FINAL REPORT for APN PROJECT

Project Reference Number: EBLU2011-02CMY(C)-Sekiya

Capacity Building of ALOS satellite data to support Mapping and Monitoring Deforestation and Degradation in Indonesia

Ecosystems, Biodiversity, and Land Use

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Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

The highlights of this project are a workshop in Indonesia and a training course in Japan.

We held a workshop on 19 July 2011 in Bogor, Indonesia, inviting Indonesian experts from not only the project collaborators, but also the other ministries, agencies and universities. In this workshop, the participants shared and organized the information on research and capacity building activities related with forest monitoring by remote sensing in Indonesia as well as political and administrative needs from Indonesian government.

Based on the information shared at the workshop, RESTEC planned and conducted the training course on Forest Monitoring in Indonesia by ALOS/PALSAR from 28 May to 7 June, 2012. RESTEC invited 8 trainees by APN fund from the Agency for the Assessment and Application of Technology (BPPT), the Ministry of Forestry Republic Indonesia (MoF) and Landak Regency (West Kalimantan province) for this training course. 2 weeks training was successfully completed and 8 Indonesian GIS/RS experts learned the basic and essential knowledge and techniques in order to utilize radar satellite data for forest monitoring. With these knowledge and techniques, they can advance their researches and operational forest monitoring in Indonesia more efficiently than ever.

Keywords

Satellite, ALOS, PALSAR, Forest, REDD+, Indonesia, Biomass, Carbon, MRV

Objectives

The main objectives of the project were:

1. To improve Indonesia's capability of forest monitoring, transferring Japanese technologies and knowledge of analyzing satellite data particularly ALOS/PALSAR.
2. To contribute the decision making in the area of forestry and carbon emission in Indonesia

Amount received and number years supported

The Grant awarded to this project was:
US$ 23,000 for Year 1
US$ 35,000 for Year 2

Activity undertaken

A workshop in Indonesia in Year 1 and a training course in Japan in Year 2 were held through this project. In addition, the related research, coordination and discussion were undertaken.

Results

The workshop in Indonesia gathered 36 participants and shared important information and requirements form Indonesia. The training course in Japan welcomed 8 Indonesian GIS/RS experts and provided basic knowledge and techniques for them.

Relevance to the APN Goals, Science Agenda and to Policy Processes

Through this project, 8 Indonesian GIS/RS experts obtained the basic skills to process and analyze ALOS/OALSAR data to provide policy makers with information on forest derived from satellite data for their decision making. These are related to the APN goals, in particular Goal 2 and Goal 3 as well as the objective of CAPaBLE. In addition, this project developed the trainees' capacities for

conducting practical training by them. The trained Indonesian experts can continuously conduct the practical training for other experts in Indonesia. This also corresponds to the strategies of APN CAPaBLE.

As for the policy aspect, involving Indonesian ministry and agency as project collaborator, this project directly meets the requirement of decision makers. We conducted a workshop in Indonesia before the training to grasps the requirement from administration side as well as universities and institutes. Furthermore, the training contained a knowledge and technique to analyze information on forest and biomass through satellite data, which met the needs from policy makers stated above and contribute to the international process to reduce carbon emission such as UNFCCC.

Self evaluation

In the first year, the workshop gathered 36 participants and shared important information about forest monitoring techniques and activities in Indonesia. This workshop also clarified Indonesian requirements to satellite remote sensing techniques. Based on the information, a training course was organized by RESTEC and 8 Indonesian GIS/RS experts joined. They were satisfied with the contents of training and learned important knowledge and techniques for forest monitoring by the Synthetic Aperture Radar (SAR) sensor.

This project helped Indonesia build capacity to monitor forest by SAR which is very powerful tool to monitor cloudy country like Indonesia. The trainees obtained enough knowledge and skills to handle Radar data and they are expected to assimilate, improve and expand their experience to other scientists in Indonesia.

Therefore, this 2 year project was very successful.

Potential for further work

More validation activities are necessary to improve the accuracy of analysis for administration (including local government) in Indonesia to use satellite – particularly SAR data – for their objectives.

Publications (please write the complete citation)

The output of this project was introduced at the international symposium and conference by project members (by their own funds). The paper titles and symposium / conference are as below.

"An Attempt to Measure Forest Biomass Using ALOS-PALSAR"
The 34th International Symposium on Remote Sensing of Environment (ISRSE)
April 2011, in Sydney, Australia

"Utilization of ALOS Satellite Data to Support Mapping and Monitoring Deforestation and Degradation in Indonesia"
The 32nd Asian Conference on Remote Sensing (ACRS)
October 2011, in Taipei, Taiwan

"Utilization of ALOS Satellite Data to Support Mapping and Monitoring Deforestation and Degradation in Indonesia (Japanese Only)"
The 37th Remote Sensing Symposium
October 2011, in Tokyo, Japan

Acknowledgments

We would like to thank to APN for its strong financial support, Dr. Shimada of JAXA to present their forest monitoring activities and their state of the art technologies. We would also like to thank to all participants to our workshop for sharing their important information.

TECHNICAL REPORT

Preface

The objectives of this project were to improve Indonesia's capability of forest monitoring by analyzing satellite data particularly ALOS/PALSAR, and to contribute the decision making in the area of forestry and carbon emission in Indonesia. We held a workshop in Indonesia to share the information and needs of forest monitoring in the first year, then second year, we conducted a training course in Japan according to the result of workshop. Unfortunately, ALOS completed its operation already, but the knowledge and skills which Indonesia obtained through this project would be very useful for next ALOS-2 satellite to be launched in 2013.

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1.0 Introduction

Since 1990's forest monitoring by the use of remote sensing in Indonesia has been carried out using Landsat images (optical images). Cloud cover is considered to be the main obstacle to get consistent images that cover the whole area of the country, resulting in about ten percent of which is always cloud covered. This situation is in contrast with the increasing need for obtaining more rapid, reliable, and consistent information of the current status of land use and land cover as well as their dynamic changes over time.

Radar data that have capacity to penetrate cloud is essential to overcome cloud problem. Integrating data from the Phased Array type L-band Synthetic Aperture Radar (PALSAR) on the Advanced Land Observing Satellite (ALOS) in the current forest monitoring system would provide cloud free results. In addition to the capability of providing cloud free information, ALOS/PALSAR data, specifically dual polarimetric data also has potential to discriminate forest cover types and other major land covers. This implies that establishment of an improved – new – reliable methods dedicated for the current forest monitoring system as well as for change detection and monitoring deforestation and degradation using of ALOS/PALSAR data is promising.

Unfortunately, we could not use new observation data from ALOS satellite in this project because ALOS completed its observation in May 2011 at the beginning of the project. However, the Japan Aerospace Exploration Agency (JAXA) has a plan to launch ALOS-2 satellite which will carry more advanced radar sensor in 2013 and we could use a large volume of ALOS archive data. Therefore, we arranged the training curriculum to prepare to use ALOS-2 data by using the ALOS archive data.

2.0 Methodology

2.1. Workshop on Forest Monitoring Needs by Satellite

We held a workshop on 19 July 2011 in Bogor, Indonesia, inviting Indonesian experts from not only the project collaborators, but also the other ministries, agencies and universities such as the National Institute of Aeronautics and Space (LAPAN), Bogor Institute of Agriculture (IPB), Gadjah Mada University (UGM), Bandung Institute of Technology (ITB), University of Indonesia (UI), the National Survey and Mapping Agency (Bakosurtanal), the Ministry of Agriculture and the Ministry of Environment.

The workshop agenda, participant list and presentation materials are attached to this report. In this workshop, the participants shared and organized the information on research and capacity building activities related with forest monitoring by remote sensing in Indonesia as well as political and administrative needs from Indonesian government. On the other hand, RESTEC introduced the latest satellite technologies and successful examples of forest monitoring as well as Japan's future satellite development and launch plan.

The main discussions and outputs at the workshop are as below.

- There some forest monitoring projects using ALOS/PALSAR data are ongoing (e.g. The Project for the Support on Forest Resources Management through Leveraging Satellite Image Information funded by JICA). Some GIS/RS experts in Indonesia have good techniques and experiences. This APN project should collaborate with these existing projects as far as possible.
- Techniques to analyze data from the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) on ALOS is also useful and should be incorporated in the upcoming training in Japan since the Indonesian experts are very interested in the classification map generated from AVNIR-2 data which was shown by RESTEC at the workshop.
- Indonesia has a strong interest in the JICA funded project in Brazil implemented by RESTEC which has been achieving great successes since 2009. RESTEC will adopt the technologies and lessons learned in the Brazil project as far as possible.
- The Ministry of Forestry mentioned that it would be very challenging to estimate forest biomass directly from the Normalized Radar Cross Section (NRCS) of PALSAR because of high density of forest in Indonesia. In this project, we will put more emphasis on forest / non-forest classification to estimate forest biomass than direct estimation from NRCS.
- The polarization is one of key factors to classify forest when ALOS-2 is launched. Therefore, the upcoming training should include a lecture of the polarization theory and hands-on training for polarization data. On the other hand, the training should cover basic theory and techniques for better understandings.

2.2. Data collection (in situ and satellite data)

We have had a plan to use in situ data provided by the Ministry of Forestry in order to verify the classification map and biomass estimation derived from ALOS/PALSAR data since the Ministry of Forestry has collected a large amount of in situ data through their branches, but the in situ data was not provided for RESTEC due to Indonesian internal conditions of data transfer and sharing. Thus, we used optical satellite data such as AVNIR-2 and the publicly available data instead of in situ data.

On the other hand, we have selected and obtained 18 scenes of ALOS data observing Borneo Island for the purposes of research and training. This data set includes the followings.

- 6 scenes of Fine Beam Dual-Polarization (FBD) data
- 2 scenes of Full Polarimetry (PLR) data
- 2 scenes of ScanSAR data
- 4 scenes of the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) data
- 4 scenes of AVNIR-2 data

PALSAR FBD data contains HH polarization and HV polarization. Both two polarizations are very useful to detect forest areas because there is a trend that HH reflects at tree canopy and HV reflects at tree trunk through leaves and branches. Therefore, FBD data is used as main data to generate forest / non-forest classification map.

PALSAR PLR data contains HH, HV, VV and VH polarizations. This is the experimental mode of ALOS/PALSAR and thus not much data is obtained during ALOS operation period. However, PLR data has a possibility to improve the accuracy of classification and detection of deforestation and degradation areas. In addition, ALOS-2 which will be launched in 2013 is expected to increase more observation capacity for PLR.

ScanSAR data contains only HH polarization and ground resolution is only 100m but the width is 350km and a very large area can be covered by solo scene. Although the accuracy would be decreased, ScanSAR can be used for more frequent monitoring as Indonesia has very large forest areas. BPPT and the Ministry of Forestry recognized the importance to monitor forest in both regional level and national level and the combination of FBD and ScanSAR data would satisfy their needs.

Both PRISM and AVNIR-2 are optical sensors on ALOS. PRISM provides black and white 2.5m ground resolution images while AVNIR-2 provides color 10m ground resolution images. Both data was used as reference map.

Target areas are some parts of Kalimantan and Sumatra Islands and we collected time series of PALSAR FBD data from 2006 to 2010 in order to detect deforestation areas.

2.3. Development of Method of Monitoring Forest in Indonesia

RESTEC developed a basic method of forest monitoring by PALSAR data customizing RESTEC's existing techniques, experiences and algorithm which were mainly done focusing domestic forest areas in Japan. The existing techniques need to be customized and adjusted to Indonesian forest because forest type in Japan is very different.

Figure 1 is a color composite image analyzed from PALSAR FBD data observing a forest area in Indonesia on 4 October 2008. FBD contains HH and HV polarizations. We placed red color on HH, green on HV and blue on HH. The original PALSAR image is black and white but forest areas are shown as light green in the color composite image.

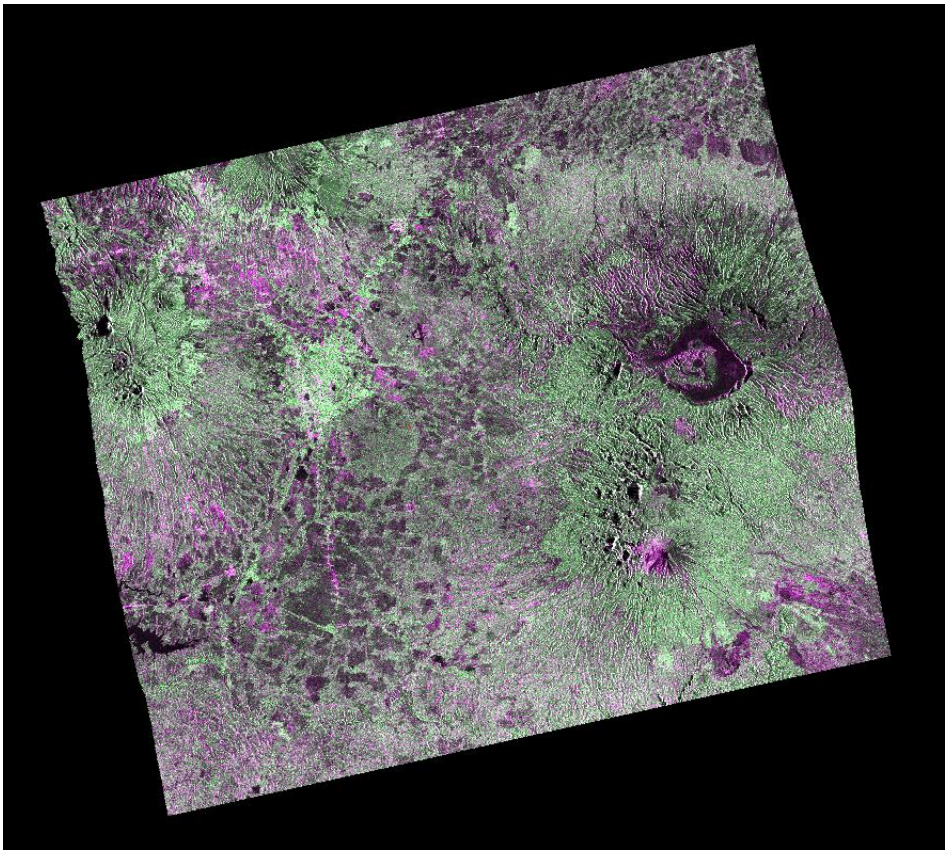

Fig 1 PALSAR FBD color composite image on 4 Oct 2008

Figure 2 is the forest / non-forest map derived from figure 1. We calculated the intensity of backscatter pixel by pixel, and settled the threshold as -13db in order to classify forest / non-forest. In the existing methodology which we conducted in forest areas in Japan, we settled the threshold as -11.5db, but we customized the method and changed its threshold because Indonesian forest types are very different. In this image, green area is shown as forest and yellow area is shown as non-forest.

We have generated the forest / non-forest map from PALSAR data observed on 25 Feb 2011 as well. Then, we compared these forest / non-forest maps and detected deforestation areas. Figure 3 shows the original PALSAR images on 4 Oct 2008 and 25 Feb 2011, and a classification map with the categories of forest (green), non-forest (yellow) and deforestation area (red). In the center of each image, we can recognize a deforestation area. A light gray area in 2008 turned to dark gray in the red box which means forest area tuned to non-forest area.

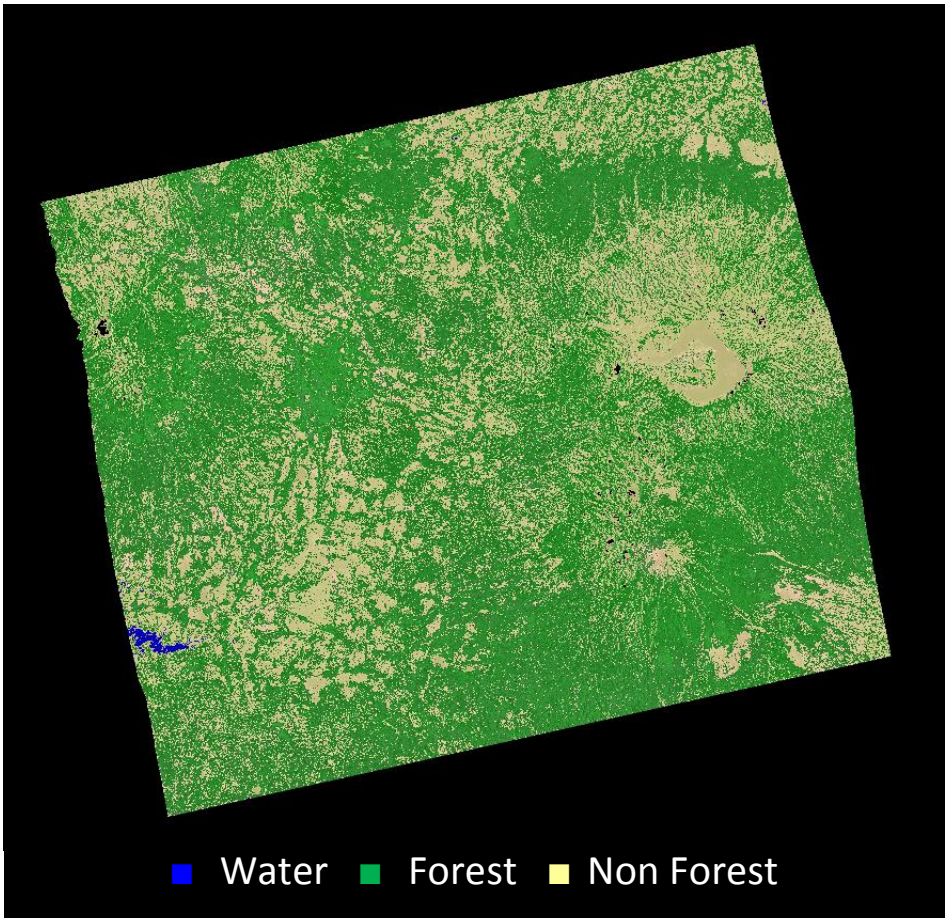

Fig 2 Forest / non-forest map derived from PALSAR FBD data on 4 Oct 2008

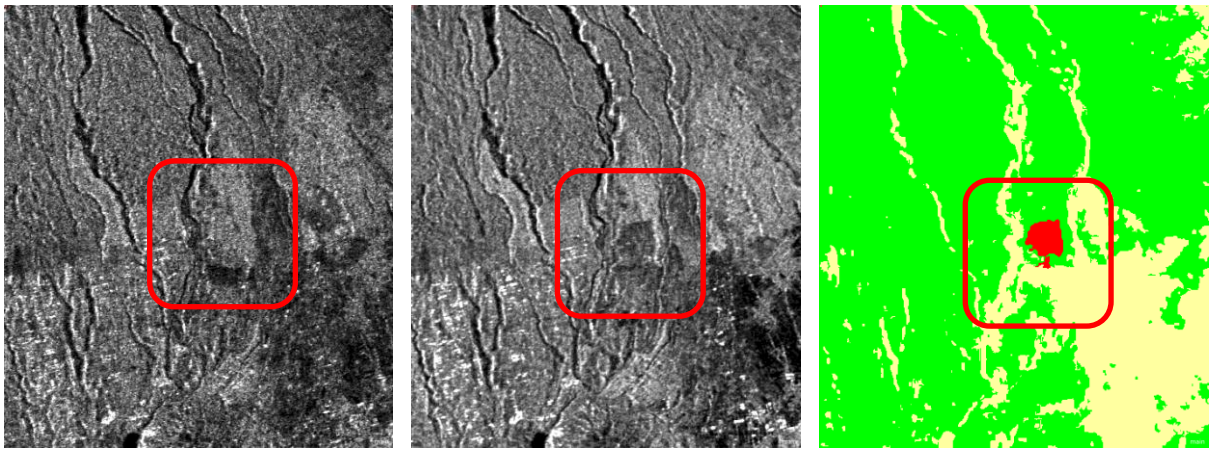

Fig 3 Deforestation area from 2008 to 2011
(left: original PALSAR data dated on 4 Oct 2008, middle: 25 Feb 2011, right: classification map)

2.4. Training Preparation

We selected 8 Indonesian GIS/RS experts who would attend the training (see table 1).They are from the Ministry of Forestry Republic of Indonesia (MoF), the Agency for the Assessment and Application of Technology (BPPT) and the local government of Landak Regency (West Kalimantan Province).

#	Organization	Name
1	MoF	Mr. Saipul Rahman
2	MoF	Ms. Destiana Kadarsih
3	BPPT	Dr. Agus Kristijono
4	BPPT	Dr. Agustan
5	BPPT	Mr. Nana Sudiana
6	BPPT	Ms. DaMayanti Sarodja
7	BPPT	Mr. Akhmadi Puguh Raharjo
8	Landak Regency	Mr. Yohanes Rahmad

Table 1 Participants of the training

The date of training course was set up as from 28 May 2012 to 7 June 2012. RESTEC arranged training rooms, equipment (PC, projector, screen, software, etc.), and round air tickets, transportations in Japan and accommodations for the trainees by the fund from APN. Daily Subsistence Allowance (DSA) was also paid for each trainee during their stay in Japan according to the APN 2011 financial regulation.

On the other hand, RESTEC selected Dr. Nobuhiro Tomiyama as a main lecturer of this training course, Mr. Makoto Ono as a supervisor and the some young scientists as supporters. We also asked Dr. Masanobu Shimada of JAXA to present state of the art technologies of satellites and Radar sensors.

2.5. Training Curriculum and Tools

The most the GIS/RS experts in Indonesia are familiar with optical satellite data, but some of them are not familiar with radar data. Therefore, RESTEC developed a training curriculum including a fundamental part of radar data. The training period was about 2 weeks and contained the following components. The complete curriculum is attached to this report as an appendix.

- Basic Theory of SAR Data (Lecture)
- PALSAR Data Handling (Lecture & Hands-on)
- Interferometry (Lecture & Hands-on)
- Polarimetry (Lecture & Hands-on)
- Generating Classification Map (Lecture & Hands-on)
- Detecting Deforestation Area (Lecture & Hands-on)
- Biomass Estimation (Lecture & Hands-on)

Regarding the tools to process and analyze PALSAR data in the training, RESTEC prepared the following software.

- PALSAR Fringe version 5.2.0
- PALSAR Processor version 2.8.0
- Phase Unwrap version 1.1.6
- MapReady version 3.0.6
- PolSARpro version 4.2.0

“PALSAR Fringe”, “PALSAR Processor” and “Phase Unwrap” were developed by RESTEC and these

were distributed to the trainees free of charge. “MapReady” was developed by the Alaska Satellite Facility (ASF) and “PolSARpro” was developed by the European Space Agency (ESA) which can be downloaded from their websites free of charge. As the trainees are expected to train other experts back to Indonesia, free software is the most important. Without these tools, they can’t process and analyze data nor conduct another hands-on training in Indonesia.

2.6. Training Implementation

The training was begun on 28 May 2012, on the day the trainees arrived in Japan. An opening ceremony was held on the afternoon of Day 1 to welcome Indonesian trainees and introduce overall training activities. Full training sessions were begun on Day 2 (29 May) with lectures of “Overview of Remote Sensing”, “Basic Theory of SAR” and “Introduction of ALOS PALSAR”. Trainees have basic knowledge and experience of satellite remote sensing. However, to understand radar remote sensing correctly, and to meet the requirement from the trainees, these basic lectures were very important. After taking “Geometric & Radiometric Features of SAR” lecture, they learned how to handle radar data including ortho-rectification and slope correction which are very important to use or overlay SAR images on GIS.

We moved to JAXA Tsukuba Space Center on Day 4 (31 May) to take a lecture from Dr. Shimada of JAXA. He introduced variety of products and research results derived from ALOS’s 3 sensors on board – PALSAR, AVNIR-2 and PRISM. One of the products which Indonesian participants had a strong interest in was L and use classification map over Riau province, Sumatra Island. JAXA team classified 10 categories from PALSAR FBD data. Its accuracy is under validation but the accuracy of their forest / non-forest map was 87.9%, he mentioned.

He also introduced ALOS-2 satellite to be launched in 2013 (see figure 4 below). Its ground resolution will be improved from 10 meter of the existing ALOS/PALSAR to 3 meter at highest while the swath will be still 50km or 70km and its ScanSAR observation mode will provide 100 meter ground resolution and 490km swath data for users.

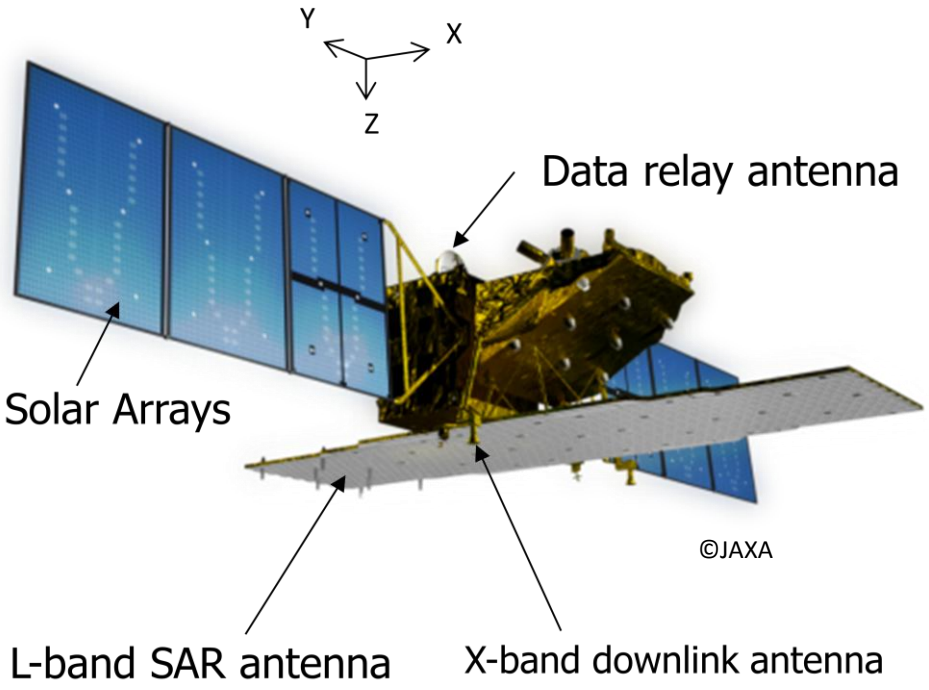

Fig 4 ALOS-2

In addition, the members participated in a facility tour of JAXA space center which showed 1/1 scale of ALOS satellite imitation model. This experience provided them with a deep understanding of satellite remote sensing.

On Day 5 (1 June), trainees learned Interferometric SAR (InSAR) and Differential InSAR (DInSAR) through lecture and hands-on training. SAR Interferometry is one of the analyses using phase information of SAR data or technology for analyzing interference of phase information of twe or more pairs of SAR data. This is also a powerful technique to extract surface height and surface movement. There are some conditions to apply InSAR technique. For example, pairs of data to be used should have same observation parameter, or should contain phase information – PALSAR level 1.5 data is not adequate. The trainees understood the theory and conditions well and successfully generated InSAR and DinSAR images from original PALSAR level 1.0 data (see figure 5 below).

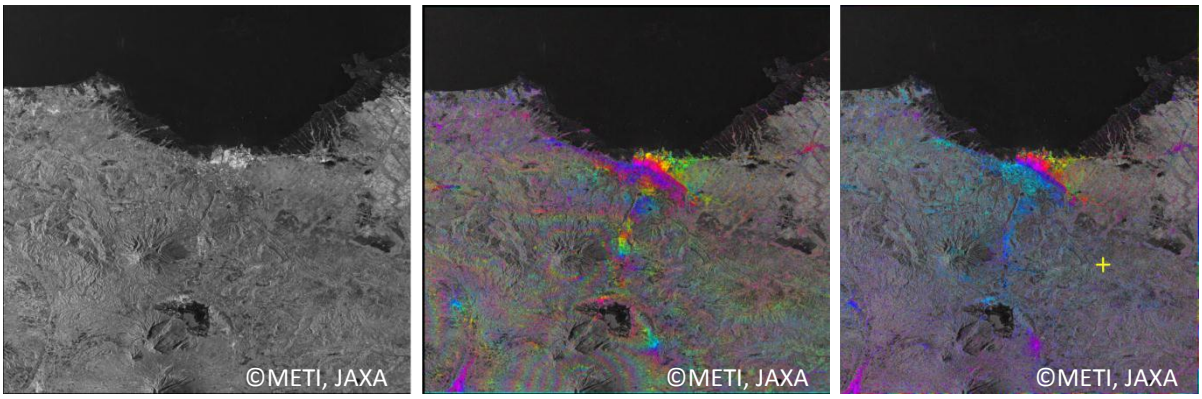

Fig 5 Generation of DInSAR image
(left: original PALSAR Intensity Image, middle: DInSAR – before removing topographic fringe, right: Result of DInSAR)

By this technique, changes of surface condition can be detected. It means that deforestation and degradation areas can be also detected. Left side of figure 6 shows DInSAR image. In the DInSAR image, some dark red areas – which are possibly logged areas – along the river (black areas) can be found. On the other hand, right image is the multi temporal analysis image – which is to be described later) of the same place and dark gray areas correspond to red areas of DInSAR image. The participants from Indonesia understood this technique through the training.

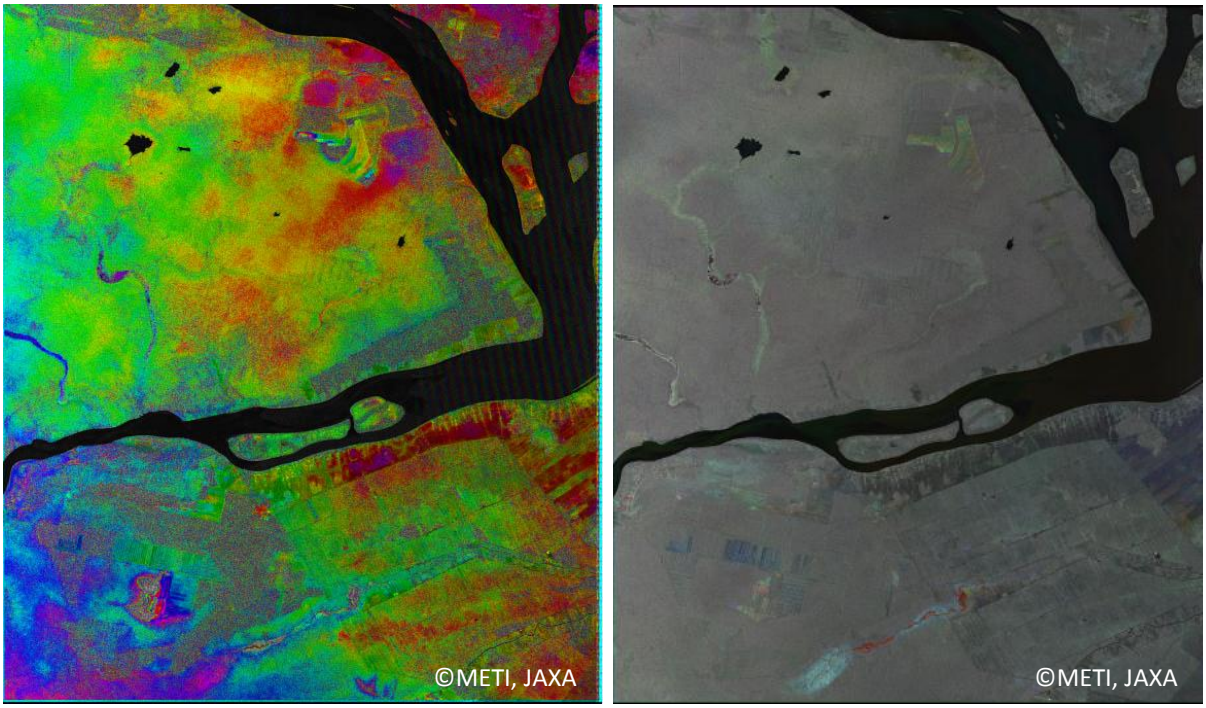

Fig 6 Comparison of DInSAR image and multi temporal analysis image
(left: DInSAR image, right: multi temporal analysis image)

On Day 6 (4 June), trainees learned about SAR Polarimetry which is very important to classify forest and non-forest because intensity of each polarization differs according to the surface or conditions of forest. ALOS/PALSAR full polarization observation (PLR) mode can detect the following 4 pairs of polarizations.

- transmitting Horizontal polarization and receiving Horizontal polarization (HH)
- transmitting Horizontal polarization and receiving Vertical polarization (HV)
- transmitting Vertical polarization and receiving Vertical polarization (VV)
- transmitting Vertical polarization and receiving Horizontal polarization (VH)

Normally, PALSAR uses only 1 or 2 pairs of polarization to observe – Fine Beam Single (FBS) mode using HH polarization and Fine Beam Dual (FBD) mode using HH and HV polarization because more pairs of polarizations decrease ground resolution and observation swath. FBS provides the highest – 10 meters – ground resolution data, but single polarization is not enough to classify forest and non-forest. Therefore, we selected FBD data which contains both HH and HV polarizations and generated forest / non-forest map covering a part of Sumatra Island. Figure 7 shows HH and HV polarization images. Right image look brighter than left as HV polarization has strong intensity on forest area. In other words, bright areas correspond to forest and dark areas correspond to non-forest. Inside red boxes on the images, gray areas are estimated logged areas and right HV image can tell us clear distinction.

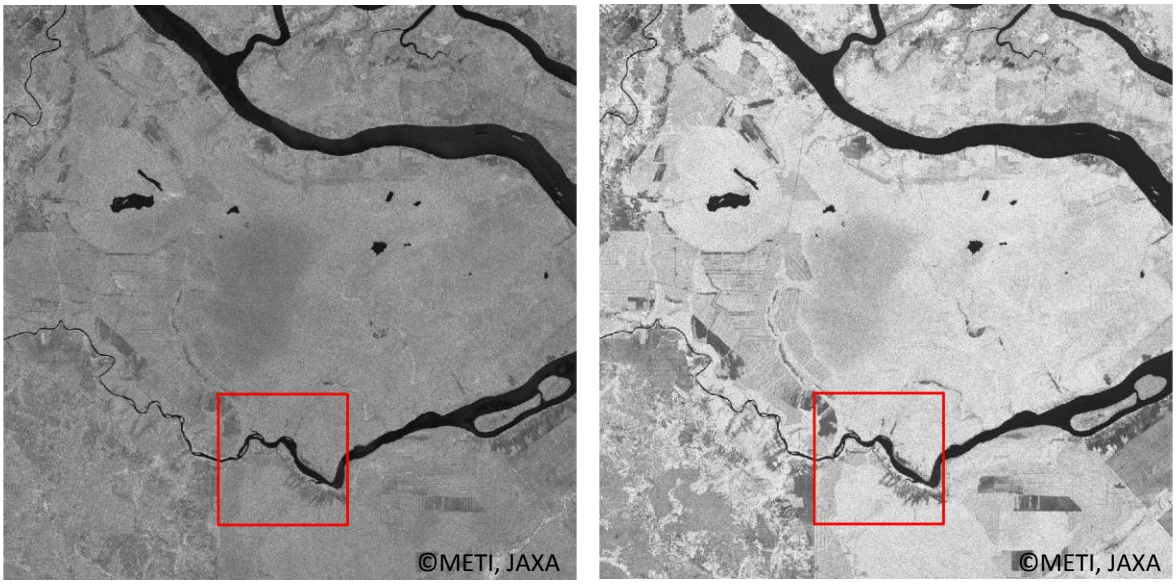

Fig 7 Comparison of HH and HV Polarization Images
(left: HH polarization Image, right: HV Polarization Image)

The trainees understood the features of polarizations and generated a color composite image from different polarization images as a next step. Left image of figure 8 shows the color composite image derived from figure 7 images. The trainees placed Red on HH image, Green on HV image and Blue on HH/HV ratio to generate this image. Forest areas look light green and water areas look dark blue on the image by which we could easily and visually understand where vegetation is. By setting up a threshold of intensity of the color composite image, a forest / non-forest map can be generated (right image of figure 8). All Indonesian participants understood and obtained a series of techniques to generate color composite images and forest / non-forest map. They are expected to teach the techniques to the other experts in Indonesia and generate more forest / non-forest maps to cover wider areas.

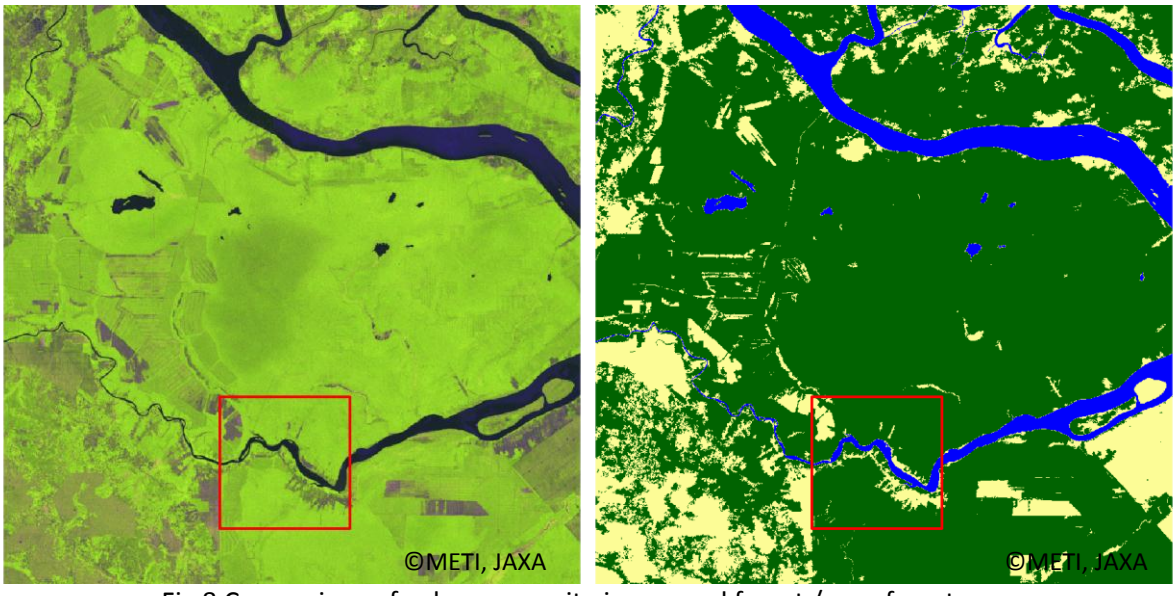

Fig 8 Comparison of color composite image and forest / non-forest map
(left: color composite image, right: forest / non-forest map)

However, the map needs to be validated and demonstrated before the administration uses it and there are at least 2 major issues for validation as below.

- ALOS completed its operation in May 2011 and we can't obtain new observation data until ALOS-2 will be launched in 2013 and finished its calibration. That means we have to validate old data even we generate forest / non-forest maps. But the surface or condition of some forests have been changed already since 2011.
- Territory of Indonesia is too large and contains many islands and types of forestry differ in each main island. We have to select target areas in main islands respectively, but it still needs a lot of resources and time to conduct enough validation. How to coordinate an efficient validation and assure necessary resources are key issues.

When validation is conducted, the forest / non-forest map is to be adjusted according to the validation result in order to improve accuracy. This step is very important and should be repeated. The accuracy of PALSAR forest / non-forest map over Riau province developed by JAXA is 87.9%, but there is no guarantee that same parameter or algorithm can be applied to the other areas because forest type or density is different in each area.

On Day 7 and 8 (5 and 6 June), our target was moved to detect deforestation and degradation areas by using multi temporal sets of SAR data. Satellite can observe a certain area over and over again – in particular Radar sensor is not affected by weather condition. This is one of advantages of satellite remote sensing and a periodical observation is very important to MRV for REDD+.

Figure 9 contains 4 temporal time series of PALSAR data from 22 June 2007 to 12 August 2009. Gray color means forest area and dark gray or black means non-forest area. These images can tell us that a certain number of trees were cut and deforestation expanded during 2 years. In order to estimate how large areas were logged and visually or clearly show the logged areas with solo image, multi temporal analysis is a good technique. By combining multiple temporal data sets, the participants learned how to generate multi temporal image shown as figure 6 (right).

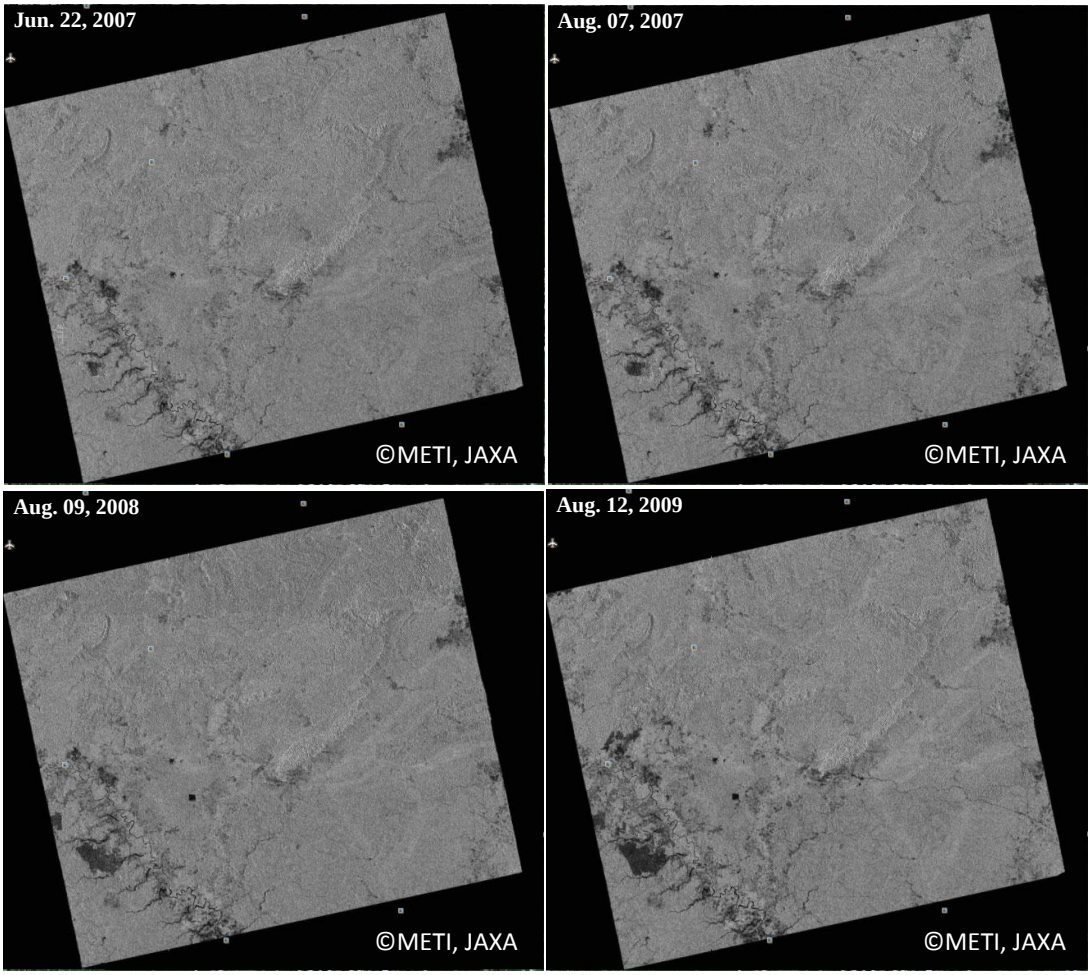

Fig 9 Time series of PALSAR data from 22 June 2007 to 12 August 2009

On Day 9 (7 June), the trainees learned a method to estimate Above Ground Biomass (AGB) directly from Radar backscattering or Sigma0. After applying radiometric terrain correction, they calculated the relationship between Sigma0 and AGB. Some researches mention that Radar backscattering is saturated around 100t/ha of AGB. Therefore, they understood that this technique is possibly applied only in low biomass areas in Indonesia such as plantations with young trees.

This 2 weeks training provided Indonesian trainees with Japanese state of the art technology to monitor forestry by satellite particularly Radar sensor such as ALOS/PALSAR. Radar sensors can obtain the information on surface for sure without any effect of whether condition. However, it is difficult to handle Radar data compared to optical one and it of course has limitations. To utilize this technology adequately, validation and understanding its accuracy are very important. We tried to utilize ground truth data collected by MoF in Indonesia, but the valuable data could not be used for this project according to data policy of Indonesia. Nevertheless, without validation, we can't tell how much Radar images are correct.

Figure 10 shows a comparison of Radar image and optical image – the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) on ALOS satellite. AVNIR-2 has 4 channels – Red, Green, Blue and Near Infrared – and provides 10 meter ground resolution color images. On behalf of validation with ground truth data, we compared to Radar image and optical image through this training. Indonesian participants are expected to conduct validations with ground truth data and improve the accuracy of Radar images.

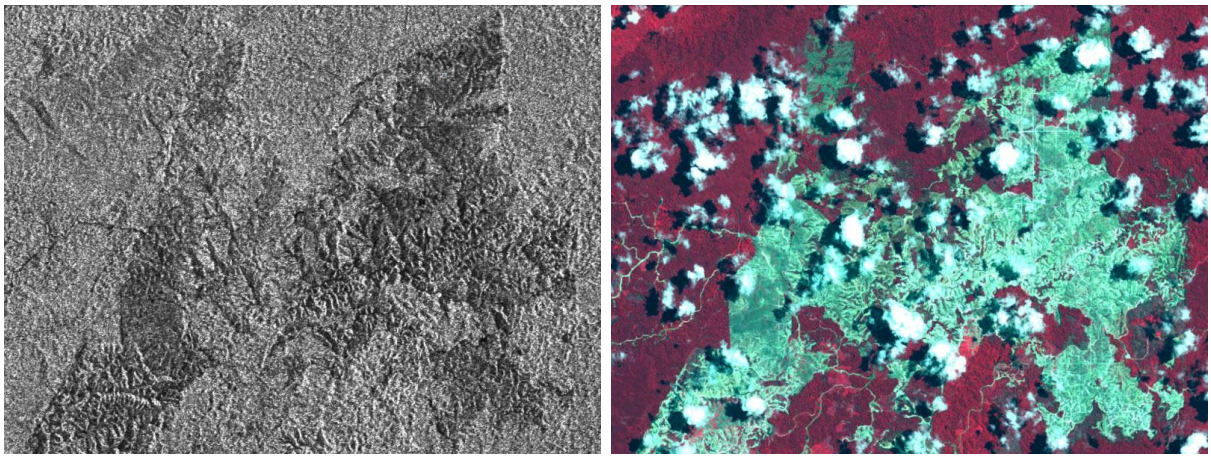

Fig 10 Comparison of Radar image (PALSAR) and Optical Image (AVNIR-2)

3.0 Results & Discussion

2 weeks training was successfully completed and 8 Indonesian GIS/RS experts learned the basic theory of Radar sensor in particular ALOS/PALSAR, Geometric & Radiometric Features of SAR, Interferometric SAR (InSAR) and Differential InSAR (DInSAR), SAR Polarimetry and forest biomass estimation. They also practiced the procedures of PALSAR Level 1.0 and 1.5 data analysis, InSAR analysis, forest area detection by dual polarization, PALSAR Polarimetry analysis, and forest biomass estimation. These are basic and essential knowledge and techniques in order to utilize radar satellite data for forest monitoring. With these knowledge and techniques, they can advance their researches and operational forest monitoring in Indonesia more efficiently than ever.

We all agreed that this training was useful and we should continue this kind of activities to improve Indonesian capacities. Fortunately or unfortunately, there many international forest monitoring activities are going on parallel. As human resource in Indonesia is very limited and satellite data access – including the aspect of finance – is also a big issue, we agreed that current and future forest and remote sensing related projects should be collaborated each other. We have listed the possible projects – past, current and near future – during the training course as below.

<Past and Current Activities>

- JAXA: ALOS Application & Verification Project (2009-2012)
  - ✓ Capacity Building Project using ALOS data consisted of 4 working groups (Vegetation including forestry, Coastal, Volcano, Mapping)
  - ✓ 50 scenes of ALOS data per year per WG were available
- JAXA: ALOS Kyoto & Carbon Initiative Phase 3 (2011-)
  - ✓ Research project. LAPAN, Bakosurtanal and IPB are the members.
  - ✓ 50 scenes of PALSAR data per year per organization are available
- GEO: Forest Carbon Tracking Task (FCT)
  - ✓ International cooperation project to demonstrate the usefulness of satellite data for forest monitoring. More operational project, Global Forest Observations Initiative (GFOI) has also been started.
  - ✓ LAPAN and MoF are the members of GEO-FCT
  - ✓ 50 scenes of PALSAR data and the other satellites data over Kalimantan and Sumatra (so called National Demonstrators or NDs) per year per ND are available.
- JICA: The Project for the Support on Forest Resources Management through Leveraging Satellite Image Information (2008-2011)

- SATREPS (JST&JICA): Wild Fire and Carbon Management in Peat-forest in Indonesia (2009-2014)
  - ✓ Research project led by Hokkaido Univ.
- Australia: Indonesian Carbon Accounting System (INCAS)

<Near Future Activities>

- Pi-SAR-L2 (airborne SAR) campaign in Indonesia
  - ✓ Workshop will be held in July, September and January to discuss how to proceed with its analysis.
  - ✓ Training will be held in November 2012 in Japan (in the framework of K&C initiative).
- JAXA and LAPAN are discussing the next ALOS Application & Verification Project (to be initiated in 2012?).
- SATREPS and APN will call for proposals in summer – autumn time for next year's research projects.
- ALOS-2 Launch in 2013
- ALOS-3 Launch in 2015 (TBD)

Regarding the satellite observation data for forest monitoring, Indonesian government or institutes will obtain or have already obtained a certain volume of SAR data, we have listed the possible data sources as below.

- JAXA ALOS Application & Verification Project (specific areas – e.g. Riau)
- JICA Project (over whole Indonesia)
- GEO-FCT (over Kalimantan and Sumatra)
- PALSAR Global Mosaic (PGM)

However, during the discussions in this training, we agreed that there still was a big gap between the requirements from forest side and capability of satellite in particular radar data. For example, the Ministry of Forestry has periodically generated their land classification map with 23 categories while PALSAR has provided the land classification map with 10 categories so far.

In order to fill the gap above and proceed with the capacity building activities in Indonesia, we have discussed as below.

- The knowledge and techniques in this training are the parts of "pre-processing". The trainees need more research and capacity building activities to make better use of satellite data in particular generating the accurate forest classification map and estimating above ground biomass. Validation with the ground survey data is very important.
- On the other hand, ALOS-2 and ALOS-3 will have more capability and possibility than ALOS-1. ALOS-2 will be launched in 2013 and will carry the advanced PALSAR sensor. For example, ALOS-2 will have both HH and HV polarization even in ScanSAR mode. Therefore, ALOS-2 launch will be one of the most important and nearest mile stone of our activities.
- We need more collaboration with the research arm of the MoF because the main missions of trainees from MoF are operational forest monitoring, and the utilization of SAR data still has research issues.
- Regarding the biomass estimation by backscattering of SAR data, we understand that the backscatter will be saturated when above ground biomass is more than 100t/ha. However,

plantation companies in Indonesia cut down their trees when it is still young. That means the backscatter of SAR data might be able to detect deforestation areas and estimate the change of above ground biomass. We need more research and validation in this field and the collaboration with plantation companies is also very important.

- In order to proceed with the activities above, in addition to APN, a block of funds from donor agencies such as JICA, Asian Development Bank (ADB) and World Bank will be needed. To apply APN again will be discussed later.
- In order to enhance our activities above, the collaboration with existing and upcoming projects will be very important. For example, Marubeni and ITTO project, the Indonesian Carbon Accounting System (INCAS), GEO's FCT and GFOI, JAXA's Post ALOS Application and Verification project and Pi-SAR-L2 campaign, etc. As a part of collaboration with JAXA, some of the trainees should participate in the training which will be held through the JAXA K&C framework in Tokyo in November 2012.

4.0 Conclusions

We held a workshop on 19 July 2011 in Bogor, Indonesia, inviting Indonesian experts from not only the project collaborators, but also the other ministries, agencies and universities such as LAPAN, IPB, UGM, ITB, UI, Bakosurtanal, the Ministry of Agriculture and the Ministry of Environment.

In this workshop, the participants shared and organized the information on research and capacity building activities related with forest monitoring by remote sensing in Indonesia as well as political and administrative needs from Indonesian government. On the other hand, RESTEC introduced the latest satellite technologies and successful examples of forest monitoring as well as Japan's future satellite development and launch plan.

Based on the information shared at the workshop, RESTEC planned and conducted the training course on Forest Monitoring in Indonesia by ALOS/PALSAR from 28 May to 7 June, 2012. RESTEC invited 8 trainees by APN fund from the Agency for the Assessment and Application of Technology (BPPT), the Ministry of Forestry Republic Indonesia (MoF) and Landak Regency (West Kalimantan province) for this training course.

2 weeks training was successfully completed and 8 Indonesian GIS/RS experts learned the basic theory of Radar sensor in particular ALOS/PALSAR, Geometric & Radiometric Features of SAR, Interferometric SAR (InSAR) and Differential InSAR (DInSAR), SAR Polarimetry and forest biomass estimation. They also practiced the procedures of PALSAR Level 1.0 and 1.5 data analysis, InSAR analysis, forest area detection by dual polarization, PALSAR Polarimetry analysis, and forest biomass estimation. These are basic and essential knowledge and techniques in order to utilize radar satellite data for forest monitoring. With these knowledge and techniques, they can advance their researches and operational forest monitoring more efficiently than ever.

We all agreed that this training was useful and we should continue this kind of activities to improve Indonesian capacities. Fortunately or unfortunately, there many international forest monitoring activities are going on parallel. As human resource in Indonesia is very limited and satellite data access – including the aspect of finance – is also a big issue, we agreed that current and future forest and remote sensing related projects should be collaborated each other.

5.0 Future Directions

Unfortunately, ALOS completed its operation at the beginning of this project. That meant we had to modify our capacity building plan as we couldn't obtain new observation data from ALOS. However,

because of that, we focused on new satellite “ALOS-2” to be launched in 2013 and had good preparation with old ALOS archive data. ALOS-2 will have more capability and possibility than ALOS and its observation data will provide more information to monitor forestry. We have some more barriers and issues to use ALOS-2 data in operational for MRV for REDD+. For example, validation is essential and ground truth data will be needed for that. Apart from data analysis, transmission of observation data will be a big issue (the volume of data will be absolutely larger than ALOS) as well. Powerful computers are also necessary to process and analyze a large amount of data.

We agreed that we should continue capacity building activities to prepare human resource, equipment, and the other environment to use ALOS-2 data. As this final report described above, the project provided Indonesian GIS/RS experts with basic knowledge and technique for ALOS-2. They are expected to assimilate, improve and expand their experience to other scientists in Indonesia and develop teams to use ALOS-2 data for forest monitoring.

Appendix 1: Workshop Agenda

The 1st Workshop Agenda on
"Utilization of ALOS satellite data to support Mapping and Monitoring Deforestation and Degradation in Indonesia"
IPB International Convention Center – BOGOR, 19 July 2011

Time	Activities	Speaker
08.00 – 08.30	Registration and Coffee morning	Secretariat / Committee
08.30 – 08.40	Opening Remarks 1. Head of PTLWB – BPPT 2. RESTEC	1. I. Justanto, MSCE, (BPPT) 2. T. Sekiya (RESTEC)
08.40 – 08.45	Self Introduction	All
08.45 – 08.55	Meeting Objectives	M. Kamei (RESTEC)
08.55 – 09.15	GEO-CFP Project Overview	Dr. A. Kristijono (BPPT)
09.15 – 09.35	GEO-CFP status and scope of APN project	M. Kamei (RESTEC)
09.35 – 09.50	ALOS and ALOS-2 status	N. Tomiyama (RESTEC)
09.50 – 10.20	Techniques for forest and biomass monitoring by ALOS/PALSAR	T. Ogawa (RESTEC)
10.20 – 10.35	Potential ALOS/PALSAR training in Japan	N. Tomiyama (RESTEC)
10.35 – 10.55	Coffee break	
10.55 – 11.15	MoF Presentation (National Forest Resour-ces Mapping and Monitoring-Deforestation and Carbon Estimation in Indonesia)	Dr. Ruandha Agung Sugardiman (MoF)
11.15 – 11.35	LAPAN Presentation (Wall to Wall Forest Carbon Mapping)	Dr. *Orbita* Roswintiarti (LAPAN)
11.35 – 11.55	IPB Presentation (The Use of ALOS PALSAR for Vegetation Mapping)	Prof. MA Raimadoya (IPB)
11.55 – 12.15	PUSLITTANAK Presentation (The use of Remote Sensing and ALOS Palsar for Peatland Mapping)	Dr. Muhrizal Sarwani (MoA)
12.15 – 12.35	BPPT Presentation (Preliminary Results of Peat Dome's Hydro-topography Detection using ALOS PALSAR)	Dr. Agustan (BPPT)
12.35 – 13.15	Discussion	
13.15	Adjourn	

Appendix 2: Workshop Participants List

Organization	#	Name
RESTEC	1	T. Sekiya
	2	M. Kamei
	3	N. Tomiyama
	4	T. Ogawa
	5	M. Kikura
JICA	6	S. Ono
Ministry of Forestry	7	Dr.Ir. Tachrir Fathoni, M.Sc
	8	Ir. Trijoko Mulyono
	9	Ir.Yuyu Rahayu
	10	Dr. Ir. Ruandha Agung Sugardiman
	11	Ir. Iman Santosa
	12	Saipul Rahman
	13	Muhammad Yazid
	14	Luluk N
Agency for The Assessment and Application of Technology (BPPT)	15	Dr. Ir. Agus Kristijono
	16	Ir. Isman Justanto
	17	Dr. Ir. Muhamad Sadly
	18	Dr. Agustan
	19	Ir. Nana Sudiana
	20	Damayanti Sarodja
	21	Dian Nuraini Melati
	22	Marina Frederik
LAPAN	23	Dr. Orbita Roswintiarti
	24	Dr. Ir. Katmoko Ari Sambodo
	25	Drs. Kustiyo
Bogor Institute of Agriculture (IPB)	26	Ir. Machmud Arifin Raimadoya
	27	Dr. Ir. M. Buce Saleh Wirakartakusumah
	28	Prof. Supiandi Sabiham
Gadjah Mada University (UGM) (From Yogjakarta)	29	Dr. Wahyu Wardana
University of Indonesia (UI)	30	Dr. Rokhmatuloh
Bakosurtanal	31	Drs. Adi Rusmanto
	32	Dr. Priyadi Kardono
	33	Jaka Suryanto
Ministry of Agriculture	34	Dr. Ir. Muhrizal Sarwani
	35	Dr. Wahyunto
Ministry of Environment	36	Ir. Hermono Sigit

Appendix 3: Training Curriculum

Training Schedule and Curriculum

Main Lecturer: Dr. Nobuhiro Tomiyama

	Day 1 (28 May)	Day 2 (29 May)	Day 3 (30 May)	Day 4 (31 May)	Day 5 (01 June)	Day off (02 June)	Day off (03 June)	Day 6 (04 June)	Day 7 (05 June)	Day 8 (06 June)	Day 9 (07 June)
	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu
9:30–10:45		Overview of remote sensing	Geometric & Radiometric Features os SAR	Move to JAXA	Interferometry			Polarimetry	Summary of SAR Data Analysis for Forestry	Classification with Multi-temporal SAR Images	Biomass Estimation
	Tea Break										
11:00–12:15		Basic Theory of SAR	Orthorectification of SAR Image	Move to JAXA	Coherence analysis			Basic Polarimetric Analysis	Comparison of SAR and OPS images in Forest region	Classification with Multi-temporal SAR Images and Coherence	Validation of Biomass Estimation
	Lunch Break				Lunch Meeting*			Lunch Break			
13:15–14:45	Opening Ceremony (14:00–15:00)	Introduction of ALOS PALSAR	Slope Correction of SAR Image	13:00–14:30 JAXA/EORC Lecture (**Dr. Shimada**)	Interferogram and Differential Interferogram(1)			Classification with Polarimetry(1)	Forest Area Detection by Dual Polarization Data (HH/HV) **Lecturer: T. Itoh**	Detecting Deforestration with Intensity Image	Review of Training Course
	Tea Break										
15:00–16:30		SAR Image Processing	SAR Image Interpretation	15:00–16:30 JAXA/TKSC Facility Tour **Passport Required**	Interferogram and Differential Interferogram(2)			Classification with Polarimetry(1)	Discussion for Future Activities	Detecting Deforestration with Coherence Analysis	Closing Ceremony
		Dinner Meeting (16:45–18:00)									

Lecture
Hands-On Training
Others

* Lunch Meeting (@meeting room) with RESTEC Executive Director, Mr. Kaname Ikeda (and T.Sekiya, N.Tomiyama, T.Sagawa, S.Ito, M.Kamei)

Appendix 4: List of Young Scientists

1. Dr. Nobuhiro Tomiyama, RESTEC, Japan, tomiyama@restec.or.jp
   As a main lecturer of this project, he developed a curriculum and conducted the training course. His main research area was agriculture but this great experience through the project provided him with broaden research areas.

2. Dr. Tatsuyuki Sagawa, RESTEC, Japan, sagawa_tatsuyuki@restec.or.jp
   He supported this project as one of sub lecturers. His main research area is seaweed bed, or marine forest. This was first time for him to support remote sensing training course for 2 weeks and enjoyed this experience with Indonesian friends.

3. Mr. Takuya Itoh, RESTEC, Japan, itoh_takuya@restec.or.jp
   His background is forestry and has supported JAXA's forest research projects. He had 1 session at the training to introduce how Japan, JAXA and RESTEC used satellite data particularly ALOS/PALSAR data in the area of forestry.

4. Mr. Takashi Ogawa, RESTEC, Japan, ogawa_takashi@restec.or.jp
   His background is forestry. Unfortunately he could not join the training course but he participated in the workshop in year 1 and presented the information about forest monitoring activities and techniques by satellite.

5. Mr. Saipul Rahman, the Ministry of Forestry, Indonesia, saipul.rahman@gmail.com
   He coordinated this training from Indonesian side and provided current and useful information about forest monitoring activities in Indonesia.

6. Dr. Agustan, BPPT, Indonesia, uttank@gmail.com
   He coordinated this training from Indonesian side. With his experience and knowledge as an expert of GIS/RS, he contributed to design the workshop and training course.

Appendix 5: Glossary of Terms

ALOS	Advanced Land Observing Satellite
ASF	Alaska Satellite Facility
AVNIR-2	Advanced Visible and Near Infrared Radiometer type 2
DInSAR	Differential InSAR
ESA	European Space Agency
FBD	Fine Beam Dual-Polarization
FCT	Forest Carbon Tracking Task
GEO	Group on Earth Observation
GFOI	Global Forest Observations Initiative
GIS	Geographical Information System
INCAS	Indonesian Carbon Accounting System
InSAR	Interferometric SAR
IPB	Bogor Institute of Agriculture
ITB	Bandung Institute of Technology
ITTO	International Tropical Timber Organization
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
MRV	Measurement, Reporting and Verification
LAPAN	National Institute of Aeronautics and Space
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PLR	Full Polarimetry
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus
RS	Remote Sensing
SATREPS	Science and Technology Research Partnership for Sustainable Development
SAR	Synthetic Aperture Radar
UGM	Gadjah Mada University
UI	University of Indonesia