LAND COVER ASSESSMENT AND MONITORING AT UNEP/EAP-AP: A RS AND GIS APPROACH[1]

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Abstract

The paper presents a synopsis of Land Cover Assessment and Monitoring Project of UNEP Environment Assessment Programme for the Asia and Pacific. The project, covers eleven countries in the region and is expanding every year, utilizes remote sensing and GIS techniques to assess and monitor land cover status of each country on a regular basis.

The broad goal of the project is to assess the present status of major land cover types of target countries using NOAA AVHRR 1 Km resolution satellite data incorporating secondary information within GIS environment. The principal purpose is to assess and monitor the land cover status of these countries in a near real time basis. It also aims to develop a methodology, strengthen the capacity of the government, train the personnel and ultimately hand over the technique to the respective countries. In the long run, it is expected that the target countries will do the similar exercise as a part of their regular land cover assessment and monitoring exercise. The role of UNEP/EAP-AP will then be to compile the data for macro analysis and reporting at the regional scale, provide technical and financial assistance and information transmission from national to regional to global and vice versa.

Another aspect of the study is to identify "hot spot" (i.e. areas undergoing major land cover transformations) areas and investigate in detail, using high resolution satellite data supplemented by field data collection.

[1] Paper presented at the " International Symposium on Vegetation Monitoring" 29-31 August, 1995, Tokyo, Japan.

Introduction

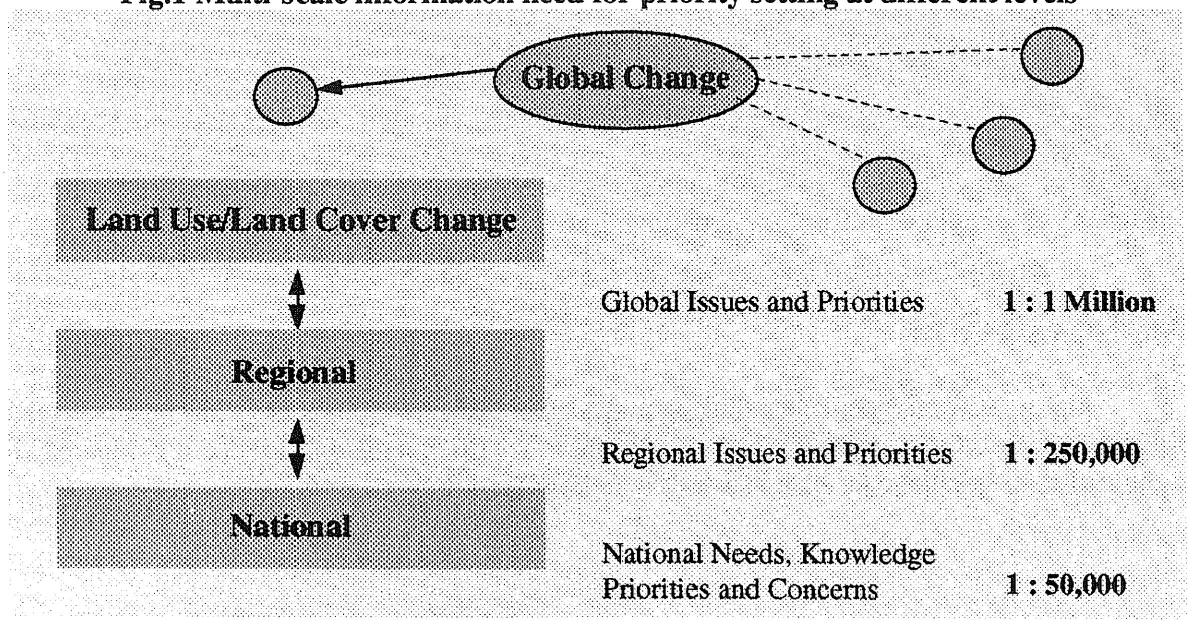
In reflection of change in kind, quantity and quality of information needed for decision makers and policy planners, UNEP through its new Environment Assessment Programme which includes GEMS (Global Environment Monitoring System), GRID (Global Resources Information Database), SoE (the State of the Environment unit) and UN system-wide Earth-Watch Coordination, focuses more on the need and capabilities of its users. As envisaged in Agenda 21 of UNCED for the need of enhanced accessibility of integrated environment and development information and enhanced national capacity to deal with such information in decision making and policy setting, UNEP has focused its attention to provide the world community with improved access to meaningful environmental data and information, and to help increase the capacity of governments to use environmental information for decision making and action planning for sustainable human development. The programme has four programme components namely assessment an reporting, data and information management, capacity building and servicing and UN system-wide Earthwatch coordination.

In line with above goals, UNEP Environment Assessment Programme for Asia and Pacific (UNEP EAP-AP), has been involving in various undertakings including the Land Cover Assessment and Monitoring of selected countries in the region.

The Project and its Rationale

Human induced land cover change occurring at an unprecedented rate and scale particularly that of forest cover change is one of the major environmental concern in the region. Such changes contribute towards the change in climate and conversely the ecosystem is subjected to the changing environmental conditions. An accurate and up-to-date information base on the status and change pattern of land cover dynamics at multi-level (national, regional and global) is pre-requisite for the sustainable management of natural resources as policy decisions are made at different levels and issues and priorities vary accordingly (Fig. 1).

Fig.1 Multi-scale information need for priority setting at different levels



Information pertaining to the present status of land cover, their change patterns and identification of driving forces for the change are lacking in many Asian and Pacific countries. The underlying reasons are multifarious and are country specific. Existing land cover data, if any, tend to be sectorial in nature and vary in primary data sources, their classification systems and data formats and are often static and non-spatial. A consolidated and harmonized effort to come up with the information utilizing the latest techniques of RS and GIS was lacking. Additionally, an interest and need for the better and timely information as an input to the decision making processes is ever increasing.

Objectives/Scope

The objectives of the project includes:

1. Regular assessment and monitoring of major land cover types in the region using Remote Sensing and GIS technology.

2. Through regular monitoring, identify "hot spot" areas (areas undergoing major land cover transformations) for detailed investigation using high resolution satellite data supplemented by field verification. The information can act as an "early warning system" to prioritize and direct the scarce resources for action plan.

3. Develop methodological guidelines and the capacity of participating countries with tools such as image processing and GIS transfer technology to the countries to make them self reliant on their regular assessment and monitoring exercise.

4. Ultimate roles of the EAP-AP are to compile and analyze time series land cover data at the regional scale.

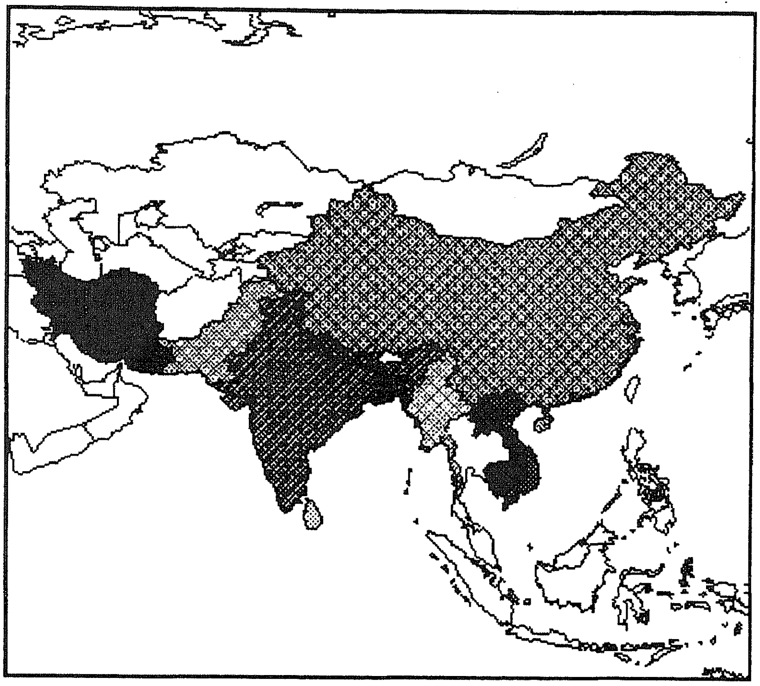
The project currently covers eleven countries viz. Pakistan, India, Iran, Sri Lanka, Nepal, China, Bangladesh, Burma, Laos, Cambodia and Vietnam. The following map shows the coverage of present project areas (Fig. 1).

The analysis of the data for Pakistan and Sri Lanka is on-going. In case of China, India and Iran, experts' from these countries will be invited to the EAP-AP and all the procedures will be discussed and exercised. On their return, they are expected to do the same exercises targeted for 1996. The present paper summarizes the experience gained from work in the six countries viz. Bangladesh, Burma, Cambodia, Lao P.D.R., Nepal and Vietnam.

Why NOAA AVHRR ?

Among several types of satellite data available, NOAA AVHRR data has been selected primarily because of its high temporal resolution, low data volume and low cost compared to high resolution satellite data such as Landsat and SPOT.

Fig. 2 Location Map Showing Coverage of the Project
(shaded countries corresponds to Project Area)



Persistent cloud cover throughout the year is a major hindrance for operational land cover monitoring over the tropics. Due to the high temporal resolution of AVHRR data, the probability of acquiring cloud free image increases. The advent of RADAR technology in remote sensing has put forward some high expectations due to their own source of energy for sensing and all weather capability, however, such technology needs further improvement for operational use. Considering these facts, it seems that AVHRR will remain the only viable source of information for land cover monitoring over a large area, at least for the next few years. The following table highlights the advantages and disadvantages of NOAA AVHRR data.

Table 1.0 Advantages and Disadvantages of NOAA AVHRR HRPT Data

Advantages	Disadvantages
1. Synoptic coverage and hence low data volume	1. Coarse resolution (1.1 km at the Nadir)
2. High radiometric resolution (10 bit)	2. Pre-processing is time consuming
3. Relatively low cost (Free!, only handling cost)	3. The methodology is not well developed
4. Twice daily coverage and hence high possibilities of having cloud free data.	4. LAC data has limited capability to record on-board

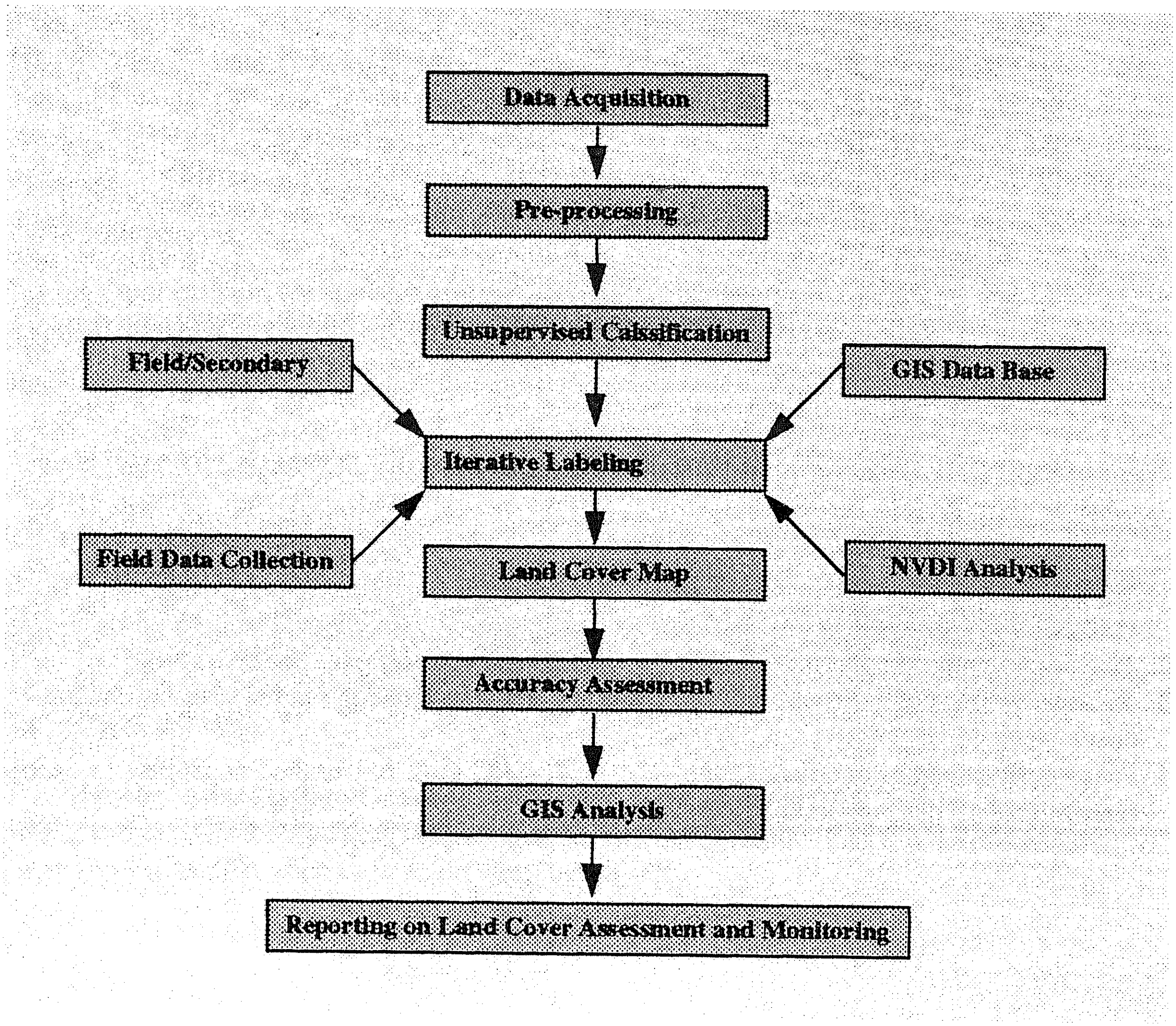
Methodology

Data Acquisition

A number of AVHRR HRPT and LAC data were acquired from different sources including NOAA NESDIS (USA), EROS Data Center (USA), NRCT (Thailand) and SMA/SMC (China). In general at least four scenes for the harvest season and four for the summer season were acquired for each country covering two time frames 1985-1986 and 1992-1993. Afternoon pass of NOAA-9 for 1985-1986 and NOAA-11 for 1992-1993 were selected for the study.

Phenological characteristics of the vegetation and hence the seasonality were given due consideration in procuring the AVHRR data. Basically data representing two seasons viz. harvest season and summer season were selected for each country. Acquiring summer season data has its clear advantage that it facilitates discriminating deciduous and evergreen forests. The selection of these data sets that exhibit complementary information was found to be informative in distinguishing different forest types and also in distinguishing forest from agricultural lands.

Fig. 2 An Overview of Methodology Used



NOAA AVHRR HRPT data were analyzed using PC ERDAS and IDRISI image processing softwares. Further analysis were performed in GIS (ARC/INFO software) environs. In-house software has been written for the down loading, band selection, calibration, geometric correction and cloud masking of AVHRR data as pre-processing steps. Fig. 2 shows the flowchart of the methodology adopted.

Pre-processing

AVHRR data pre-processing mainly consisted of: data extraction and noise removal, radiometric calibration, geometric correction, and cloud masking procedures.

The HRPT Level-1B received in packed format were converted from BIL to BSQ format using appropriate programs. The original radiometric resolution of 10 bit pixel values was maintained by using two bytes for each pixel for all 5 channels. The bad/noisy lines were than identified by visual inspection of each channel of an image. All such bad/noisy lines were marked as being areas of "no data" by assigning zero values.

Radiometric calibration were performed based on the procedures outlined by European Space Agency (ESA) Handbook on "SHARP LEVEL-2 : Development Procedures and Format Specifications" and by NOAA Technical Memorandum NESS 107 on "Data Extraction and Calibration of TIROS-N/NOAA Radiometers".

Due to the lack of readily available atmospheric data in South and South East Asia atmospheric correction was not performed. Besides, although several possible approaches for the correction of water vapor absorption and aerosol scattering exist, there is presently no agreement on an acceptable method for atmospheric corrections. Some methods need further validation and are far from straight forward (IGBP, 1992).

The bi-directional reflectance effect caused by the viewing geometry and surface angular anisotropy also affects the AVHRR channels 1 and 2 (Gutman 1990). The bi-directional effect depends upon the vegetation type and could differ from one type to another. In order to correct the effect of viewing direction, angular corrections should be developed for different vegetation types and different seasons. However, images taken at large view angles (off-nadir views) which fall at the extreme of the scan line was excluded and thus, such effects, due to atmospheric scattering and absorption, and viewing geometry, are partly reduced.

A two step procedure has been used for the geometric correction of AVHRR images. The images were first resampled to a reference map projection based on location data generated by orbital model navigation and then further corrected by a linear first order rectification based on ground control points.

Interactive visual cloud masking procedure was used to identify the threshold value for clouds. Use of such an interactive cloud screening procedure proved to be highly effective in removing the clouds without losing useful data.

Finally, country masks was generated by rasterizing the vector boundaries of the study area obtained form the World Data Bank II.

Classification

Unsupervised classification was performed followed by interacting labeling. Secondary information were fully utilized during the analysis. Field trips were organized to collect secondary data and for results validation.

Results and Discussions

Land Cover Assessment

The utility of AVHRR HRPT data for discriminating and delineating of major land cover types proved to be promising. Land cover maps of 1992/93 and 1985/86 were produced for each countries accompanied with country report, the later is in the process of publication. Major land cover types discerned were forest, crop land, grass land, marshes, barren land, shrub land, savannas, rock, snow and waterbodies. Forest have been further subdivided into evergreen, deciduous and mangrove forest. Country specific variations in selecting the classes and details were noted to be of practical use. For example, Boro rice in Bangladesh has been classified as a separate class.

The following observations were noted regarding the Land Cover classification systems.

1. The contrast between forest and non-forest areas was distinct in the images acquired during the harvest season. In this season much of the agricultural crops, predominantly rice in this region, is being harvested. However, there is problem of discriminating evergreen and deciduous forest at this time. To avoid this problem, images taken during the summer season were utilized to discriminate evergreen and deciduous forest. By combining these results, improvements in the results were accomplished. This clearly demonstrates the usefulness of multi-temporal satellite data.

   It is to be noted here that the harvest season and summer season varies slightly among these countries. For example, harvest season for rice extends up to December in the case of Vietnam and up to March in the case of Bangladesh. Therefore, season selection should be considered carefully. This variation in season causes variation in the Phenological characteristics of the vegetation and in the cropping system.

2. Mangrove forest in the Sundar Ban possesses a very distinct signature to be classified as a separate class. Smaller patches of mangrove forests in Burma and Vietnam were also detected. Swamp forest on the other hand possesses a unique identity and has been classified as separate class. Due to the difference in Phenological characteristics of the vegetation and their corresponding unique signature, several forest types were discriminated with a reasonable accuracy.

3. It is very difficult to distinguish forest and some other vegetation types such as tea gardens in Bangladesh spectrally without the help of secondary information. With the help of ancillary information and GIS as a tool, it is possible to classify it as a separate class. Plantations areas less than the resolution of AVHRR data were not able to discriminated in the present study neither the Beach forests occurring in a narrow strips along the coastlines.

4. Shifting cultivation, conversion of forest to agricultural land, forest fire and indiscriminate felling are found to be the main reasons for the deforestation in these countries. Population pressures and the change in consumption patterns were identified as two detrimental factors contributing to deforestation. Shifting cultivation is no longer sustainable practice. Examples of unsustainable types of shifting cultivation can be found in northern Laos and in the Chittagong hill tracts of Bangladesh.

5. A clear demarcation of national boundary between Bangladesh and India and Thailand and Laos/Cambodia was visualized due to the devoid of vegetation in Bangladesh and Thailand side.

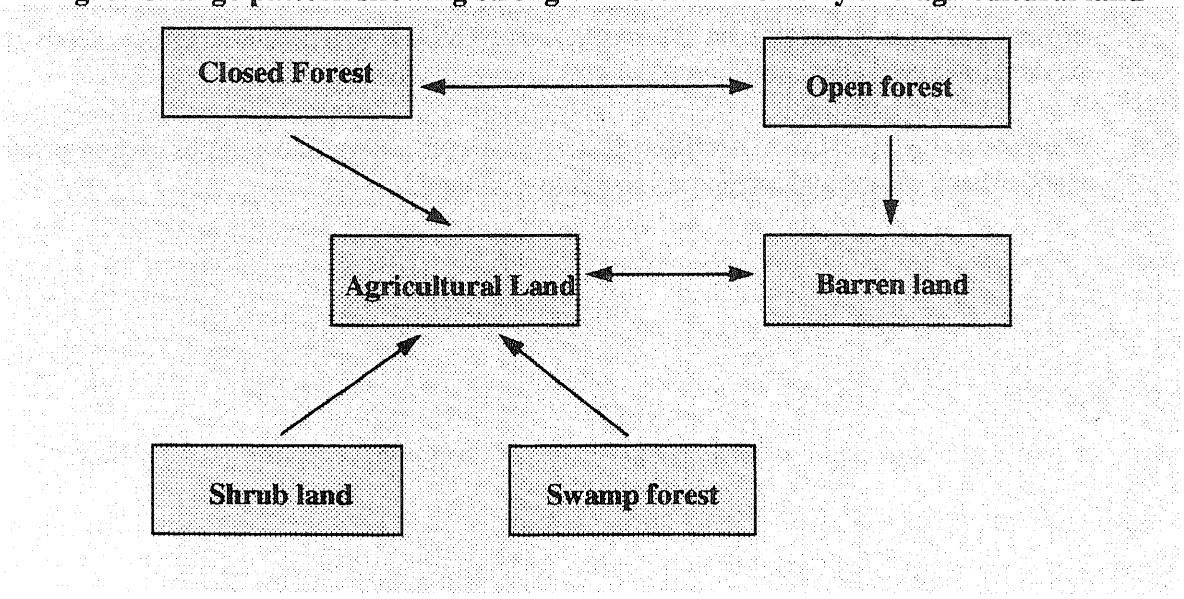
6. Mosaic of forest and shifting cultivated areas in Northern Laos were invisible in the AVHRR data because of its low resolution. Similar problem was encountered in discriminating small patches of forest areas in Vietnam.

Change Detection

Change in land cover has been attributed by various reasons and those reasons are site specific. Shifting cultivation has been identified as a major cause of forest destruction which is prominent in case of Laos and in the Chittagong hill tracts of Bangladesh. Conversion of forest to agricultural land was noticed in many countries including the Terai region of Nepal and southern part of Burma. Conversion of swamp forest to other land use were noticed in the Mekong Delta in Vietnam.

The pattern of conversion varies from place to place. The following diagram shows the conversion pattern and its strong linkages between forestry and agricultural land. Although there is a reciprocal relationship of change between closed forest and open forest, the change from closed forest to open forest is much, much higher than the change from open forest to closed forest. Similar explanations hold true for other classes.

Fig. 3. Change pattern showing strong link between forestry and agricultural land



Hot Spot Areas Investigation

Once the areas where there is major land cover transformation occurring called "hot spots" are identified, the next step is to investigate the area in detail using high resolution satellite data. The primary data source for hot spot area detection is the high resolution satellite data such as SPOT, Landsat and ERS-1. Three "hot spot" areas has been identified and is being analyzed in Northern Laos, Mekong Delta and in Chittagong Hill Tract of Bangladesh.

Conclusions and Recommendations

The experience gained so far illustrates both the potential and limitations of AVHRR HRPT data for national/regional tropical forest assessment and monitoring endeavors within the framework of land cover assessment and monitoring project of UNEP environment assessment programme for the Asia and Pacific. From the study following conclusions and recommendations could me made.

1. This exercise demonstrated that the NOAA AVHRR is a major source of information for land cover assessment and monitoring at the macro scale. "Hot Spot" areas could be identified for further investigation with high resolution data and field verification;

2. The availability and reliability of ancillary data for the analysis of AVHRR data are of utmost importance in order to come up with better classification results. Analysis of the data by the local experts definitely improves the precision and quality;

3. A number of data sources for acquiring and distributing AVHRR data both within and outside the region were identified but a systematic data archiving is lacking;

4. The acquisition of data should be done carefully considering the phonology and structure of the forest vegetation, seasonality and agricultural practices in particular;

5. Various land cover classification systems exists, a consolidated and harmonized land cover classification system for the purpose of NOAA AVHRR classification needs to be developed with the coordination of concerning agencies;

6. Pre-processing of NOAA AVHRR data is time consuming and tedious. Appropriate standardized means and techniques needs to developed.

Acknowledgments

A number of individuals in various organizations including Mekong Secretariat, ICIMOD, GTZ and IUCN contributed towards the realization of the project. A number of government agencies in various countries including, the Land Use Mapping Office in Cambodia, Forest Inventory and Planning office in Laos, Survey Department and Forest Department in Nepal, Institute of Forest Inventory and Planning in Vietnam, Forest Department in Burma and Local Government Engineering Department, SPARSSO, and Forest Department in Bangladesh extended their profound cooperation and help to the project. **Our sincere thanks to all.**

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