Asia-Pacific Network for Global Change Research

Regional, multi-scaled, multi-temporal land-use and land cover data to support global change research and policy making: a SEARRIN LUCC Project

Final report for APN project 2004-04-CMY-Skole

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SEARRIN
SOUTHEAST ASIA REGIONAL RESEARCH & INFORMATION NETWORK

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2004-04-CMY-Skole

Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

This project supported a series of activities centered on the application of remote sensing analysis of land use and land cover in Southeast Asia and the development of geospatial data and data products for environmental monitoring and management. In addition to product development, regional scientists participated in scientific workshops and advanced training within the region. Furthermore, under this project a regional application has been developed for the Mekong River Basin countries implementing state of the art web-GIS to support the Mekong River Commission Forest Assessment. This new application resides at NAMRIA in the Philippines. Central to the on-going efforts of SEARRIN, this project included a strong capacity building component that included field-level training in forest fractional cover validation techniques, advanced remote sensing analysis methods, and web-GIS development. Perhaps the most exciting development as a result of the project work is a new, formal collaboration between SEARRIN scientists and the Mekong River Commission Secretariat, who have asked to serve as a conduit between SEARRIN scientists (who develop data products and information) and the managers and policy-makers at the national and regional levels (who require data and information in order to implement natural resources policies).

Objectives

The main objectives of the project were:

1. The development of empirical, accurate geospatial land use and land cover data derived from remotely sensed data,
2. The development of spatial data infrastructure and support tools for open access to support regional scientists and decision-makers, and
3. Capacity building for regional scientists and natural resource management agency personnel (many who are members of SEARRIN).

Amount received for each year supported and number of years supported

Two years of support totalling US$117,500.00 (YR1: US$75,000.00; YR2: US$42,500.00).

Participating Countries

Participating countries included: Cambodia, China, Lao PDR, Indonesia, Malaysia, Philippines, Thailand, United States of America, and Vietnam.

Work undertaken

Work undertaken under this project included (1) a series of four workshops over the course of two years, (2) the development of a geospatial database, (3) an on-line web-GIS data application, (4) capacity building, and (5) fieldwork. In July 2003 a training workshop on open, distributed, web-GIS was conducted in Bangkok, Thailand at GISTDA, who are a primary archive for remotely sensed satellite data used by SEARRIN in mapping land use and land cover in Southeast Asia. In August 2003 a project planning and training workshop was held in Hanoi, Vietnam. Training centered on field data collection protocols for forest fractional cover assessments and expert validation of regional forest cover. A science workshop was conducted in August 2004, co-hosted by Nong Lam University in Ho Chi Minh City, Vietnam, on Geospatial Information and Sustainable Natural Resources. Our project's final workshop was held July 2005 with the Mekong River Commission Secretariat in Vientiane, Lao PDR and colleagues from Cambodia, Lao PDR, Thailand, and Vietnam. This workshop centered on developing a

common, agreed-up definition of forest cover accepted by the four Lower Mekong Basin countries and useful in developing data information and products derived from remotely sensed data to support the Mekong River Commission mission. This collaboration sets in motion an appropriate outlet for the SEARRIN data products derived through remote sensing analysis and useful to policy makers who seek and obtain information from the MRC.

A number of data products were generated under this project. These include a series of expert validated forest cover maps generated by the regional teams which provide a baseline data set for twenty-four Landsat scenes through insular and peninsular Southeast Asia. Continuous-fields measurements, or fractional cover assessments, were also developed from Landsat data for areas in Thailand and Malaysia and are on-going in the other six SEARRIN countries (Cambodia, China, Lao PDR, Indonesia, Philippines, and Vietnam. A preliminary country-wide forest fractional cover assessment was developed for Thailand. In addition to data development through remote sensing analysis, field validation was conducted by the SEARRIN teams in their respective countries as well as by MSU scientists at four different sites (Cuc Phoung National Park and Can Gio Mangrove Biosphere Reserve in Vietnam, and Vang Vieng and Pak Ou District, Luang Prabang Lao PDR).

Capacity building continued under this project and included advanced training in remote sensing techniques with regional scientists and web-GIS application development with GISTDA in Thailand and NAMRIA in the Philippines. Three visiting scholars, two from the Institute of Geography in Copenhagen, Denmark and one from the Forest Inventory and Planning Institute in Vietnam received training and support at MSU as part of this APN project.

A final project web-site has been developed providing open access to data and information generated as part of this project. In addition, there is link to an on-line, web-GIS application that is being hosted at NAMRIA, Philippines and will be used to provide GIS data and information as part of the project's collaboration with the Mekong River Commission Secretariat to support their forest assessment initiative, a project SEARRIN scientists are now supporting as a result of the work competed under the APN project.

Results

In summary the final results of this project include:

- Capacity building for regional scientists in advanced remote sensing analysis, field data collection for validation and calibration of land use/cover derived data and fractional cover (continuous-fields) derived data, and web-GIS development and applications
- Development of on-line spatial decision support systems for (1) regional remotely sensed data and (2) the Mekong River Commission Forest Assessment
- Land use and land cover data sets for case study areas in Southeast Asia
- Forest fractional cover data sets for case studies in Southeast Asia and for the country of Thailand
- Development of a spatial database that includes multi-scaled data and information: *in situ*, Landsat raw and derived land use/cover and fractional cover, IKONOS, ASTER VNIR, and MODIS.
- Collaborative agreement between Michigan State University researchers, regional SEARRIN scientists and the Mekong River Commission Secretariat whereby land cover data products and information developed by SEARRIN scientists will be

provided to the MRC for outreach to the regional policy and natural resource management communities at local, national, and regional scales.

Relevance to APN scientific research framework and objectives

The efforts and results of this project meet a number of the APN scientific research objectives and dovetail quite strongly with the APN scientific research framework. The project is relevant to goal one ("supporting regional cooperation in global change research on issues particularly relevant to the region") by including eight regional countries in the project and focusing on forest cover dynamics in the region as a whole. The project is relevant to goals two ("strengthening the interactions among scientists and policy makers, and providing a scientific input to policy decision-making and scientific knowledge to the public") and five ("cooperating with other global change networks and organizations") in particular by developing the institutional linkage between SEARRIN scientists and the Mekong River Commission Secretariat whose mission is to provide accurate information to regional policy makers in the Lower Mekong River Basin. The project is relevant to goals three ("improving the scientific and technical capabilities of nations in the region") and four ("facilitating the standardization, collection, analysis and exchange of scientific data and information relating to global change research") by utilizing workshops and scientific meetings to establish a set of common protocols and procedures for developing land use/cover and fractional cover datasets and in providing capacity building though training. Finally, the project is relevant to goal six ("facilitating the development of research infrastructure and the transfer of know-how and technology") in large part by developing web-GIS applications and again through capacity building activities.

Self evaluation

The project has succeeded in building capacity with regional scientists, developing a set of land use and land cover data products, developing on-line data portals using state-of-the-art web-GIS technologies, and developing the institutional linkage between data producers (MSU/SEARRIN scientists) and data users (policy makers and natural resource managers) through a collaboration with the Mekong River Commission Secretariat. The results from this APN funded project are not, however, a single, one-time project. The progress made under this project is on-going and mark an important milestone in the SEARRIN LUCC achievements. Further data products are required if we are to meet the demands of the end user community. The researchers and co-investigators who participated in this project have established a protocol for monitoring forest cover changes and degradation and plan to continue providing data products and information to the MRC and the LUCC community at large through the mechanisms established under this project. In addition, we plan to submit for peer review publication a number of papers as a result of the efforts supported by this APN project.

Potential for further work

As mentioned above, there continues to be a demand for accurate spatial data specific to land use and land cover in the region. These data are important for policy makers and natural resource managers alike, and will continue to be important as economic changes and policy actions play out in landscape level changes that impact human well-bieng and the natural environment. There is a continuing need for capacity building in the region with respect to geographic information sciences and remote sensing analysis in particular. Collaboration between and among regional scientists and researchers from as far away as the United States fosters understanding and improved management, particularly with respect to trans-boarder issues of land use and land cover. These kinds of focuses will only become more and more important as the economies of the Southeast Asian counties

become more and more integrated with each other and in the global economy.

Publications

CD-ROMS:

- Proceedings from workshop: Geo-Spatial Information and Sustainable Natural Source Management in the 21st Century, Nong Lam University, Ho Chi Minh City, Vietnam, August 16, 2004
- Proceedings from workshop: Workshop on Remote Sensing, GIS and Forest Resource Management in the Lower Mekong River Basin, Mekong River Commission Secretariat, Vientiane, Lao PDR, July 5 – 6, 2005.

Websites:

- http://www.globalchange.msu.edu/SEARRIN/APN_2003_08/
- http://www.globalchange.msu.edu/SEARRIN/APN_2004_04_CMY/
- http://202.90.128.189/mrc/

Papers to be submitted for peer reviewed publication:

- National park efficacy: A study of Tam Dao National Park, Vietnam
- Forest-Fallow-Farm: Land cover dynamics in the uplands of Laos
- The mangroves of Southern Vietnam: What does the historic Landsat archive reveal?
- Mekong River Forest Cover Assessment: Towards a common definition and protocol.

References

None.

Acknowledgments

We would like to acknowledge the support of Nong Lam University and the Mekong River Commission Secretariat for co-sponsoring two of the workshop held under this APN project. We would also like to acknowledge the continued dedication of all the SEARRIN colleagues from each of the regional countries for their dedication to this project and on-going activities in the region. Finally, we would like to acknowledge the START International Secretariat for managing this APN grant.

Technical Report

Preface

This APN project was completed through the diligence of a network of scientists from eight countries in Southeast Asia and the United States, the SEARRIN science network. The effort of this project has been on the development of geospatial land use and land cover data derived from remotely sensed earth observations, the continued capacity building in advanced techniques of GIS and remote sensing, and the development of linkages to institutions to facilitate the distribution and use of these data sets and information products. The work is on-going as new challenges face the region with respect to global change. It is our hope that these contributions support sustainable natural resource management throughout Southeast Asia.

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1.0 Introduction

Understanding global change – terrestrial, atmospheric, climatic, and the human dimensions of global change requires basic, accurate scientific data. Solutions to the adverse human and ecological consequences resulting from global changes also require basic and accurate data. Understandings of global change as well as the plans and policies for mitigation are often incorrect and misguided, in part, due to insufficient basic and accurate data. This APN project has developed a suite of accurate, scientific data products derived from earth observation satellite data for Southeast Asia. Accurate geospatial and multi-temporal land use and land cover data derived through empirical observations are imperative, primary data sets for:

- developing more complete understandings of carbon sources and sinks and therefore climate change,
- identifying impacts on ecosystem as well as species biodiversity at local, national and regional scales, and
- understanding the complex nexus of human and biophysical impacts on and responses to land use and land cover change, particularly with regards to extreme climatic events (for example, the human and economic costs caused by downstream flooding as a result of upstream deforestation and land miss-use).

It has been the overall goal of this project to develop and provide such accurate geospatial land use and land cover data to the global change science community and to land use managers and policy makers in the region in order to (1) improve our scientific understandings of the processes that link land use and land cover change to the 21st century global change issues (impacts of biodiversity, climate change, urbanization, etc.) we currently face, and (2) to allow for informed land use and policy decisions aimed at sustainable development. This project helps fill a current gap in linking regional land use/cover trends and conditions to policy makers at local, national and regional scales.

The objectives of this project included:

- the development of empirical, accurate geospatial land use and land cover data,
- the development of tools and products to provide users (global change scientists, land use managers, and policy makers) access to these data sets and information, and
- continued capacity building and collaboration between SEARRIN scientists and new project partners from Southern China.

Objective 1: ***Empirically observed primary data***. This project analyzed earth observation satellite data developing a series of derived land use and land cover products validated using expert knowledge, field-based measurement and data, and very high-resolution (4-meter resolution multi-spectral, 1-meter resolution panchromatic) IKONOS data. Using common analytical methods a series of case study sites served as validation areas for a regional forest cover product. New methods of remote sensing analysis were also tested to produce forest fractional cover and vegetation continuous fields measurements estimated from remotely sensed Landsat ETM+ data at key case study areas.

Objective 2: ***Data access***. The second objective of this project was to develop applications and outreach products providing access to these data sets and the resulting information. Locked up data sets are of little use to global change scientists, land use managers and policy makers. Through the development of a web portal, users have access to the digital, geospatial data and information via FTP download and through a state-of-the-art web-GIS application.

Objective 3: ***Capacity building and regional collaboration***. Developing primary data sets and tools to provide access to them within the SEARRIN framework (and with an additional team from China), has provides an opportunity for continued regional collaboration among a rich and diverse set of scientists and professionals and has also provided opportunities for further capacity building. Advancements in remote sensing analyses as well as in Internet-based applications are rapid. The SEARRIN-US team has been at the forefront in both of these areas under the leadership of Dr. David Skole. SEARRIN projects, this one included, benefit from the close collaboration and annual science meetings and workshops through funded opportunities that allow for training in these new techniques. SEARRIN members have continued to learn from each other in an open and collegial partnership, bound together through common national and regional interests and goals related to global change research.

2.0 Methodology

The project efforts centered on (1) the development of accurate geospatial, data products derived from remotely sensed earth observation satellite data, (2) the development of a web-GIS application and webpage providing access to these data products and information, (3) supporting policy makers and natural resource managers by providing data and information products specific to land use and land cover. The following

sub-sections detail the analytical methods for the geospatial data products, both land cover and fractional cover, and the development of the data access applications – in both of these sub-sections capacity–building training were integral. A final sub-section provides information specific to the rationale for linking with the Mekong River Commission Secretariat.

2.1 Data product development and validation

Under this APN project SEARRIN scientists developed geospatial, land use and land cover data sets derived from remotely sensed earth observation data. As part of the process an archive of remotely sensed and *in situ* data sets has been developed. These data include: Landsat MSS, TM, and ETM+, ASTER VNIR, IKONOS, GPS point and line data for *in situ* measurement of canopy closure (digital fish-eye photos) and land use/cover digital photos for validation. A baseline forest cover dataset for Indochina was derived from the analysis of Landsat ETM+ data for the year 2000 at the Center for Global Change and Earth Observation. Expert classification of a sampling of these data as well as a number of Landsat scenes in China, Malaysia, Indonesia, and the Philippines were completed by SEARRIN regional scientists as a validation standard for the Indochina, regional, assessment.

The method used to derive land use using the Landsat ETM+ data was as follows:

- Acquisition of cloud free, leaf-on level 1G, radiometric and geometrically calibrated data in EOS-HDF file format
- Import and preprocessing of multi-spectral bands 2,3,4,5 to create stack of bands, 2, 3, 4 and NDVI [Normalized Difference Vegetation Index = (band 4 – band 3) / (band 4 + band 3)].
- Unsupervised (isodata) algorithm clustering the data to 45 bins at 95% confidence level.
- Reclassification of the clustered bins to the following classes: Forest, non-forest, water, cloud, cloud shadow. Process may include masking mixed clusters numerous times and re-running unsupervised clustering to separate classes.
- Data conversion from raster to vector
- Heads-up GIS recoding and/or digitizing to eliminate erroneous classes.

The following Landsat ETM+ data were provided to the SEARRIN regional teams as a contribution from the Tropical Rain Forest Information Center, a member of NASA's Federation for Earth Science Information Partners (ESIP) under the direction of Dr. David Skole. TRFIC holds the largest archive of Landsat data outside the US National archive and the various international ground receiving stations, such as GISTDA in Thailand.

Expert classification data sets are listed below in table 1. Figure 1 shows the location and distribution of the data. Figure 2 shows the Landsat data in false-color composite bands 5, 4, 3 (RGB) and the derived land cover map for path 116 row 49 acquired 18 May 2001, a site in the Philippines.

Table 1: Landsat Validation Sites

Country	Path	Row	Acquisition Date

China	120	38	3 November 200
	119	38	15 January 2001
	118	38	14 January 2000
Cambodia	127	50	25 March 2000
	125	50	27 March 2000
	125	51	24 December 2000
Indonesia	127	59	26 April 2000
	125	61	1 September 1999
	117	60	26 August 2000
Lao PDR	129	46	2 November 2000
	126	48	11 November 1999
	125	50	27 March 2000
Malaysia	127	57	20 September 2001
	121	59	8 July 2001
Philippines	116	49	18 May 2001
	116	50	3 April 2002
	117	53	5 February 2002
Thailand	130	50	25 December 1999
	129	54	4 December 2000
	128	48	27 December 1999
	127	50	25 March 2000
	131	47	18 December 2000
Vietnam	124	50	4 March 2000
	126	48	11 November 1999
	127	45	4 November 2000

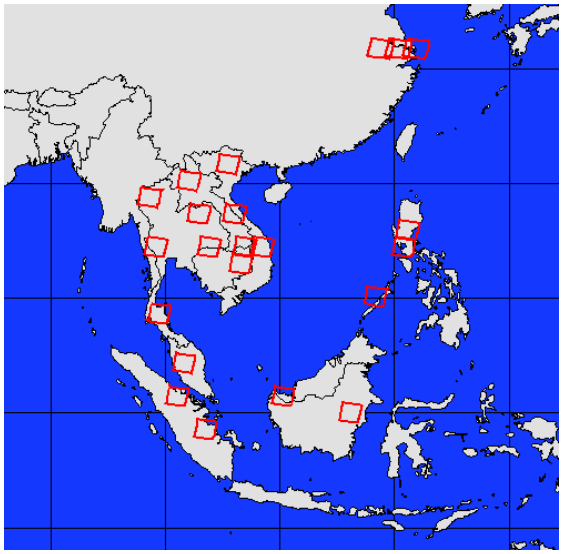


Figure 1: Location of Validation Scenes

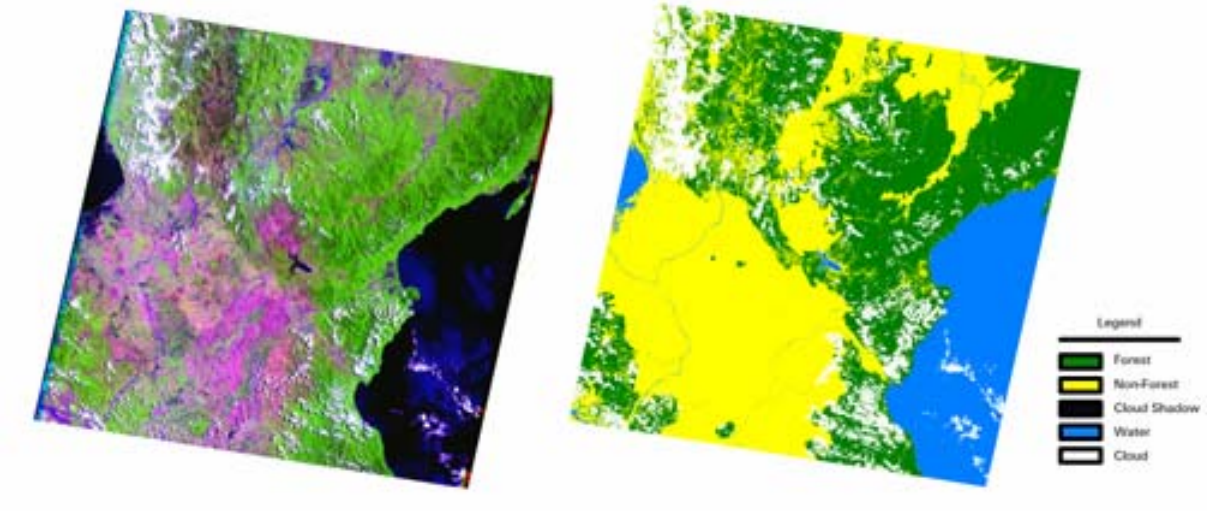


Figure 2: Landsat derived land cover

Validation of the baseline regional forest cover data sets for Indochina (figure 3) is being completed through comparison of the expert land cover products, developed independently by the SEARRIN regional teams, with those Landsat path/row tiles analyzed at the Center for Global Change and Earth Observations at Michigan State University. Expert classified data are co-registered with the data MSU baseline data sets and confusion matrices are completed for the land cover classes.

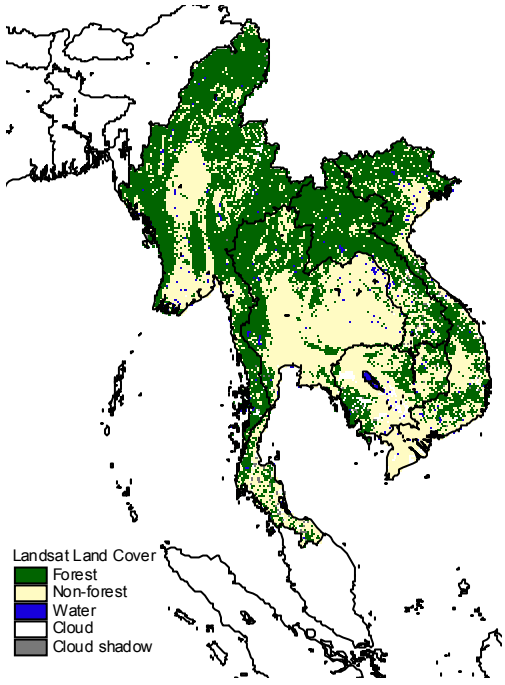


Figure 3: Indochina Forest Cover

Continuous fields of vegetation cover, or fractional cover, is an emerging method of analysis for remotely sensed earth observation that provides qualitative measures of vegetation with respect to biophysical features. In the natural world, vegetation cover

does not always form hard edges between land cover types. Rather the boundary between deciduous forest and mixed evergreen or between primary forest and thirty-year fallow is a continuum of vegetation cover. Fractional cover provides a measure of vegetation density and is useful in detecting degraded forest from selective logging, fire, or disease and pest outbreak. Continuous fields of vegetation cover analysis has proven quite useful in measuring or estimating land cover in such areas as cotton agriculture, where areas are relatively flat and less healthy patches are less dense than more healthy patches. The method of analysis is still being refined, however, in mountainous areas where topographic effects are problematic to the algorithm. Methods of correction are emerging, though; often these require additional datasets (e.g. SAR or multi-look high resolution data used to develop digital elevation models in order to apply BRDF corrections) which are not always available.

The method used to derive fractional cover using the Landsat ETM+ data was as follows:

- Radiometric conversion of Landsat ETM+ data from raw digital numbers to top of atmosphere reflectance (TOA) or apparent reflectance

  Conversion of digital number (DN) to radiance: radiance = gain · DN + offset or radiance – (LMAX – LMIN)/255 · DN + LMIN

  Conversion of radiance to TOA: $P_P = (\pi \cdot L_\lambda \cdot d^2) / (Esun_\lambda \cdot \cos\theta)$

  Where:

  P_P = Unitless planetary reflectance

  L_λ = Spectral radiance at the sensor's aperture

  d = Earth-Sun distance in astronomical units from nautical handbook

  $Esun_\lambda$ = Mean solar exoatmospheric irradiances

- Input TOA corrected ETM+ bands 4 (near infrared) and 3 (red) and output MSAVI (modified soil-adjusted vegetation indices) data set.

  MSAVI = $(\rho$ nir – ρ red / ρ nir + ρ red$)$ · $(1 + L)$ where L is the soil adjusted factor.

- Identify 100% soil and 100% vegetation end-members for inputs to fractional cover model (*fc*), a linear un-mixing model, output vegetation continuous fields data set.

  fc = $(VI - VI_{soil}) / (VI_{veg} - VI_{soil})$ where VI = vegetation indices, VI_{soil} = end-member of 100% soil, and VI_{veg} = end-member of 100% vegetation (or canopy closure).

Fractional cover data sets have been developed using this method by the SEARRIN country team scientists for case studies in each of the SEARRIN countries. A preliminary assessment of forest fractional cover has been developed for Thailand using Landsat data for the target year 1999/2000. Figure 4 shows a vegetation fractional cover product for northern Thailand (Landsat ETM+ path 131 row 47 acquired 18 December 2000.

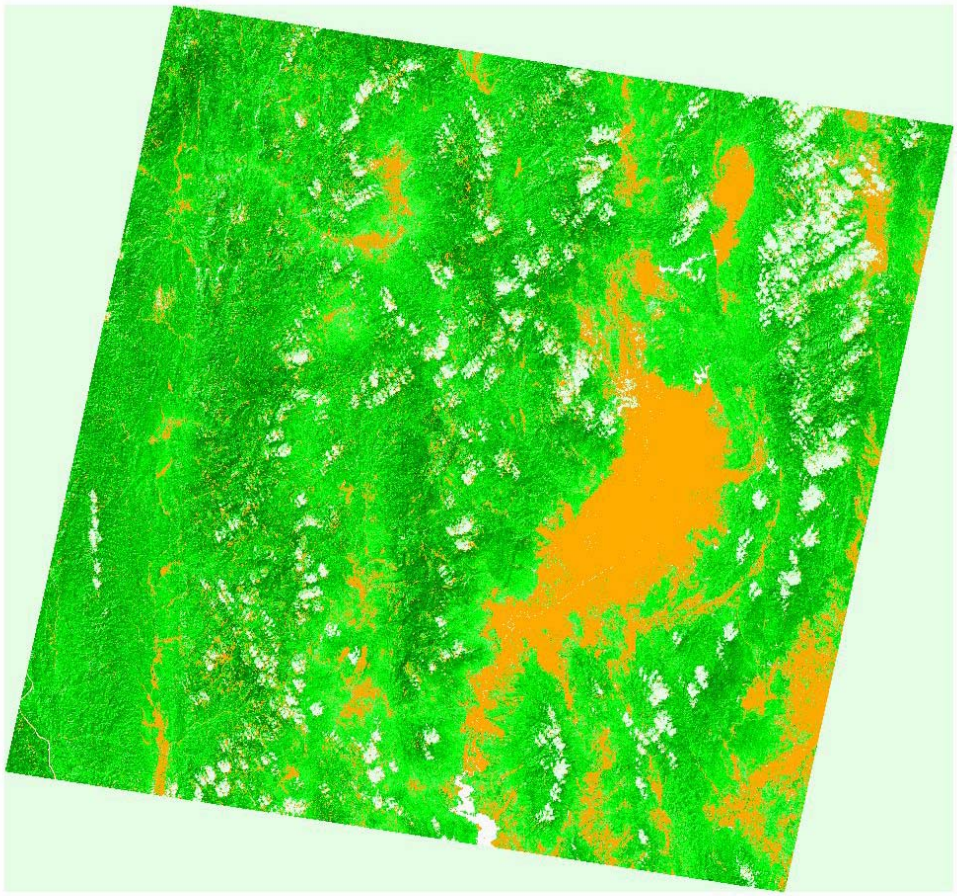


Figure 4: Fractional cover product

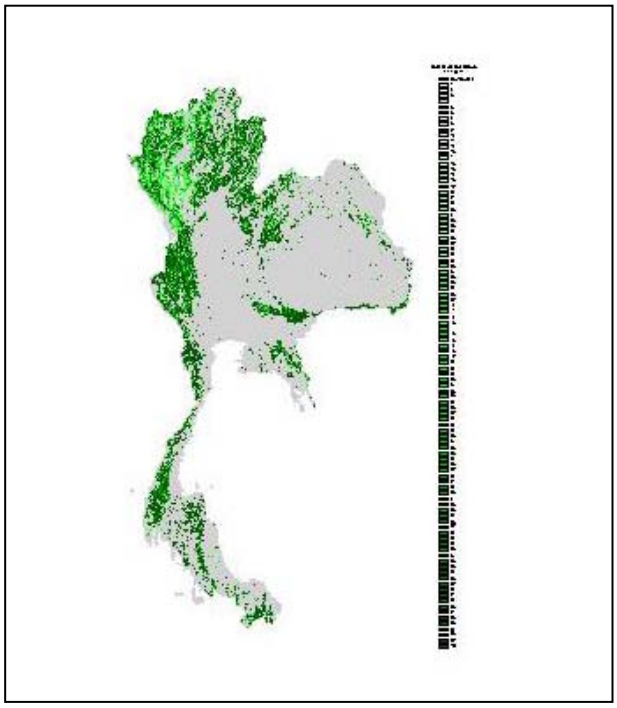


Figure 5: Forest Fractional Cover Thailand

In addition to the case study sites where Landsat based-estimates of fractional cover and field based measurements are being collected for validation and calibration, a preliminary assessment of forest fractional cover has been developed for Thailand for 1999/2000 (figure 5). Thirty-one Landsat scenes were processed using the above method for estimating forest fractional cover and then merged together to form a wall-to-wall mosaic. The same scenes were used to create a forest/non-forest classification. This forest/non-forest data set was then used to mask the non-forest areas from the fractional cover data set creating a forest fractional cover data product.

Field level data have been collected throughout each of the eight Southeast Asian countries who are part of the SEARRIN science team. These data points include GPS locations, digital photographs of the surrounding land cover, digital fish-eye photographs of forest canopy, and field notes on the land cover and land use. These *in situ* measurements are integral to the validation of the land cover derived data. Digital fish-eye photographs are analyzed in GAP-Light software. These ground-based measurements are then used to validate and calibrate the fractional cover estimates derived from the remotely sensed earth observation data. The fieldwork data has been compiled in a database. Figure 6 shows an example from the database for a field site in Chiang Mai, Thailand. The information includes: GPS location, land use classification, land cover description, digital photos in cardinal directions of the site, date of data collection, digital fish-eye photo of forest canopy, analysis output from GAP-Light software for canopy data. The field data are also spatially enabled and have been transformed into GIS data layers. Figure 7 shows the sample sites from fieldwork in Pak Ou District, Luang Prabang Province, Lao PDR, overlaid with a recent Landsat ETM+ scene.

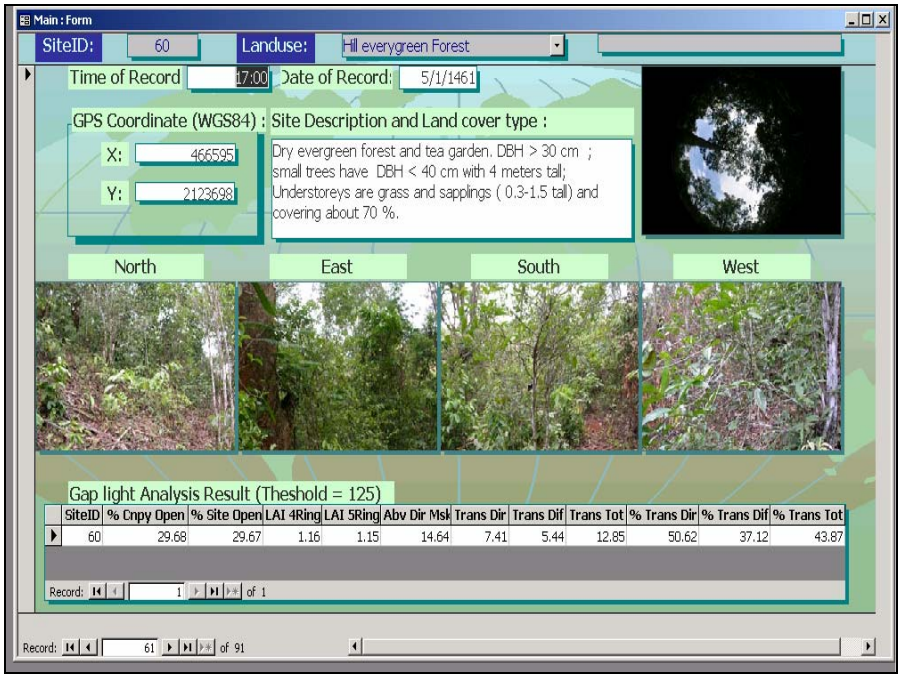


Figure 6: Field measurement database

Fieldwork was conducted in the following locations:

- Cambodia: Vernsay District
- China: Yangtze River Delta
- Indonesia: Berau, East Kalimantan

- Lao PDR: Pak Ou District, Luang Prabang Province
- Malaysia: Sempadi, Sarawak
- Philippines: Mount Makiling National Park
- Thailand: Chiang Mai Province
- Vietnam: Tam Dao National Park and Cuc Phuoung National Park

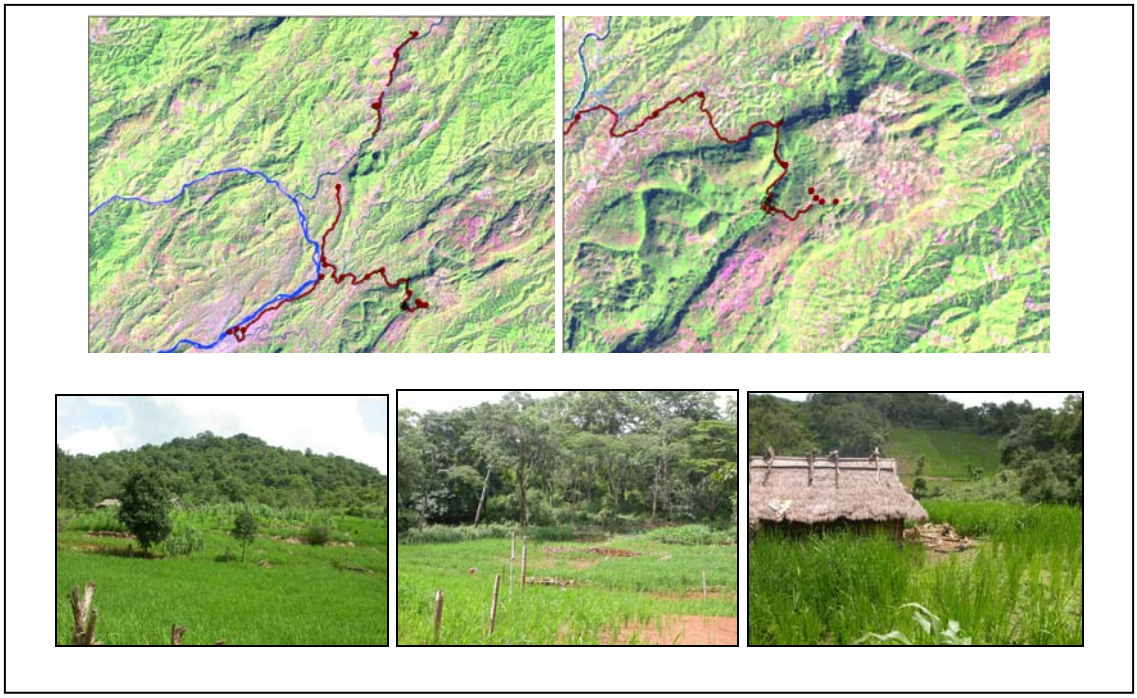
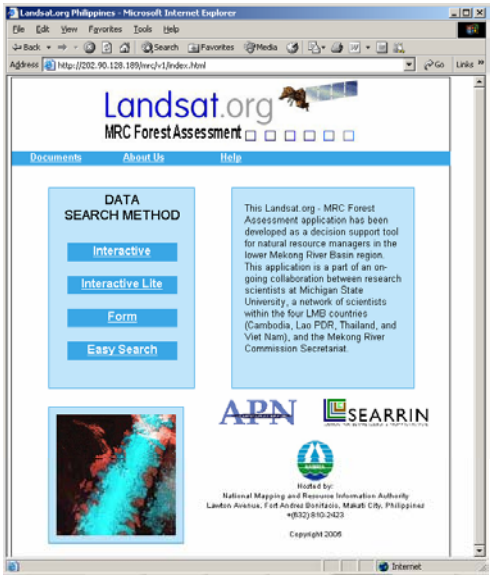


Figure 7: Fieldwork Luang Prabang, Lao PDR

2.2 Data access

Data access is one key to supporting policy makers and natural resource managers. To facilitate access to the data and information generated as a result of this APN project two efforts have been initiated (1) the development of a project website with links to project datasets, and (2) the development of a web-GIS data application. The web URL is: http://www.globalchange.msu.edu/SEARRIN/APN_2004_04_CMY/. From the main page are links to project background information, the workshop proceedings, and data sets, as well as a link to the on-line web-GIS application.

The web-GIS data application has been developed based on state-of-the-art web-enabled GIS technology. This technology has been developed at the Center for Global Change and Earth Observations through customization of COTS technology (Arc IMS) interfaced with organic coding. The application utilizes distributed, spatially enabled databases and map services. Under *Map Services* we group a set of tools that are used to present interactive maps to a user via WWW. The core of the application is a re-use of technology designed specifically for the Tropical Rain Forest Information Center and the Landsat.org application. Its core technology is something we have named *Access7*. *Access7* provides the user interface via the WWW for catalog browse and search. A CGI application, written in Perl, accepts inputs for date ranges, WRS path/row, and cloud cover and queries the TRFIC Catalog for granules fitting those inputs. A world map displaying the location of the queried WRS path/row is created with DHTML and static GIF images. Thumbnail browse products are displayed for each granule by linking to a remote USGS WWW server application with a unique URL. This unique URL is returned by the TRFIC Catalog with the query results.



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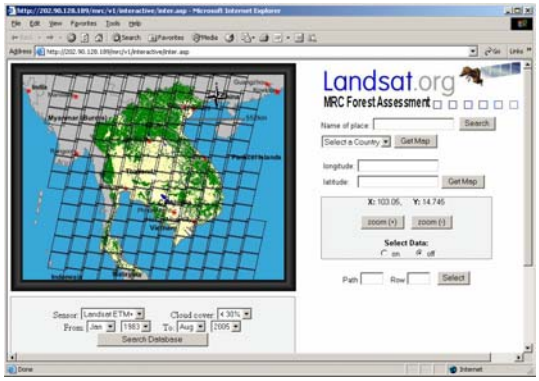

Interactive

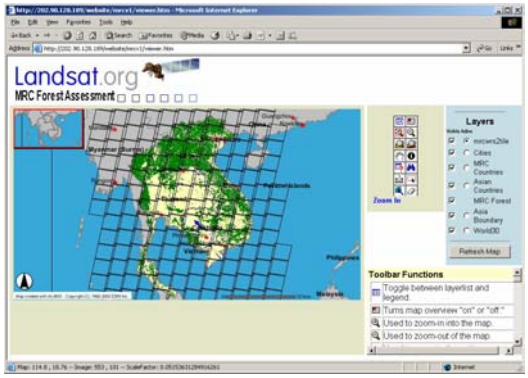

Figure 8: Web-GIS Portal Supporting the MRC Forest Assessment

The "MRC Forest Assessment" application provides the search and browse function for Landsat data but really centers on the contribution of unique land use and land cover data layers developed under this APN project (figure 8). Users have access, directly from their desktops to these data and information through the web-GIS portal. The main website allows for a full web-GIS enabled interactive map server and an "interactive lite" version with scaled-down functions. The "lite" version, we have discovered through past experiences, is more appropriate for users where Internet connectivity has low throughput. Two additional portals (Form and Easy Search) provide text based options. The application is still in an on-going development stage, but certainly ready for "live" status. Additional data sets will be added to the application over time.

2.3 Supporting policy makers and natural resource managers

A formal linkage has been established between SEARRIN colleagues from Cambodia, Lao PDR, Thailand, Vietnam, and the United States and the Mekong River Commission Secretariat in Vientiane, Lao PDR. The mission of the MRC is "to promote and co-ordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well-being by implementing strategic programmes and activities and ***providing scientific information and policy advice***". SEARRIN is supporting the MRC in efforts by providing derived data products assessing forest cover changes in the lower Mekong River Basin. An important part of the linkage was established under this APN project at our workshop 5-6 July 2005 at the MRC Secretariat. This meeting was co-hosted by the Watershed Management Component of the Agriculture Irrigation and Forestry Programme of the MRC and GTZ, the German international development assistance agency. A prerequisite of the MRC data needs for a watershed that spans multiple countries was the development of an agreed-upon definition of "forest cover". This, of course, is no small task. The results of the workshop, however, that worked from the commonality between each of the definitions used by the

four LMB countries, was a common definition, from which data sets will be developed. This information will initially be piloted at two case study sites: (1) National University of Laos, Faculty of Forestry training and model forest in Sangthong district, Lao PDR, and (2) Siem Riep, Cambodia.

3.0 Results & Discussion

Project results from the analysis of remotely sensed earth observations data for land use and land cover change in Southeast Asia are presented below. The following sections provide synthesis results and discussion points for key project case studies as well as the overall regional validation effort.

3.1 Regional Forest Cover Validation

To date, thirteen of the twenty-two expert classified Landsat scenes have been compared to the regional classification and confusion matrices developed. Table 2 below shows an example of the confusion matrix for Landsat ETM+ path 125, row 50, acquired 27 March 2000. This scene covers Southern Laos and Northwest Cambodia.

Table 2: Confusion Matrix for Path 125 Row 50

Path: 125 Row: 50 Confusion Matrix - All Classes

		Actual (Expert Analysis)						
		Forest	Non-Forest	Water	Cloud	Cloud Shadow	Predicted Total	Predicted Error %
Predicted	Forest	21120416	1104993	57	433073	2985	22661524	6.800549
	Non-Forest	2697694	11121382	828	61908	1192	13883004	19.89211
	Water	11617	72958	185010	1069	4938	275592	32.86815
	Cloud	545	97911	0	1041296	3	1139755	8.638611
	Cloud Shadow	20251	42188	122	39516	34232	136309	74.88647
	Actual Total	23850523	12439432	186017	1576862	43350	38096184	28.61718
	Actual Error %	11.4467385	10.595741	0.5413484	33.964037	21.033449	15.5162628	87.94%
Proportion True		88.5532615	89.404259	99.458652	66.035963	78.966551		

Table 3 shows the results for the thirteen validation scenes covering Laos, Thailand, Philippines and China. The results show overall accuracies ranging from 65.86 % (scene in China) to 98.50 % (scene in Philippines). The range in proportion of forest area predicted correctly ranges from a low of 5.86 % (scene in China) to a high of 99.73 % (scene in Laos). Seven of the thirteen validation scenes compared at above 80 % accuracy for correctly predicting forest area, five ranged between 31 – 56 % accuracy. The scenes with the lowest accuracy in correctly predicting forest cover area were also the scenes with the lowest overall forest cover in the scenes (8.62 and 8.31 %) and are two of the three scenes in China. These preliminary results are promising in that the regional forest cover map for Indochina appears to be within 80 – 90 % accuracy when using the expert classification products as validation. There are areas for improvement, specifically in the over-estimation of forest cover in the upland areas. This is one reason why the uplands have become a focus for SEARRIN and the efforts to more accurately understand the vegetation dynamics which will prove useful in supporting the needs of the Mekong River Commission and the Lower Mekong Basin countries.

Table 3: Accuracy Assessment Table for Regional Forest Cover Validation

Country	Path	Row	Date	Accuracy	P-For	P-NF	P-W	% F	% NF
Laos	129	46	02-Nov-00	79.08%	99.73%	27.70%	99.86%	71.00%	28.55%
	126	48	11-Nov-99	65.86%	96.87%	34.72%	91.78%	30.51%	43.86%
	125	50	27-Mar-00	87.94%	88.55%	89.40%	99.45%	62.61%	32.65%
China	120	38	03-Nov-00	82.92%	46.89%	96.45%	76.17%	23.44%	69.05%
	119	38	15-Jan-01	91.25%	31.99%	98.45%	88.13%	8.31%	76.05%
	118	38	14-Jun-00	88.40%	5.86%	97.18%	96.57%	8.62%	67.56%
Philippines	117	53	05-Feb-02	93.58%	86.51%	92.39%	99.71%	17.61%	39.82%
	130	50	25-Dec-99	98.50%	94.19%	85.88%	99.63%	10.27%	1.82%
	129	54	04-Dec-00	78.70%	56.95%	87.92%	95.31%	55.45%	40.78%
Thailand	128	48	27-Dec-99	91.94%	54.09%	99.67%	74.30%	34.68%	26.65%
	127	50	25-Mar-00	85.80%	53.02%	99.15%	39.49%	15.10%	81.55%
	131	47	18-Dec-00	93.58%	86.51%	92.39%	99.71%	21.53%	74.29%
	127	50	25-Mar-00	95.71%	97.18%	96.53%	65.23%	74.74%	15.84%

P-For Proportion of Forest correctly predicted
P-NF Proportion of Non-forest correctly predicted
P-W Proportion of Water correctly predicted

3.2 Tam Dao National Park

Tam Dao is a "cigar-shaped" range of mountains approximately 80 kilometers long and 10 – 15 kilometers wide. The mountainous massif runs northwest to southeast. The range contains twenty peaks, many at elevations of 1000 meters or more, which overlook the edge of the Red River delta. The tallest peak is Mount Tam Dao Bac at 1,592 meters. Tam Dao is located about 70 kilometers northwest of Hanoi, the capital city of Vietnam, and lies within three provinces[1]. The northeast face of the mountain chain lies in the Song Cong River watershed; the southwest face lies in the Pho Day River watershed. Water discharge from the mountain streams is year-round with floods occurring in the height of rainy season (August) and lower water levels occurring in dry season. Tam Dao lies within a tropical monsoon climate zone and has a mean annual rainfall of 2,800 mm of which 90% falls between April and October with August typically receiving the greatest amount. Rainfall is slightly greater on the east side of the park due to humid tropical ocean winds.

The Tam Dao National Park was established in March 1996, by Prime Ministerial Decision No. 136/TTg. In 1977 a portion of the current extent of the park (19,000 ha) had been designated a nature reserve. The park currently comprises a total area of 36,883 ha. Of the total area, 17,295 ha are designated as a strict protection area or Core Zone, 17,286 ha a forest rehabilitation area or Ecological Zone, and 2,302 ha an administrative and service area. The Core Zones are areas at elevations greater than 400 meters. The Ecological Zones are areas at elevations between 100 – 400 meters. There is also a designated buffer zone comprising 15,515 ha.

[1] The park is located in Son Duoung district, Tuyen Quang province, Dai Tu district, Thai Nguyen province, and Lap Thach, Tam Dao and Me Lihn disctricts, Vinh Yen province.

Lowland evergreen forests[2] (700 – 800 m) and lower montane evergreen forests[3] (< 800m) dominate the natural forest landscape. At the highest elevations, the park also contains elfin forests[4]. The park boasts high biological diversity (490 species of vascular plants, 58 species of mammals, 158 species of birds, 46 species of reptiles, and 19 species of amphibians recorded by FIPI conducted field surveys). Tam Dao is one of the few areas in Vietnam where two globally threatened species, the Imperial Eagle (*Aquila heliaca*) and the Fairy Pitta (*Pitta nympha*), have been recorded. The park is also home to about 95,500 people from eight different ethnic groups who are primarily involved in agriculture production.

In parks where the explicit goal is to conserve or preserve natural resources, success might be determined by how many elephants remain in the wild, or how many wild orchid "poachers" are fined, or how much forest cover remains. Measurements of efficacy, therefore, can be quite variable. In the case of a park where maintaining forest cover is of primary importance, measuring efficacy can be as simple as measuring changes in forest area over time. Measuring forest cover changes using field-based observation can, however, be quite expensive in terms of human and economic capital, particularly in parks that are often expansive, remote, and rugged. The use of remote sensing data is a cost-effective alternative to field-based measurements. Earth observation data, with high spatial resolution and annual temporal frequency, can be used to accurately measure forest cover changes over large geographic areas. Therefore, multi-temporal satellite data analysis can provide a measure of park efficacy[5].

Table 4 shows the results of the land cover analysis for the four time periods by cover type as area (hectares) and percent change over time. Table 5 shows the percentage of the total area by forest and non-forest classes for each time period.

Table 4: Tam Dao NP Area and Percent Change by Land Cover

	Area in Hectares				% Change			
Land Cover	**1975**	**1993**	**2000**	**2003**	**1975-1993**	**1993-2000**	**2000-2003**	**1975-2003**
Forest	34052.77	32400.73	32879.72	34631.1	-4.85%	1.48%	5.33%	1.70%
Non-forest	6133.137	7761.861	7179.478	5432.49	26.56%	-7.50%	-24.33%	-11.42%
Water	0	78.13845	115.7456	98.91	100.00%	48.13%	-14.55%	100.00%
Total	40185.91	40240.73	40174.94	40162.5				

Table 5: Tam Dao NP Percentage of Total Area by Cover Type

	% Cover			
Land Cover	**1975**	**1993**	**2000**	**2003**
Forest	84.74%	80.52%	81.84%	86.23%
Non-forest	15.26%	19.29%	17.87%	13.53%
Water	0.00%	0.19%	0.29%	0.25%
Total	100.00%	100.00%	100.00%	100.00%

[2] *Fabaceae, Dipterocarpaceae, Meliaceae, Burseraceae, Myrtaceae*, and *Anacerdiaceae* families
[3] *Fagaceae, Lauraceae, Spotaceaea, Aceraceaea, Theaceae, Hamamelidaceae, Sapotaceae* and *Ericaceae* families
[4] *Ericaceae* and *Theaceae* families
[5] A satellite-based analysis of forest cover change for a national park provides **one** measure of park efficacy. Understanding the complex nexus of factors (social, cultural, economic, political, biophysical, and historical) for why there is success or failure in park efficacy is beyond the scope of this analysis.

In 1975 there were 34,052.77 ha of forest cover, 6,133.14 ha non-forest and no area in water[6] in Tam Dao national park. By 2003, forest cover had increased slightly by 578.33 ha, non-forest areas had declined by 700.65 ha, and the development of a reservoir within the park boundary accounted for 98.91 ha of water. Between 1975 and 2003 change in forest and non-forest areas in Tam Dao were dynamic. Between 1975 and 1993, forest cover declined by 1652.04 (4.85%) ha and non-forest areas increased by 1628.73 ha (26.56%). Between 1993 and 2000 forest areas increased slightly and non-forest areas declined. This trend continued between 2000 and 2003 with a greater increase in forest area and further decrease in non-forest area.

Rates of change in forest and non-forest areas over the four time periods are shown in Table 6. Analyzing only two dates, 1975 and 2003, to assess the annual rate of change over the 28 year period (20.65 ha/year increase in forest area) would mask the dynamic decline and increase in forest and non-forest areas. The first period of analysis, 1975 – 1993 shows a 91.78 ha/year decline in forest area. The next period, 1993 – 2000, shows a 68.43 ha/year increase in forest cover. And, the final period, 2000 – 2003, reveals a dramatic 583.79 ha/year increase in forest cover.

Table 6: Tam Dao NP Annual Rates of Forest and Non-Forest Change

	ha/yr	
Period	**Forest**	**Non-forest**
1975-1993	-91.78	90.48
1993-2000	68.43	-83.20
2000-2003	583.79	-582.33
1975-2003	20.65	-25.02

Twenty field observations collected in August 2001 were use to measure the accuracy of the forest/non-forest analysis of the 2000 ETM+ data. Of the field points collected, eleven were in forested areas and nine were in non-forested areas. The analysis correctly mapped 18 of the 20 field points, incorrectly mapping two of the non-forest points as forest. Table 7 shows the confusion matrix with omission and commission error percentages as well as the mapping accuracies for the two classes.

Table 7: Tam Dao NP Confusion Matrix for the ETM+ 2000 Data Analysis

	Landsat 2000		Total	Omission	Commission	*Mapping Accuracy
Field Data	Forest	Non-forest				
Forest	11	0	11	0.00%	18.18%	84.62%
Non-Forest	2	7	9	22.22%	0.00%	77.78%
Total	13	7	20			
Overall Classification Accuracy			90.00%			

* Mapping Accuracy (MA) for any Class X

A similar accuracy assessment of the land cover classification for the Landsat ETM+ data from 2003 was completed using very high-resolution (4-meter multi-spectral) IKONOS data acquired January 4, 2002. 190 systematic sample points were used to compare forest, non-forest, and water classes between the land cover data derived from the analysis of the Landsat ETM+ imagery and the visual assignment of these classes using the IKONOS data. Each sample point was classified as forest, non-forest, or water based on visual interpretation of the points overlaid atop of the IKONOS imagery (forest = 150,

[6] No water mapped at 57-meter resolution.

non-forest = 38, water = 2). Using the "intercept" operation in ArcInfo these 190 sample points were merged with the land cover data from the Landsat analysis (forest = 157, non-forest = 31, water = 2). 170 points were correctly classified for an overall classification accuracy of 93.16 %. Table 8 shows the confusion matrix for the accuracy assessment of the Landsat ETM+ 2003 land cover analysis.

Table 8: Confusion Matrix for the ETM+ 2003 Data Analysis

	Landsat 2003			Total	Omission	Commission	*Mapping Accuracy
Ikonos	Forest	Non-forest	Water				
Forest	147	3	0	150	2.00%	6.67%	91.88%
Non-Forest	10	28	0	38	26.32%	7.89%	68.29%
Water	0	0	2	2	0.00%	0.00%	100.00%
Total	157	31	2	190			
Overall Classification Accuracy			93.16%				

* Mapping Accuracy (MA) for any Class X

In both accuracy assessments (Landsat ETM+ 2000 & 2003), omission errors for classifying non-forest areas were relatively high (22.22% and 26.32) indicating that the analysis may be underestimating the amount of non-forest area in both dates. While the overall classification accuracy for the two analyses is high (90.00% and 93.16%), the mapping accuracy for these two dates, specific to the non-forest class, is 77.78% (yr. 2000) and 68.29% (yr. 2003). The low mapping accuracy/high omission error may, in part, be a result of the relatively small area in non-forest by comparison to forest area. Assuming some degree of accuracy in the land cover analyses; non-forest areas account for less than 20% of the total area in any of the four data analysis years.

The multi-temporal analysis of Landsat data for the Tam Dao National Park provides one measure that indicates successful park efficacy in the environmental conservation of forest cover. The analysis shows decline in forest cover in the years preceding the establishment of the park in 1996 (1975 – 1993), and an increase in forest cover after 1996 (1993 – 2000 & 2000 – 2003). It is known, that prior to the establishment of the park, the forests of Tam Dao were a source of raw materials for construction, paper products, and fuel. The former Ministry of Forestry reports that from 1986 – 1990 nearly 2.4 million m^3 of timber, 18.7 million m^3 of firewood, and 70 million m^3 of bamboo were extracted from the north-central provinces of Vietnam (an area that includes Tam Dao). The increase in forest cover after 1993 may be a result, in part, of the creation of the park, the establishment of a boundary and protection policies, after 1996. However, this increase is also likely attributable to government sponsored reforestation and plantation forest activities. The Vietnamese Government Program 327, established in 1993, focused on re-greening barren land and hills, protecting existing forest areas, promoting natural regeneration and establishing forest plantations. Between 1993 and 1998, 1516.2 hectares were planted in Tam Dao National Park under Program 327 and sustained a 90 % survival rate after replanting.

Additional analysis using remotely sensed data acquired in 1996 or 1997, close to the date of the park's establishment, would contribute significantly to this study. The time step in the analysis of data between 1993 and 2000 shows an increased annual rate of change in forest cover of 63.43 ha/year. While 1993 is the year in which reforestation activities were started under Government Program 327, it is not clear from this analysis if forest cover continued to decline between 1993 – 1996, prior to the park's creation. The rate of change, 63.43 ha/year, between 1993 and 2000 may simply be an average of continued rates of decline before 1996 and then rates of increase after 1996.

3.3 Mangrove system in Southern Vietnam

While results are still preliminary regarding the disturbance and recovery in the mangrove areas of Southern Vietnam, some description may be valuable at this point. The results from the multi-temporal satellite data analysis will measure the extent of mangrove destruction in the Ca Mau peninsula and the area east of Ho Chi Minh City (now known as Can Gio Mangrove Biosphere Reserve) from the effects of defoliation used during the Vietnam War. These two areas have experienced very different land use and land cover change dynamics as a result of national policy and also international economics. Can Gio has fully recovered as a healthy mangrove system from the national efforts of reforestation and protection. The Ca Mau peninsula, on the other hand, has transformed over time from some mangrove recovery to conversion to rice agriculture and then to shrimp and fish aquaculture in response to international demand and the economic reform policy of the 1980s, *doi moi*. There are questions currently being researched regarding potential health risks of food raised in areas where dioxins were used during the Vietnam War. The study highlights how land use and land cover change dynamics respond to political and economic changes at national and international levels and how these changes vary over space and time. Figure 9 shows two Landsat scenes for the Ca Mau peninsula. The image on top was acquired 3 January 1973 and shows the defoliant stripping in the mangrove forest. The image on the bottom is a composite of data acquired 16 January 2001 and 17 March 2002 and shows large areas of former mangrove land cover converted to aquaculture, areas also defoliated in the last 1960s early 1970s with herbicide containing dioxin.

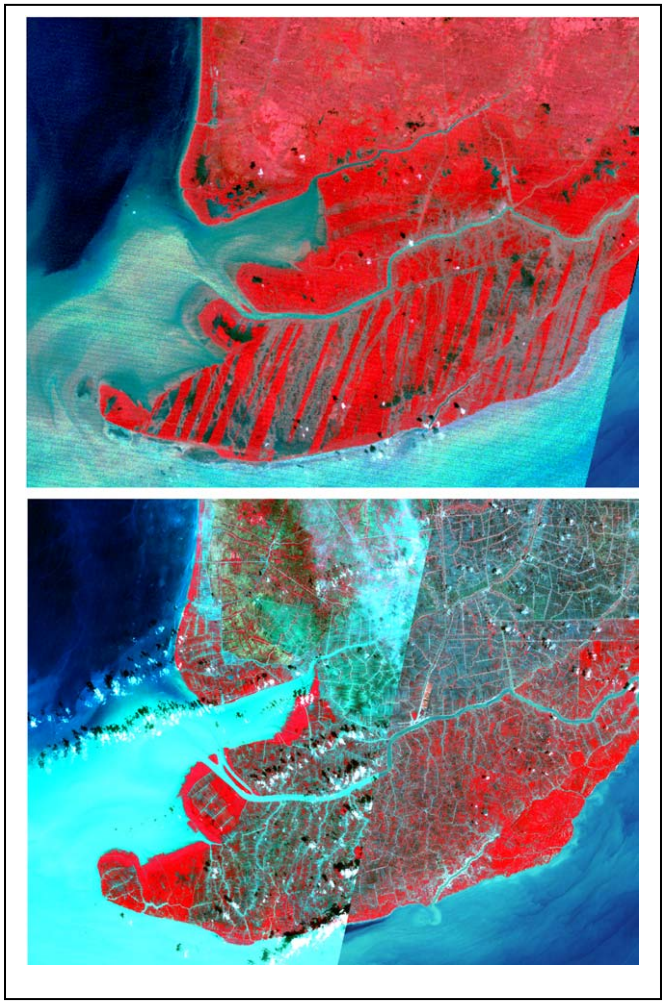

Figure 9: Ca Mau Peninsula, Vietnam - Mangrove Decline

3.5 Upland shifting cultivation in Laos

Preliminary work has also been completed for an analysis using inter-annual and inter-seasonal Landsat data in order to quantify the forest-fallow-farm dynamics in upland shifting cultivation areas. This initial case study is in northern Laos. Synoptic land cover assessment that do not include high temporal frequency over estimate forest cover in these particular landscapes in part due to complications from topographic effects from mountainous areas and also from the mixing of spectral signatures between fallow and forest. Analysis of data with a higher temporal frequency allows us to map vegetation as it moves out of field into fallow.

Table 9 shows the results of a change matrix for two classes, vegetation and non-vegetation for two dry season Landsat scenes, from 2000 and 2001. Areas that remained non-vegetated are accepted as cleared lands. Areas that transitioned from non-vegetation to vegetation are assumed to be 1-year fallows. However, those areas that remained vegetated in the two years and those areas that transition from vegetation to non-vegetation are problematic. For example, it is not certain what percentage of the persistent vegetation is 1-year, 2-year, 3-year fallow or longer and what percent is 50-year or older forest. In the areas that transitioned from vegetation to non-vegetation is not certain how much of this area was re-cleared young fallow (1 to 5 years), re-cleared longer fallow (5 – 15 years), or cleared "primary" forest.

Table 9: Inter-annual land cover - Shifting cultivation in Laos

Land cover	Area (ha)
Remained Vegetation	28245.51
Vegetation 2000 - Non-Vegetation 2001	4598.64
Non-Vegetation 2000 - Vegetation 2000	3391.38
Remained Non-vegetation	4669.29

Data in table 10 show the transition between vegetation (V) and non-vegetation (NV) for a three year period (2000-2001-2002). From this three-year study, the actual transitions begin to become apparent: 3409.47 ha are 1-year fallow, 2788.38 ha are 2-year fallow, 603 ha were cleared in 2000, left fallow one year and cleared again in 2002 and so on. Figure 10 shows an example of the dynamic spatial and temporal nature of shifting cultivation in Northern Laos. This image is a composite of three Landsat band fives from three years: 2000 – 2001 – 2002. Gray areas are persistent vegetated and non-vegetated areas. Areas of color signify patches of land that have transitioned (been cleared or abandoned) sometime within the three years.

Table 10: Shifting Cultivation Transitions 2000-2001-2002

Land cover	Area (ha)
V-V-V	25666.02
V-V-NV	2579.49
NV-NV-V	3409.47
NV-NV-NV	1189.17
NV-V-V	2788.38
NV-V-NV	603
V-NV-V	2897.01
NV-NV-NV	1772.28

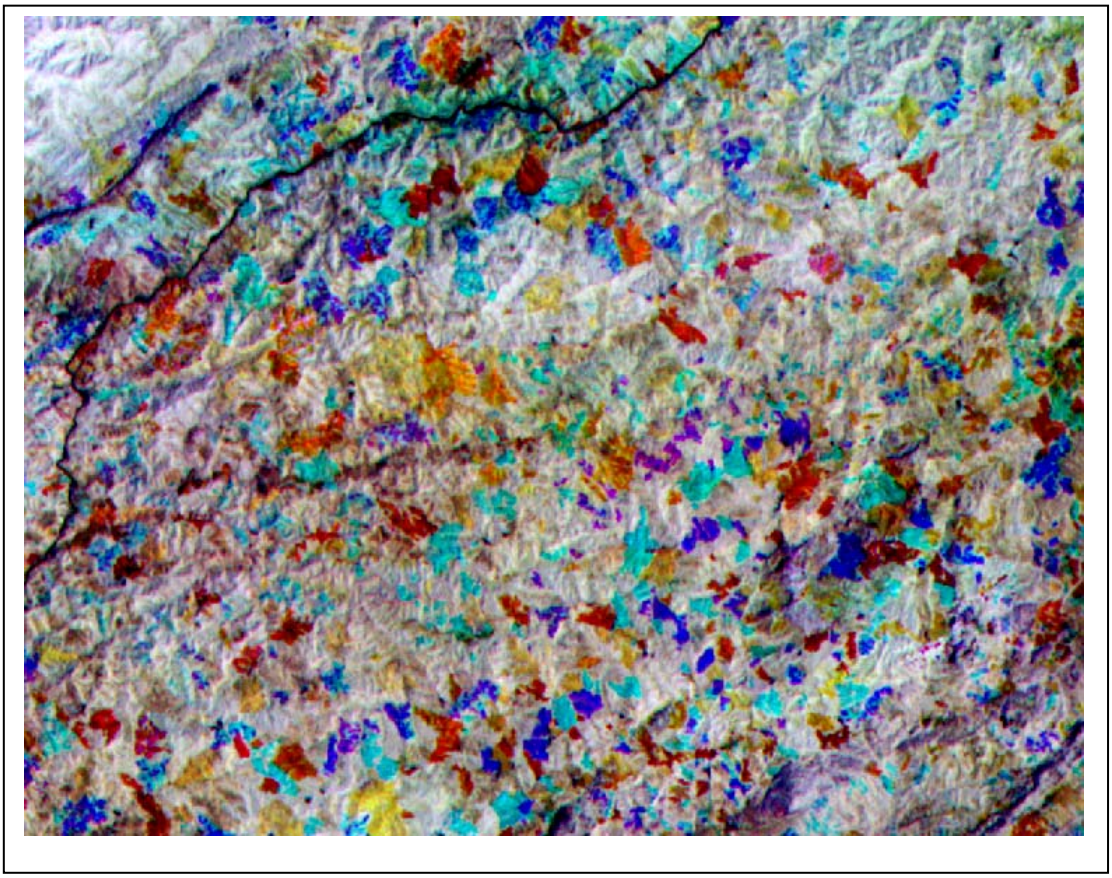

Figure 10: Shifting Cultivation in Northern Laos - mosaic of three dates

3.6 Fractional Cover: Chiang Mai, Thailand

The goal for this analysis is to calibrate and validate the fractional cover products derived from Landsat image. This analysis involved with ground survey to take canopy photographs using a fish-eye lens camera, and the use of gap light analyzer software to derive the information on the biophysical properties from a range of forest cover types. It is noted that not all of the photograph are in forest cover of 100 %. Some photos in areas with 10-30%, 30-50%, and 50-70% forest cover can be taken from the field. Some non-fish-eye plain digital pictures in non-forest areas were collected as well, with GPS points. This information can be used to validate the non-forest classes.

For these field measurements, 77 samples from three forest types were chosen (Table 11). Only 19 samples were taken from non-forest areas. Three criteria were considered for conducting field survey: (1) *fc* values from the satellite image; (2) accessibility to the selected sites; and (3) ratio of forest land use on the classified satellite image of the same scene at a finer level of information.

Table 11: Ratio of forest land use and the selected sample sites

Land Use	Area (sq.km)	Percent	Number of samples
Hill evergreen forest	6833	26.862	23
Mixed deciduous forest	8741	34.362	29
Dipterocarp forest	9863	38.776	25
Total	25437	100.00	77

Field measurements of *fc* and other biophysical variables were taken between March-May 2004 to cover 91 sample sites in Chiang Mai, Lumpang and Lumphun Provinces. Forest biophysical properties from each site are characterized by tree height,

stem height, canopy density, DBH, LAI, and fractional cover. It is noted that the ground survey period does not correspond with the time of image data acquisition, which may underestimate *fc* values in some forest areas. Chiang Mai sampling sites include Doi Suthep area, area around Maekwang reservoir, Khun Wang area in Maechaem district, Maegat and Huai Num Dung in Mae Taeng district. The Thung Kwien and Doi Khun Tan areas were chosen as sampling sites from Lumpang Province.

The forest database was developed in Microsoft access based on a result of gap light analysis. Forest biophysical properties such as average of canopy open, average LAI, and average of site open from different land use types were recorded. This digital database includes photos from fish-eye camera from all survey locations measured by a GPS. They can be linked into a GIS data layers such as soil, geology, and other attributes for more studies. Table 12 represents result of gap light analysis from hill evergreen forest, mixed deciduous forest, dipterocarp forest, and non-forest areas. It was found that the average canopy open from hill evergreen forest (25 %) is lower than those obtaining from other forest types, whilst the average of LAI is higher than the others. As was expected, Avg. of % Canopy Open from non-forest areas such as paddy filed is nearly 97 %, with an average site open of about 71 %. These figures correspond with the fractional cover image at the same location.

Table 12: Example of gap light analysis from forest and non-forest areas

Landuse	Avg. Of % Cnpy Open	Avg. Of LAI 5Ring	Avg. Of Trans Dif	Avg. Of % Site Open	Avg. Of % Trans Tot
Field crops	71.59	0.41	11.16	71.53	77.86
Dipterocarp forest	41.35	0.82	7.90	41.35	54.84
Hill evergreen forest	25.34	1.45	4.53	25.33	30.47
Mixed deciduous forest	31.73	1.17	5.75	31.73	39.49
Orchard	38.98	1.05	6.76	38.96	46.18
Paddy field	96.81	0.04	14.11	96.74	96.67
Shrubs	43.61	0.85	7.75	43.60	40.73

4.0 Conclusions

This project supported a series of activities centered on the application of remote sensing analysis of land use and land cover in Southeast Asia and the development of geospatial data and data products for environmental monitoring and management.

The main objectives of the project were:

1. The development of empirical, accurate geospatial land use and land cover data derived from remotely sensed data,
2. The development of spatial data infrastructure and support tools for open access to support regional scientists and decision-makers, and
3. Capacity building for regional scientists and natural resource management agency personnel (many who are members of SEARRIN).

The project has succeeded in developing a suite of land use and land cover products derived from remotely sensed data, building an archive of information and data products to support policy making and natural resource management. There is still much to do and the information gained from the efforts these past two years have proved insightful in where next the SEARRIN efforts are required; certainly in continued information and analysis on the forest dynamics in the uplands of Southeast Asia, and in developing the algorithms for estimated forest biophysical properties from remotely sensed data.

Capacity building with colleagues in Southeast Asia and outreach to policy makers and natural resource managers remains a high priority for SEARRIN.

5.0 Future Directions

In addition to on-going LUCC research; developing accurate measurements of land use and land cover changes, analyzing the human dimensions of these changes as well as their impacts (biodiversity, human health and well being), two specific areas of future direction are at the forefront of our activities: (1) the development of operational forest monitoring to support the Mekong River Commission forest assessment and (2) the application of remote sensing and GIS to support carbon mitigation. The follow on to this APN project and our final workshop with the MRCS will be two pilot studies to refine the protocol for developing forest cover and forest cover change data and information that meets the requirements of the MRCS forest assessment. The focus has commitments from SEARRIN team members in the four Lower Mekong Basin countries, the MRCS Watershed Management Component of the Agriculture, Irrigation, and Forestry Programme and the Center for Global Change and Earth Observations at Michigan State University.

The carbon mitigation project is an effort to marry payments for environmental services (PES) with the carbon exchange. In summary, to make carbon markets work effectively, it is necessary to develop straightforward, but rigorous methods for measurement and monitoring. The voluntary carbon credit market offers new opportunities to reduce emissions of greenhouse gases, increase agricultural revenues for poor farmers, and stabilize environmental and natural resource degradation in developing countries. Effectively engaging rural communities in carbon financial markets allows a form of payment for environmental services that can improve natural resource management and create mechanisms for institutional capacity building. However, building carbon markets will require sound standards and protocols for measurement, monitoring and carbon accounting. Buyers will not be willing to invest or purchase carbon credits without sound standards. This project aims to develop such standards and protocols and field-test them. Use of remote sensing and GIS to create landscape wide accounting is innovative in this area. This will enable communities to participate and manage the village landscape as a whole for net emission reductions and removals. We plan to seek funding to support these efforts for local communities in Vietnam, the Philippines, and possibly Laos and Indonesia.

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Appendix

Conferences/Symposia/Workshops

Workshop: Regional, multi-scaled, multi-temporal land-use and land cover data to support global change research, and policy-making: a SEARRIN LUCC Project

28 – 31 August 2003
Hanoi, Vietnam
Hotel Horison
40 Cat Linh, Hanoi, Vietnam
Tel: 844-7332438 Fax: 844-7330888

APN/SEARRIN meeting in Hanoi

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AGENDA

August 28, 2003

07:00 – 08:00 Breakfast (Thuy Tien Hotel)
08:00 Taxis from Thuy Tien Hotel to Horison Hotel
08:15 – 09:00 Registration
09:00 – 10:45 Opening Remarks
- Prof. Dr. Bui Hoc, Rector of Ha Noi University of Mining and Geology
- Dr. Nghiem Vu Khai, Vice Chairman of Section for Science, Technology and Environment, National Congress of Vietnam.
- Dr. Hoang Minh Hien, Disaster Management Center, Central Committee for Flood and Storm Control, SEARRIN-Vietnam Team Leader
- Dr. Dave Skole, CGCEO-MSU, SEARRIN-US Team Leader & Project PI
- Dr. Anond Snidvongs, APN Liaison Officer

10:45 – 11:00 Coffee/Tea Break
11:00 – 11:20 Participant Introductions
11:20 – 12:00 Project Overview I (J. Samek)
12:00 – 13:30 Lunch
13:30 – 14:15 Project Overview II (J. Samek)
14:15 – 15:15 Round-table Discussion (J. Samek)
- Team case study site selections
- Data requirements
- Project time line

15:15 – 15:35 Coffee/Tea Break
15:35 – 16:15 Round-table Discussion (continued…)
- Team case study site selections
- Data requirements
- Project time line

16:15 – 17:00 Review of meeting agenda, days 2 – 4, logistics

August 29, 2003

07:00 – 08:00 Breakfast (Thuy Tien Hotel)
08:00 Taxis from Thuy Tien Hotel to Horison Hotel
08:30 – 08:45 Review of Fractional Cover (J. Samek)
08:45 – 09:15 Overview of Forest Biophysical Properties and Available Data Products (J. Qi)
09:15 – 10:00 Fractional Cover Analysis of Landsat data (J. Qi and J. Samek)
10:00 – 10:20 Coffee/Tea Break
10:20 – 11:00 Fractional Cover Analysis of Landsat data (continued…)
11:00 – 14:00 Bus from Hanoi to Ha Long Bay (lunch on bus)
14:00 – 18:00 **Ha Long Bay boat tour: Land use and land cover at the water/land interface**
18:00 – 19:30 Dinner in Ha Long Bay
19:30 – 22:30 Bus from Ha Long Bay to Thuy Tien Hotel in Hanoi

August 30, 2003

08:00 – 09:00 Breakfast (Thuy Tien Hotel)
09:00 Taxis from Thuy Tien Hotel to Horison Hotel
09:30 – 10:15 Advanced Methods in Fractional Cover Analysis (J. Qi)

- Correcting for topographic effects
- Correcting for seasonality and vegetation differences (e.g. leaf-off phrenology)
- Data resolution (scale) issues (e.g. IKONOS, Landsat, MODIS/SPOT VGT)

10:15 – 10:35 Coffee/Tea Break
10:35 – 12:00 Advanced Methods in Fractional Cover Analysis (continued…)
12:00 – 13:30 Lunch
13:30 – 14:00 Fractional Cover Field Work for Validation and Calibration (J. Samek and J. Qi)
14:00 – 15:00 Regional data validation (J. Samek & D. Skole)

- Presentation
- Open Discussion

15:00 – 15:20 Coffee/Tea Break
15:20 – 16:00 Project SDSS (J. Samek)

August 31, 2003

07:00 – 08:00 Breakfast (Thuy Tien Hotel)
08:00 Taxis from Thuy Tien Hotel to Horison Hotel
08:30 – 09:15 FOA/LCCS Presentation and Discussion (J. Samek)
09:15 – 10:30 Project Review (J. Samek)

- Objectives and outputs
- Time line
- Task

10:30 – 11:00 Coffee/Tea Break
11:00 – 12:30 Open Discussion on Future Activities
Closing Remarks

- Dr. Hien, SEARRIN-VN Leader and Project Co-I
- Dave Skole, SEARRIN-US Leader and Project PI

Workshop: Data Information Systems and Services (DISS) For Satellite-Based Earth Observation Data: Development Of On-Line Applications For Distributed Data Archives - SEARRIN Web-GIS Technologies Training – APN Project 2003-08

9 – 11 July 2003
GISTDA, Bangkok, Thailand

Participants:

Country	Name	Organization
United States	Dr. David Skole	Director , Center for Global Change and Earth Observations, Michigan State University
United States	Mr. Jay Samek	Coordinator, SE Asia Programs, Center for Global Change and Earth Observations, Michigan State University
United States	Mr. Oscar Castaneda (telecom)	Data and Information Systems Administrator, Center for Global Change and Earth Observations, Michigan State University
United States	Mr. Chris Barber (telecom)	Data and Information Systems Administrator, Center for

		Global Change and Earth Observations, Michigan State University
Thailand	Dr.Darasri Dowreang	Deputy Director, GISTDA
Thailand	Ms.Praneet Disariyakul	Director, Office of Business Development, GISTDA
Thailand	Mr.Chanchai Peanvijarnpong	Director, Space Technology Center, GISTDA
Thailand	Dr.Surachai Rattanasermpong	Director, Geo-informatics Center, GISTDA
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Thailand	Ms.Ramping Simking	Chief, Geo-information Data Base Section, GISTDA
Thailand	Ms.Supapis Polngam	Chief, Data Application Section, GISTDA
Thailand	Dr. Chaowalit Silapathong	Chief Data Standardization section, GISTDA
Thailand	Ms.Kandasri Limpakom	Computer Scientist, GISTDA
Thailand	Mr.Thaweesil Ukhahapanyakul	Computer Scientist, GISTDA

Additional Thai participants from:

- GISTDA's Regional Centers,
- Royal Thai Survey Department (RTSD),
- Department of Public Works and Town and Country Planning,
- Ministry of Agriculture and Cooperatives, and
- Ministry of Natural Resources and Environment

AGENDA

Wednesday, July 9, 2003 (9:00 – 17:00)

- Introductions
- General overview of GISTDA on-line data and data information system Satellite Data CBS and WMS
- General overview of CGCEO on-line data and data information system (Dave Skole)
- Technical overview of GISTDA on-line data and data information system
- Technical overview of on-line data and data information system (Jay Samek)
- Open discussion (question and answer) on web-based GIS, database management and integration, etc.

Thursday. July 10, 2003 (9:00 – 17:00)

- Technical specifications of CGCEO on-line data and data information system (Jay Samek, Oscar Castaneda, and Chris Barber)
- Software and hardware requirements for on-line data and data information system

Friday July 11, 2003 (9:00 – 17:00)

- Administrative discussions to formalize specific system-sharing agreements
- Near-term plans

Workshop: Geo-Spatial Information and Sustainable Natural Source Management in the 21st Century

Nong Lam University
Ho Chi Minh City, Vietnam
August 16, 2004

AGENDA

0845 – 0930	Registration
0930 – 0945	Opening remarks, **Dr. Bui Cach Tuyen**, Rector of Nong Lam University, HCMC.
0945 – 1010	Keynote Address, **Dr. David Skole**, Director, Center for Global Change & Earth Observations, Michigan State University, USA (CGCEO-MSU, USA)
1010 – 1030	Coffee/tea break
1030 – 1200	Presentations (20 minutes each) • **Jay Samek** (CGCEO-MSU, USA), "CGCEO-MSU Projects in Southeast Asia" • **Dr. Do Xuan Lan** (FIPI, MARD, Hanoi), "Application of RS And GIS for Land Use/Land Cover Change Study in Vietnam" • **Nguyen van Nhan** (IRMC), Spatial analysis for assessment of soil fertility: a case study in paddy growing areas of tien giang province, the mekong delta **(Vietnam)** • **Hoang Huu Cai,** Nong Lam University, "Overview of Application of GIS and Remote Sensing in Natural Resource Management Reseaches at Nong Lam University" (20 minutes)
1200 – 1330	Lunch at Tuyet Restaurant
1330 – 1530	Presentations , 20 minutes for each • **Jay Samek**, "Data systems and services, Web-GIS, & advanced techniques in RS" • **Ngo An** (Sub-FIPI, MARD), Ho Chi Minh City), "GIS and natural resources management towards sustainable development" • **Nguyen Thanh Hung**, (SIG) Ho Chi Minh City), Land cover changes between 1968 and 2003 in Cai nuoc, Ca mau peninsula, Vietnam • **Nguyen Kim Loi**, Nong Lam University (NLU), "Decision support System for Sustainable Watershed Management in Dong Nai Watershed: Conceptual Framework and Proposed Research Technique" • **Vo Van Viet**, Nong Lam University**:** "Using GIS for agricultural land suitability evaluation a case study at dong thap province.
1530 – 1600	Coffee/tea break
1600 – 1630	Open discussion/questions/comments
1630 – 1700	Closing remarks • **Dr. David Skole** • **Hoang Huu Cai**

Workshop on Remote Sensing, GIS and Forest Resource Management in the Lower Mekong River Basin

Mekong River Commission Secretariat
Vientiane, Lao PDR
July 5 – 6, 2005

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AGENDA

Tuesday, July 5, 2005

0900 – 0920 Opening Remarks (Mr Christoph Feldkotter) + Problem Statement (Dr David Skole)
0920 – 0940 Workshop Objectives (Dr Jay Samek)
0940 – 1010 MRCS Role in Bridging Science and Policy Making (Dr Kim Geheb)
1010 – 1030 Coffee / Tea Break
1030 – 1100 Overview of Data Exchange and Sharing at MRCS (Mr Ulf Hedlund)
1100 – 1130 Wetland Inventory and Valuation Programme: Wetland Mapping (Mr Meng Monirak)
1130 – 1200 Remote Sensing Activities at MRCS (Ms. Manithaphone Mahaxay)
1200 – 1330 Lunch
1330 – 1500 Review: Forest Cover Definitions + Mapping Approaches used in the Lower Mekong Basin Countries
Lao PDR: Mr Thatheva Saphangthong, Information Center, Department of Planning, Ministry of Agriculture and Forestry
Thailand: Mr Suchin Khantisomboon, Department of National Park Wildlife and Plant Conservation, Ministry of Natural Resources and Environment
Cambodia: Mr Teang Sokhom, Dept. of Forestry and Wildlife, Forestry Administration
1500 – 1530 Coffee / Tea Break
1530 – 1600 [contd] Review: Forest Cover Definitions + Mapping Approaches used in the Lower Mekong Basin Countries Vietnam: Dr Do Xuan Lan, Forest Res. and Env. Ctr., Forest Inventory and Planning Institute
1600 – 1630 Discussion: Comparison of Forest Cover Definitions + Mapping Approaches used in the Lower Mekong Basin Countries
1630 – 1645 Day 1 wrap-up, review for day two, announcements

Wednesday, July 6, 2005

0900 – 0915 Day 2 Objectives: Data Needs and Definitions for Forest Resource Management in the LMB (Dr Jay Samek)
0915 – 0950 Data Quality and Accuracy: Issues and Requirements (Mr Christoph Feldkoetter)
0950 – 1030 Emerging Trends in RS – The Fractional Cover Approach (Dr David Skole)
1030 – 1050 Coffee / Tea Break
1050 – 1200 Open Forum: Definition of Forest + Classification of Forest Cover with RS Data [Goal: An agreed-upon Working Definition of Forest]
1200 – 1330 Lunch
1330 – 1415 [contd] Open Forum: Definition of Forest + Classification of Forest Cover with RS Data
1415 – 1515 Open Forum: Analysis Protocol and Process for Remote Sensing Based Forest Cover Mapping [Goal: Case Study Projects, Time-Line, Tasks, Data Requirements identified]
1515 – 1545 Coffee / Tea Break
1545 – 1600 Conclusion + Actions (Dr Jay Samek)
1600 – 1630 Closing Remarks (Dr David Skole & Mr Christoph Feldkoetter)

Funding sources outside the APN

Work related to this project was also sponsored by:
NASA (TRFIC 2) REASON CA (PI Dr. David Skole)

In kind contribution from:

- National University of Laos, Faculty of Forestry
- Vietnam Forest Inventory and Planning Institute
- Philippine National Mapping and Resource Information Authority
- Cambodian Ministry of Environment
- Earth Observation Centre at the Universiti Kebangsaan Malaysia
- Perguruan Profesional dalam Teknologi Maklumat dan Komunikasi (BPPT) Indonesia
- Chiang Mai University, Thailand
- Mahidol University, Thailand
- Royal Thai Forestry Department
- Philippine Atmospheric, Geophysical & Astronomical Services Administration

- Nanjing University, China
- Mekong River Commission Secretariat

Glossary of Terms

DN	digital number of spectral data from remotely sensed imager
EOS-HDF	Earth Observing System - Hierarchical Data Format
ETM+	Enhanced Thematic Mapper Plus
fc	Fractional cover (continuous fields of vegetation)
FTP	File transfer protocol
GIS	Geographic Information Systems
LUCC	Land use and land cover change
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MSAVI	Modified Soil-Adjusted Vegetation Index
NAMRIA	Philippine National Mapping and Resource Information Authority
NDVI	Normalized Differential Vegetation Index
PAGASA	Philippine Atmospheric, Geophysical & Astronomical Services Administration
SEARRIN	Southeast Asian Regional Research and Information Network
URL	Uniform Resource Locator (Internet, World Wide Web address)
VNIR	Visible and near infrared wavelength