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Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

PROJECT PROPOSAL

Regional Forest Observations for Sustainable Forest Management

Institute of Forest Resource Information Techniques
Chinese Academy of Forestry

Nov. 1, 2017

Project title	Regional Forest Observations for Sustainable Forest Management
Supervisory agency	State Forestry Administration, China
Executing agency	Institute of Forest Resource Information Techniques, Chinese Academy of Forestry
Expected project duration: 01/01/2018 to 30/6/2020, 30 months	
Target area (project locations and context) Greater Mekong Subregion and Malaysia (maps are shown in Annex I)	

Total budget(USD)	**Expected APFNet grant(USD)**	**Conouterpart contribution (USD)** (in cash and in-kind)
699,860	**499,860**	**200,000**

Project summary:

With rapid development of social and economic in the Asia and Pacific, forests in the region face an increasing number of threats and pressures. More and more economies and international organizations committed to improving forest coverage through promoting forest restoration and enhance sustainable forest management. How to effectively evaluate and assess the forest resource in large scale has become a common concern of many economies especially developing economies in the AP region. Multi-temporal earth observation data characterize the forest gain and loss activities spatially and timely. This provides a good way to map the active forest gain and loss regions. In our previous APFNet project of *Forest Cover and Carbon Mapping in the Greater Mekong Subregion (GMS) and Malaysia*, we have developed algorithms for forest cover mapping and carbon estimation, produced forest maps of 2005 and 2010, and forest above ground biomass map of 2005, which have provided significant baseline analysis and assessment on the forests resource change in the region and enhance the capacity building of economies in the GMS region on forests resources monitoring.

The phase two project aims to further enhance the capacity building on forest resources monitoring in the GMS and Malaysia for sustainable forest management and climate change adaptation. Specifically, based on the Phase I project achievement, this the project will further enhance the capacity building of the related economies in the region on forest mapping and carbon estimation using advance remote sensing technologies and strengthen the networking in the region on forest monitoring. The outcomes of the project will support the development of forest management strategic of the economies in the region.

The specific objectives of this project are: 1) to further enhance the capacity on regional level forest resource monitoring and analysis through applying medium resolution remote sensing data, analyze forest changes, and link the change characteristics with forest polices; 2) to enhance the capacity on stand level forest inventory through applying high resolution remote sensing data and airborne laser scanning technology; 3) to further strengthen the networking on forest monitoring in the region through establishing a mechanism for regional forest observations and provide related capacity building supports.

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Abbreviations and acronyms

ALS	Airborne laser scanning
CAF	Chinese Academy of Forestry
GF	Gao Fen, China high-resolution earth observation program
GMS	Greater Mekong Subregion
IA	Implementation Agency
MSI	Multispectral imager on board of Sentinel-2 A/B satellites developed by European Space Agency
OLI	Operational Land Imager on board of Landsat-8 satellite developed by NASA and the U.S. Geological Survey (USGS)
RFO	Regional Forest Observation
WFV	Wide Field of View

1. Background and Rationale

With rapid development of social and economic in the Asia and Pacific, forests in the region face an increasing number of threats and pressures. More and more economies and international organizations committed to improving forest coverage through promoting forest restoration and enhance sustainable forest management. The Greater Mekong Subregion (GMS) and Malaysia is rich in forest resources, which comprises Cambodia, the People's Republic of China (Yunnan province and Guangxi province), Lao People's Democratic Republic, Malaysia, Myanmar, Thailand, and Viet Nam. The rich human and natural resource endowments of the GMS region have made it a new frontier of Asian economic growth. Indeed, the GMS region has the potential to be one of the world's fastest growing areas. Increasingly, modernization and industrialization are emerging from a process of transition and transformation. The Mekong economies are gradually shifting from subsistence farming to more diversified economies, and to more open, market-based systems. Meanwhile, the commercial relations among the six Mekong economies are increasing, notably in terms of cross-border trade, investment, and labor mobility. Moreover, natural resources are beginning to be explored and utilized on a multiple national basis. Through the Belt and Road Initiative, an increasing cooperation and communications are expected.

Forest monitoring is important for the estimation and evaluation of the state of forest resources, carbon sequestration, and the results of forest program implementation. Remote sensing technology provides an efficient way to characterize these forest changes in large scales. Hansen et al (2013) generated annual global forest change during 2000~2012 using time series Landsat data. Chen et al (2014a) published global land cover map of 2000 and 2010 based on Landsat and Huan Jing (Environment)-1 data. Such multi-temporal remote sensing products have been used widely for forest gain / loss and driving forces analysis (Olofsson et al., 2014; Liu et al., 2014). It provides a key source of information for the crackdown on illegal logging, forest fire monitoring and early warning and reduction of forest degradation, forest gain from afforestation and reforestation, and the improvement of forest quality. Also, forest monitoring to support sustainable forest resources management can provide the earth observation data and technical support needed by economies to fulfill their obligations effectively arising from international environmental agreements.

In our previous APFNet project of Forest Cover and Carbon Mapping in the Greater Mekong Subregion and Malaysia, we have developed algorithms for forest cover mapping and carbon estimation, produced forest maps of 2005 and 2010 at 30 m spatial resolution, and forest above ground biomass map for 2005 at 500 m spatial resolution. There are also some other international projects which focus or cover this region, e.g., NASA LCLUC SE Asia Network (SEARIN), EU TREES project, China Global Land Cover (GLC) project. All of these studies

are based on occasionally projects. Further enhancement in capacity building on forest resources monitoring and carbon mapping is still lack in this region.

A forest spatial distribution and dynamic information with continuous coverage and routinely update is needed to make better forest resource protection and utilization. With the new developments of earth observation technologies, more and more medium and high spatial resolution remote sensing data are available with free or reasonable low cost. The airborne Lidar technology is getting more operational applications and decreasing cost. These factors bring an opportunity to establish a mechanism for better forest mapping purpose and link to sustainable forest management activities.

2. Goal and Objectives

The primary goal of this project is to further enhance capacity building on forest monitoring in the region through applying advanced remote sensing technology in different scale and strengthen the network on regional forest monitoring by establishing a mechanism for regional forest observations. The proposed approach will integrate multi-sources remote sensing data, ground measurements and geospatial technologies. The outcomes of this project will help to clarify how, when and where the forests changes in each economy. For selected sites, stand level inventory method will be developed and demonstrated. Our proposed approach will determine forest coverage and biomass towards the following specific objectives:

1) To further enhance the capacity on regional level forest resource monitoring and analysis through applying medium resolution remote sensing data, analyze forest changes, and link the change characteristics with forest polices;
2) To enhance the capacity on stand level forest inventory through applying high resolution remote sensing data and airborne laser scanning technology;
3) To further strengthen the network on forest monitoring in the region through establishing a mechanism for regional forest observations and provide related capacity building supports.

3. Outputs and Strategic Activities

For Objective 1: To further enhance the capacity on regional level forest resource monitoring and analysis through applying medium resolution remote

sensing data, analyze forest changes, and link the change characteristics with forest polices

Output 1: Forest coverage map of 2017 at 30 m spatial resolution

Following the methods and classification legend we developed in phase one of the project, the forest coverage map of 2017 at 30 m spatial resolution will be produced. The Landsat-8 OLI data will be used as main source with Sentinel-2 and China GF-1 WFV data as compensation sources. This will provide a new benchmark map every five years.

Activity 1.1 Remote sensing data collection and processing

The 2017 Landsat-8 OLI data will be downloaded from USGS. Then the data will be checked for cloudy coverage and image quality. For those areas with data gaps of OLI, we will search and download the Sentinel-2 MSI data from ESA, or the GF-1 WFV data from CRESDA. These images will be collected and processed by IFRIT, CAF. Then distribute to each IA.

Activity 1.2 Reference data collection and processing

The reference data containing land cover maps, field measurements, and forest inventories around 2017 will be collected. These data provide fundamental training and validation data for remote sensing products. These data will be compiled into GIS layers with the UTM projections as remote sensing data.

Activity 1.3 Remote sensing data classification and evaluation

The 40 labels and definitions of the classes in project phase one will be used. Each IA will do classification work of their own region. Land Cover Sample Collection Tool will be used to collect reference data for each scene. This work will be done by each economy and checked by independents or consultancies of CAF. Then the forest map product will be evaluated with these reference data.

Activity 1.4 2017 forest coverage map product generation

Then the forest coverage maps generated by each IA will be compiled and mosaiced by CAF. The product will include a map of whole region, each IA's area and a 1*1 degree tiled map.

Output 2: Forest change and driving forces analysis during 2005~ 2017

By compiling the phase 1 and phase 2 products, forest change maps of 2005, 2010, and 2017

will be produced. Then this change maps will be statistically analyzed at pixel level, county / province level and economy level. The active forest change areas will be analyzed with forest policies and international factors.

Activity 2.1 Guidance and workshop for forest changes analysis

Develop forest change analysis guidance. Organize a forest change analysis workshop to transfer methods described in the guidance.

Activity 2.2 Forest change maps of 2005, 2010, and 2017

Produce forest change maps of 2005-2010, 2010-2017, and 2005-2017. The level one change map will include changes between forest and non-forest types. The level two change map will include transform classes information, which include the sources and directions of forest loss and gain areas.

Activity 2.3 Forest change driving forces and policy analysis

Analyze forest change maps at 5*5 km^2, and 10*10 km^2, county / province level and economy level. The intensive forest change areas will be mapped. Then link intensive forest change areas to forest policies and international factors. For example, intensive forest gain areas might be caused by REDD+, forest restoration, ecological conservation programmes. On the other hand, intensive forest loss areas might be related to forest logging activities, large forest disaster events, urban development, etc.

For Objective 2: To enhance the capacity on stand level forest inventory through applying high resolution remote sensing data and airborne laser scanning technology

Output 3: Stand level inventory maps using high resolution data in selected sites

This work will be done for selected sites with intensive forest management needs (usually for a forest administration unit, e.g., forest farm, forest administration bureau). High spatial resolution data (better than 5 m, e.g. Chinese GF-2 data with 1/4 m resolution) will be collected. This work is mainly targeted for demonstration and capacity building. The internal needs are essential to do this work. It is planned to have 2~3 sites for this work.

Activity 3.1 High resolution remote sensing collection and processing

High spatial resolution data will be collected, which include those satellites with spatial resolution better than 5 m. e.g., Chinese GF-2 data with 1/4 m resolution, ZY-3 with 3.5 m.

These data will be corrected geometrically using reference maps.

Activity 3.2 Forest management unit segmentation

The orthorectified data will be segmented into small homogeneous patches, i.e., segments. According to other attributes like tree species composition and terrain information, the segmentation results will be merged or divided into forest management unit (i.e. sub-compartment).

Activity 3.3 Parameters determination for each forest management unit

For airborne lidar data available area, forest parameters (e.g. height, canopy density, volume density) for each forest management unit will be estimated based on a few of field plots and lidar metrics. Otherwise, forest parameters will be determined using field plots in each management unit.

Activity 3.4 Training workshop for stand level inventory

The forest stand level inventory guide will be developed. A training workshop and field practice will be organized to transfer methods described in the guidance.

Output 4: Forest carbon maps estimated using airborne laser scanning technology in selected sites

This work will be done for selected sites with local or national needs. The airborne Lidar technology will be used for this work. The CAF-LiCHy (or other lidar sensors) airborne system, which including a waveform Lidar, CCD camera, and Hyperspectral sensor, will be used for the airborne data collection with resolution at 0.2~1 m. The system operation, data processing and technique support will be provided by APFNet grant and IFRIT hardware platforms. The field data collection and aircraft cost will be covered by the counterpart fund of each economy. This work is mainly targeted for demonstration and capacity building. As REDD+ and some other carbon related programs need reliable carbon accounting methods, we will develop and demonstrate this cutting-edge method. The internal needs are essential to do this work. We plan to have 2~3 pilot sites for this work.

Activity 4.1 Airborne lidar data collection and processing

Collect airborne lidar data through new flights or other data flew recently. Then process the lidar point cloud data into ground, vegetation and other point types. Generate lidar metrics using height normalized point cloud data.

Activity 4.2 Field plot data collection and processing

Field plots will be designed using stratification sampling method. For each field plot, individual tree will be measured. The central coordinates will be recorded using accurate GNSS coordinates. Then calculate forest carbon density at plot level according to allometric equations.

Activity 4.3 Forest carbon estimation

Forest carbon estimation models will be built using lidar metrics and field measurements. Regression tree model and machine learning models will be explored.

Activity 4.4 Training workshop for forest carbon estimation

The forest carbon estimation guide will be developed. A training workshop and field trip will be organized to transfer methods described in the guidance.

For Objective 3: To further strengthen the network on forest monitoring in the region through establishing a mechanism for regional forest observations and provide related capacity building supports

With the enriching of remote sensing data availability and ever-growing forest values, annual forest observation is becoming necessary and feasible. We will establish a mechanism for annual regional forest observations and build an open cooperative team to fulfill designed tasks at various scales. This mechanism includes a management office in CAF, an international forest remote sensing expert team from involved economies, and a web service based collaboration environment. Through this mechanism, we process and run forest change detection product at CAF for this regional scale forest mapping activities as described in objective 1. Then experts from each economy will check and update the forest change product with more reference data and some field work. After the change product has been checked and confirmed, experts from each economy will come to CAF for 1-3 months to make final forest change product and write the annual forest change analysis report. For the forest stand level work described in objective 2, we will organize related experts and facilities for those applied areas.

Output 5: Establish a mechanism for regional forest observations

Activity 5.1 Method development for annual forest change detection

Develop annual forest change detection method using time-series remote sensing data at 30 m spatial resolution. Senior level scientists will be invited to work together to fulfill this

method.

Activity 5.2 Annual forest change detection in selected sites of each IA

Algorithm development and demonstration at 30 m spatial resolution forest/non-forest mapping forest fractional cover data from Landsat, Sentinel, Chinese GF satellites will be used. It is planned to have 6~10 sites for this work.

Activity 5.3 Practice guides development

A series of practice guides related to regional forest observation will be developed. During this project period, we will develop annual forest change detection guide and stand level inventory guide. According to the geomatics technology development and forest management requirement, more guides will be developed during the implementation.

Activity 5.4 Design and test regional forest observations mechanism

Design regional forest observations, and develop a web service based collaboration environment for the regional forest observation platform. A management office will be set up in CAF, an international forest remote sensing expert team from involved economies will be established, and a web service based on collaboration environment will be constructed. Hardware, software, remote sensing data will be provided to each economy. Provincial level forest changes will be mapped and analyzed to fulfill forest mapping related tasks.

Output 6: Enhance capacity building through the Regional Forest Observations (RFO) mechanism in the region

Activity 6.1 RFO training

We will host training workshops in the field of forest remote sensing and geospatial related topics. A training workshop of annual forest change detection will be organized. Training workshops listed in Activity 2.1, Activity 3.4, and Activity 4.4 are also within this RFO training scope.

Activity 6.2 RFO visiting scholar

One scientist from each IA will work at IFRIT/CAF for three months to test the established mechanism for regional forest observations. These scholars will be funded by APFNet project. We will also seek more funding opportunities like Talent Young Scholarship Programme of Ministry of Science and Technology (MOST) from Chinese Government (http://www.tysp.org/) to encourage more scholar exchanges.

Activity 6.3 RFO output dissemination and delivery

An output dissemination and delivery symposium will be arranged in the last season of this project. Forest policy makers, managers, and delegates from involved economies and international agencies will be invited. The regional forest observations mechanism will be initiated. After RFO mechanism operated routinely, we will have annual meeting to discuss and disseminate annual forest observation results.

4. Risks and assumptions

In general, this project risk is low. The project teams have built close cooperation and already carried out the 1st phase project successfully. The forest mapping technologies have been developed in the 1st phase project. The annual forest change detection method has been tested in selected sites of Yunnan and Guangxi. The method will be adapted to large data volume and more forest regions. The tool will be developed through this project. The tools and technologies of stand level inventory and forest carbon estimation have been developed in previous projects. We will develop application guidance and test in selected sites of this region.

The challenge is forest change driving forces and policy analysis. Each implementation agency (IA) will include an expert in the field related forest economy or policy to enhance this work. And the EA will also invite international experts in this field to provide consultant service. All the involved economies are interested in this work of annual forest change mapping. During this project, we will adapt current methods toward regionally operational applications. We will communicate with policy makers and managers to facilitate this work to national needs for further support.

5. Human Resources and capacity assessment

Human resources:

Professor Li Zengyuan: Deputy Director of Institute of Forest Resources Information Technique, Chinese Academy of Forestry. He has engaged in research of remote sensing techniques of vegetation ecology and environment for many years, and has published about 100 research papers in national and international Journals of remote sensing. He is now the member of Committee of Experts, Committee of Strategy Research Experts of the National Remote Sensing Centre of China; He is vice chairman of Committee of Core Experts for

Spatial information system software testing and evaluation; committee member of National Technical Committee on Remote Sensing of Standardization Administration of China; vice chairman of Association of Remote Sensing of Environment; vice chairman of Beijing Society for Information Technology in Agriculture; associate editor of Journal of Remote Sensing. He has won one second-class and one third-class National Prize for Progress in Science and Technology, one first-class prize for Progress in Science and Technology issued by the former National Forestry Ministry, and one second-class prize for Progress in Science and Technology issued by the Chinese Academy of Science.

Professor Pang Yong: received his bachelor degree in Forestry from Anhui Agriculture University in 1997, the M.Agr. degree from the Chinese Academy of Forestry in 2000, and the Ph.D. degree from the Chinese Academy of Science in 2006. He was a Postdoc in Colorado State University from Oct. of 2006 to Oct. of 2008 and visiting professor in the University of British Columbia. Currently, he is deputy director of the Forest Remote Sensing Lab, the Institute of Forest Resource Information Techniques, Chinese Academy of Forestry. His research interests include surface height and vegetation spatial structure parameters from Lidar and imagery data, modeling of Lidar waveforms from forest stands, and development of algorithms for forest parameter retrieval from remote sensing data.

Mr. Chivin Leng: Deputy Director of the Department of Forestry and Community Forestry, Cambodia focal point of REL/MRV to UN-REDD, Cambodia.

Prof. Li Chungan: Forest remote sensing professor in Guangxi University (GXU), Nanning, China.

Mr. Dai Huabing: Director of Geomatics Institute in the Guangxi Forest Inventory and Planning Institute, Nanning, China.

Dr. Sithong Thongmanivong: Vice Dean, Faculty of Forestry, National University of Laos.

Dr. Khali Aziz Hamzah: Director of the Technical Services Division, Forest Research Institute of Malaysia.

Dr. Myat Su Mon: Assistant Director of Forest Department, Myanmar.

Mr. Sukan Pungkul: Deputy Director of Forest Information Center, Royal Forest Department of Thailand.

Mr. Nguyen Huy Dzung: Deputy Director of Forest Inventory and Planning Institute, Viet Nam.

Prof. Yue Cairong: Director of Geomatics Center, Southwest Forestry University, Kunming, China.

Dr. Huang Chengquan: Professor in the Department of Geographical Sciences, University of Maryland, USA.

Capacity:

Several stakeholders have sent the support letters to IFRIT-CAF to support this project. They are listed below:

- General Directorate of Administration for Nature Conservation and Protection/ MOE, Cambodia
- Guangxi Forest Inventory & Planning Institute, China
- Faculty of Forestry of National University of Laos
- Forest Research Institute Malaysia
- Forest Department, Myanmar
- Royal Forest Department, Thailand
- University of Maryland
- Forest Inventory & Planning Institute, Viet Nam

The support letters of each economy are attached. These participated institutes are nominees recommended by focal points of each economy. And the focal points will sign on the formal contract, which will represent their official agree and support of this project's work.

An international science steering committee with regional forest mapping knowledge and experiences in Asian-pacific region will be established. Tools will be developed for high resolution data processing, annual forest change, stand level inventory, and carbon accounting. These technologies will be transferred to each participated economy through training and cooperation visit. Working groups in each county will fulfill specific activities.

Through our research in Phase I, we have developed a strong, scientifically based research team and gained local pilot research experience. The partnering universities and organizations chosen for Phase II are all well known for forest and climate change research in the region. Particularly, they have accumulated long-term historical data, both in climate change and forest management, which will allow our research team to conduct research more effectively and efficiently in this phase of the project.

6. Budget, funding resources and financial management

For a detailed budget, please refer to Annexes D and E. The Institute of Forest Resource Information Techniques (CAF) and the Guangxi Forest Inventory and Planning Institute would like to contribute $200,000 in kind to the research. The IFRIT supports will contribute through high resolution remote sensing data and airborne instruments. The GX-FIPI supports will contribute through ground plots and aircraft.

IFRIT has a sound financial management system controlled by professional accountancy staff, and an effective financial and research management control framework for the monitoring of the use of funding. Funding will be managed by the Budget Office of IFRIT. Each Implementation Agency will manage their sub-funding through their budget offices. The project will follow systematic approaches to project management, including reporting, review, monitoring, and evaluation, and these will be adopted by the collaborating agencies to ensure successful implementation of the project. The project team will follow the established procedures of annual plans, bi-annual progress reports, and quarterly review to identify any gaps between the actual and planned activities.

Throughout the project implementation, annual work plans will be developed to provide detailed information about project planning and other issues. Biannual and annual progress reports will be prepared covering the expenditures, progress, and achieved outputs according to the annual plan in the middle and at the end of each project year. A financial audit report will be submitted by the Executing Agency (EA) to APFNet to indicate the opening balance, expenditure incurred to date, and the closing balance for the project account. Upon completion of the project, EA will produce a completion report to summarize the activities, inputs, expenditures, achieved outputs and objectives during the entire implementation phase and will identify any major differences between planned and realized budgets.

7. Monitoring and evaluation

A systematic and comprehensive approach, including reporting, review, monitoring, and evaluation, has been developed and adopted by the EA and IAs in the previous project. The second phase of the project will follow the management approaches that were developed and used in the first phase.

A monitoring system will be adopted to identify any gaps between the actual situation and the planned situation once the second phase is initiated, depending on the indicators related to each activity listed in the logical framework matrix (Annex A). Afterwards, corrective

actions may be necessary to ensure the efficiency and effectiveness of project implementation when needed.

A periodic progress review (after the completion of each output) will be conducted by the EA and IAs to guarantee that the project implementation is on track to achieve the anticipated objectives. This will be done using the associated logical framework matrix and work plan (Annex D) in the project documents as a reference. By actively interacting with project staff involved in the project implementation, and by assessing the progress of the project according to the annual plan, recommendations and changes in actions will be suggested in order to better support the success of the project.

A midterm review and a final evaluation will be conducted in the middle of the project implementation and after the completion of the project, respectively. APFNet will be directly involved in these activities. For the midterm review, experts in the related field will be invited to review the project documents (including proposal, annual plans, and process reports), listen to presentations, interview project team members, and provide evaluations on the project progress status and recommendations for improvements. For the final evaluation, the focus will be on the project final output, the completion report and the technical report. It will also evaluate the potentials of the project output for applications and future development.

8. Dissemination and sustainability

The main users of the proposed project are economies in the GMS and organizations interest in the region, which include the scientific community (e.g. national forest institutes, IPCC, GEO-GFOI, GOFC-GOLD), policy makers of each economies' forestry and/or environment agencies, education community (e.g. the Forestry University of Vietnam, National University of Laos, Forestry University of Myanmar, AIT), commercial companies (e.g. pulp companies, local forest owners), and – in the context of cooperation and scientific support – also international or regional organizations (e.g. FAO, APFNet, ASEAN or MRC).

The outputs and findings from this project will be disseminated to the various interested stakeholders. Some of the project findings and outputs will be published in the form of a technical book, scientific papers and proceedings. The training guides on annual forest change detection, forest stand map generation and carbon estimation will be disseminated to various stakeholders through training and technology transfer. At the end of the project, relevant government agencies in different economies, particularly the forestry departments will have better understanding on the forest cover and forest changes and will contribute to

better management of this ecosystem in the future.

Though the established regional forest observations mechanism, the forest map will be updated annually through forest change detection results. This work is linked closely with the goal of APFNet, and each economy's forest management plans. The high resolution forest inventory and corban accounting works are linked with forest management activities and valuing of ecosystem service. These multiple funding possibilities will make this mechanism run operationally.

Annex A: Project sites map and relevant information

The area of the Regional Forest Observations for Sustainable Forest Management ranges from 92.2° to 119.3° east longitude and 0.8° to 29.2° north latitude, with total land area of 317,242,000 ha and total population of 348 million. It includes Cambodia, the People's Republic of China (Yunnan province and Guangxi province), Lao People's Democratic Republic, Malaysia, Myanmar, Thailand, and Viet Nam.

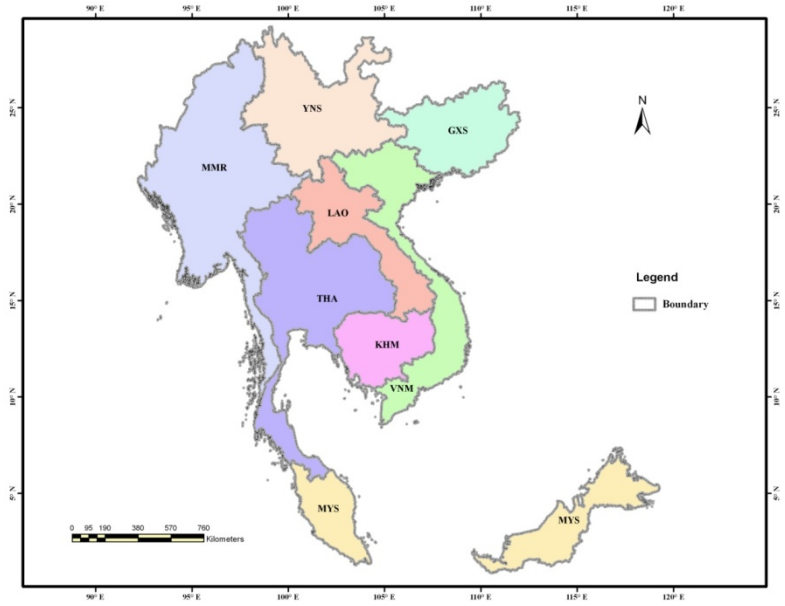
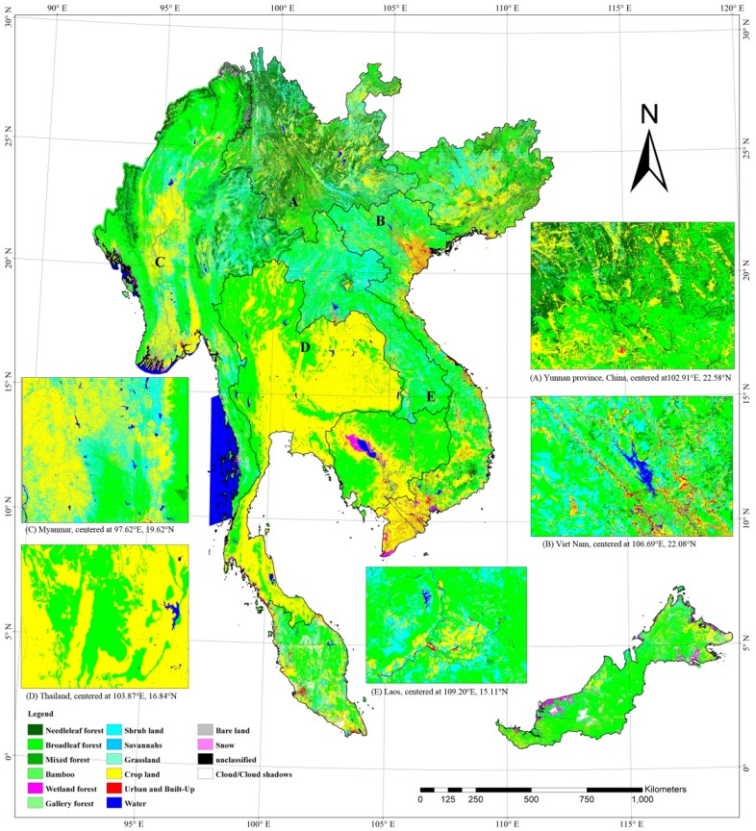


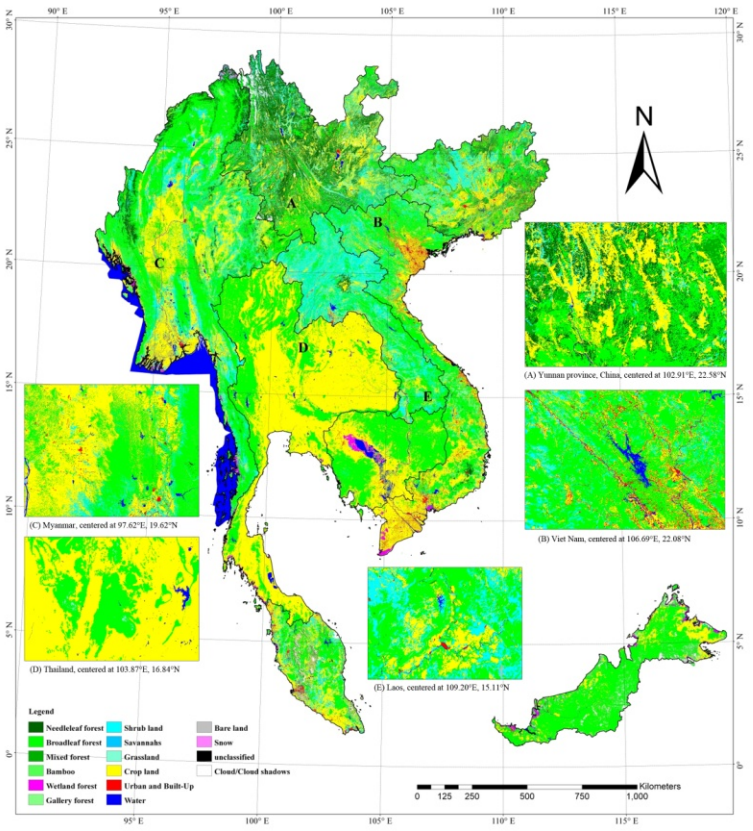
Figure A1. Study Area of the GMS and Malaysia Demonstration Project.

In our previous project, the forest cover maps of 2005 and 2010 were produced. Most economies had high forestry coverage over 50%. The needle-leaf forests were mainly distributed in Northern Myanmar, Yunnan and Guangxi of China. The forests in Malaysia, Cambodia, Laos, Viet Nam, Thailand and middle-south of Myanmar were dominated by broadleaf forests. The crop lands were mainly distributed in the Mekong Delta, Central-Eastern of Thailand, Central-South of Myanmar and central part of Guangxi of China. Along the coasts, there were some mangrove forests.

Annex A: Project sites map and relevant information



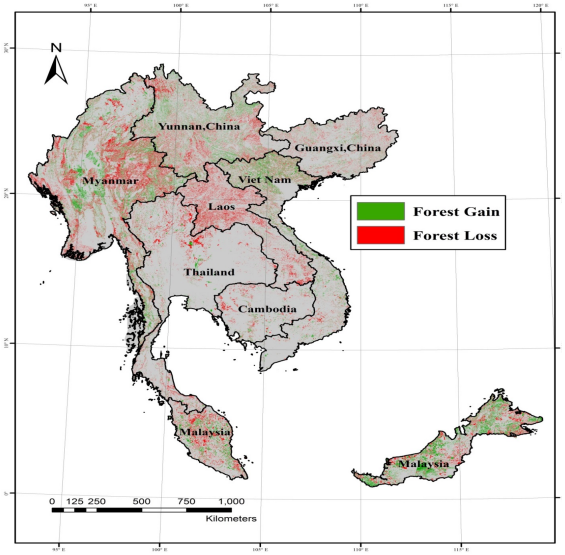
2005 forest cover map in the GMS & Malaysia



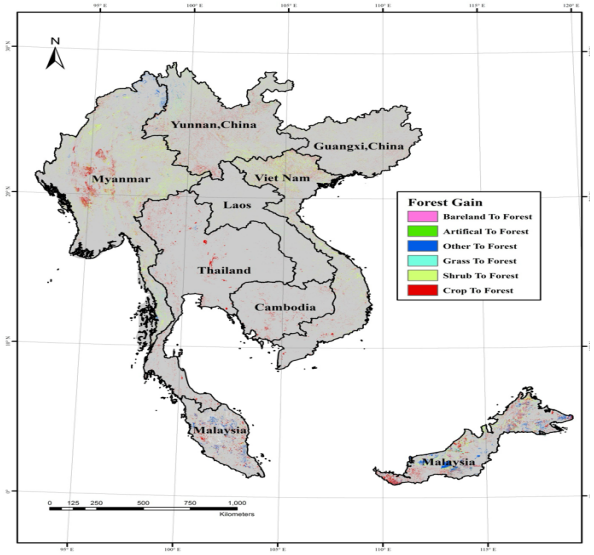
2010 forest cover map in the GMS & Malaysia

Forest coverage was 48.4% and 46.2% in 2005 and 2010 respectively for the whole region. The forest net loss was 2.2% from 2005 to 2010. The forest losses were mainly located in northeast of Myanmar, Laos, Malaysia, and Yunnan province of China. The Forest gains were mainly occurred in east Malaysia, northern of Viet Nam, central-north of Myanmar, and Yunnan of China. The most forests and non-forests were stable during this period.

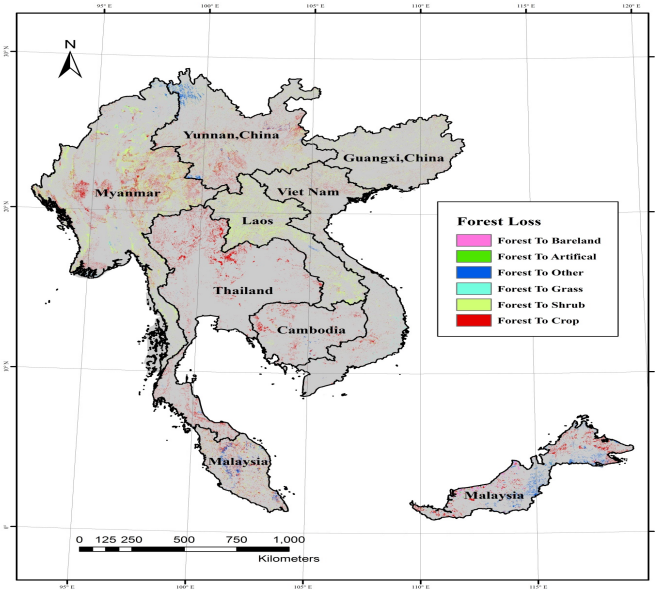
Annex A: Project sites map and relevant information



Forest Gain and Loss Between 2005 and 2010 in GMS & Malaysia



The Sources of Forest Gain Between 2005 and 2010 in GMS & Malaysia



The Directions of Forest Loss Between 2005 and 2010 in GMS & Malaysia

Annex B: Project logical framework

Items	Intervention logic	Objectively verifiable indicators of achievement[5]	Sources of information and means of verification[6]	Assumptions[7]
Goal(s)[1]	To further enhance capacity building on forest monitoring in the region through applying advanced remote sensing technology in different scale and strengthen the network on regional forest monitoring by establishing a mechanism for regional forest observations.	Develop tools for regional forest mapping purpose. Build an international working team and establish a mechanism for forest observations using remote sensing technologies.	1. Tools will be delivered to IAs during the project; 2. Forest change map and driving factors analysis will be documented; 3. Reports, extension notes and publications will be submitted to APFNet	The project is based on experiences obtained from the previous project. No factors are beyond our control so far.
Objectives[2]	To further enhance the capacity on regional level forest resource monitoring and analysis through applying medium resolution remote sensing data, analyze forest changes, and link the change characteristics with forest polices; To enhance the capacity on stand level forest inventory through applying high resolution remote sensing data and airborne laser scanning technology; To further strengthen the network on forest monitoring in the region through establishing a mechanism for regional forest observations and provide related capacity building supports.	Forest coverage map of 2017 at 30 m spatial resolution; Forest change and driving forces analysis during 2005~ 2017; Documents of stand level inventory using high remote sensing data, forest carbon maps estimation using ALS, regional forest observations mechanism	Map product accuracy report; Forest change evaluation with other factors like policies and natural disturbances; International cooperative work report for regional forest observations mechanism	Ditto

Annex B: Project logical framework

Expected outputs Output 1	Forest coverage map of 2017 at 30 m spatial resolution	Spatial coverage, time and resolution, classification accuracy.	Database report, Map product accuracy report;	/
Activity 1.1 Activity 1.2 Activity 1.3 Activity 1.4	Remote sensing data collection and processing Reference data collection and processing Remote sensing data classification and evaluation 2017 forest coverage map product generation	Datasets will be collected and archived. Forest map product will be evaluated through classification accuracy evaluation.	Database report Map product accuracy report;	/
Output 2	Forest change and driving forces analysis during 2005~ 2017	Spatial coverage, time and resolution, classification accuracy.	Database report, Map product and accuracy report;	More reference information like forest policies and forest programmes, disturbances are very helpful.
Activity 2.1 Activity 2.2 Activity 2.3	Forest change maps of 2005, 2010, and 2017 Active forest changes analysis Forest change driving forces and policy analysis	Change map Forest changes analysis report.	Change map product and analysis report	/
Output 3	Stand level inventory maps using high resolution data in selected sites	Sub-compartment level zonification and attributes	Stand level inventory products	/

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Activity 3.1 Activity 3.2 Activity 3.3	High resolution remote sensing collection and processing Forest management unit segmentation Factors determination for each forest management unit	Datasets will be collected and archived. Stand level inventory map.	Satellite data and field data Stand level inventory map and report.	/
Output 4	Forest carbon maps estimated using airborne laser scanning technology in selected sites	Forest carbon estimation report using ALS	Forest carbon map product.	/
Activity 4.1 Activity 4.2 Activity 4.3	Airborne lidar collection and processing Field plot data collection and processing Forest parameters estimation	Datasets will be collected and archived. Parameter estimation method. Forest carbon map.	ALS data and field data Forest carbon map and report.	/
Output 5	Establish a mechanism for regional forest observations	Establish a mechanism for annual regional forest observations and build an open team to fulfill designed tasks at various scales.	International cooperative work report for regional forest observations mechanism	Active participations from involved institutes and other international experts are helpful.
Activity 5.1 Activity 5.2 Activity 5.3 Activity 5.4	Method development for annual forest change detection Annual forest change detection of 2015-2018 in selected sites of each IA Practice guides development Design and test regional forest observations mechanism	Annual forest change detection tools development. Practice guides of annual forest change detection guide and stand level inventory guide. Demonstration change maps in test sites of each economy. Report on the stainability of this mechanism.	International cooperative work report for regional forest observations mechanism Practice guides Demonstration results.	/
Output 6	Enhance capacity building through the RFO mechanism in the region	Develop activities of training workshops, visiting scholars, and routinely reports related to RFO purpose.	International cooperative work report for regional forest observations mechanism	Active participations from involved institutes and other international experts are helpful.

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Activity 6.1 Activity 6.2 Activity 6.3	Training workshops RFO visiting scholar Output Dissemination and Regional Forest Observations Kick-off Meeting	One training workshop. 6-8 visiting scholars and reports. Output dissemination and impacts from multiple agencies.	RFO reports Output dissemination workshops.	/

Annex C: Project organizational chart