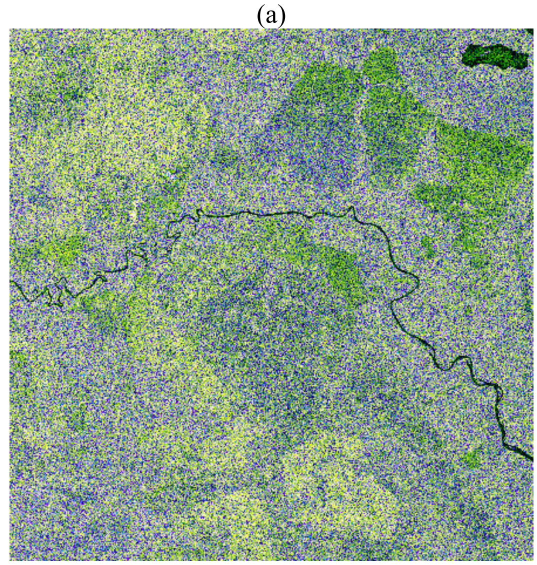
3.1 Step-1 : ASAR/APP Exploration

Synthetic Aperture Radar (SAR) plays an important role in tropical areas where cloud problems are severely occur. An attempt to use of Japanese ERS (JERS)/SAR L-band data to map wetland vegetation in Brazilian Amazon, was given in [5]. While this previous study utilized only single SAR imagery, further attempts to improve mapping purposes or extraction of forest parameters were made by using coherence data taken from interferometric pairs [4]. However, problems have been identified related to SAR interferometry, mostly due to time gap of repeat pass acquisition which leads to decorrelation. Further studies have been found also to extend the use of SAR interferometry for land use applications (for instance, see [14]).

This step involved the use of Envisat/ASAR APP (Alternating Polarization Precision) data to monitor the test site. While provision of fully polarimetric data is eventually available with the launch of Japanese ALOS/PALSAR (and the future by Canadian Radarsat-2), Envisat ASAR is the only spaceborne sensor able to provide partial polarimetric data nowadays. ASAR sensor use incoherent acquisition to construct polarimetric data. Eventhough, preservation of phase information can not be maintained [6]. Despite limitation of partial polarimetric data, this step showed that further explorations can be pursued for valuable monitoring purposes.

In this case, ASAR/APP image was displayed on each polarization type (VV and VH), for visual inspection. It was found that VV image was suitable for detection of pulp timber plantation and oil palm plantation, as shown in Fig. 2(a). These two plantation types were the mayor actors for deforestation in this Province. Further to this visual aspect, PolSAR PRO [11] was used to generate the RGB color quick look as given in Fig. 2(b). The quick look was used for the selection of the Area Of Interest (AOI) of both type of plantation, for further PolSAR analysis.

(a)



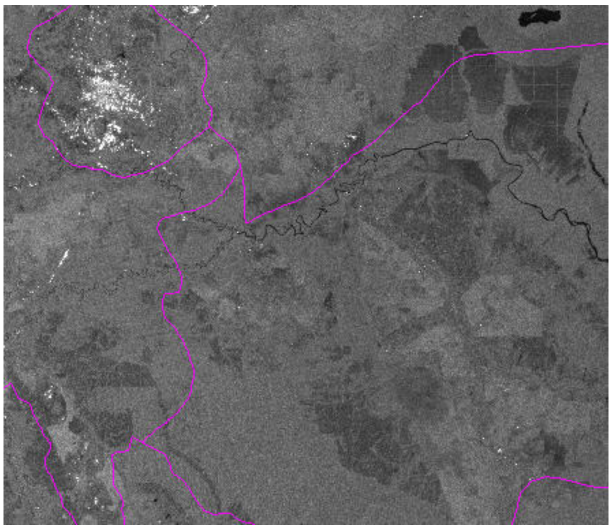
(b)

Fig.2. ASAR/APP VV Pol. In B/W (a) and as a quick look in color display (b). Timber plantation at the top right (green), and oil palm plantation at the bottom centre (yellow).

3.2 Step-2 : ASAR/WSM Exploration

Based on the findings at Step-1 above, another effort was made by using ASAR/WSM VV Pol. Image. The intension was to get a low cost monitoring approach. Fig. 3 below clearly shows that WSM image could be used for monitoring of these two plantation types, although it has lower resolution compared to ASAR/APP.

WSM VV provides wider coverage, but the image has almost equal characteristic like APP VV. Although it has little bit low contrast. Overlaid with different type of land cover polygons (timber plantation and estate plantation), it allowed to differentiate pulp timber plantation and oil palm plantation, as performed on medium resolution APP VV. Therefore, it can be used for visual inspection for these type of plantation



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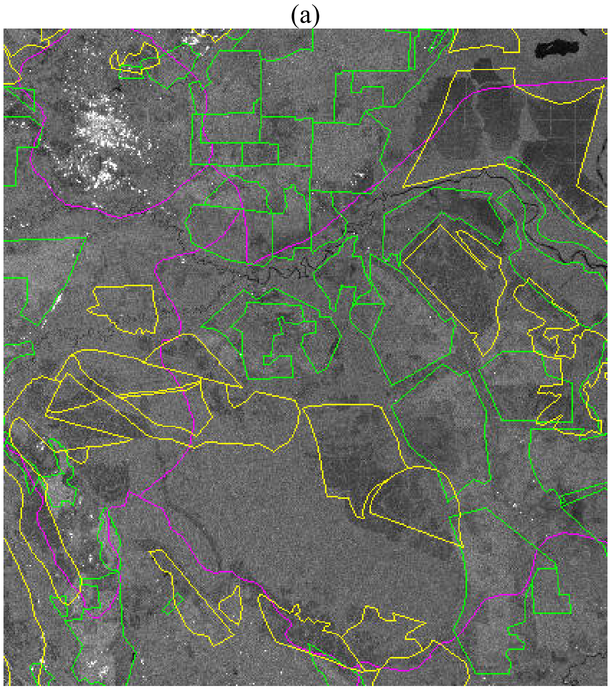


(b)

Fig. 3. ASAR/WSM VV Polarization display (a) and its combination with plantation polygon (b). Yellow polygon for timber plantation and green polygon for estate plantation.

3.3 Step-3 : PolSAR PRO Analysis

Classification methods based on polarimetric data generally can be grouped into two major approaches. The first is based on image processing techniques such as fuzzy c-mean [13] or expectation maximization [7]. Another approach relies on scattering mechanism inherent to polarimetric SAR data.

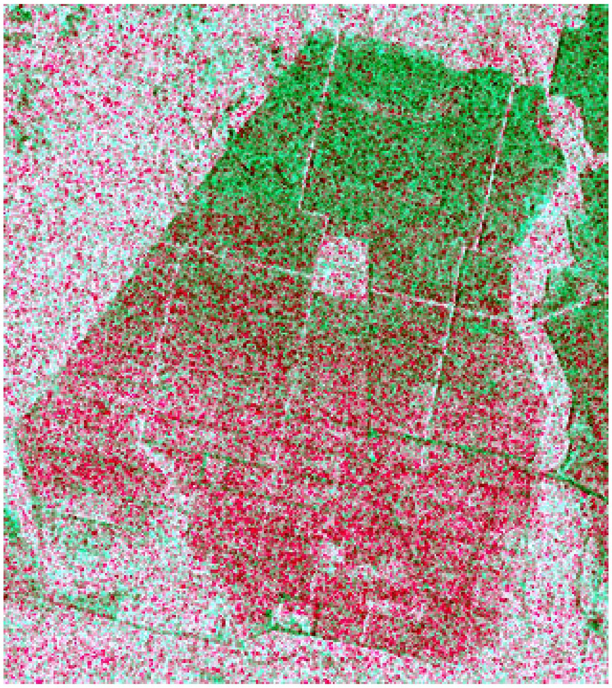
Based on complex Wishart distribution of polarimetric covariance matrix, a classification scheme to take into account all information contained in the polarimetric data was constructed [8]. Later, the classification strategy has been implemented to support expanding information extraction through decomposition theorems. By using unsupervised method, a successful combination of Cloude-Pottier decomposition and complex Wishart classification was presented in [9]. Another paper with similar methodology and employing Freeman-Durden decomposition was found in [10].

In this paper, analysis of ASAR APP data involves qualitative and quantitative procedures applied for Envisat partial polarization image [11]. The qualitative analysis was taken earlier in order to have preliminary information about the data. In this step, a color composite image was constructed by combining images of I22, (I12-I11) and I12 into red, green and blue channels respectively. The analysis was done separately for pulp timber plantation and oil palm plantation.

Pulp Timber Plantation

In order to minimize speckle effects, quantitative analysis begins with polarimetric speckle filtering. In this research, Lee polarimetric filter was used. A 3 by 3 kernel size was used in order to maintain sharpness of the image. Guided by a planting activities plot, four training sets was selected representing four different classes. Based on these training sets, Wishart supervised classification was performed. Classification performances were reviewed through the accuracy matrix table.

Since planting process was conducted continuously, there was overlap or unclear separation between 2001 and 2002 planting crops. The difference between 2001 and 2002 plants should be one year, but due to slow growth of *Acacia crasicarpa* in water-logged condition, vigor of this vegetation looks similar. In order to focus into the testing of the classification procedure, the four classes were simplified and rearranged into three classes only, namely : 2001+2002 planting, 2003 planting/Clear-cut (CC) and Natural Forest (NF).



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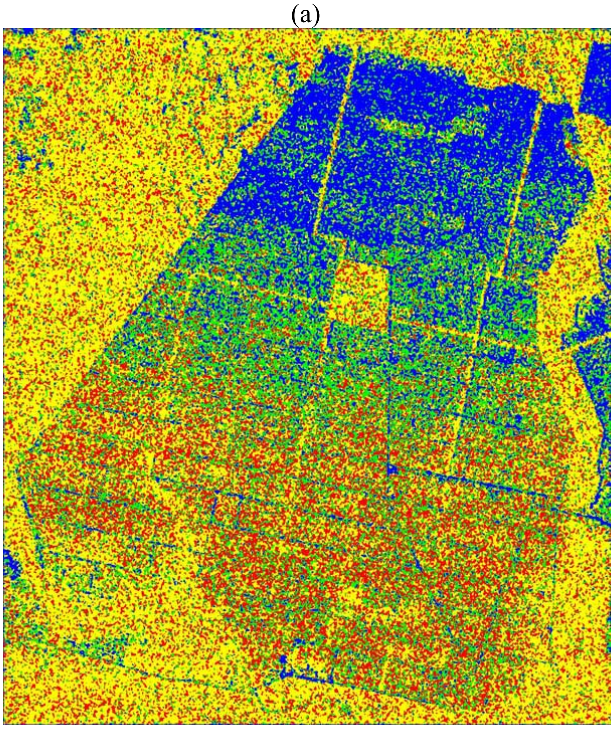


(b)

Fig. 3. Wishart supervised classification of three classes (a) and four classes (b). Color code for (a): red: 2001 + 2002 planting, green: 2003 planting/clear-cut (CC), blue: natural forest (NF). Color code for (b): red: 2001 planting, green: 2002 planting, blue: 2003 planting/clear-cut (CC), and yellow: natural forest (NF).

The result of Wishart supervised classification for these three classes is presented in Figure 3(a). As indicated, redefinition of classes presents more compact grouping. In this case, the classification delivers acceptable result. In general, more than 70 percent accuracy is achieved. Although it is clear from picture the transition in 2002 planting date. Detailed accuracy information is shown in Table 1.

Table 1. Accuracy matrix for 3 classes.

	2001+2002	2003/CC	N.Forest
2001+2002	70.29	11.50	18.20
2003/CC	14.01	83.77	2.22
N.Forest	35.61	3.70	60.69

For more complex application, such as implementation of Kyoto Protocol, previous finding should be extended by ungrouping the 2001+2002 planting class into two separated classes. The protocol specially mentions the importance of Afforestation, Reforestation and Deforestation (ARD) monitoring. In order to support the monitoring of the protocol, a test was arranged to separate the two planting date (2001 and 2002) into a two separate classes, guided by field data. The result of Wishart supervised classification of four classes is presented in Figure 3(b).

Table 2 indicates that in general, separation between 2001 and 2002 planting dates appear to be difficult. Although mixed pixels between those two classes are generally low, disturbances from natural forest are obvious. As indicated from ground data, numerous disruptions are found in natural forest. This may explain partly for the possible reasons of these high biases.

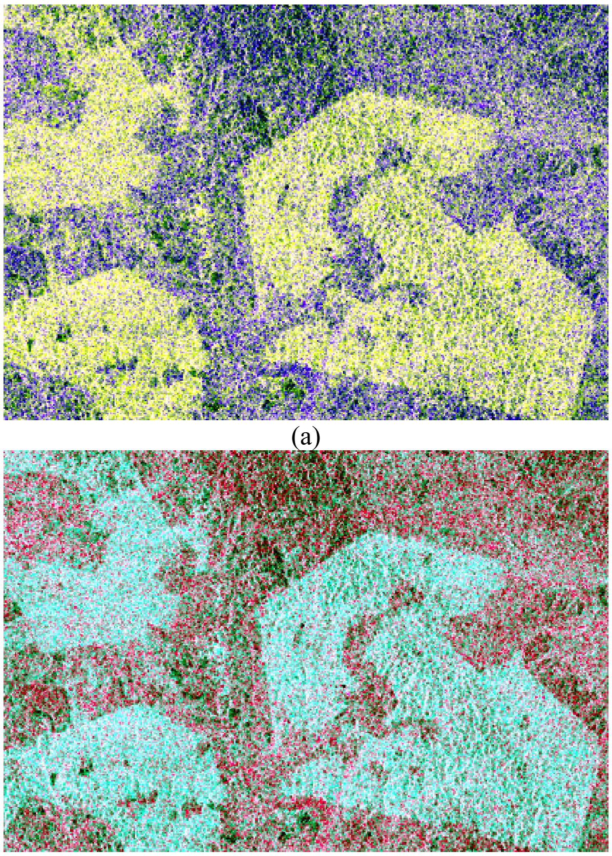
Table 2. Accuracy matrix for 4 classes.

	2001	2002	2003/CC	N.Forest
2001	47.04	26.43	2.74	23.78
2002	19.21	48.22	19.41	13.16
2003/CC	0.23	13.78	83.77	2.22
N.Forest	19.78	15.84	3.70	60.69

Difficulties of gaining better achievement in this case are also possibly due to the fact of data imbalance. As indicated before, discrimination is generally due to capability of I12 channel to separate classes. However, this capability of I22 channel is limited for specific targets separation, for instance between natural forest and clear cut/logged forests.

Oil Palm Plantation

Oil palm plantation is the main source of raw material for oil palm mill to produce Crude Palm Oil (CPO). Total annual world consumption of CPO in 2006 was 32.7 million tons. The total export of CPO from Indonesia in 2006 was 11.5 million tons or 37 percent export market share of world consumption. Due to the recent increasing trend of fossil fuel oil price, the Government of Indonesia issued a new policy on energy. The Policy includes CPO as part of renewable energy component, to reduce the cost of fossil fuel subsidies on state budget.



(a)

(b)

Fig.4. Clear detection of oil palm plantation by using Lee redefined filter on ASAR/APP VV-VH Pol image, displayed in two different colors.

The conditions of good CPO export price and the potential increase of domestic demand for renewable energy source, will be a strong thrust for the expansion of oil palm plantation in the near future (big estate or community plantation). This drive if not well managed and controlled will cause deforestation and its derivative disasters : loss of biodiversity, forest fire, land slide, flood, flash flood and drought. An effective monitoring method by using available EO satellite missions, therefore is the only choice to cover wide coverage for the huge area like Indonesia.

Existing approach using optical sensor shows the difficulties to detect oil palm from its surrounding except for very high resolution images (Quick Bird, Ikonos). An effort was made to explore the potential of Envisat ASAR AP and WS modes imageries to detect oil palm plantation in addition to the pulp timber plantation, at moderate and low monitoring cost. Fig.4 shows the result of first effort to detect oil palm plantation on ASAR/APP VV, VH Polarization image. The color images displayed were processed by using Lee redefined filter, which shows the ability to clearly detect oil palm plantation from its surrounding land covers. Based on this positive indication, further analysis will be done for immediate operational applications. Application on ASAR/WSM already mentioned previously in Fig.2.

4. CONCLUSIONS

The result above shown the positive progress achieved in ESA/Envisat AOE-869 Team. The study applied the available PolSAR method direct to the ground, by using partial polarization image (ASAR/APP VV-VH Pol.) and ASAR/WSM VV Pol. image for its on-going research targets. The following are several findings as important conclusions :

1. ESA policy to provide free access to PolSAR PRO software package has created great impacts : **all singing all dancing** situation, for the application of SAR polarimetry worldwide, including developing country like Indonesia.
2. The study has proven the ability of Envisat/ASAR APP VV-VH Pol. and ASAR WSM VV Pol. for detection and identification of tropical pulp timber and oil palm plantation.
3. The test site should be considered to be included in the planned super sites, as part of the follow up to POLinSAR 2007 Workshop. This will allow the possibility for further study of the future EO SAR missions including compact polarimetry (CP) SAR sensor and new methods in PolSAR and POLinSAR.
4. ScanSAR/WSM coverage display should be included in DESCW software and future CP SAR sensor , as it play very important role for cost effective monitoring of : clear cut, timber plantation, oil palm plantation and flood (including detection of recently 2004 Indian Ocean Tsunami affected area in Indonesia).

5. Polarization signature and polarization synthesis utilities are suggested to be included for Envisat ASAR/AP analysis, as an addition to PolSAR PRO.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. APRIL, *Plantation Forest Inventory Protocol*, Riaupulp Forestry Standard Operating Procedure, RPF-PLG-1008E-PR, 2003

2. ESA, *Experiment Plan, INDREX II – Indonesian Radar Experiment, Campaign over Tropical Forest in L- and P-Band*, Draft, European Space Agency (ESA), 2004.

3. ESA, *The Changing Earth, New Scientific Challenges for ESA's Living Planet Programme,* ESA SP-1304, European Space Agency (ESA), Publications Division, ESTEC, P.O. Box 299, 2200 AG Noordwijk, The Netherlands, 2006.

4. Eriksson L.E.B., Santoro M., Wiessman A. and Schmullius C., Multitemporal JERS repeat pass coherence for growing stock volume estimation of Siberian forest, *IEEE Trans. Geosci. Remote Sensing.*, vol. 41, pp. 1561-1570, 2003.

5. Hess L.L., Melack J.M., Novo E.M.L.M., Barbosa C.C.F.and Gastil M., Dual-season mapping of wetland inundation and vegetation for the central Amazon basin, *Remote Sensing Environ.*, vol. 87, pp. 404-428, 2003.

6. Inglada J., Souyris J.C., Henry C. and Tison C., Incoherent SAR polarimetric analysis over point targets, *IEEE Geosci. Remote Sensing Letters*, vol. 3, pp. 246-249, 2006.

7. Kersten P.R., Lee J.S.and Ainsworth T.L., Unsupervised classification of polarimetric synthetic aperture radar images using fuzzy clustering and EM clustering, *IEEE Trans. Geosci. Remote Sensing*, vol. 43, pp. 519-527, 2005.

8. Lee J.S., Grunes M.R. and Kwok R., Classification of multi-look polarimetric SAR imagery based on complex Wishart distribution, *Int. J. Remote Sensing.*, vol. 15, 1994.

9. Lee J.S., Grunes M.R., Ainsworth T.L., Du L.J., Schuler D.L. and Cloude S.R., Unsupervised classification using polarimetric decomposition and the complex Wishart classifier, *IEEE Trans. Geosci. Remote Sensing.*, vol. 37, pp. 2249-2258, 1999.

10. Lee J.S., Grunes M.R., Pottier E. and Ferro-Famil L., Unsupervised terrain classification preserving polarimetric scattering characteristics, *IEEE Trans. Geosci. Remote Sensing.*, vol. 42, pp. 722-731, 2004.

11. Pottier E., Ferro-Famil L., Allain S., Cloude S.R., Hajnsek I., Papathanassiou K., Moreira A., Williams M., Pearson T. and Desnos YL., An Overview of the PolSAR PRO v3.0 Software. The Educational Toolbox for Polarimetric and Interferometric Polarimetric SAR Data Processing, Proceeding of the *POLinSAR* 2007 Workshop – *3rd International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Iinterferometry*, Frascati, Italy, 22-26 January 2007, European Space Agency (ESA SP-644)

12. Raimadoya M.A., Dobson M.C., van Rensburg R. and Trisasongko B.H., Envisat-Indonesia Radar Biomass Experiment (EIRBEX), *Proceedings of 2004 Envisat & ERS Symposium*, Salzburg, Austria, 6-10 September 2004, European Space Agency (ESA SP-572).

13. Rignot E., Chellapa R. and Dubois P., Unsupervised segmentation of polarimetric SAR data using the covariance matrix', *IEEE Trans. Geosci. Remote Sensing*, vol. 30, pp. 697-705, 1992.

14. Strozzi T., Dammert P.B.G., Wegmüller U., Martinez J.M., Askne J.I.H., Beaudoin A. and Hallikainen M., Landuse Mapping with ERS SAR Interferometry, *IEEE Trans. Geosci. Remote Sensing*, vol. 38, pp. 766-775, 2000.