MAPPING WETLANDS AND FLOODS IN THE TONLE SAP BASIN CAMBODIA USING AIRSAR DATA

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ABSTRACT

In order to ensure a balance between economic development and a healthy Mekong Basin environment supporting natural resources diversity and productivity critical to the livelihood of its 65 million inhabitants, the Mekong River Commission (MRC) has been investigating the use of radar to remotely characterize and monitor the diversity, complexity, size and connectivity of the Basin's aquatic habitats. The PACRIM AIRSAR Mission provided an opportunity to evaluate the usefulness of radar technology to derive information for assessing, forecasting and mitigating possible cumulative and long-term impacts of development on the natural environment and the people's livelihood.

INTRODUCTION

The Tonle Sap-Great Lake (TSGL) located in western Cambodia supports one of the most productive and biodiverse freshwater ecosystems in the world. The flow into the TSGL from the Mekong River system during the wet season (July-October) expands its surface area from 250,000 ha to 1.25M ha inundating large areas of forest and woodlands. These wetlands it turn provide a unique freshwater fish habitat with an annual catch representing 75% of Cambodia's inland fish production and generating an estimated US$70M in income.

With the reversal of water flow back into the Mekong system from November on into the dry season, large areas of flooded land on the lakes edge are successively exposed and used for agriculture. In this fertile zone of migrating waters about 48,000ha are planted with 'receding rice' and another 24,000ha with other field crops. UNDP estimates a farm gate value of this agricultural production of US$75M.

The reversal of flow from the Mekong and Bassac rivers into the TSGL results from the failure of the distributaries in the lower Mekong downstream from Phnom Penh to cope with the wet season flood discharge flowing into the Gulf of Thailand. Water backs up and gradually floods into the TSGL. In the dry season the water draining back into the Mekong increases downstream flow by an estimated 16% providing much needed water for irrigation in southern Cambodia and Vietnam and reducing the risk of salinity intrusion upstream from the tidal regions. What makes this unique hydrological cycle possible is the low relief and flat elevations throughout central Cambodia.

The highest recorded flood level in the TSGL area is just below 10 m above mean sea level. The depth of water in the TSGL varies from 1-2 m in the dry season to 7-8 m in the wet season. At high water levels, the TSGL accounts for 7% of the surface area of Cambodia.

ENVIRONMENTAL DEVELOPMENT

Land use as well as environmental planning and natural resource zoning in the TSGL area are intimately linked to the flooding patterns imposed on the lake by the Mekong discharge which governs not only the water levels but also the availability of water at any time. Developments occurring within the larger Mekong region (Figure 1) are therefore critical to the future sustainability of livelihood patterns currently found within the downstream countries of Cambodia and Vietnam.

The Mekong River Commission (MRC) was established in 1995 to 'promote and co-ordinate sustainable management and development of water and related resources for the mutual benefit of the countries and the well being of people by implementing strategic programmes and activities and by providing scientific information and policy advice.' The MRC countries are Cambodia, the LAO People's Democratic Republic, Thailand and Vietnam. The People's Republic of China and Myanmar are dialogue partners as they share headwater tributary areas of the upper Mekong. Clearly the greatest threat to the present hydrology of the TSGL is the building of dams and water diversion schemes in the upper Mekong Basin.

Within the TSGL region there are significant pressures being placed on the natural environment that result from its high economic value which unless unchecked will lead to serious

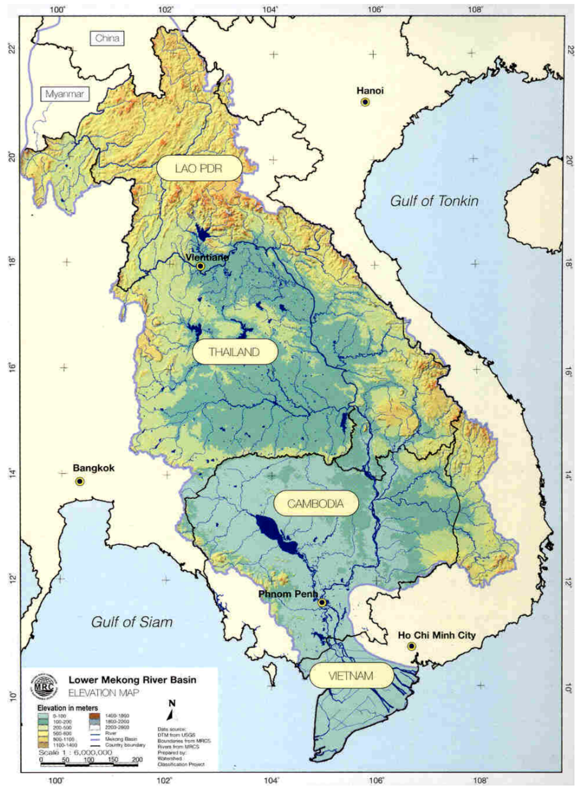

Figure 1: Mekong River System

environmental degradation and which together threaten the natural productivity and sustainability of this wetland ecosystem. These pressures include:

- Increased population
- Overfishing and loss of species
- Wetland forest decline as a result of clearing, firewood harvesting and charcoal production.
- Invasion of exotic species including water hyacinth, mimosa and the golden apple snail.
- Water pollution from silt and agrochemical runoff.
- Reduced bird, reptile and mammal population though hunting.
- Eco-tourism.

These environmental pressures are exacerbated by political and socio-economic problems arising out of Cambodia's recent history. Foremost amongst these are:

- Severe poverty;
- Young age population;
- Inequality of access rights;
- Insufficient rights of land tenure;
- Cultural and ethnic divisions; and
- Badly weakened civil society.

The Government of Cambodia, the MRC and other agencies are currently working towards the preparation of policies and the implementation and strategies that seek to promote sustainability and minimize the negative impacts of economic development on the natural environment of the TSGL.

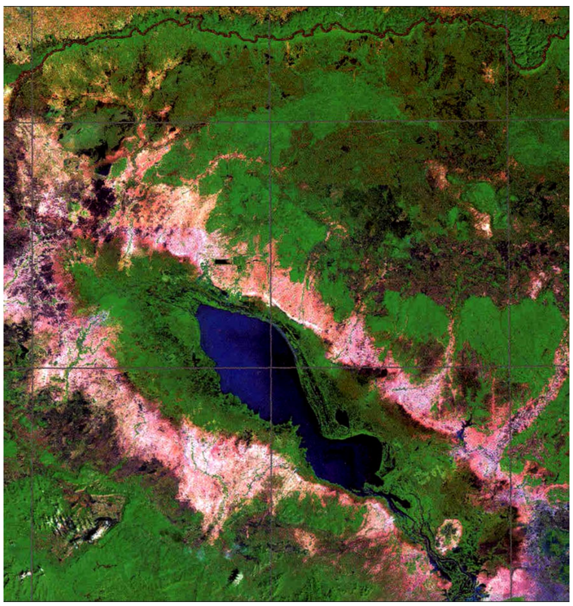

Figure 2: SPOT 'true colour' image of the Tonle Sap-Great Lake (courtesy SPOT ASIA).

SCIENCE OBJECTIVES

AIRSAR data was collected over the Tonle Sap and Angkor regions of Cambodia during the NASA PACRIM2 Mission in September 2000 on behalf of the MRC and Sydney University. Collaboration between the MRC, Sydney University, UNSW and the CSIRO have continued in order to investigate the application of polarimetric and topographic radar datasets to issues of wetland and hydrographic analysis and to the study of anthropogenic impacts on the interpretation of historic landscapes (see Fletcher, Evans and Tapley, these proceedings).

As wetlands are often remote, difficult to access and temporally dynamic, the use of remotely sensed data provides the only realistic means of acquiring information on a regular and systematic basis. In this project, AIRSAR imagery is being used to produce a baseline dataset showing the extent of flooding in the northwestern section of the TSGL in September 2000 against which subsequent seasonal changes in the extent and duration of flooding can be assessed using other radar and optical datasets acquired from spaceborne systems. In addition, the multi-parameter capabilities of AIRSAR are being used to map the extent, structure and composition of the various wetland communities present at the time of data capture in September 2000.

The major aim is to combine and integrate radar and optical datasets in order to map the extent of inundation that occurred in September 2000, which was the highest flood in recent times; to analyze the pattern of floodwater recession and to characterize the wetland habitats present in the region. More specific objectives can be stated as follows:

1. Map the extent of inundation in the northwestern section of the TSGL during a period of maximum flooding (September 2000);
2. Map the location, distribution, type and status of wetland habitats in the region
3. Provide a baseline inventory of wetland environments from which to map the pattern of flood recession using operational radar datasets including multi-temporal RADARSAT made available by MRC.

4. Identify and map the distribution of permanent wetland areas on the margins of the TSGL;
5. Register AIRSAR and dry season ASTER optical imagery to determine total areal extent subject to seasonal flooding;
6. Identify settlements and areas of agricultural change associated with the pattern of floodwater recession within the aquatic zone; and
7. Provide information on the nature of the changes taking place within the aquatic zone for use in resource management, planning and policy determinations.

STUDY AREA

The study region is defined by the area covered by the AIRSAR flightlines Angkor 20-1, Angkor 20-2 and Angkor 20-3 at the northwestern end of the TSGL. In all 8 flight lines of data each 110 km long were collected. All flight lines were in XTIIP mode at 40 MHz resulting in C-band DEM, Cvv-data and L-band and P-band polarimetry being available. Two additional projects are planned to make use of this data for environmental applications, namely, the construction of DEM's for catchment and hydrological modeling and the construction of a land use and land cover map for the entire region. In this investigation into the status and condition of aquatic environments additional AIRSAR data adjacent to and east of the study area could be processed to extend the study area. This will depend on satisfactory results accruing from this investigation.

WORK TO DATE

The processed data from JPL was received in November-December 2001. Pre-processing and registration were completed and a series of 1:50,000 scale image maps using different polarization combinations were generated over the study area for use in the field.

Fieldwork was undertaken in the TSGL and Angkor area during January 2002 for ground data collection and for verifying the integrity of the data in respect to the range of aquatic habitats present and for generating a preliminary set of land cover classes for both the wetland and terrestrial environments. A helicopter conducted transect over the flooded wetlands was employed to validate 31 test sites. This information is currently being used to establish a set of suitable land cover classes.

In-house software developed at UNSW by Dong et.al. (2000) and Horn et al. (2002) is being used to classify trial areas in the wetlands. This segmentation software based on a modified Gaussian Markov Random Field Model generates output including the mean and standard deviation statistics of the original data and a vector file of the edge locations of segments. The use of statistical information instead of arbitrary segment number means that standard classification routines can be successfully used on radar imagery.

Ancillary datasets available to the project include RADARSAT, JERS-1 and ASTER optical data and have yet to be analyzed to determine flood recession patterns.

DISCUSSION

Preliminary analysis shows that it is possible to accurately map the limit of the extent of the flooding that occurred in late September in the TSGL area. With appropriate ground information a number of well-defined wetland cover classes can be identified on the imagery. These include, open water, macrophytes, floating grasses, scrubland, forest trees, mangroves and open water surfaces. These cover classes can also be replicated and their distribution mapped using the UNSW segmentation software. Further work is needed to resolve problems associated with incidence angle effects, data drop out and artifacts associated with open water surfaces before the image swaths are mosaicked and the entire scene classified.

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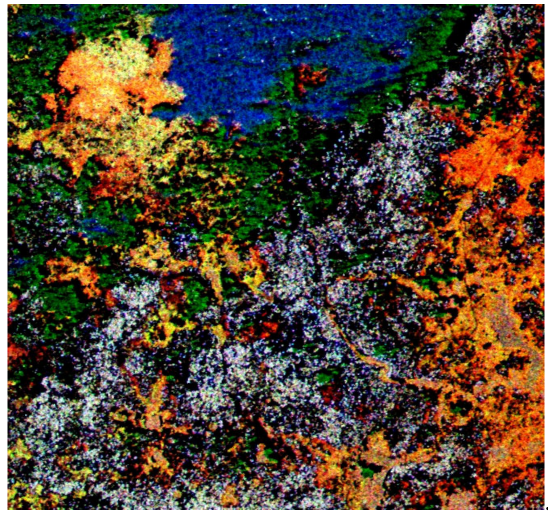

Figure 3: Image subset of Cvv, Lvv and Pvv AIRSAR data. Yellow-orange shows macrophytes and floating grasses, green shows brushland and scrub, white shows forest trees and blue shows open water.

Figure 4: Macrophytes, floating grass and scrubland

Figure 5: Flooded forest and woodlands