ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

CAPaBLE Programme Final Report



Project Reference Number: CBA2015-04NSY-Avtar

Developing a Training Module to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR Framework in support of REDD+ MRV System

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Final Report submitted to APN

OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

This project sought to build national capacity of various stakeholders who are related to forestry sector in India, Sri Lanka and Cambodia, which can further contribute towards Reducing Emission from Deforestation and forest Degradation (REDD+) related activities. An inception meeting was organized in Cambodia with the help of various stakeholders to discuss about the content of hands-on-training programme to monitor forest cover and deforestation using advanced remote sensing techniques. The main objectives of the project were: (1) to develop a hands-on-training module to monitor forest cover and deforestation using SAR data (2) to build the capacity by providing hands-on-training to various stakeholders who are involved in REDD+ related activities in their country. Advanced remote sensing methods using Synthetic Aperture Radar (SAR) and optical sensor data were demonstrated to monitor forest more accurately beyond IPCC tier 1 values.

The project collaborators fully supported the project. Field level forest inventory data was also collected in each of the project country. We have also trained the participants in collecting and managing forest inventory data. Forest inventory data collected will be useful for further research and training module development for estimating forest carbon stocks. Both stakeholders and collaborators have shown strong interest in this kind of training programme through demonstrations and hands-on-training, and to learn new knowledge and techniques.

The Measurement Reporting and Verification (MRV) system developed under this project demonstrates significance of advanced remote sensing sensor data such as Phased Array L-band Synthetic Aperture Radar (PALSAR) in forest monitoring. PALSAR can provide better results as compared to optical sensors in tropical countries and we have trained various stakeholders to use PALSAR data during the hands-on-training programme. We have concluded that most of the stakeholders are not well aware about use of PALSAR data although they have learned that PALSAR can provide better results in forest study. After the training programme they become proficient in using PALSAR data and in future most of the stakeholders will use optical and SAR data for forest monitoring.

Keywords

REDD+, Measurement, Reporting and Verification (MRV), Deforestation, Synthetic Aperture Radar (SAR), Capacity building

Objectives

The main objectives of the project were:

1. to develop and conduct a training program on forest cover and deforestation monitoring using JAXA's Advanced Land Observation Satellite (ALOS) for REDD+ MRV system focusing on PALSAR data because most of the tropical countries have limitations of acquisition of cloud free optical sensor data.
2. to achieve sustainability in the forest resources in Cambodia, Sri Lanka and India by making sustainable forest management plan using updated information about forest cover and deforestation hot spots based on advanced Remote Sensing techniques such as Synthetic Aperture Radar (SAR)
3. to provide an operational measurement, reporting and verification (MRV) system to Cambodia, Sri Lanka and India.

Amount received and number years supported

The Grant awarded to this project was:
US$ 40,000 for Year 1:

Activity undertaken

(1) The inception workshop was organized in Phnom Penh from 2-3 November, 2015 to finalize content of hands-on-training programme to monitor forest cover and deforestation using advanced remote sensing techniques and schedule of training programme in each country and their arrangements. We also discussed about suitable methodologies, data sources and software suitable for participants. All the collaborators agreed to support the programme.
(2) Training about establishment of biomass plot and collection of forest inventory data for measurement of forest carbon were also demonstrated during the inception workshop to develop homogeneous method for field data collection.
(3) First hands-on-training programme was organized at University of Peradeniya, Sri Lanka from 8 -10 January, 2016.
(4) Second hands-on-training programme was organized at Jawaharlal Nehru University and Allahabad University, India from 13 – 15 May and 17-18 May, 2016 respectively.
(5) Third hands-on-training programme was organized in Cambodia from 28 June – 1st July, 2016. We also had closing ceremony of the APN project and discussion about future direction.

Results

The key findings from project includes:

1. Development of hands-on-training module to process PALSAR data to monitor forest cover and deforestation.
2. Development of methodologies for establishment of biomass plot to collect forest inventory data for forest carbon stock estimation.
3. Various stakeholders from all project countries were trained to use satellite data especially PALSAR and Landsat data to monitor forest cover and deforestation.
4. We had also demonstrated how to use recent satellite data to update the existing forest cover of individual country which will be helpful in making sustainable forest management plan for future.
5. Active engagement of various stakeholders is necessary for the success of REDD+ MRV so we further asked the participants to generate biomass map of their country based on forest inventory data and existing methodology developed by Avtar et al., 2013.

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

The proposed research was a capacity development programme to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UNCECAR). Now UNCECAR has established an International Network for Advancing Transdisciplinary Education (INATE) to promote transdisciplinary approach to knowledge generation and project implementation. Proposed research aimed to support Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation. The project emphasized to promote and strengthen the capacity and knowledge to monitor forest cover and effects of deforestation. The study focused on

forests in Cambodia, Sri Lanka and India. These countries come under UN-REDD+ umbrella therefore they need to establish an operational MRV system to monitor forest cover and its change required for forest carbon accounting. The project included meetings and training workshops in the regions. The importance of REDD+ MRV system was also recently recognized at the UNFCCC (United Nations Framework Convention on Climate Change) COP 21 (Conference of Parties) conference in Paris. The project contributed to the APN's science agenda by promoting sustainable forest management by implementing REDD+ mechanism. The goals of this project were: Goal (1): Support regional cooperation on sustainable forest management between Cambodia, Sri Lanka and India towards REDD+. Goal (2): Strengthening interactions among scientists and policy makers at the policy forum to provide inputs in REDD+ policies implementation Goal (3): Strengthening scientific and technical capabilities in the proposed countries to monitor forest cover and deforestation by establishing MRV system required for REDD+ Goal (4): Cooperating with the UNU's existing UN-CECAR/INATE network and other institutions such as JAXA, UN agencies, NGOs etc. and involvement of their experts.

Self Evaluation

The tasks and activities completed were in one year and project objectives were accomplished successfully. Training module for forest cover and deforestation monitoring were developed with the help of Japan Aerospace Exploration Agency (JAXA). We also got support from ESRI to use ArcGIS data for developing the training module. We faced some challenges during the inception meeting because our main focus was to develop training programme based on SAR data to monitor forest cover and deforestation but after the inception meeting majority of the participants and collaborators showed their interest in use of both optical and SAR data for forest monitoring. So finally it was agreed upon to develop the training programme to use both optical and SAR data for forest cover and deforestation monitoring. We had excellent collaborators who provided all the support as well as the information about existing REDD+ project in their country to avoid the overlapping. The training programme received considerable attention in all project countries because majority of the participants never used SAR data for forest cover and deforestation monitoring. During the training participants learned to use SAR data for forest study and post training programme participants realized the potential of SAR data in forest mapping and how user friendly it is. We strongly believe that this kind of program is important for various stakeholders from developing countries who are not exposed to advanced data and analysis techniques and they can switch from use of conventional methods to advanced methods of utilizing remote sensing data and techniques. We have published one book, three conference papers and one peer-reviewed journal paper based on the research conducted under this project. One more manuscript is under preparation and will be published in 2017.

Potential for Further Work

We have learned many significant lessons during organizing different workshops and training programme as well as during interaction with various participants. We realized that these kinds of hands-on-training programme are more feasible for various stakeholders and participants can teach other participants after the training programme because we provide them with all the training material, data and software and they can further share this with their colleagues. The collaborators are now in a position to continue such training programmes to develop the capacity of other participants by providing this training as a course. Asian Institute of

Technology (AIT) was very keen to organize similar training on REDD+ to develop the capacity of various stakeholders in Asia-Pacific region and currently we are discussing about how to expand such kind of training programmes to other counties. We are also planning to develop additional training programme to monitor forest biomass using high resolution SAR data in combination texture analysis (Avtar et al., 2013 and Thapa et al.,2015). We are also considering to incorporate community based forest carbon measurement in the forest carbon estimation. This project can be further extended and contribute towards community based forest carbon monitoring. Developing and testing additional training module about future projections of forest cover and biomass under various scenarios is also one of the potential topic for future work.

Publications

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2. Ram Avtar, (2016) Spatial Modelling and Scenario Analysis to Estimate Aboveground Forest Biomass in Cambodia Using High Resolution SAR Data. Green Talents Alumni Conference-2016, Berlin, Germany (27-28 October, 2016)
3. Ram Avtar, Osamu Saito, Rajesh Thapa, Ridhika Aggarwal (2016), Spatial Modeling and Scenario Analysis to Simulate Forest Cover in Cambodia. International Conference on Scanarios and Models of Biodiversity and Ecosystem Services in support of Decision Making, CORUM, Montpellier, France (24-26 August, 2016)
4. Aggarwal R. and Ram Avtar, (2016), Monitoring Forest Biomass Using L- Band SAR Data in Cambodia for REDD+, ICSS 2016, Stellenbosch, South Africa (2-3 March, 2016)
5. Ram Avtar, (2016) Geospatial Techniques for REDD+, Nova Publication (Under review)

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1. Ram Avtar, R. Suzuki, W. Takeuchi, H. Sawada, (2013). PALSAR 50m mosaic based national level biomass estimation for REDD+ policies implementation. PLOSone, 8, 10, e74807, 1-11.
2. Thapa, Rajesh, Bahadur; Watanabe, Manabu; Motohka, Takeshi; Shimada, Masanobu (2015). Potential of high-resolution ALOS‐PALSAR mosaic texture for aboveground forest carbon tracking in tropical region. Remote Sensing of Environment, 160, 122-133.

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TECHNICAL REPORT

Preface

The proposed research was a capacity development programme to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UNCECAR)/INATE. Supported Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation. It aimed to promote and strengthen the capacity and knowledge to monitor forest cover and its changes due to deforestation. The study was focused on forests in Cambodia, Sri Lanka and India. We held an inception workshop in Cambodia to discuss about the content of hands-on-training programme. After the inception workshop, we conducted hands-on-training programme in partner countries. These countries come under UN-REDD+ umbrella therefore they need to establish an operational MRV system to monitor forest cover and its changes, which are required for forest carbon accounting.

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1. Introduction

Tropical forests contain about 40% of the carbon stock in the terrestrial biomass (Dixon et al. 1994; Phillips et al. 1998; Watson et al. 2000). The most alarming global threat in the forest sector is deforestation and forest degradation. It contributes about 20% of greenhouse gases (GHG) (IPCC, 2014; Gibbs et al., 2007; Werf et al., 2009), making deforestation as a second largest source of CO_2 emissions. The rapid economic growth, increasing demand for agricultural land, forestry products, illegal logging, urbanization are the main factors for the deforestation and forest degradation (Rudel et al., 2009). Curbing the deforestation through improved forest management practices, offers one of the most cost-effective and potential means of the emission reduction (Putz et al., 2008), and can be achieved by implementation of the reducing emissions from deforestation and forest degradation (REDD+) policies. REDD+ mechanism not only helps to reduce emission of CO_2 from the deforestation but also protect biodiversity, forest derived ecosystem services, and improve the socio-economic condition of the local and indigenous people, who depend on forests for their livelihood (Dudley, 2010). REDD+ assists developing countries, to develop strategies for reduction of deforestation and forest degradation, alleviate poverty, and socio-economic development of indigenous people.

To reduce emissions from deforestation and forest degradation, there is an urgent need to establish the Measurement, Reporting and Verification (MRV) system. This requires accurate and reliable forest information, which will be useful for estimating forest carbon stocks and carbon accounting (Maniatis, 2010). Implementation of REDD+ policies will provide financial incentives to the signatory country, which is conserving and enhancing the forest carbon stocks. Therefore, measurement of the forest cover, deforestation and forest biomass has become very crucial because such economic assessment requires precise and reliable methods to estimate forest carbon stocks at national level (Gibbs et al., 2007; Saatchi et al., 2011). Satellite based remote sensing techniques have played a crucial role in the estimation of forest cover and deforestation monitoring. However, estimation of forest biomass is still under the development because of uncertainties. In recent studies, it has been proved that remote sensing based forest cover, deforestation and biomass monitoring is cost and time effective as compared to that of forest inventory data, and it can provide spatial and temporal information of forest cover, deforestation and biomass distribution (DeFries et al., 2007). Mapping of forest area is also necessary for sustainable management and utilization of forest resources. Forests play an important role in terrestrial carbon flux and therefore, any significant change in the forest cover from local to global scale will affect the carbon cycle.

There are various methodologies to monitor forest cover, deforestation and forest biomass estimation using remote sensing techniques. However, selection of the method depends on the site, data availability, types of forests etc. In this project three tropical counties India, Cambodia and Sri Lanka has been studied so monitoring of forest cover and deforestation using optical data will not be significant because of unavailability of cloud free data. Therefore, this project was focused on development of a hands-on-training module using Synthetic Aperture Radar (SAR) data to monitor forest cover and deforestation without limitations of clouds and season. Recent study by Walker et al., 2010; Almeida-Filho et al., 2009; Avtar et al., 2012 has shown the potential of dual-polarized L-band Synthetic Aperture Radar (SAR) data acquired by the Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar sensor (PALSAR) system for differentiation between different types of forest and deforestation. Use of full polarimetric data also shows the potential

to differentiate various forest types (Avtar et al., 2011). The most accurate way to monitor forest types and deforestation is ground based monitoring. However, these traditional techniques are often time consuming, labour intensive, difficult to implement, especially in remote areas, and they cannot provide the spatial distribution of forests in large areas. Moreover, this method cannot provide historical information about the forest if no ground data exists (Sivanpillai et al., 2006). Therefore, remote sensing data supplemented with ground survey data can provide inexpensive and fast monitoring of forest cover and deforestation. The high penetration capability of SAR allows more information extraction about plants structural parameters to improve forest types and deforestation monitoring (Lu, 2006, Avtar et al., 2012, Avtar et al., 2013). Japan Aerospace Exploration Agency's (JAXA's) Phased Array L-band type Synthetic Aperture Radar (PALSAR) data has potential to monitor forest cover and deforestation in tropical countries, as this is the first long-wavelength (L-band, 23-cm wavelength) SAR satellite sensor to have the capability of collecting polarimetric data (Mitchard et al., 2011; Carreiras et al., 2012). The purpose of this capacity development program was to design a training module to monitor forest cover and deforestation using PALSAR data. This project addressed challenges and opportunities to monitor forest cover and deforestation at the national level using advanced remote sensing techniques by focusing on Cambodia, India and Sri Lanka. The countries selected for this project have an enormous potential for conservation of forest resources under the REDD+ mechanism and the policy makers in these countries are aware of the problems and opportunities in this area. Hence this project will act as bridge between scientists and policy makers by providing them with the necessary scientific evidences of forest cover and deforestation trend in their countries. This information will be useful to make sustainable forest management plan and by finding potential sites afforestation, reforestation, community forestry activities etc. We have demonstrated forest cover and deforestation monitoring methodology for Cambodian forests (Avtar et al., 2011, 2012). The training module developed under this project is open to public to share and disseminate methodology to monitor forest cover and deforestation and develop the capacity of researchers, students, policy makers, practitioners, local people, government officials, NGOs etc. There is very little peer-reviewed research on REDD+ MRV system in proposed countries (Cambodia, India and Sri Lanka). So this will help to attract people to work in this field. In future, we will develop similar hands-on-training module for forest biomass monitoring using remote sensing data based on the availability of forest inventory data of individual countries.

2. Project Methodology

Proposed research was focused on capacity development programme to monitor forest cover and deforestation to support REDD+ MRV system. The main aim of this training program is to design a hands-on training module to monitor forest cover and deforestation to develop capacity of researchers, students, policy makers, practitioners, local people, government officials, NGOs etc. We have collaboration with partner countries as well as Japan Aerospace Exploration Agency (JAXA) and ESRI which helped us to design the hands-on-training material.

2.1 Inception workshop

We held an inception workshop in Cambodia, inviting experts from Cambodia as well as collaborators from partner countries. We had invited experts from different organization to

share their experiences during the brainstorming session that could help in designing the training module. The workshop agenda, participant list and other 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. On the other hand, JAXA and UNU-IAS introduced the latest satellite technologies and successful examples of forest monitoring in south-east Asian region as well as importance of advanced sensors.

The main discussions and outcomes of inception meeting are as below.

- Development of training module using optical and SAR data processing so users will have a wide range of applications in forestry sector and users will also have choice to work on both data.
- Training module will be more focused on SAR data processing because its being an advanced technique and limited knowledge.
- Local partners will provide the information about the deforestation hot spots.
- JAXA and UNU-IAS will prepare the data set for the training programme with the help of research assistant
- The local partners will help in logistics as well as collection of scientific data that can be utilized during the training programme.
- Tentative schedule of the training programme: January in Sri Lanka, March or April in India and August or September in Cambodia

2.2. Data collection (in situ and satellite data) and development of training module

We requested our project partners to provide in-situ data that could be useful to develop the training programme as well as in order to verify the classified map using PALSAR and Landsat data. Project partners helped us to provide in-situ data through their network. We have downloaded PALSAR data from JAXA under ALOS PI free of charge and Landsat data from USGS, which is publically available for developing the training programme. We have downloaded data for each country to develop the training programme beforehand so we can use same data during the training programme in proposed countries.

2.2.1. PALSAR data

PALSAR FBD data (Fine Beam Dual-polarization) of ALOS satellite (Advanced Land Observing Satellite) was downloaded from JAXA. It has two polarization channel HH (horizontal transmit and horizontal receive) and HV (horizontal transmit and vertical receive). HH and HV 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 classification map. We were not able to provide a training programme using PALSAR full polarimetric data because PALSAR full polarimetric data have less coverage in proposed countries as well as limited time and resources. We have adopted national level approach to monitor forest therefore, we developed training module with national level coverage. There are various levels of PALSAR data processing 1.0, 1.1 and 1.5 but this training programme designed using level 1.5 as well as PALSAR 50m orthorectified mosaic data. PALSAR 50m orthorectified mosaic data can be downloaded from JAXA freely (http://www.eorc.jaxa.jp/ALOS/en/kc_mosaic/kc_map_50.htm). Figure 1 shows PALSAR 50m orthorectified mosaic product from JAXA Kyoto and carbon initiative.

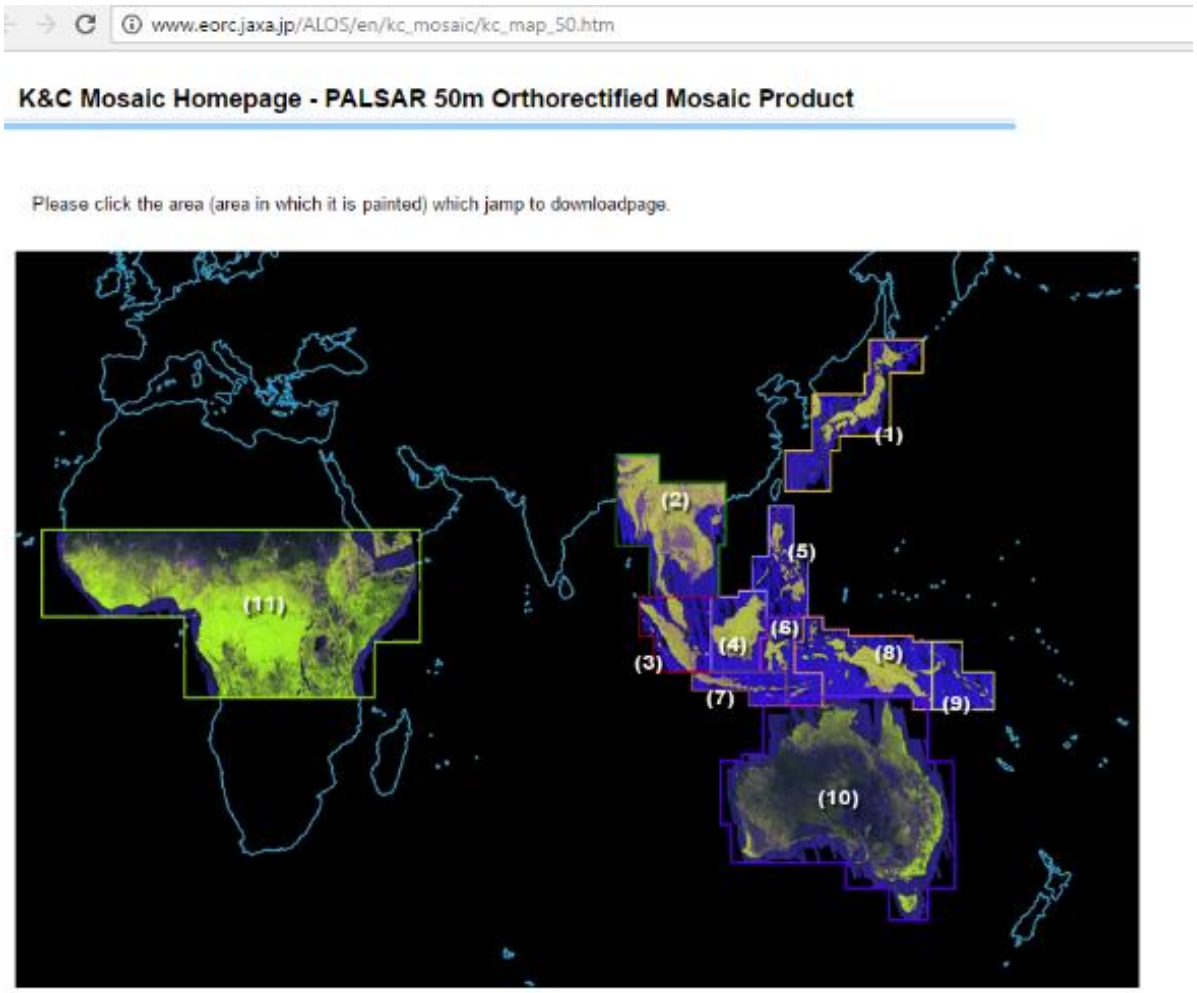


Figure: 1 PLASAR 50m mosaic data

For the PALSAR processing we used LandUseClassification (LUC) software, which is developed by JAXA to process ALOS data. We have provided printed manual to all the participants to learn various processing steps to generate forest cover map. Processing methodology of LUC software is as follows:

2.1.1.1 Processing flow

There are two basic processing flows in LUC software tool.
a. Segmentation process
b. Classification process

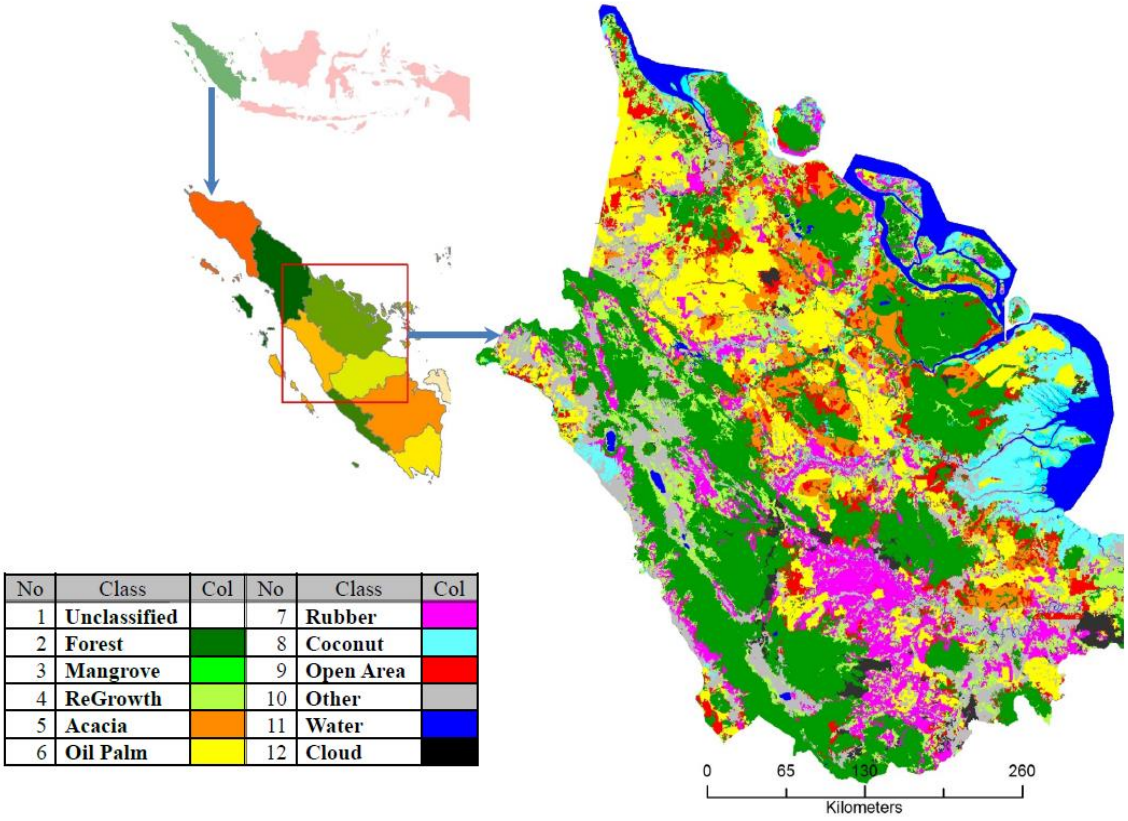
a. Segmentation
Segmentation process has two functions.

- Segment input image and output a result as image file.
- Calculate object features with various statistics from the segmented object and output the result as a text file.

Segmentation process divides image into objects with homogeneous features in order to preserve the classification precision due to influence of noises. This tool uses the region-growing methods.

b. Classification

Classification process classifies the objects based on the features calculated from segmentation procedure. It uses OpenCV as image processing libraries. Five types of classifier can be selected. The classifiers are Random Trees, Support Vector Machine, Multi-Layer Perceptron, Bayes, and Boost. A land use/cover classification map and accuracy compared against the ground truth map at (pixel by pixel) are output at the end of the process. This training programme was designed using Random Tree classification algorithm because of higher accuracy and less processing time as compared to other classification methods. Figure 2 shows PALSAR based forest cover map of Riau province of central Sumatra. The area was classified into 12 classes. Most of the area covered by forest area followed by plantation.



No	Class	Col	No	Class	Col
1	Unclassified		7	Rubber	
2	Forest		8	Coconut	
3	Mangrove		9	Open Area	
4	ReGrowth		10	Other	
5	Acacia		11	Water	
6	Oil Palm		12	Cloud	

Figure 2: Classified image based on PALSAR data using LUC

We have also demonstrated how multi-temporal data is useful to identify deforested area. We collected time series PALSAR data in order to detect deforested areas. Figure 3 shows PALSAR data is sensitive to monitor deforestation even within 6 weeks of time interval. The value of mean σ^0 HV is very low for deforested area due to the absence of volume scattering. The mean σ^0 HH for some deforested plot has shown a higher value in the recent cutover forest, but it decreases over a period of time. This high value of σ^0 HH in recent deforested area might be because of the presence of wooden logs, which increases surface roughness. Therefore, in case of deforested area, the σ^0 HV shows a sudden change as compared with σ^0 HH. In figure 3 A, B, C, D square clearly shows recent deforested area.

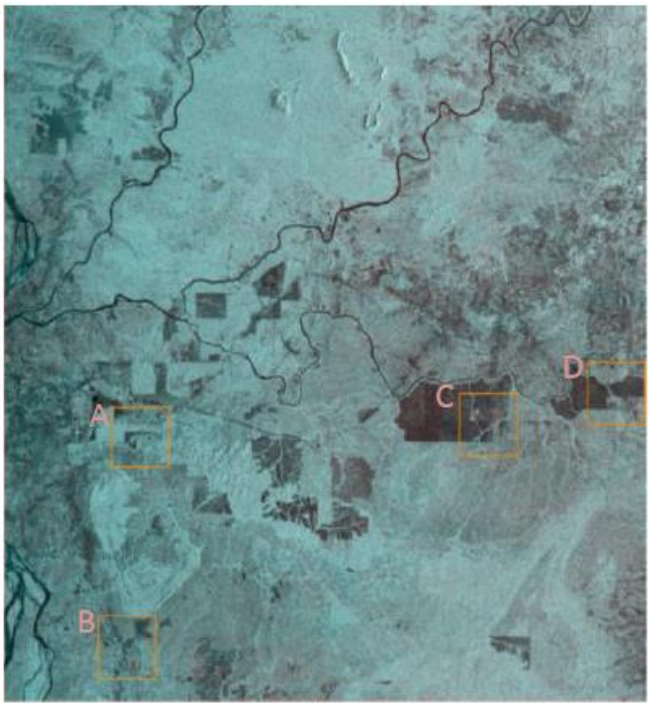


Figure 3: R:G:B color composite of PALSAR data acquired on 2014/10/19 (R) and 2014/12/05 (GB)

2.2.2. Landsat data:

Landsat data was obtained from US Geological Survey's Earthexplorer (http://earthexplorer.usgs.gov/). We used the Landsat-8 Operational Land Imager (OLI) image, which were clouds-free for each study site. Landsat-8 images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. Approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi). In this training programme we used band 6 (Shortwave infrared), band 5 (Near Infrared), band-4 (Red) and band-3 (Green) of Landsat-8 data because these bands are most suitable bands for vegetation study. Figure 4a shows R:G:B color composite image of Landsat-8 data. ArcGIS 10.3 software were used to pre-process satellite images such as band stacking, mosaicking and clipping. Finally, we applied supervised classification algorithm to classify Landsat data using Spatial Analyst tool of ArcGIS. Supervised classification uses the spectral signatures obtained from training samples to classify an image. ArcGIS based maximum likelihood classifier were used to classify the Landsat data.

Maximum Likelihood Classifier:

a) This classifier quantitatively evaluates both the variance and covariance of the trained spectral response patterns when deciding the fate of an unknown pixel.
b) To do this the classifier assumes that the distribution of points for each cover-type are normally distributed.
c) Under this assumption, the distribution of a category response can be completely described by the mean vector and the covariance matrix.
d) Given these values, the classifier computes the probability that unknown pixels will belong to a particular category.

We have developed the training manual and distributed among all the participants to follow step by step procedure to process Landsat data to generate forest cover map of the area. Figure 4b shows the land use/land cover map of the area. Most of the area is covered by forest followed by agricultural area. The main agricultural crops are rubber, coconut, chili, onion, etc. Water bodies cover about 4.3 % of land area to supply water for agriculture and other purposes. Built-up area and home garden cover 12.8 % of the area.

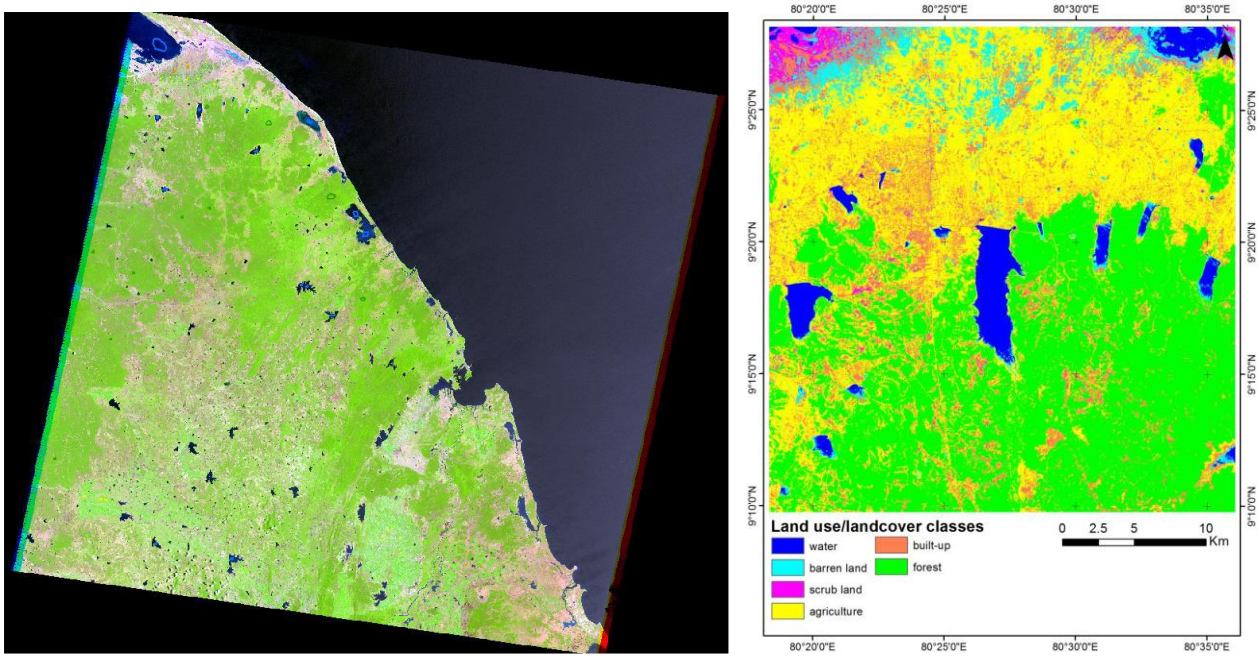


Figure 4: (a) Landsat-8 OLI (R:G:B = band 6: band 5: band 4) colour composite (b) classified image

Finally, we were able to develop two training modules for forest cover and deforestation monitoring first one is based on PALSAR data processing using LUC software developed by JAXA and second one is based on Landsat data processing using ArcGIS software. We also encouraged participants to use QGIS for Landsat data processing.

2.3. Training curriculum

The most the participants in the project countries were familiar with optical satellite data, but not have enough knowledge about SAR data. Therefore, we developed a training curriculum including a fundamental part of radar data and its application. The training period was three days and contained the following components. The complete curriculum is attached to this report as an appendix.

- Building block of REDD+ (Lecture)
- Basics of Remote Sensing (Lecture)
- Basics Theory of SAR Data (Lecture)
- PALSAR Data Handling and applications (Lecture & Hands-on)
- Polarimetry (Lecture & Hands-on)
- PALSAR data processing and Classification Map (Lecture & Hands-on)

- Detecting Deforestation Area (Lecture & Hands-on)
- Landsat data handing and applications (Lecture & Hands-on)
- Landsat data processing and classification (Lecture & Hands-on)
- Forest inventory data collection (field work)

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

- LandUseClassification (LUC) software developed by JAXA
- ArcGIS developed by ESRI

We have also mentioned about use of other software to process PALSAR and Landsat data such as MapReady was developed by the Alaska Satellite Facility (ASF) and "PolSARpro" was developed by the European Space Agency (ESA), The Next ESA SAR Toolbox (NEST) was developed by the European Space Agency (ESA) and QGIS, which can be downloaded from their websites free of charge.

2.4. Training and Capacity Building

Through the course of the one-year project four training programmes and capacity building were scheduled. It involved various stakeholders from researchers, students, policy makers, practitioners, scientists, local people, government officials, NGOs etc. Field training to demonstrate how to collect forest inventory data were also conducted for biomass estimation.

3. Results & Discussion

The project successfully completed its objectives and related activities that is required for completion of the project. In one-year time period project collaborators stay the course to successfully implement project activities including inception workshop, development of training material and hands-on-training programme based on suggestions during the inception workshop. We have collected the field data with the help of collaborator to process the satellite data and developed the training programme. Forest cover maps of the study area were developed by participants and they also learned how to detect deforestation using multi-temporal PALSAR and Landsat data.

Four hands-on-training programmes were successfully completed in partner countries and participants learned the basics of REDD+ mechanism and why it is required for climate change mitigation and adaptation. We have also demonstrated how MRV system will be useful to curb deforestation and enhancing forest carbon stocks. Participants learned more about various techniques to monitor forest and how advanced techniques can help to provide accurate results. During the training workshop participants also learned basic of remote sensing and SAR data. We have provided detailed information about the PALSAR and Landsat data and various applications in forestry field. We provided basic and essential knowledge and techniques in order to utilize radar satellite data for forest monitoring. With these knowledge and techniques, participants can advance their knowledge to monitor forest in their country more efficiently. We have provided various information about how to download satellite data, which processing tool is good for different types of data and how to process the satellite data to accurately monitor forest and deforestation. Table 1 shows the details of training sessions. We have trained 133 participants during the four training programme in Sri Lanka, India and Cambodia. We have developed the training module and distributed among all the participants and allowed them to share with their colleagues to teach the techniques to other experts in their country to generate forest cover and deforestation map to cover wider areas. We have

also trained the participants in collecting and managing forest inventory data. Forest inventory data collected will be useful for further research and training module development for estimating forest carbon stocks.

Table 1. Training and capacity building activities

Training	Location	Dates	No. of participants
Hands-on-training to monitor forest	University of Peradeniya, Sri Lanka	8th - 10th January, 2016	26
Hands-on-training to monitor forest	Jawaharlal Nehru University, New Delhi, India	13th – 15th May, 2016	30
Hands-on-training to monitor forest	Allahabad University, Uttar Pradesh, India	17th – 18th May, 2016	42
Hands-on-training to monitor forest	Phnom Penh, Cambodia	28th June – 1st July 2016	35

We all agreed that this training was useful and we should continue this kind of activities to improve capacity of various stakeholders in respective country. We have also requested to our collaborator and participants to share their knowledge/skills with the people who are involved in forest related activities. During the discussion, we have noticed there are some other international forest monitoring activities are going on parallel therefore, we requested our partners to share their experiences about this training programme with other people who are involved in different projects and how to use the resources holistically and synergistically towards the success of REDD+. We also agreed to provide and share different forest related activities among each other so in the future we can come up with other project/training programme. In fact, we are planning to develop future research proposal based on existing network of people. We have also requested our collaborator to share additional field data (inventory data) over larger areas and across various forest types so we can develop a training programme as well as biomass map of the area based on different forest types. In this training programme we were not able to generate biomass map because of limited no. of forest inventory data but in future we are planning to develop forest biomass map of proposed country. We have already developed and published biomass map of Cambodia using PALSAR data (Avtar et al., 2013). The accuracy and validation of biomass map could be improved by providing more inventory data. We have proposed to involve local communities within the forest areas, who are often using forest resources and managing these resources can provide more information about forest as well as inventory data.

The main benefit of this training programme to the participants in Asia-Pacific region is development of skills/knowledge to process SAR data. Now JAXA has also released PALSAR-2 data for 2015 so all the participants and collaborator can use this data to update existing forest cover map and to monitor deforestation hotspots. We have noticed some limitation of this training programme for example we were not able to produce different categories of forest map because of limitation of ground data and our approach were national level for REDD+. In order to overcome the limitations of this training programme we had discussed during the final workshop meeting in Cambodia.

- 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.

- We need more collaboration with the researcher who are working on PALSAR data.
- PALSAR based biomass estimation could be one of the potential area of research and training module development although it needs more advanced research to overcome the limitations of saturation.
- In order to proceed with similar training programme we need to find funding agency who can support new project on biomass estimation training in future.
- Project outcomes and material should be disseminated through various networks.
- In future we can start working on development of a training programme to estimate forest cover and biomass considering various future projections and scenarios.

4. Conclusions

With focus on increasing deforestation and forest degradation in South-east Asian counties, this joint collaborative project aimed to design a training module to monitor forest cover, deforestation accurately and robustly for REDD+ MRV system. The development and awareness of REDD+ MRV system is very limited in the proposed countries, hence this project helped to transfer knowledge and technology to monitor forest cover, deforestation robustly. This project helped to enhance the capacity of local and regional scientists and ensure greater public participation through the involvement of students, local communities and civil society representatives. This project is also helpful to strengthen partnerships locally as well as regionally. The countries selected for this project have an enormous potential for conservation of forest resources under the REDD+ mechanism and the policy makers in these countries are aware of the problems and opportunities in this area. Hence this project acted as bridge between scientists and policy makers by providing them with the necessary scientific evidences of forest cover and deforestation trend in their countries. This information will be useful to make sustainable forest management plan and by finding potential sites for afforestation, reforestation, community forestry activities etc. During the training programme we also trained the participants in collecting and managing forest inventory data. Forest inventory data will be useful for further research and training module development for estimating forest carbon stocks.

We have conducted training programme in partner countries and demonstrated why advanced remote sensing techniques are required for successful implementation of REDD+ MRV to overcome limitations of conventional remote sensing techniques. The training module is based on SAR and optical data so it could attract more people in future. Basic and essential knowledge and techniques to process SAR data for forest monitoring were provided during the training workshop by resource persons. With these knowledge and techniques, they can advance their research and operational forest monitoring more efficiently in future. During the workshop, participants shared their experiences and knowledge that could be useful for development of future training programme.

5. Future Directions

This training programme can be further extended because PALSAR-2 25m resolution data of 2015 is also freely available so this training programme can be extended and process PALSAR-2 data which will be useful to update the existing forest cover data. However, the main problem with this training programme is ground data because of limited time of the project we were not able to validate our results. We had asked our collaborators to further work on the data and validate the results. If we have ground data, then we can validate our

results more accurately. Another issue that we had faced was availability of high speed computer, most of the participants were interested in province level data processing so use of high specification computers are necessary for processing and analysing large amount data. We are planning to organize similar training programme in Asian Institute of technology (AIT) to further extend and trained more participants around Asia-Pacific region. We are also working with all the collaborators and trying to develop a new training module for forest biomass estimation as well as for projecting forest cover and biomass under different scanarios. In future we are planning to involve more local communities to strengthen and empower them as well as ensure them to provide a training programme focusing on local communities because they are main individuals who manage and utilize forest resources.

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Appendices

Final report of workshop and training programmes

FINAL REPORT of the Inception-Workshop on Developing a Training Module to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR Framework in support of REDD+ MRV System

Date and Venue

The inception-workshop took place on 2-3 November 2015 at the Phnom Penh Hotel in Phnom Penh City of Cambodia. The international guests arrived at the venue one day before, on 1 November 2015, in order to meet for fine-tuning of the agenda and coordination of facilitation. All the international guests were well received by Mr. Chann Sophal and discussed about the workshop facilities.

Purpose

The purpose of the inception workshop is to present about the Asia Pacific Network for Global Change Research (APN-GCR) funded project to the project members and expert community; project goals, objectives, and activities; discuss about the activities implementation and management arrangements. Discussion about the roles of various partners and stakeholders in the project implementation.

International Guests

The international members were Prof. Srikantha Herath, Senior Academic Programme Officer, United Nations University, Institute for the Advanced study of Sustainability (UNU-IAS), Japan; Prof. Saumitra Mukherjee, Jawaharlal Nehru University, New Delhi, India; Prof. Sarath Abayakoon, University of Peradeniya, Sri Lanka; Dr. Rajesh Thapa, Japan Aerospace Exploration Agency (JAXA), Japan and Dr. Ram Avtar, UNU-IAS, Japan. The list of local participants is attached as Annexure#1

The Inception-workshop

The inception workshop was opened with registration of all the participants and Cambodian national anthem. Later on Mr. Chann Sophal invited H.E. Ung Sam Ath, Deputy Director General, Forestry Administration, Cambodia. H.E. Ung Sam Ath gave a wonderful opening remark on behalf of H.E. Chheng Kimsun. He warmly welcomed all the participants and mentioned about the importance of Measurement, Reporting and Verification (MRV) system for REDD+ implementation. He has also mentioned about the importance of capacity development programme to enhance the capacity by providing training to use advanced remote sensing techniques. After H.E. Ung Sam Ath opening remarks, Mr. Sophal invited Prof. Srikantha Herath for the opening remarks.

Photograph captured during the opening remarks

Prof. Herath welcomed all the participants on behalf of UNU-IAS, Japan. He warmly thanks to the Forestry Administration, Cambodia for Coordinating and hosting this workshop and other partner institutions in India and Sri Lanka. He mentioned about the timing of this workshop is very appropriate because recently UN and its member states has adopted global development agenda (SDGs) after a long discussion. So for the implementation of SDGs we need to consider social, environmental and economic dimensions. We need to take a very strong position for the sustainability of earth system and at the same time provide development. REDD+ is an excellent mechanism to implement this idea. We need to access the ability of various forest types for the carbon sequestration. Therefore, this training programme will be useful to develop the capacity of various stakeholders by providing them training programme on use of advanced remote sensing techniques to monitor forests.

Group photograph of all the participants

This project will also open up new opportunities for multi-country partnership to learn/share the knowledge. After Prof. Herath's open remarks, Mr. Sophal called all the participants for the group photograph. After the group photograph Mr. Sophal, invited Dr. Ram Avtar for giving

an overview about UN-REDD+ programme and APN funded project. Dr. Avtar talked about the importance of REDD+ mechanism in the climate change mitigation and why Measurement, Reporting and Verification (MRV) system is useful for the implementation of REDD+ mechanism. Different limitations of remote sensing techniques and how multi-sensor remote sensing techniques can overcome the limitations of one sensor by adapting multi-sensor data. Later on Dr. Avtar presented about the case study on Cambodia forest cover, deforestation and forest biomass monitoring using multi-sensor data. He also presented about the APN project and what are the expectations from this capacity development programme. For details please see the attached slides of Dr. Avtar's talk.

After Dr. Avtar's presentation, Mr. Sophal invited Prof. Herath to discuss about the capacity development programme and how UNU and UNCECAR network is working in this field. Prof. Herath gave a brief introduction about the UNU and UNCECAR network and why capacity development programme is useful in the implementation of UN-REDD+ programme. For details please see the attached slides of Prof. Herath's talk.

After Dr. Herath's presentation, Mr. Sophal invited Dr. Rajesh Thapa from JAXA, Japan to present about various methodologies to monitor forest in south-east Asia. Dr. Thapa gave a very comprehensive presentation use of various satellite data to monitor forest cover, deforestation and forest biomass. His talk clearly showed the limitations of optical data in tropical regions and use of PALSAR data have wider application. For details please see the attached slides of Dr. Thapa's talk. After Dr. Thapa's talk we had a question/answer session, where we had discussion about various issues related to REDD+ and forest monitoring.

After Dr. Thapa's talk we had a lunch break and all the participants enjoyed delicious Cambodian food and enjoyed chatting with each other to know more about each other.

After the lunch break Prof. Saumitra Mukherjee of Jawaharlal Nehru University, India presented about the Indian forest status and REDD+ progamme in India. He briefly explained about the role of Indian remote sensing satellites in forest monitoring and REDD+ implementation. For details please see the attached slides of Prof. Mukherjee's talk. After Prof. Mukherjee, Prof. Abayakoon of Peradeniya University, Sri Lanka presented about the REDD+ programme in Sri Lanka and role of university led capacity development programme in Sri Lanka. For details please see the attached slides of Prof. Abayakoon's talk. After Prof. Abayakoon's talk we had a coffee break before going to discuss about the project implementation in partner counties. We had arranged the room and changed the sitting arrangements. We discussed about how this project can help the Cambodian forestry administration to develop the capacity of various stakeholders. Some of the staff of forestry administration gave suggestion if we can include both optical and Synthetic Aperture Radar

(SAR) based training in the upcoming training programme. This issue was widely discussed among all the participants and finally we decided to develop a training programme using optical (Landsat) and SAR (PALSAR) data. We had also discussed about how the schedule and the time line of the training programme. We also discussed about the role of local partners and UNU to organize upcoming training programme in all three countries (Sri Lanka, India and Cambodia). We had also discussed about the study site so the collaborator agreed to send the site information within one month so UNU team can start preparing of the datasets for the training programme. Prof. Abyakoon agreed to conduct the first training programme in Sri Lanka on 8-10 January, 2016. All the participants expressed strong support and interest in this project and actively participate in the upcoming training programme. At the last Prof. Herath closed the session by giving a brief closing remark by thanking all the staff members, organizer, participants for making a workshop successful.

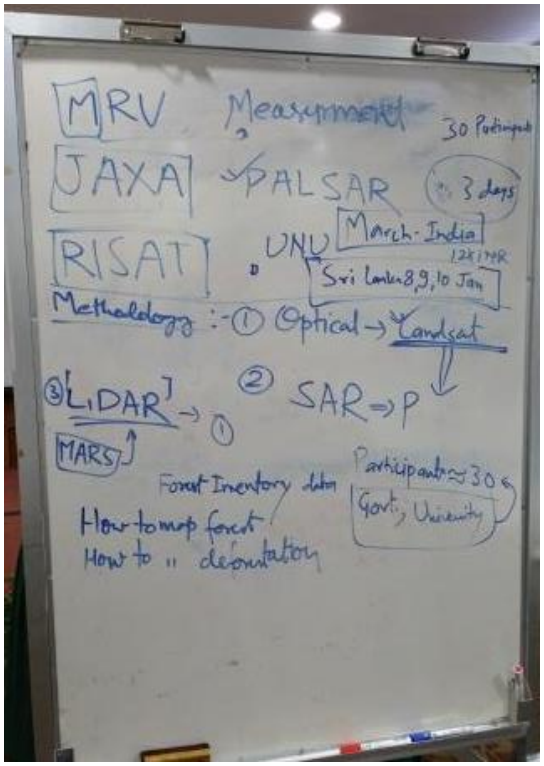


Photo captured during the discussion session to note down the points

2nd day of the workshop we started our journey from Phnom Penh hotel to Tamao Zoo forest, which is about 50 km from Phnom Penh. Mr. Chann Sophal came accompanied us to the Tamao Zoo forest site and explained about the forest and various wild life animals. Dr. Avtar demonstrated about how to measure the forest biomass by making and collecting the forest inventory data. Dr. Avtar demonstrated about how to make a forest sample plot and how to measure Diameter at Breast Height (DBH) and height and how to estimate forest biomass using existing allometric equations.

Photo captured while demonstrating about the collection of forest inventory data

Outcomes of the Inception Workshop:

The participants and collaborators agreed on the following recommendations for their future work:

- We need to develop a training programme using optical and SAR data processing so users will have a wide range of applications in forestry sector
- We will give more emphasis on SAR data processing because its being an advanced technique
- Local partners will provide the information about the deforestation hot spots.
- JAXA and UNU-IAS will prepare the data set for the training programme with the help of research assistant
- The local partners will help in logistics as well as collection of scientific data that can be utilized during the training programme.
- Schedule of the training programme is tentative: January in Sri Lanka, March or April in India and August or September in Cambodia
- In India Delhi and Allahabad could be two locations for the training programme. JNU and University of Allahabad will support this activity. Prof. Anupam Dikshit will help in organizing the workshop in Allahabad University, Uttar Pradesh, India.

Annexure#1 **Local participants during the Inception workshop**

No	Names	Institution	Other Matters
1	H. E. Dr. Chheng Kimsun (H.E. Ung Sam Ath)	FA	Director General (Deputy Director General)
2	H. E. Tim Sipha	FA	Director of DLE
3	Dr. Sokh Heng	FA	Director of IRD
4	Dr. Keo Omaliss	FA	Director of DWB
5	Dr. Huot Punleu	FA	Director of DAP
6	Mr. Meas Makara	FA	Director of DFC
7	Mr. Bun Vanna	FA	Director of DFIC
8	Mr. Uon Sam Ol	FA	Deouty Director of DPP
9	Mr. Nheuk Ratanakpich	FA	Director Tamao Zoo
10	Mr. Vorn Monin	RUA	Dean of Forestry Science Faculty
11	Dr. Dennis J. Cengel	FA	Technical Adviser, ITTO
12	Mr. Hiroshi Nakata	FA	Technical Adviser, FA
13	Mr. Chann Sophal	Cambodia	Project Partner
14	Ms Rin Chenda	FA	WS Assistance/registration officer

FINAL REPORT of the Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System: University of Peradeniya, Sri Lanka

Date and Venue

The hands-on-training programme took place on 8-10 January 2016 at the University of Peradeniya, Sri Lanka. The international guests arrived at the venue one day before, on 7th January 2016, in order to meet for fine-tuning of the agenda and coordination of facilitation. We have checked the computer facilities and configure the internet connection and installed the required software for the training programme. We also checked the conference facilities and arrangements for the opening ceremony. All the international guests were well received by Prof. Sarath Abayakoon and Director of Engineering Design Centre (EDC) and discussed about the workshop facilities.

Purpose

The purpose of hands-on-training was to develop the capacity of various stakeholders to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UN-CECAR)/INATE. The training program was to support Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation as well as to promote and strengthen the capacity and knowledge to monitor forest cover and its changes due to deforestation. The main attraction of this training program was to use Synthetic Aperture Radar (SAR) data for forest cover and deforestation monitoring because most of the tropical countries have limitations of acquisition of cloud free optical satellite data. The training programme was funded by the Asia Pacific Network for Global Change Research (APN-GCR) under CapDev programme.

International Guests

The international members were Prof. Srikantha Herath, Senior Academic Programme Officer, United Nations University, Institute for the Advanced study of Sustainability (UNU-IAS), Japan;

Dr. Rajesh Thapa, Japan Aerospace Exploration Agency (JAXA), Japan and Dr. Ram Avtar, UNU-IAS, Japan.

Agenda

The training team agreed an agenda prior to the training programme (attached as Annexure #2), which was approved by the resource persons and organizer, as follows:

Day 1

• Opening and Introduction about APN programme

• Forest monitoring in Sri Lanka and REDD+ project

• Basics of Remote sensing and application in forestry sector

Day 2

• Hands on training using SAR data

• LetsSAR training

Day 3

• Hands-on-training using Landsat data

• ArcGIS trainings for land cover classification

• Field visit to demonstrate collection of inventory data

Adjustments had to be made to the agenda, in light of various considerations, such as delay in the previous session, the degree of tiredness of participants, who had travelled very early to the training venue

Participants:

The training programme was attended by twenty-six (26) participants. The list of participants is attached as Annexure#3. We had participants from diverse background and institutions.

The Training programme

Day 1 (8th January, 2016)

The training programme was opened with registration of all the participants and candle-lighting ceremony. Later on Prof. Leelananda Rajapaksha, Dean Faculty of Engineering was invited to give an opening remark to all the participants. He warmly welcomed all the participants and mentioned about the importance of capacity development programme to enhance the skills/knowledge. He has also mentioned why forest monitoring is important. After Prof. Rajapaksha, we invited Prof. Srikantha Herath for the opening remarks from UNU-IAS side. Prof. Herath welcomed all the participants on behalf of UNU-IAS, Japan. He warmly thanks to the University of Peradeniya, Sri Lanka for coordinating and hosting this training programme and EDC, University of Peradeniya for making all the arrangement. He gave a brief summary about the UN-CECAR/INATE related activities in Asia-Pacific region and why this kind of

platform is necessary for organizing capacity development programme. He mentioned about the timing of this training programme is very appropriate because recently United Nations and its member states has adopted global development agenda (SDGs) after a long discussion. So for the implementation of SDGs we need to consider social, environmental and economic dimensions. He has also mentioned how this training programme will be useful to support goal no. 13, 15 and 17 of SDGs. We need to take a very strong position for the sustainability of earth system and at the same time provide development. REDD+ is an excellent mechanism to implement this idea. We need to access the ability of various forest types for the carbon sequestration. Therefore, this training programme will be useful to develop the capacity of various stakeholders by providing them training programme on use of advanced remote sensing techniques to monitor forests. This project will also open up new opportunities for multi-country partnership to learn/share the knowledge. After Prof. Herath's open remarks, we called Director EDC and Prof. Abayakoon for a short remark.

Photographs: Prof. Rajapaksha and Prof. Herath during the opening ceremony

Photograph captured during the opening address by Prof. Rajapaksha

Later on we have asked all the participants to introduce themselves as an ice-breaker so all the participants become familiar with each other and finally we took a group photograph of all the participants.

After the group photograph we invited Dr. Ram Avtar for giving an overview about UN-REDD+ programme and APN funded project. Dr. Avtar talked about the importance of REDD+ mechanism in the climate change mitigation and why Measurement, Reporting and Verification (MRV) system is useful for the implementation of REDD+ mechanism. Different limitations of remote sensing techniques and how multi-sensor remote sensing techniques can overcome the limitations of one sensor by adapting multi-sensor approach. Later on Dr. Avtar presented about the forest cover, deforestation and forest biomass monitoring using multi-sensor remote sensing. He also presented about the APN project and what are the expectations from this capacity development programme. For details please see the attached slides of Dr. Avtar's talk.

Group photograph of all the participants during opening ceremony

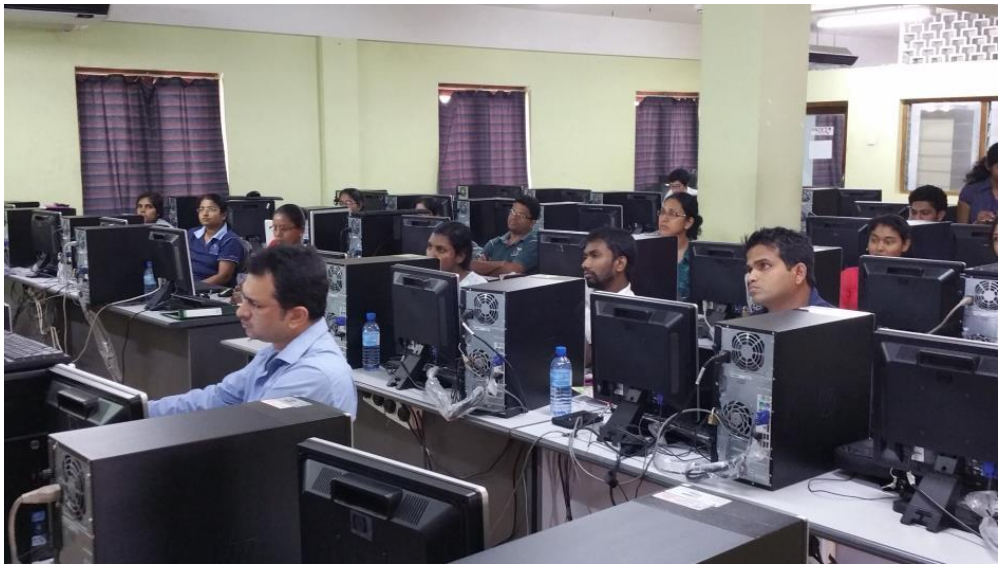
After Dr. Avtar's presentation, we invited Prof. Abayakoon to briefly explain about the training programme and discussion during the APN's inception workshop in Cambodia. After Prof. Abayakoon's talk, we invited Prof. Nissanka to discuss about the forest monitoring in Sri Lanka and REDD+ project in Sri Lanka. He has covered various types of forests in Sri Lanka and their distribution and what is the current status of forest monitoring in Sri Lanka and how REDD+ MRV is important for forest conservation. He has also shared the results of the current work by one of his Ph D student about forest inventory data collection and their limitations and how remote sensing data or this training programme will be useful to upscale the ground based information (inventory data) to the large scale. After Dr. Niisanka's talk we had a

question/answer session, where we had discussion about various issues related to REDD+ in Sri Lanka and how to make REDD+ successful. After Prof. Nissanka's talk we had a lunch break and all the participants enjoyed delicious Sri Lankan food and enjoyed chatting with each other to know more about each other and their ongoing research work.

After Prof. Nissanka's presentation, we invited Dr. Ram Avtar from UNU to present about basics of remote sensing that provides a broad understanding of the spatial analysis techniques and their use in many aspects of global environment. He presented about basic principles of Remote Sensing and Image Interpretation, different types of remote sensing techniques and further about Digital Image Processing (DIP), image classification and various applications. He also introduced various satellite sensors available for earth observation and use in change detection that could help to understand long-term local and global changes and climate change issues. The aim of the lecture was to familiarize participants with the theoretical background and practical application of Remote Sensing. Dr. Avtar also discussed about application of remote sensing in forest monitoring especially focusing on forest cover, deforestation and forest biomass estimation using optical and SAR data. After Dr. Avtar's presentation we had a question/answer session, where we discussed why we should think about multi-sensor remote sensing techniques rather than conventional optical sensor based monitoring of and forest.

After Prof. Nissanka's presentation, we invited Dr. Rajesh Thapa from JAXA, Japan to present about various methodologies to monitor forest in south-east Asia. Dr. Thapa gave a very comprehensive presentation use of various satellite data and role of JAXA's Advanced Land Observation Satellite (ALOS) data to monitor forest cover, deforestation and forest biomass. He has shared various case studies working on ALOS data in Southeast Asia. He has also shared the results based on optical data and their limitations in tropical regions. He shared his current findings based on Phased Array L-band type Synthetic Aperture Radar (PALSAR) data. For details please see the attached slides of Dr. Thapa's talk. After Dr. Thapa's talk we had a question/answer session, where we had discussion about why we need to make a shift from optical to SAR sensor in tropical forest monitoring.

After Dr. Thapa's session we asked the students to check the system requirement and installation of the software for the next day hands on training programme.



Photograph captured during the training session

Day 2 (9th January, 2016)

Day 2 started with the morning session by Dr. Rajesh Thapa from JAXA, to present Introduction on Land use/cover classification using PALSAR mosaic data. In his talk he discussed about JAXA's software tool and data, Image processing flow, application of PALSAR mosaic data. At the beginning he discussed about the JAXA's software for LULC classification. Later on he discussed about the availability of PALSAR data because there was question how to access the PALSAR data. He has shared a link from where participants can download PALSAR 50m and 25m mosaic data free of charge (http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm). Later on he discussed about how JAXA have developed the forest and non-forest map and how to use it. He also shared some of his experiences while working on the development of PALSAR mosaic dataset as well as development of forest and non-forest map. Later on he presented about the software in details and how to run the software on the window system. He has discussed about various types of image processing flow in LULC classification and which classification algorithm will be useful for particular type of study area. He has also discuss about importance of ground truth data in the classification and how should collect the ground truth data for higher accuracy. He has shared an example of Riau province of Indonesia and classification results. He has also compared the results based on various classification schemes and accuracy assessment and processing time.

In the next session by Dr. Thapa, he presented about LUC Tool of JAXA in details and how it process the data especially PALSAR data. The detail of the LUC tool is available online on (http://www.eorc.jaxa.jp/ALOS-2/en/doc/pal2_tool.htm). Before starting the hands-on-training on LUC tool he explained about reference material in brief which includes: region growing

algorithm in segmentation, random tree, decision tree, support vector machine (SVM), artificial neural network (ANN), Bayesian classifier etc. After this he started demonstrating about how to use the LUC software. We have provided the LUC software training manual before the training programme so that helps all the participants to follow the steps for the classification. After Dr. Thapa's morning session, we had a lunch break. During the lunch break participants shared their experiences in the land use land cover classification.

Right after the lunch session we started PALSAR data processing using LUC software. Dr. Thapa was explaining all the steps in details and all the participants was following the processing steps to process PALSAR data. Dr. Ram Avtar was helping the participants during the processing of PALSAR data. Dr. Thapa explained all the steps to process PALSAR data and participants followed the same steps to generate the forest cover map of the study area. Finally, Dr. Thapa demonstrated how to identify deforested area based on classification results and change in backscattering information. He mentioned if the area is deforested then there is sudden change in the backscattering value of cross polarization channel (HV) of PALSAR data. He also mentioned about the importance of HV band in forest and deforestation monitoring.

If you are interested to use the training data and manual you can easily access from the INATE and JAXA website. For details please see the attached slides of Prof. Thapa's talk.

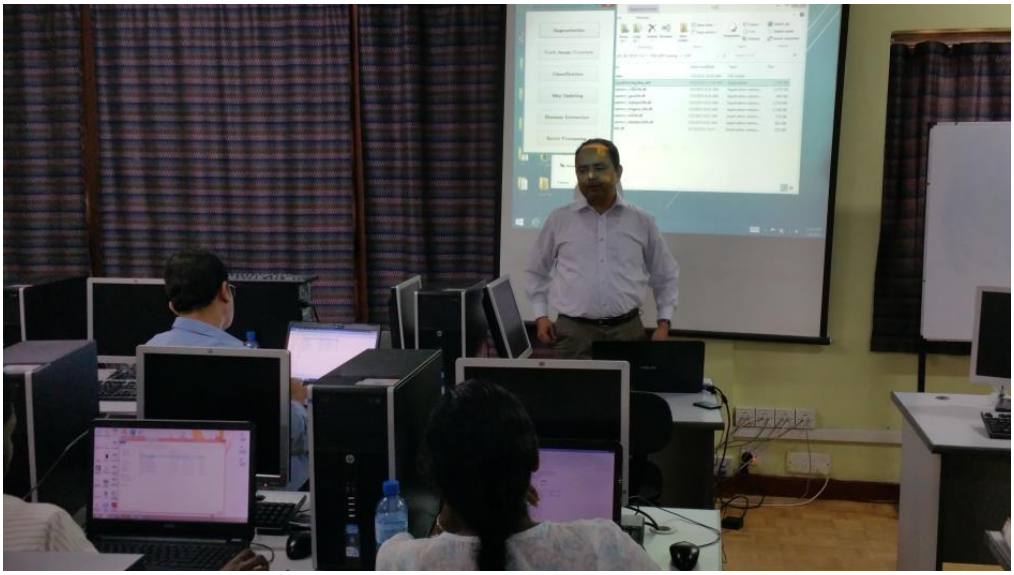


Photo captured during the LUC training session

Day 3 (10th January, 2016)

As we set in the agenda, day 3rd mainly covers a hands-on-training programme to demonstrate how to use Landsat data for forest cover and deforestation. The second half of the day was

for the field visit to demonstrate all the participants how to collect forest inventory data. We have installed ArcGIS software to all the systems and activated the licence. We have also provided the ArcGIS licence to all the participants so even after the training programme, participants can use ArcGIS at their respective institute to process satellite data and other GIS related work.

Dr. Avtar has presented about how to acquire Landsat data from USGS earthexplorer (http://earthexplorer.usgs.gov/). Later on he demonstrated about how to use Landsat data for forest cover classification. He created a stack image of Landsat data and generated a Normalized Difference Vegetation Index (NDVI). He also demonstrated how to visually and digitally interpret Landsat data to identify various objects on the earth surface. The outcome of this session was to demonstrate the participants about how to process Landsat data and acquire useful information for their use.

He discussed about various types of classification scheme in ArcGIS and finally selected Maximum Likelihood Classification (MLC) based on his previous experiences. He provided the manual how to classify the Landsat data using MLC in ArcGIS to all the participants and followed all the steps. Finally, all the participants generated forest cover map of the study area and compared the results to generate forest cover and deforestation sites. For details please see the attached slides of Dr. Ram's talk.

All the participants expressed strong interest in the training programme and actively participated during the training programme. We had certificate distribution ceremony. We have given certificate of participation to all the participants after the training programme. Prof. Nissnaka, Prof. Abayakoon, Dr. Thapa and Dr. Ram distributed certificates to all tha participants. At the last Prof. Nissanka, Prof. Abayakoon and Dr. Ram gave a closing remark by thanking all the staff members, organizer, participants for making the training programme successful. Participant also shared his experience during the training programme and usefulness of such capacity development programme. After the closing ceremony, we had a lunch break. During the lunch break participants shared their experiences during the whole training programme.

Photo captured during the closing ceremony

Right after the lunch all the participants ready to go to the field. University of Peradeniya hired a bus for all the participants to go to the field and bus took about 20 minute to reach to the forst site in Hanathana forest. Which is mainly pinus plantation forest. In the field Dr. Avtar demonstrated about how to measure the forest biomass by making and collecting the forest inventory data. Dr. Avtar demonstrated about how to make a forest sample plot and how to measure Diameter at Breast Height (DBH) and tree height and how to estimate forest biomass using existing allometric equations. Finally, we have collected one plot data in 20x20m forest plot.

Photo captured during forest inventory data collection

Annexure# 2

Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System

8th – 10th January, 2016

Workshop venue: University of Peradeniya, Sri Lanka

Aim:

The aim of the hands-on-training programme is to develop the capacity of various stakeholders to use various remote sensing data (optical and Synthetic Aperture Radar (SAR)) to monitor forest cover and deforestation. The training programme aims to develop a better understanding to use optical and SAR data to monitor forest cover and deforestation that will be useful for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation.

Organizers:

United Nations University Institute of the Advanced Study of Sustainability (UNU-IAS) Tokyo, Japan Aerospace Exploration Agency (JAXA), Asia Pacific Network for Global Change Research (APN-GCR), University of Peradeniya- Sri Lanka

Programme schedule:

Date/Times	Subject	Resource Persons
January 08, 2016		
09:30-10:00	Registration/Coffee	
10:00-10:20	Opening Remarks	- Prof. Leelananda Rajapaksha -Prof. Srikantha Herath
10:20-10:30	Group Photo	
10:30-11:00	APN capacity development hands-on-training overview	Dr. Ram Avtar
11:00 – 12:00	Forest monitoring in Sri Lanka and REDD+ project	Prof. S. P. Nissanka and Prof. Abayakoon
12:00 -13:00	Lunch	
13:00 – 14:30	Basics of Remote Sensing and application in forestry sector	Dr. Ram Avtar
15:00-16:30	Forest monitoring using SAR data	Dr. Rajesh Thapa

16:30 – 17:00	Installation of software and data download	Dr. Ram Avtar Dr. Rajesh Thapa
January 09, 2016		
9:30 – 11:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
11:00 – 11:15	Coffee break	
11:15 – 12:30	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
12:30 – 13:30	Lunch	
13:30 – 15:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
15:00 – 15:15	Coffee break	
15:15 – 17:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
January 10, 2016		
9:30 – 11:00	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
11:00 – 11:15	Coffee break	
11:15 – 12:25	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
12:25-12:35	Closing remarks	
12:35 – 13:35	Lunch	
13:35 – 17:00	Field visit to demonstrate, collection of forest inventory data	Dr. Ram/Dr. Thapa/Prof. Abayakoon/Prof. Nissanka

Annexure# 3

List of participants

No	Name of Participants	Institute/University	Designation
1	Ms. M. A. Sureka Krishanthi	Land Use Policy Planning Department	Land Use Policy Planning Officer
2	Ms. W. V. N. Sudarshani	Survey Department of Sri Lanka	Remote Sensing Technological Officer
3	Mr. P.R.W. Karunarathne		Remote Sensing Technological Officer
4	Ms. Nadeeka Senani Wijewardana	National Water Supply & Drainage Board	Institutional Development Officer
5	Ms. Thilanka Athawuda Gunarathne	University of Peradeniya	Senior Lecturer
6	Ms. Dulani Priyangani Wijewardana	University of Peradeniya	Instructor
7	Mr. Nuwan Sampath Bandara Kekulandara	Forest Department	Assistant Conservator of Forests
8	Mr. Sajeeva Srinath Kosgolla	University of Peradeniya	Instructor
9	Dr. (Mrs.) Hemalie Kalpalatha Nandalal	University of Peradeniya	Senior Lecturer
10	Dr. Jagath Gunatilake	University of Peradeniya	Head, Department of Geology
11	Mr. G.I. Wanasinghe	University of Peradeniya	Lecturer
12	Ms. T. Tamasha Fernado	Central Environmental Authority	Senior Environmental Officer
13	Mr. Ajith Rohana Gunawardena	Central Environmental Authority	Assistant Director

14	Mr. Raushan Kumara	FAO, Sri Lanka	Programme officer
15	Ms. I P Chamkia Jayathilaka	Kandy City Waste water management project National water supply and drainage board	GIS technician
16	Mr. Kelum Indunil Ananda	Kandy City Waste water management project National water supply and drainage board	Civil Engineer
17	Mr. G J Tharindu Kumara Hannagala	University of Peradeniya	Graduate student
18	Ms. D K Wanniacrachchi	University of Peradeniya	
19	Dr. S P Nissanka	University of Peradeniya	Senior Lecturer
20	Ms. A K D Prabodhani Ananda	Central Engineering Consultancy Bureau	Draughtaman
21	Ms. Pinnadoowage Thilini De Silva	Central Engineering Consultancy Bureau	Technical Officer
22	Ms. H M Janaki Mangala Jumari Herath	Central Engineering Consultancy Bureau	Engineer
23	Mr D A V J Chaturanga	Central Engineering Consultancy Bureau	Engineer
24	Mr. T M M P Dimutana	Hapugatenna Estate	Management Trainee
25	Mr. W A A E Karunarathe	University of Peradeniya	Research Assistant
26	Mr. K H N C De Silva	University of Peradeniya	Research Assistant

FINAL REPORT of the Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System: JNU, New Delhi

Date and Venue

The hands-on-training programme took place on 13th – 15th May 2016 at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India. The international guests including Dr. Rajesh Thapa, Dr. Ram Avtar and Ms. Ridhika Aggarwal arrived before the programme to discuss about agenda and coordination of facilitation as well as to fine-tune the training material and update with respect to Indian scenario. We checked the computer facilities and configured the internet connection and installed the required software for the training programme. We also checked the conference facilities and arrangements for the opening ceremony. All the international guests were well received by Prof. Saumitra Mukherjee and Dean School of Environmental Sciences, Jawaharlal Nehru University and discussed about the workshop facilities.

Purpose

The purpose of hands-on-training was to develop the capacity of various stakeholders to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UN-CECAR)/INATE. The training program was to support Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation as well as to promote and strengthen the capacity and knowledge to monitor forest cover and its changes due to deforestation. The main attraction of this training program was to use Synthetic Aperture Radar (SAR) data for forest cover and deforestation monitoring because most of the tropical countries have limitations of acquisition of cloud free optical satellite data. The training programme was funded by the Asia Pacific Network for Global Change Research (APN-GCR) under CAPaBLE programme.

International Guests

The international members were Dr. Rajesh Thapa, Japan Aerospace Exploration Agency (JAXA), Japan; Dr. Ram Avtar, United Nations University, Institute for the Advanced study of Sustainability (UNU-IAS), Japan and Ms. Ridhika Aggarwal, UNU-IAS, Japan.

Agenda

The training team agreed on an agenda prior to the training programme (attached as Annexure #4), which was approved by the resource persons and organizer, as follows:

Day 1

• Opening and Introduction about APN programme

• Forest monitoring in Sri Lanka and REDD+ project

• Basics of Remote sensing and application in forestry sector

Day 2

• Hands on training using SAR data

• LetsSAR training

Day 3

• Hands-on-training using Landsat data

• ArcGIS trainings for land cover classification

• Field visit to demonstrate collection of inventory data

Adjustments had to be made to the agenda, in light of various considerations, such as delay in the previous session, the degree of tiredness of participants, who had travelled very early to the training venue.

Participants:

The training programme was attended by thirty (30) participants. The list of participants is attached as Annexure#5. We had participants from diverse background and institutions.

The Training programme

Day 1 (13th May, 2016)

The training programme was opened with registration of all the participants and opening ceremony. We started the programme with a prayer and lightening of candle. Later on Prof. I. S. Thakur, Dean School of Environmental Sciences was invited to give an opening remark to all the participants.

Photographs: Prof. I S Thakur and Dr. Bhoop Singh during the lightening of candle

Prof. Thakur warmly welcomed all the participants and mentioned about the importance of capacity development programme to enhance the skills/knowledge. He has also mentioned why forest monitoring is important. After Prof. Thakur, we invited Dr. Bhoop Singh from Department of Science and Technology (DST), Government of India for the opening remarks. He has been working as a Director of natural resource management division of DST so he had shared various case studies related to forest management in India and how Government is trying to improve the forest resources in India. He explained about significant role of geospatial data in forest management and implementation of REDD+ policies. He also offered shared various information to download data and information from DST portal for the success of REDD+ in India. On behalf of UNU-IAS, Dr. Ram Avtar welcomed all the participants. He warmly thanked Jawaharlal Nehru University, New Delhi for coordinating and hosting the training programme and making all the necessary arrangement. He gave a brief summary about the UN-CECAR/INATE related activities in Asia-Pacific region and explained the importance of necessity of University Network for organizing various courses and capacity development programme. He mentioned about the timing of this training programme is very appropriate because Paris agreement says that *"Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests".* REDD+ is an excellent mechanism to implement this idea. Therefore, this training programme will be useful to develop the capacity of various stakeholders by providing them training programme on use of advanced remote sensing techniques to monitor forests. This project will also open up new opportunities for multi-country partnership to learn/share the knowledge. At the last Prof. Saumitra Mukherjee welcomed all the participants and discussed about his involvement in APN project and why multi-country projects are essential.


Photographs: Prof. I S Thakur and Dr. Bhoop Singh during the opening ceremony

Later on we have asked all the participants to introduce themselves as an ice-breaker so all the participants become familiar with each other and finally we took a group photograph of all the participants. After the group photograph we invited all the participants for refreshment. All the participants enjoyed high tea and discussed about their interest in remote sensing/GIS training programme.

Photograph during the opening ceremony

Group photograph of all the participants during opening ceremony

After the high tea, we invited Dr. Ram Avtar for giving an overview about UN-REDD+ programme and APN funded project. Dr. Avtar talked about the importance of REDD+ mechanism in the climate change mitigation and why Measurement, Reporting and Verification (MRV) system is useful for the implementation of REDD+ mechanism. Different limitations of remote sensing techniques and how multi-sensor remote sensing techniques can overcome the limitations of one sensor by adapting multi-sensor approach. Later on Dr. Avtar presented about the forest cover, deforestation and forest biomass monitoring using multi-sensor remote sensing. He also presented about the APN project and what are the expectations from this capacity development programme. After Dr. Avtar's presentation, we invited Prof. Mukherjee to briefly explain about the training programme and discussion during the APN's inception workshop in Cambodia. After Prof. Mukherjee's talk, we invited Dr. Bhoop Singh to present about the forest monitoring in India and how DST is working towards managing natural resources in India. He has also shared various research related to REDD+ projects in India. He has covered various problems in forestry sector of India and how remote sensing can contribute towards managing forest resources.

After Dr. Bhoop Singh's talk we had a lunch break and all the participants enjoyed delicious Indian vegetarian food and enjoyed chatting with each other to know more about each other and their ongoing research work.

After Lunch break, we invited Dr. Ram Avtar from UNU to present about basics of remote sensing that provided a broad understanding of the spatial analysis techniques and their use in many aspects of global environment. He presented about basic principles of Remote Sensing and Image Interpretation, different types of remote sensing techniques and further about Digital Image Processing (DIP), image classification and various applications. He also

introduced various satellite sensors available for earth observation and use in change detection that could help to understand long-term local and global changes and climate change issues. The aim of the lecture was to familiarize participants with the theoretical background and practical application of Remote Sensing. Dr. Avtar also discussed about application of remote sensing in forest monitoring especially focusing on forest cover, deforestation and forest biomass estimation using optical and SAR data. After Dr. Avtar's presentation, we had a question/answer session, where we discussed about significance of SAR and optical sensor data in Indian forestry sector. We also had discussion about saturation and limitations of SAR and optical sensors and how multi-sensor remote sensing can play a significant role to monitor forest more accurately.

After Dr. Avtar's presentation, we invited Dr. Rajesh Thapa from JAXA, Japan to present about various methodologies to monitor forest in south-east Asia. Dr. Thapa gave a very comprehensive presentation on use of various satellite data and role of JAXA's Advanced Land Observation Satellite (ALOS) data to monitor forest cover, deforestation and forest biomass. He shared various case studies working on ALOS data in Southeast Asia. He also shared the results based on optical data and their limitations in tropical regions. He shared his current findings based on Phased Array L-band type Synthetic Aperture Radar (PALSAR) data. For details please see the attached slides of Dr. Thapa's talk. After Dr. Thapa's talk we had a question/answer session, where we had discussion about why we need to make a shift from optical to SAR sensor in tropical forest monitoring.

After Dr. Thapa's session we asked the students to check the system requirement and installation of the software for the next day hands on training programme.

Photograph captured during the presentation of Dr. Avtar and Dr. Thapa

Day 2 (14th May, 2016)

Day 2 started with the morning session by Dr. Rajesh Thapa from JAXA, to present Introduction on Land use/cover classification using PALSAR mosaic data. In his talk he discussed about JAXA's software tool and data, Image processing flow, application of PALSAR mosaic data. At the beginning he discussed about the JAXA's software for LULC classification. Later on he discussed about the availability of PALSAR data because there were questions on accessibility to PALSAR data. He has shared a link from where participants can download PALSAR 50m and 25m mosaic data free of charge (http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm). Later on he discussed about how JAXA has developed forest and non-forest map and how to use it. He also shared some of his experiences while working on the development of PALSAR mosaic dataset as well as development of forest and non-forest map. Later on he presented about the software in details and how to run the software on window system. He has discussed about various types of image processing flow in LULC classification and which classification algorithm will be useful for particular type of study area. He also discussed about importance of ground truth data for carrying out classification and how to collect ground truth data for higher accuracy. He shared an example of Riau province of Indonesia and classification results. He also compared the results based on various classification schemes and accuracy assessment and processing time.

In the next session by Dr. Thapa, he presented about LUC Tool of JAXA in details and how it process the data especially PALSAR data. The detail of the LUC tool is available online on (http://www.eorc.jaxa.jp/ALOS-2/en/doc/pal2_tool.htm). Before starting the hands-on-training on LUC tool he explained about reference material in brief which includes: region growing algorithm in segmentation, random tree, decision tree, support vector machine (SVM), artificial neural network (ANN), Bayesian classifier etc. After this he started demonstrating about how to use the LUC software. We have provided the LUC software training manual before the training programme so that helps all the participants to follow the steps for the classification.

After Dr. Thapa's morning session, we had a lunch break. During the lunch break participants shared their experiences in the land use land cover classification.

Right after the lunch session we started PALSAR data processing using LUC software. Dr. Thapa explained all the data processing steps in details and the participants followed the instructions to process PALSAR data. Dr. Ram Avtar was helping the participants during the processing of PALSAR data. Dr. Thapa explained all the steps to process PALSAR data and participants followed the same steps to generate the forest cover map of the study area. Finally, Dr. Thapa demonstrated how to identify deforested area based on classification results and

change in backscattering information. He mentioned if the area is deforested then there is sudden change in the backscattering value of cross polarization channel (HV) of PALSAR data. He also mentioned about the importance of HV band in forest and deforestation monitoring.

If you are interested to use the training data and manual you can easily access from the JAXA website. You can also enjoy video lecture on youtube (https://www.youtube.com/watch?v=3e3eIi-lDYo)

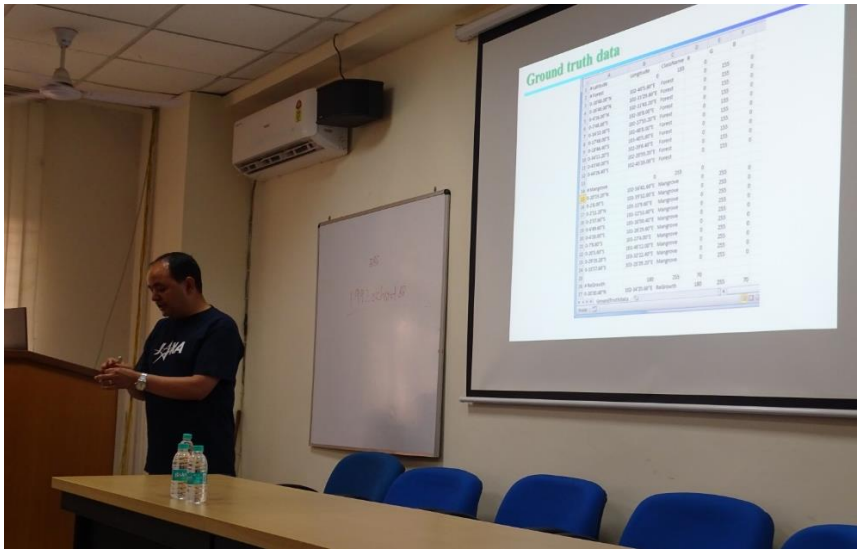


Photo captured during the LUC training session

Day 3 (15th May, 2016)

As we set in the agenda, day 3rd mainly covered a hands-on-training programme to demonstrate how to use Landsat data for forest cover and deforestation. The second half of the day was for the field visit to demonstrate all the participants how to collect forest inventory data. We have installed ArcGIS software to all the systems and activated the licence. We have also provided the ArcGIS licence to all the participants so even after the training programme, participants can use ArcGIS at their respective institute to process satellite data and other GIS related work.

Dr. Avtar has presented about how to acquire Landsat data from USGS earthexplorer (http://earthexplorer.usgs.gov/). Later on he demonstrated about how to use Landsat data for forest cover classification. He created a stack image of Landsat data and generated a Normalized Difference Vegetation Index (NDVI). He also demonstrated how to visually and digitally interpret Landsat data to identify various objects on the earth surface. The outcome of this session was to demonstrate the participants about how to process Landsat data and acquire useful information for their use.

He discussed about various types of classification scheme in ArcGIS and finally selected Maximum Likelihood Classification (MLC) based on his previous experiences. He provided the manual how to classify the Landsat data using MLC in ArcGIS to all the participants and followed all the steps. Finally, all the participants generated forest cover map of the study area and compared the results to generate forest cover and deforestation sites. For details please see the attached slides of Dr. Ram's talk.

All the participants expressed strong interest in the training programme and actively participated during the training programme. We invited Prof. Chintamani Mohapatra, Rector JNU, New Delhi for the closing remark and certificate distribution. He gave a brief closing remark by thanking all the participants, organizer and supporter including APN-GCR, JAXA, UNU-IAS. He has also shared India's role in climate change mitigation and adaptation and how REDD+ framework is useful to sustainably manage forests. Later on, we had certificate distribution ceremony and we distributed certificate of participation to all the participants after the training programme. At the last Prof. Mukherjee, and Dr. Ram gave a closing remark by thanking all the staff members, organizer, and participants for making the training programme successful. Two participant also shared his experience during the training programme and usefulness of capacity development programme. After the closing ceremony, we had a lunch break. During the lunch break participants shared their experiences during the whole training programme.

Photograph captured during closing ceremony

Right after the lunch all the participants were ready to go to the field to learn how to collect forest inventory data. All the participants travelled to the forest site in Delhi. In the field Dr. Avtar demonstrated about how to measure the forest biomass by collecting the forest inventory data. Dr. Avtar demonstrated about how to make a forest sample plot and how to measure

Diameter at Breast Height (DBH) and tree height and how to estimate forest biomass using existing allometric equations. Finally, we have collected one plot data in 30x30m forest plot.


Photo captured while demonstrating about the collection of forest inventory data

Annexure#4

Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System

13^{th} – 15^{th} May, 2016

Workshop venue: Jawaharlal Nehru University, New Delhi, India

Aim:

The aim of the hands-on-training programme is to develop the capacity of various stakeholders to use various remote sensing data (optical and Synthetic Aperture Radar (SAR)) to monitor forest cover and deforestation. The training programme aims to develop a better understanding to use optical and SAR data to monitor forest cover and deforestation that will be useful for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation.

Organizers:

United Nations University Institute of the Advanced Study of Sustainability (UNU-IAS) Tokyo, Japan Aerospace Exploration Agency (JAXA), Asia-Pacific Network for Global Change Research (APN), Jawaharlal Nehru University, New Delhi, India.

Programme schedule:

Date/Times	Subject	Resource Persons
May 13, 2016		
09:30-10:00	Registration/Coffee	
10:00-10:20	Welcome/Opening Remarks	Prof. I S Thakur Dr. Bhup Singh Dr. Ram Avtar Prof. Saumitra Mukherjee
10:20-10:30	Group Photo	
10:30 -10:45	High tea	
10:45-11:00	APN capacity development hands-on-training overview	Dr. Ram Avtar
11:00 – 12:00	Forest monitoring in India and REDD+ project	Dr. Bhup Singh
12:00 -13:00	Lunch	

13:00 – 14:30	Basics of Remote Sensing and application in forestry sector	Dr. Ram Avtar
14:30 – 14:45	Coffee break	
14:45-16:30	Forest monitoring using SAR data	Dr. Rajesh Thapa
16:30 – 17:00	Installation of software and data download	Dr. Ram Avtar Dr. Rajesh Thapa
May 14, 2016		
9:30 – 11:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
11:00 – 11:15	Coffee break	
11:15 – 12:30	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
12:30 – 13:30	Lunch	
13:30 – 15:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
15:00 – 15:15	Coffee break	
15:15 – 17:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
May 15, 2016		
9:30 – 11:00	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
11:00 – 11:15	Coffee break	
11:15 – 12:25	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
12:25-12:35	Certificate distribution and closing remarks	Prof. Chintamani Mohapatra/Prof. S. Mukherjee
12:35 – 13:35	Lunch	
13:35 – 17:00	Field visit to forest site to demonstrate how to collect the inventory data	

Annexure#5

List of the participants

No	Name of Participants	Company Name
1	Priyadarshini Singh	School of Environmental Sciences, JNU
2	Chandrashekhar Azad Vishwakarma	School of Environmental Sciences, JNU
3	Ratan Sen	School of Environmental Sciences, JNU
4	Payam Sajadi	School of Environmental Sciences, JNU
5	Harshita Asthana	School of Environmental Sciences, JNU
6	Deepali Singh	School of Environmental Sciences, JNU
7	Nidhi Roy	School of Environmental Sciences, JNU
8	Vikas Rena	School of Environmental Sciences, JNU
9	Pradeep Kumar	School of Environmental Sciences, JNU
10	Jyoti Kushwaha	School of Environmental Sciences, JNU
11	Dr.Amit Singh	TERI University
12	Dr.Chander Kumar Singh	TERI University
13	Dr.Kumari Rina	Gujrat Central University
14	Dr.Bir Abhimanyu Kumar	Indira Gandhi National Open University (IGNOU), New Delhi
15	Dr.V.Venkatraman	Indira Gandhi National Open University (IGNOU), New Delhi
16	Dr.Sudhir Kumar Singh	Allahabad University
17	Dr.Ravi Prakash Singh	NRSC HYDERABAD
18	Dr.Neha Singh	BARODA UNIVERSITY
19	Ridhhika Aggarwal	UNU-IAS, Japan
20	Purvesh Patel	Defence Terrain Research Laboratory, DTRL, New Delhi
21	Amit Kumar	Defence Terrain Research Laboratory, DTRL, New Delhi
22	Seema Yadav	Guru Gobind Singh Indraprastha University, New Delhi
23	Anand	Guru Gobind Singh Indraprastha University, New Delhi
24	Chindu Chandran	Guru Gobind Singh Indraprastha University, New Delhi
25	Piyush Gupta	National Informatics Centre, Delhi
26	Mukesh Kumar	School of Environmental Sciences, JNU
27	Mayank Krishna	School of Environmental Sciences, JNU
28	Ankur	Rajiv Gandhi Proudyogiki VIshwavidhyalaya, Bhopal

29	Raj Kumar Singh	International Center for Agriculture Research in Dry Areas (ICARDA)
30	Ankita Gupta	Rajiv Gandhi Proudyogiki VIshwavidhyalaya, Bhopal

FINAL REPORT of the Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System: Allahabad University, Uttar Pradesh, India

Date and Venue

The hands-on-training programme took place on 17th – 18th May 2016 at the Centre for Environmental Science, Allahabad University, Uttar Pradesh, India. The international guests including Dr. Rajesh Thapa and Dr. Ram Avtar arrived one day before the programme to discuss about agenda and coordination of facilitation as well as to fine-tune the training material. We checked the computer facilities and configured the internet connection and installed the required software for the training programme. We also checked the conference facilities and arrangements for the opening ceremony. All the international guests were well received by Prof. Anupam Dikshit of Allahabad University and discussed about the workshop facilities.

Purpose

The purpose of hands-on-training was to develop the capacity of various stakeholders to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UN-CECAR)/INATE. The training program was to support Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation as well as to promote and strengthen the capacity and knowledge to monitor forest cover and its changes due to deforestation. The main attraction of this training program was to use Synthetic Aperture Radar (SAR) data for forest cover and deforestation monitoring because most of the tropical countries have limitations of acquisition of cloud free optical satellite data. The training programme was funded by the Asia Pacific Network for Global Change Research (APN-GCR) under CAPaBLE programme.

International Guests

The international members were Dr. Rajesh Thapa, Japan Aerospace Exploration Agency (JAXA), Japan; Dr. Ram Avtar, United Nations University, Institute for the Advanced study of Sustainability (UNU-IAS), Japan.

Agenda

The training team agreed on an agenda prior to the training programme (attached as Annexure #6), which was approved by the resource persons and organizer, as follows:

Day 1

- Opening and Introduction about APN programme
- Forest monitoring in Sri Lanka and REDD+ project
- Basics of Remote sensing and application in forestry sector

Day 2

- Hands on training using SAR data
- LetsSAR training
- Hands-on-training using Landsat data
- ArcGIS trainings for land cover classification

Adjustments had to be made to the agenda, in light of various considerations, such as delay in the previous session, the degree of tiredness of participants, who had travelled very early morning to the training venue.

Participants:

The training programme was attended by forty-two (42) participants. The list of participants is attached as Annexure#7. We had participants from diverse background and institutions.

The Training programme

Day 1 (17th May, 2016)

The training programme was opened with registration of all the participants and opening ceremony. We started the programme with a prayer and lightening of candle. Later on Prof. R. L. Hangloo, Vice-Chancellor of Allahabad University was invited to give an opening remark to all the participants.

Photographs: Prof. Anupam Dikshit and Prof. R. L. Hangloo during the lightening of candle

Prof. Hangloo warmly welcomed all the participants and mentioned about the importance of capacity development programme to enhance the skills/knowledge. He has also mentioned about importance of forest in providing various products to human beings. Prof. Hangloo also emphasized role of Vanmahotsava programme of Govt. of India and how it is helping to improve the forest resources. After Prof. Hangloo, we invited Dr. R. Gopichandran Director, Vigyan Prasar, New Delhi for a brief remark. He mentioned about role of Vigyan Prasar to enable access to appropriate information in a timely manner aligned with India's developmental imperatives so that her citizens will be able to acquire the necessary scientific insights to improve their core strengths in all sectors of learning with implications for sustainable development. The logical framework of science communication, therefore, emphasizes enriched learning and enhanced abilities for well-informed action. He also explained about significance of capacity development programme especially for those who have less knowledge about recent development in science and technology. On behalf of UNU-IAS, Dr. Ram Avtar welcomed all the participants. He warmly thanked Allahabad University for coordinating and hosting the training programme and making all the necessary arrangement. He gave a brief summary about the UN-CECAR/INATE related activities in Asia-Pacific region and explained the importance of necessity of University Network for organizing various courses and capacity development programme. He mentioned about the timing of this training programme is very appropriate because Paris agreement says that *"Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests".* REDD+ is an excellent mechanism to implement this idea. Therefore, this training programme will be useful to develop the capacity of various stakeholders by providing them training programme on use of advanced remote sensing techniques to monitor forests. This project will also open up new opportunities for multi-country partnership to learn/share the knowledge. At the last

Prof. Saumitra Mukherjee welcomed all the participants and discussed about his involvement in APN project and why multi-country projects are essential.

Photographs: Prof. R. L. Hangloo and Dr. R. Gopichandran during the opening ceremony

Later on we have asked all the participants to introduce themselves as an ice-breaker so all the participants become familiar with each other and finally we took a group photograph of all the participants. After the group photograph we invited all the participants for refreshment. All the participants enjoyed high tea and discussed about their interest in remote sensing/GIS training programme.

Group photograph of all the participants during opening ceremony

After the high tea, we invited Dr. Ram Avtar for giving an overview about UN-REDD+ programme and APN funded project. Dr. Avtar talked about the importance of REDD+ mechanism in the climate change mitigation and why Measurement, Reporting and Verification (MRV) system is useful for the implementation of REDD+ mechanism. Different limitations of remote sensing techniques and how multi-sensor remote sensing techniques can overcome the limitations of one sensor by adapting multi-sensor approach. Later on Dr. Avtar presented about the forest cover, deforestation and forest biomass monitoring using multi-sensor remote sensing. He also presented about the APN project and what are the expectations from this capacity development programme. After Dr. Avtar's presentation, we invited Dr. Gopichandran to present about the Indian forest and various forest management practices in India. He gave some case studies about slash and burn cultivation in North-eastern part of India and how traditional knowledge is useful to manage forest in India. He also presented about recent forest fire in Uttrakhand region and what kind of initiative government should take to minimize impacts of forest fire on biodiversity and ecosystem services. He also shared some case studies on REDD+ projects in India.
After Dr. Gopichandran's talk we had a lunch break and all the participants enjoyed delicious Indian vegetarian food and enjoyed chatting with each other to know more about each other and their ongoing research work.

After Lunch break, we invited Dr. Sudhir Singh from Allahabad University to give a lecture on basics of remote sensing. He taught about basic principles of Remote Sensing and Image Interpretation, different types of remote sensing techniques and further about Digital Image Processing (DIP), image classification and various applications. He also introduced various satellite sensors available for earth observation and use in change detection that could help to understand long-term local and global changes and climate change issues. The aim of the lecture was to familiarize participants with the theoretical background and practical application of Remote Sensing. After Dr. Sudhir's talk, we had a question/answer session, where students interacted with all the resource persons to know more about role of remote sensing techniques in forestry sectors.

Photograph captured during the presentation of Dr. Gopichandran and Dr. Sudhir

After Dr. Sudhir's talk, we invited Dr. Rajesh Thapa from JAXA, Japan to share his experiences while developing various methodologies to monitor forest in south-east Asia. Dr. Thapa gave a very comprehensive presentation on use of various satellite data and role of JAXA's Advanced Land Observation Satellite (ALOS) data to monitor forest cover, deforestation and forest biomass. He shared various case studies working on ALOS data in Southeast Asia. He also shared the results based on optical data and their limitations in tropical regions. He shared his current findings based on Phased Array L-band type Synthetic Aperture Radar (PALSAR) data. For details please see the attached slides of Dr. Thapa's talk. After Dr. Thapa's session we asked the students to check the system requirement and installation of the software for the next day hands on training programme.

Photograph captured during the presentation of Dr. Thapa and question/answer session

Day 2 (18th May, 2016)

Day 2 started with the morning session by Dr. Rajesh Thapa from JAXA, to present Introduction on Land use/cover classification using PALSAR mosaic data. In his talk he discussed about JAXA's software tool and data, Image processing flow, application of PALSAR mosaic data. At the beginning he discussed about the JAXA's software for LULC classification. Later on he discussed about the availability of PALSAR data because there were questions on accessibility to PALSAR data. He has shared a link from where participants can download PALSAR 50m and 25m mosaic data free of charge (http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm). Later on he discussed about how JAXA has developed forest and non-forest map and how to use it. He also shared some of his experiences while working on the development of PALSAR mosaic dataset as well as development of forest and non-forest map. Later on he presented about the software in details and how to run the software on window system. He has discussed about various types of image processing flow in LULC classification and which classification algorithm will be useful for particular type of study area. He also discussed about importance of ground truth data for carrying out classification and how to collect ground truth data for higher accuracy. He shared an example of Riau province of Indonesia and classification results. He also compared the results based on various classification schemes and accuracy assessment and processing time.

In the next session by Dr. Thapa, he presented about LUC Tool of JAXA in details and how it process the data especially PALSAR data. The detail of the LUC tool is available online on (http://www.eorc.jaxa.jp/ALOS-2/en/doc/pal2_tool.htm). Before starting the hands-on-training on LUC tool he explained about reference material in brief which includes: region growing algorithm in segmentation, random tree, decision tree, support vector machine (SVM), artificial neural network (ANN), Bayesian classifier etc. After this he started demonstrating about how to use the LUC software. We have provided the LUC software training manual before the training programme so that helps all the participants to follow the steps for the classification. After Dr. Thapa's morning session, we had a coffee break. Right after the coffee break, we started PALSAR data processing using LUC software. Dr. Thapa explained all the data processing steps in details and the participants followed the instructions to process PALSAR data. Dr. Ram Avtar was helping the participants during the processing of PALSAR data. Dr. Thapa explained all the steps to process PALSAR data and participants followed the same steps to generate the forest cover map of the study area. Finally, Dr. Thapa demonstrated how to identify deforested area based on classification results and change in backscattering information. He mentioned if the area is deforested then there is sudden change in the backscattering value of cross polarization channel (HV) of PALSAR data. He also mentioned about the importance of HV band in forest and deforestation monitoring.

If you are interested to use the training data and manual you can easily access from the JAXA website. You can also enjoy video lecture on youtube (https://www.youtube.com/watch?v=3e3eIi-lDYo). After Dr. Thapa's hands-on-training, we had a lunch break.

Photograph captured during the LUC training session by Dr. Thapa and Dr. Avtar

Right after the lunch break, Dr. Avtar started a session on use of Landsat data to monitor forest cover and deforestation. Dr. Avtar has presented about how to acquire Landsat data from USGS earthexplorer (http://earthexplorer.usgs.gov/). Later on he demonstrated about how to use Landsat data for forest cover classification. He created a stack image of Landsat data and generated a Normalized Difference Vegetation Index (NDVI). He also demonstrated how to visually and digitally interpret Landsat data to identify various objects on the earth surface. The outcome of this session was to demonstrate the participants about how to process Landsat data and acquire useful information for their use.

He discussed about various types of classification scheme in ArcGIS and finally selected Maximum Likelihood Classification (MLC) based on his previous experiences. He provided the manual how to classify the Landsat data using MLC in ArcGIS to all the participants and followed all the steps. Finally, all the participants generated forest cover map of the study area and compared the results to generate forest cover and deforestation sites. For details please see the attached slides of Dr. Ram's talk. All the participants expressed strong interest in the training programme and actively participate during the training programme. We invited Prof. R. R. Tiwari, Dean, School of Science, Allahabad University for the closing remark and certificate distribution. He gave a brief closing remark by thanking all the participants, organizer and supporter including APN-GCR, JAXA, UNU-IAS. Later on, we had certificate distribution ceremony and we distributed certificate of participation to all the participants after the training programme. At the last Prof. Dikshit, and Dr. Ram gave a closing remark by

thanking all the staff members, organizer, and participants for making the training programme successful. At the last participants also shared his experience during the training programme and usefulness of capacity development programme.

Photographs captured during closing and certificate distribution ceremony

Annexure # 6

Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System

17th – 18th May, 2016

Workshop venue: University of Allahabad, Allahabad, Uttar Pradesh, India

Aim:

The aim of the hands-on-training programme is to develop the capacity of various stakeholders to use various remote sensing data (optical and Synthetic Aperture Radar (SAR)) to monitor forest cover and deforestation. The training programme aims to develop a better understanding to use optical and SAR data to monitor forest cover and deforestation that will be useful for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation.

Organizers:

United Nations University Institute of the Advanced Study of Sustainability (UNU-IAS) Tokyo, Japan Aerospace Exploration Agency (JAXA), Asia-Pacific Network for Global Change Research (APN) and University of Allahabad, Uttar Pradesh, India.

Programme schedule:

Date/Times	Subject	Resource Persons
May 17, 2016		
09:30-10:00	Registration/Coffee	
10:00-10:20	Opening Remarks	Prof. Rattan Lal Hangloo Dr. R. Gopichandran Prof. Anupam Dixit
10:20-10:30	Group Photo	
10:30-11:00	APN capacity development hands-on-training overview	Dr. Ram Avtar
11:00 – 12:00	Forest monitoring in India and REDD+ project	Dr. R. Gopichandran
12:00 -13:00	Lunch	
13:00 – 14:30	Basics of Remote Sensing and application in forestry sector	Dr. Sudhir Kumar Singh
15:00-16:30	Forest monitoring using SAR data	Dr. Rajesh Thapa
16:30 – 17:00	Installation of software and data download	Dr. Ram Avtar

		Dr. Rajesh Thapa
May 18, 2016		
9:30 – 11:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
11:00 – 11:15	Coffee break	
11:15 – 12:30	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
12:30 – 13:30	Lunch	
13:30 – 15:00	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
15:00 – 15:15	Coffee break	
15:15 – 16:30	Hands-on-training using optical data	Dr. Ram Avtar/ Dr. Rajesh Thapa
16:30-17:00	Closing remarks and certificate distribution	Prof. R R Tiwari Prof. Anupam Dixit

Annexure# 7

List of participants in Allahabad

Sr. No	Name	Institution
1	Mr. Hemant Kumar	San Higginbottom Institute of Agriculture, Technology and Sciences, (SHIATS) Allahabad
2	Mr. Irjesh Sonker	Department of Earth and Planetary Sciences, University of Allahabad, Allahabad
3	Mr. Jaiveer Singh Dhewa	SHIATS
4	Miss. Mariya Hasnat	Department of Earth and Planetary Sciences, University of Allahabad, Allahabad
5	Mr. Pradeep Kumar	Indian Institute of Technology, BHU
6	Mr. Vikram Gaurav Singh	KBCAOS, University of Allahabad
7	Miss. Saroj Ahirwar	Dr. Hari Singh Gour University, Sagar, M.P.
8	Miss Shraddha Srivastava	Department of Earth and Planetary Sciences, University of Allahabad, Allahabad
9	Mr. Shyam Kumar Sharma	Department of Earth and Planetary Sciences, University of Allahabad, Allahabad
10	Mr. Nirmal Kumar	KBCAOS, University of Allahabad
11	Miss. Rati Shukla	MNNIT, Allahabad
12	Mr. Mukund Pratap Singh	MNNIT, Allahabad
13	Mr. Narendra Singh	MNNIT, Allahabad
14	Mr. Vivek Singh	MNNIT, Allahabad
15	Mr. Sandeep Kumar Yadav	Department of Geography, University of Allahabad
16	Mr. Manoj Kumar Yadav	Department of Geography, University of Allahabad
17	Miss. Pragati Singh	Department of Geography, University of Allahabad
18	Mr. Kamlesh Kushwaha	IGFRI, Jhansi
19	Prof. A S Raghuvanshi	Director, IESD, BHU
20	Mr. Mohammed Sultan Mansor Alshayef	Aligarh Muslim University
21	Anil Kumar	SHIATS
22	Varsha Pandey	IESD, BHU, Varanasi
23	Anil Sharma	IESD, BHU, Varanasi

24	Durgesh singh	University of Allahabad
25	Ajay Tiwari	Jiwaji University Gwalior
26	Nirdesh Kumar Ravi	University of Allahabad
27	Sarvesh kr. Tripathi	University of Allahabad
28	Er. Sarves Pathak	University of Allahabad
29	Dr. Rajesh Dubey	University of Allahabad
30	Dr. Annad Pandey	University of Allahabad
31	Dr. Richa Tandon	University of Rewa Madhaya Pradesh
32	Dr. Santosh Kant	Center for RT & O
33	Ratnakar Misra	University of Allahabad
34	Dr. Amitabh Shad	University of Agra
35	Abhinav Srivastava	CEPT University Ahmedabad Gujrat
36	Shubham Bajpai	University of Allahabad
37	Divya Raghuvanshi	University of Allahabad
38	Benu Tripathi	University of Allahabad
39	Ruby Pandey	University of Allahabad
40	Dr. Harendra Singh	University of Allahabad
41	Dr. Yunus Ali. P	Aligarh Muslim University
42	Dr. Pawan Jha	University of Allahabad

FINAL REPORT of the Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System: Phnom Penh, Cambodia

Date and Venue

The hands-on-training programme took place on 28th June – 1st July 2016 at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India. The international guests including Dr. Rajesh Thapa, Dr. Ram Avtar, and Dr. Hadi Firman arrived before the programme to discuss about agenda and coordination of facilitation as well as to fine-tune the training material and update with respect to Indian scenario. We checked the computer facilities and installed the required software for the training programme. We also checked the conference facilities and arrangements for the opening ceremony. All the international guests were well received by Mr. Chann Sophal, Deputy Director, Institute of Forest and Wildlife Research and Development, Phnom Penh, Cambodia and discussed about the workshop facilities. Dr. Manzul Hazarika from Asian Institute of Technology (AIT) joined the meeting on 30th June.

Purpose

The purpose of hands-on-training was to develop the capacity of various stakeholders to monitor forest cover and deforestation using remote sensing techniques under the UNU's existing University Network for Climate Change and Ecosystem Adaptation Research (UN-CECAR)/INATE. The training program was to support Measurement, Reporting and Verification (MRV) system required for Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation as well as to promote and strengthen the capacity and knowledge to monitor forest cover and its changes due to deforestation. The main attraction of this training program was to use Synthetic Aperture Radar (SAR) data for forest cover and deforestation monitoring because most of the tropical countries have limitations of acquisition of cloud free optical satellite data. The training programme was funded by the Asia Pacific Network for Global Change Research (APN-GCR) under CAPaBLE programme.

International Guests

The international members were Dr. Rajesh Thapa, Japan Aerospace Exploration Agency (JAXA), Japan; Dr. Ram Avtar, United Nations University, Institute for the Advanced study of Sustainability (UNU-IAS), Japan, Dr. Manzul Hazarika, Asian Institute of Technology (AIT), Thailand and Dr. Hadi Firman, AIT, Thailand.

Agenda

The training team agreed on an agenda prior to the training programme (attached as Annexure #8), which was approved by the resource persons and organizer, as follows:

Day 1

• Opening and Introduction about APN programme

• Forest monitoring in India and REDD+ project

• Basics of Remote sensing and application in forestry sector

Day 2

• Hands on training using SAR data

• LetsSAR training

Day 3

• Hands-on-training using Landsat data

• ArcGIS trainings for land cover classification

• Closing ceremony and final workshop meeting

Day 3

• Field visit to demonstrate collection of inventory data

Adjustments had to be made to the agenda, in light of various considerations, such as delay in the previous session, the degree of tiredness of participants, who had travelled very early to the training venue.

Participants:

The training programme was attended by thirty-five (35) participants. The list of participants is attached as Annexure#9. We had participants from diverse background and institutions.

The Training programme

Day 1 (28th June, 2016)

The training programme was opened with registration of all the participants and opening ceremony. We started the programme with a national song of Cambodia. Mr. Chann Sophal invited all the guests to the stage and invited Ms. Vong Sopanha, Deputy Director General of Forestry Administration of Cambodia to give an opening remark to all the participants.

Photographs during opening ceremony

Ms. Vong Sopanha warmly welcomed all the participants and mentioned about the importance of REDD+ in Cambodia. She shared similar programme launched by various organization in Cambodia to conserve forest as there are problems related to forest conflict, agriculture expansion, slash and burn etc. Ms. Sopanha mentioned that use of advanced remote sensing techniques not only help in managing and conserving forests but also provide a sustainable tool for making sustainable forest management plan for future. Ms. Sopanha encouraged all the participants' to develop their skills/knowledge by learning advanced techniques to monitor forest. She has shared some of the initiatives by forestry administration for implementing REDD+ in Cambodia. She also offered use of existing data and information for further upgradation. On behalf of UNU-IAS, Dr. Ram Avtar welcomed all the participants. He warmly thanked Jawaharlal Nehru University, New Delhi for coordinating and hosting the training programme and making all the necessary arrangement. He gave a brief summary about the UN-CECAR/INATE related activities in Asia-Pacific region and explained the importance of necessity of University Network for organizing various courses and capacity development programme. He mentioned about the timing of this training programme is very appropriate because Paris agreement says that *"Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests".* REDD+ is an excellent mechanism to implement this idea. Therefore, this training programme will be useful to develop the capacity of various stakeholders by providing them training programme on use of advanced remote sensing techniques to monitor forests. This project will also open up new opportunities for multi-country partnership to learn/share the knowledge. After Dr. Avtar's welcome remark, we invited Dr. Rajesh Thapa from JAXA to share his experiences while working in world renowned space agency. He shared some interesting case studies in South-east Asia and how JAXA is supporting various activities. At the last Mr. Chann Sophal welcomed all the participants and discussed about his involvement in APN project and why multi-country projects are essential.

Photographs: Dr. Avtar and Dr. Thapa during the opening ceremony

Later on we have asked all the participants to introduce themselves as an ice-breaker so all the participants become familiar with each other and finally we took a group photograph of all the participants. After the group photograph we invited all the participants for refreshment. All the participants enjoyed high tea and discussed about their interest in remote sensing/GIS training programme.

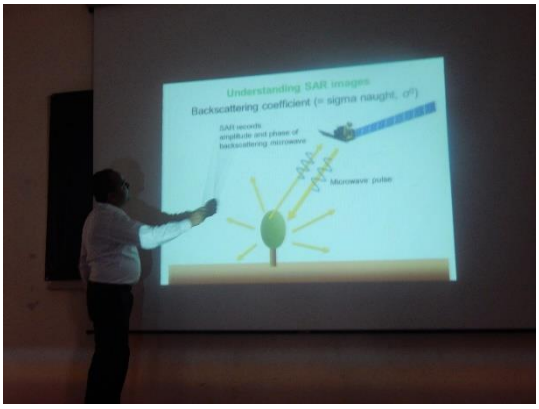
Group photograph during the opening ceremony

After the high tea, we invited Dr. Ram Avtar for giving an overview about UN-REDD+ programme and APN funded project. Dr. Avtar talked about the importance of REDD+ mechanism in the climate change mitigation and why Measurement, Reporting and Verification (MRV) system is useful for the implementation of REDD+ mechanism. Different limitations of remote sensing techniques and how multi-sensor remote sensing techniques can overcome the limitations of one sensor by adapting multi-sensor approach. Later on Dr. Avtar presented about the forest cover, deforestation and forest biomass monitoring using multi-

sensor remote sensing. He also presented about the APN project and what are the expectations from this capacity development programme. After Dr. Avtar's talk, we had a lunch break and all the participants enjoyed delicious Cambodian food and enjoyed chatting with each other to know more about each other and their ongoing research work.

After Lunch break, we invited Dr. Ram Avtar from UNU to present about basics of remote sensing that provided a broad understanding of the spatial analysis techniques and their use in many aspects of global environment. He presented about basic principles of Remote Sensing and Image Interpretation, different types of remote sensing techniques and further about Digital Image Processing (DIP), image classification and various applications. He also introduced various satellite sensors available for earth observation and use in change detection that could help to understand long-term local and global changes and climate change issues. The aim of the lecture was to familiarize participants with the theoretical background and practical application of Remote Sensing. Dr. Avtar also discussed about application of remote sensing in forest monitoring especially focusing on forest cover, deforestation and forest biomass estimation using optical and SAR data. After Dr. Avtar's presentation, we had a question/answer session, where we discussed about significance of SAR and optical sensor data in Indian forestry sector.

After Dr. Avtar's presentation, we invited Dr. Rajesh Thapa from JAXA, Japan to present about various methodologies to monitor forest in south-east Asia. Dr. Thapa gave a very comprehensive presentation on use of various satellite data and role of JAXA's Advanced Land Observation Satellite (ALOS) data to monitor forest cover, deforestation and forest biomass. He shared various case studies working on ALOS data in Southeast Asia. He also shared the results based on optical data and their limitations in tropical regions. He shared his current findings based on Phased Array L-band type Synthetic Aperture Radar (PALSAR) data. For details please see the attached slides of Dr. Thapa's talk. After Dr. Thapa's talk we had a question/answer session, where we asked about participant's experiences in processing PALSAR or Landsat data and what kind of difficulties they had faced while processing the data. After Dr. Thapa's session we asked the students to check the system requirement and installation of the software for the next day hands on training programme.

Photographs during training by Dr. Avtar and Dr. Thapa

Day 2 (29th June, 2016)

Day 2 started with the morning session by Dr. Rajesh Thapa from JAXA, to present Introduction on Land use/cover classification using PALSAR mosaic data. In his talk he discussed about JAXA's software tool and data, Image processing flow, application of PALSAR mosaic data. At the beginning he discussed about the JAXA's software for LULC classification. Later on he discussed about the availability of PALSAR data because there were questions on accessibility to PALSAR data. He has shared a link from where participants can download PALSAR 50m and 25m mosaic data free of charge (http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm). Later on he discussed about how JAXA has developed forest and non-forest map and how to use it. He also shared some of his experiences while working on the development of PALSAR mosaic dataset as well as development of forest and non-forest map. Later on he presented about the software in details and how to run the software on window system. He has discussed about various types of image processing flow in LULC classification and which classification algorithm will be useful for particular type of study area. He also discussed about importance of ground truth data for carrying out classification and how to collect ground truth data for higher accuracy. He shared an example of Riau province of Indonesia and classification results. He also compared the results based on various classification schemes and accuracy assessment and processing time.

In the next session by Dr. Thapa, he presented about LUC Tool of JAXA in details and how it process the data especially PALSAR data. The detail of the LUC tool is available online on (http://www.eorc.jaxa.jp/ALOS-2/en/doc/pal2_tool.htm). Before starting the hands-on-training on LUC tool he explained about reference material in brief which includes: region growing algorithm in segmentation, random tree, decision tree, support vector machine (SVM), artificial neural network (ANN), Bayesian classifier etc. After this he started demonstrating about how

to use the LUC software. We have provided the LUC software training manual before the training programme so that helps all the participants to follow the steps for the classification.

After Dr. Thapa's morning session, we had a lunch break. During the lunch break participants shared their experiences in the land use land cover classification.

Right after the lunch session we started PALSAR data processing using LUC software. Dr. Thapa explained all the data processing steps in details and the participants followed the instructions to process PALSAR data. Dr. Ram Avtar was helping the participants during the processing of PALSAR data. Dr. Thapa explained all the steps to process PALSAR data and participants followed the same steps to generate the forest cover map of the study area. Finally, Dr. Thapa demonstrated how to identify deforested area based on classification results and change in backscattering information. He mentioned if the area is deforested then there is sudden change in the backscattering value of cross polarization channel (HV) of PALSAR data. He also mentioned about the importance of HV band in forest and deforestation monitoring.

If you are interested to use the training data and manual you can easily access from the JAXA website. You can also enjoy video lecture on youtube (https://www.youtube.com/watch?v=3e3eIi-lDYo)

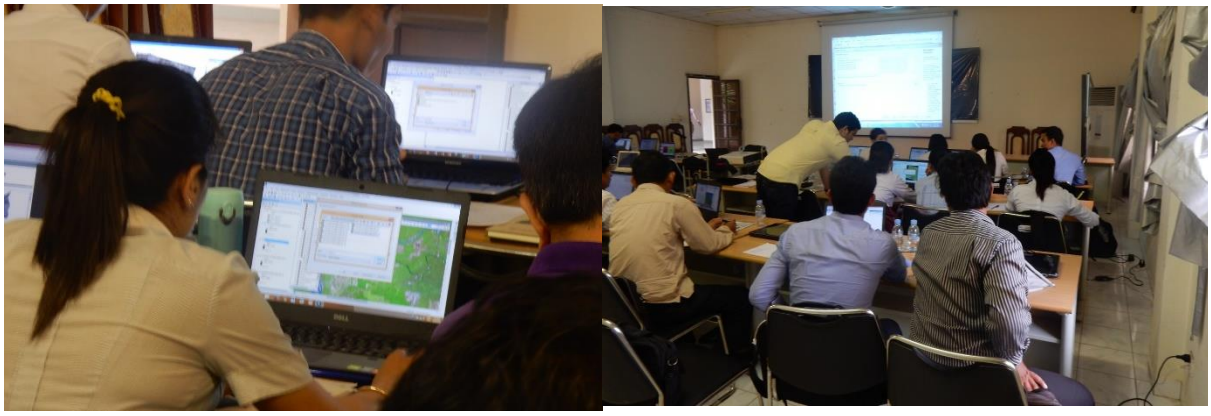
Day 3 (30th June, 2016)

As we set in the agenda, day 3rd mainly covered a hands-on-training programme to demonstrate how to use Landsat data for forest cover and deforestation. The second half of the day was for the field visit to demonstrate all the participants how to collect forest inventory data. We have installed ArcGIS software to all the systems and activated the licence. We have also provided the ArcGIS licence to all the participants so even after the training programme, participants can use ArcGIS at their respective institute to process satellite data and other GIS related work.

Dr. Avtar has presented about how to acquire Landsat data from USGS earthexplorer (http://earthexplorer.usgs.gov/). Later on he demonstrated about how to use Landsat data for forest cover classification. He created a stack image of Landsat data and generated a Normalized Difference Vegetation Index (NDVI). He also demonstrated how to visually and digitally interpret Landsat data to identify various objects on the earth surface. The outcome of this session was to demonstrate the participants about how to process Landsat data and acquire useful information for their use.

He discussed about various types of classification scheme in ArcGIS and finally selected Maximum Likelihood Classification (MLC) based on his previous experiences. He provided the manual how to classify the Landsat data using MLC in ArcGIS to all the participants and

followed all the steps. Finally, all the participants generated forest cover map of the study area and compared the results to generate forest cover and deforestation sites. For details please see the attached slides of Dr. Ram's talk. After Dr. Avtar's talk, we had lunch break and all the participants enjoyed Cambodian food.



Photographs during training by Dr. Avtar

After the lunch we had closing final workshop meeting and closing ceremony of the training programme. We requested other collaborators from Sri Lanka and India but because of their busy schedule they could not join the final workshop. Finally, we asked Dr. Manzul Hazaika from AIT, Thailand for the final workshop because he was interested to organize similar training programme in AIT. We started our final workshop meeting by brain storming session and main point of discussion was: (a) what is the best way to continue this training programme? (b) how to prepare training material into teaching format etc.

We discussed these two points with all the participants and resource persons and finally we come up with ideas to provide all the training material to everyone so they can also learn by themselves. Dr. Hazarika suggested to continue such kind of training programme by local partners and the local collaborators can use this training material in the form of regular course.

All the participants expressed strong interest in the training programme and actively participate during the training programme. We invited Dr. Hazarika from AIT for the closing remark and certificate distribution. He gave a brief closing remark by thanking all the participants, organizer and supporter including APN-GCR, JAXA, UNU-IAS. Later on, we had certificate distribution ceremony and we distributed certificate of participation to all the participants after the training programme. At the last Mr. Sophal and Dr. Ram gave a closing remark by thanking all the staff members, organizer, and participants for making the training programme successful. Some participants also shared his experience during the training programme and utility of capacity development programme.

Photographs captured during the final workshop meeting and closing ceremony

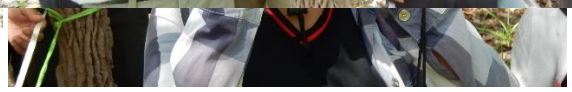
Day 4 (1st July, 2016)

On the last day of the workshop, we started our journey from Phnom Penh to Tamao Zoo forest, which is about 50 km from Phnom Penh. Mr. Chann Sophal came accompanied us to the Tamao Zoo forest site and explained about the forest and various wild life animals. Dr. Avtar give a small talk before starting the demonstration. Dr. Avtar mentioned what are key points we should keep in our mind while collecting forest inventory data: (a) Sampling design which includes stratification of the area, plot shape, plot size, sample size, plot allocation etc. (b) Ground data collection which includes implementation steps, carbon pools to be measured,

required equipment. Dr. Avtar also gave the training to use different instrument to get higher accuracy for example how to use Global Positioning System (GPS), DBH tape, Hypsometer etc. Later on all the participants established a 30x30 m plot for inventory data collection. All the participants worked very actively to establish the plot and measured all the tree species, DBH, height and crown diameter. After collection of forest inventory data Dr. Avtar demonstrated how to use ground based information and calculate total forest biomass using existing allometric equations. Finally, we went for lunch nearby Tamao forest site and after the lunch we came back to Phnom Penh.





Photographs captured while demonstrating about the collection of forest inventory data

Annexure#8

Hands-on-training to Monitor Forest Cover and Deforestation using Advanced Remote Sensing Techniques under UN-CECAR/INATE Framework in support of REDD+ MRV System

28th June – 1st July, 2016

Workshop venue: Forest and Wildlife Training Center

Phnom Penh, Cambodia

Aim:

The aim of the hands-on-training programme is to develop the capacity of various stakeholders to use remote sensing data (optical and Synthetic Aperture Radar (SAR)) to monitor forest cover and deforestation. This capacity development programme will strengthen the scientific knowledge about forest cover and deforestation monitoring to develop a better understanding about role of forests in Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism implementation.

Organizers:

United Nations University Institute of the Advanced Study of Sustainability (UNU-IAS) Tokyo, Japan, Asia-Pacific Network for Global Change Research (APN), Japan Aerospace Exploration Agency (JAXA) and Forestry Administration, Cambodia

Programme schedule:

Date/Times	Subject	Resource Persons
June 28, 2016		
09:30-10:00	Registration/Coffee	
10:00-10:20	Inaugural session	Ms. Vong Sopanha, Deputy Director General, FA Dr. Rajesh Thapa Dr. Ram Avtar
10:20-10:30	Group Photo	
10:30 -10:45	High tea	
10:45-11:00	APN capacity development hands-on-training overview	Dr. Ram Avtar

11:00 – 12:00	Forest monitoring in Cambodia and REDD+ project	Dr. Ram Avtar and Mr. Chann Sophal
12:00 -13:00	Lunch	
13:00 – 14:30	Basics of Remote Sensing and application in forestry sector	Dr. Ram Avtar
14:30 – 14:45	Coffee break	
14:45-16:30	Forest monitoring using SAR data	Dr. Rajesh Thapa
16:30 – 17:00	Installation of software and data download	Dr. Ram Avtar Dr. Rajesh Thapa
June 29, 2016		
9:30 – 11:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
11:00 – 11:15	Coffee break	
11:15 – 12:30	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
12:30 – 13:30	Lunch	
13:30 – 15:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
15:00 – 15:15	Coffee break	
15:15 – 17:00	Hands-on-training using SAR data	Dr. Rajesh Thapa/Dr. Ram Avtar
June 30, 2016		
9:30 – 11:00	Hands-on-training using optical data or forest biomass estimation using SAR data	Dr. Ram Avtar/ Dr. Rajesh Thapa
11:00 – 11:15	Coffee break	
11:15 – 12:25	Hands-on-training using optical data or forest biomass estimation using SAR data	Dr. Ram Avtar/ Dr. Rajesh Thapa
12:25-12:35	Certificate distribution and closing remarks	Dr. Srikantha Herath Mr. Chann Sophal
12:35 – 13:35	Lunch	
13:35 – 17:00	Final workshop meeting to discuss about following points: • Brain storming session • What is the best way to continue this training programme?	Dr. Srikantha Herath Dr. Rajesh Thapa Dr. Ram Avtar Mr. Chann Sophal and all participants

	• How to prepare training material into teaching format etc.	
July 1, 2016		
9:30 – 4:00	Forest inventory data collection in Tamao forest site	

Annexure# 9

List of participants in Cambodia

No.	Name of participants	Institute
1	MR. TITH BORA	Institute of forest and wildlife Research and Development
2	MrR. MAN VUTHY	Institute of forest and wildlife Research and Development
3	MR. KHEAN CHAY	Institute of forest and wildlife Research and Development
4	MR. SEAB KIMSRIM	Institute of forest and wildlife Research and Development
5	MR. TO BORIN	Institute of forest and wildlife Research and Development
6	MR. SEM RIDA	Institute of forest and wildlife Research and Development
7	MS. RIN CHENDA	Institute of forest and wildlife Research and Development
8	MS. HIENG SOKNY	Forestry Administration
9	MS. CHHIT SOPHAL	Prek Leap National School of Agriculture, Forestry Administration, Phnom Penh
10	MR. PREAP SAM	FA/Department of Public Procurement
11	MR. YI NAROM	FA/Department of Public Procurement
12	MR. CHEAT VICHETH	FA/Department of Public Procurement
13	MR. DIM KONGHEAN	FA/Department of forest Industry and International Cooperation
14	MR. UNG KEOPISETH	FA/Department of forest Industry and International Cooperation
15	MR. PHUN VEASNA	FA/Department of forest Industry and International Cooperation
16	MR. CHHIN NAVIN	FA/Department of Wildlife and Biodiversity
17	MR. CHOUT TITHSOPHEA	FA/Department of Wildlife and Biodiversity
18	MR. YEN SROY	FA/Department of Wildlife and Biodiversity
19	MR. MENG CHANNA	FA/Department of Wildlife and Biodiversity
20	MR. VAN VON	Forestry Administration
21	MR. PIN CHHAYNITH	Forestry Administration

22	MR. LAY PIDEN	Phnom Tamao research center
23	MR. YONG ROTHANA	Phnom Tamao research center
24	MR. SENG SOPANHA	Royal University of Agriculture, Phnom Penh
25	MR. SEK CHENDA	Royal University of Agriculture, Phnom Penh
26	MR. RETH SOPHEARUM	Royal University of Agriculture, Phnom Penh
27	MS. KHUM WABOTA	Royal University of Agriculture, Phnom Penh
28	MR. NHIM CHANNTEKLIM	Royal University of Agriculture, Phnom Penh
29	MS. CHHORN CHAMROEUN	Royal University of Agriculture, Phnom Penh
30	MS. NGOV NAVY	Royal University of Agriculture, Phnom Penh
31	Mr. Kol Sreyneagn	Royal University of Agriculture, Phnom Penh
32	MR. Yuon Chhengkea	Royal University of Agriculture, Phnom Penh
33	Ms. Sophal Sok	Royal University of Agriculture, Phnom Penh
34	Dr. Hadi Firma	Asian Institute of Technology, Thailand
35	Mr. Chann Sophal	Forestry Administration of Cambodia (FA), Phnom Penh