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REMOTE SENSING AND ENVIRONMENTAL EVALUATION IN THE MEKONG BASIN

Avijit GUPTA
School of Geography, University of Leeds
Leeds LS2 9JT, UK
E-mail: avijit@foxhill.demon.co.uk
and
CHEN Ping
Centre for Remote Imaging, Sensing and Processing
National University of Singapore, SINGAPORE 119260
E-mail: crschenp@nus.edu.sg

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ABSTRACT: We demonstrate the importance of remote sensing in geomorphology and environmental application, using only visual evaluation and some data-processing techniques. As a part of an ongoing project, 14 000 km^2 of the middle Mekong Basin in Lao PDR and Thailand is being studied. This is an area of several parallel steep-sided ridges and valleys. The river varies between narrow steep rock-cut reaches and wider sections where sandbars and floodplain alluvium mask the bedrock in the channel. The rainfall is mostly between 2000–4000 mm a year and seasonal. The population is thin and the land is in either agriculture (mostly shifting) or forest (partly degraded). Data collection and developmental planning are carried out currently by the Mekong River Commission, an intergovernmental body associated with the riparian states and donor countries.

We show that researchers generally familiar with the area can (1) determine the form and behaviour of the river and (2) evaluate the environmental impact of future development projects by visually interpreting 20-m resolution SPOT images and using simple software. Our findings checked in the field were reasonably accurate. We also show both time-based changes and seasonal alteration of erosion processes and sediment transfer by superimposition of scenes of the same areas. Given the repeated imaging of parts of the world, an enormous amount of data therefore lie available in various archives for environmental applications. This type of approach is a very useful tool for environmental evaluation at the prefeasibility stage of a project.

1. INTRODUCTION

We submit that the application of remote sensing is not as widespread as it should be among the geomorphologists and environmental managers. This could be partly due to the impression that one needs to use sophisticated and specialised techniques for any meaningful analysis. In this paper we demonstrate that visual interpretation of satellite scenes and application of spatial data processing techniques could release very useful information. Such information is valuable both for understanding the physical environment and for environmental impact analysis. As scenes of the same area have been archived over a number of years, it is now also possible to trace physical changes over time and extrapolate the trend to the future.

At the Centre for Remote Imaging, Sensing and Processing, National University of Singapore, we have been studying the 20-m SPOT scenes of the Mekong Basin for a number of years. Most of the study has focused on 14 000 km^2 of the middle Mekong Basin in Lao PDR. We use selected extracts from the ongoing study to illustrate the application of remote sensing in geomorphology and environmental analysis using very simple techniques. The choice of the study area is governed by several factors.

- The Mekong is one of the largest rivers of the world and the chosen area is difficult of access and of limited data availability.
- Several development projects have been proposed for this area.
- The chosen area is too large for quick field reconnaissance but at 20-m resolution can be well studied from satellite images.
- Enough scenes have been archived for (1) a longitudinal study of the area over time and (2) monitor seasonal changes through a calendar year.

We intend to extend the study to as much of the basin as feasible. Two of the earlier papers from this project have already been published and one is currently in press (Gupta 1998; Chen et al, 2000; Gupta et al., in press).

2. THE STUDY AREA

The Mekong flows in a pan-shaped basin that drains into the South China Sea. Its basin stretches across six countries: China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. It is the 8th and 10th largest river in the world for mean discharge and average suspended sediment load respectively (Meade, 1996). We discuss 13 969 km^2 of the middle Mekong Basin in Lao PDR in this paper (Fig. 1). This is an area of steep-sided flat-topped ridges and valleys with the Mekong and several ridges running parallel in the NNE-SSW direction. The rock types are Palaeozoic folded sedimentary and metamorphic rocks (sandstone, shale, schist, chert, limestone and local volcanic exposures) and Mesozoic sedimentary rocks (sandstone, limestone, evaporites). Extrusive rocks associated with an ancient suture zone also locally occur in the area. The structural trend is NNE, a direction also followed by a set of faults, and in general by the river and the ridges, although the Mekong at times has changed course abruptly to flow across the structural trend. The ridge tops rise to over 1000 m and the steep slopes of the area are illustrated by the Mekong flowing at an elevation below 250 m only 5 km away.

Figure 1. Land clearance for agriculture next to the Mekong River. Note steep slopes, natural dense vegetation, and a tributary channel draining to the Mekong through the cleared fields.

Annual rainfall is heavy over most of the basin, 2000-4000 mm. The rain is strongly seasonal with 85-90% arriving in the southwest monsoon between May and October. The seasonality is accentuated by the arrival of the summer snowmelt from eastern Tibet where the headwaters of the Mekong are. As a result, the Mekong has an extremely seasonal discharge with 80% of the annual flow arriving between June and November, 30% in one month (September). Large floods, like the one in September 2000, happen also in the wet season, superimposed on an already high river.

The course of the river varies between narrow steep-sided reaches cut in rock and wider reaches where the banks are still steep but the bedrock in the channel is covered by sand accumulation. Numerous bedrock protrusions, several metres high, are found in the channel and in places rock ribs almost stretch across the entire river. These are remnants of a former period when rapid channel erosion took place, and these protrusions currently form barriers leading to sand accumulation on the upstream side. During high water only the tops of the rock protrusions are visible. In the dry season, the wider sections of the Mekong exhibit a mosaic of sand, rocks and pools of ponded water. At low stage, the surface of the sandbars could be as much as 10 m above the river with the top of the banks rising another 10 metres. The banks are either in rocks or, more commonly, formed of several massive brownish silty sandy beds resting on bedrock. The sand moving in the river, however, is yellow and coarser.

3. A SELECTION OF FINDINGS

3.1. Environmental evaluation

Our previous work on the images of the study area showed considerable vegetation clearance on the slopes between 1996 and 1998, the years for images that were used. The clearance tends to follow valleys, which are governed by geological lineations. The clearances start in small patches on the side slopes of tributary valleys but tend to coalesce with each other. The clearances have been mapped visually (Gupta et al., in press) and by NDVI analysis (Chen et al., 2000). Although vegetation removal has happened on all kinds of slopes, about a quarter of these clearances are on slopes of more than 25º. We associated such clearances with accelerated erosion and sediment transfer via slopewash and small streams to the Mekong. It was noted that the bars in the Mekong increased in size (66.3% increase in area) between 1996 and 1998 (Chen et al., 2000). The lower water stage at the time of the second scene prevented further quantitative measurements. It was, however, possible to map the study area from the images to show: (1) potential sites for active slope failures, (2) areas with high potential for erosion and sediment release, (3) points where sediment is entering the Mekong, and (4) where sediment is accumulating in the river (Gupta et al., in press).

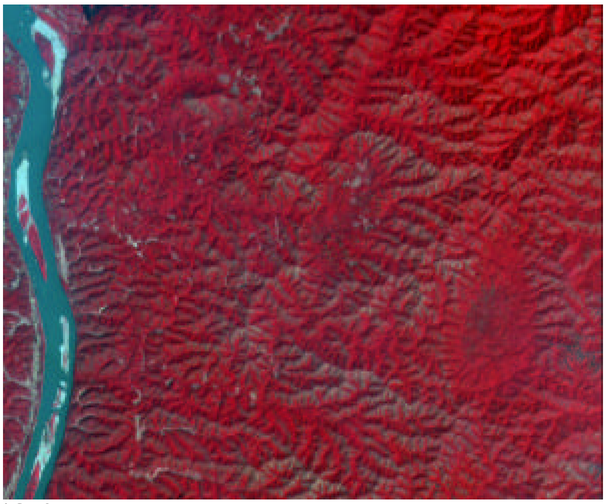
3.2 Field checking

The work so far was carried out without any field checking. One of the authors had been in the middle Mekong Basin about six years ago as a tourist and without any expectation of working in the future in this area. After the maps were completed, a field visit was undertaken for a quick checking of the accuracy of the findings. The conclusions reached from the careful visual inspection of the images were verified as correct in the field. There was cleared land on steep slopes, some of which were from logging, but most of it was for shifting cultivation of hill paddy along with vegetables such as cucumber and long beans (Fig. 1). Such fields are usually abandoned after a couple of years and new areas cleared within a short distance of the village. The mixed patches of cleared and partly vegetated land on slopes are sites with high potential of sheet and gully erosion and sediment transfer. The form and behaviour of the river as interpreted from the images also matched the Mekong in the field. Sediment movement on the steep slopes was demonstrated by the presence of debris flow tracks and small channels. Sediment was also seen at tributary junctions, as insets against the banks, and upstream of rock protrusions. We submit therefore that visual interpretation of these images could correctly describe the landforms and operating processes when carried out by a geomorphologist. It is of course, difficult to attribute numerical measures to the findings (except areal ones) in the absence of appropriate hydrological data collection.

3.3. Time-based changes

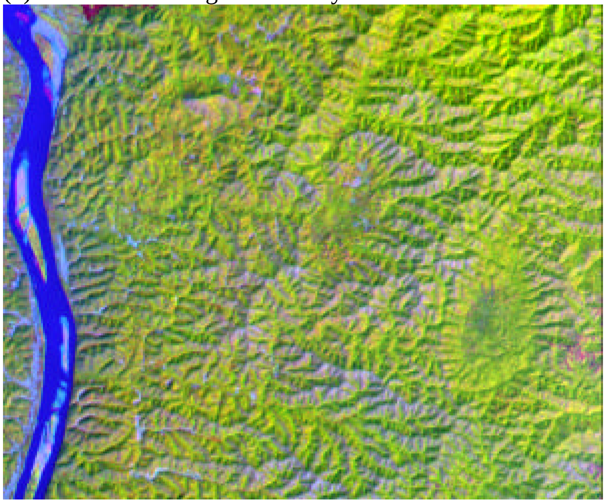
We found clear SPOT images of the same scene for 15 different dates between January 1996 and October 1999. We have also seen a Landsat image for the same area for 22 December 1992. Given the seasonal pattern of the Mekong River, we decided to compare images of the same period. By comparing the winter dry season images dated 8 January 1996 and 5 February 1999 (Fig. 2) we reached the following conclusions.

1. More land was cleared in the three years between 1996 and 1999. The clearance was along small valleys and across midslopes. This happened on both sides of the river. The additional land clearance is shown in grey in the superimposed diagram in Figure 2.
2. Some cleared land was abandoned and allowed to go under vegetation but the total land clearance increased remarkably.
3. Greater sediment accumulation was seen in the channel in suitable places such as between an existing bar and the channel bank, as dictated by the channel geometry, at tributary mouths, and where near-bank eddies developed during low flows. So far we have not been able to quantify the changes in the absence of river stage information. The changes in bar geometry, however, are being plotted to illustrate the areal extent of changes. The loss of bar areas by erosion is shown in red in the superimposed diagram and the additional sand accumulation in a bluish tint.
4. Examination of the image dated 7 January 1998, in between the two dates listed above, supports the progressive nature of change and suggests that the intensity of land clearance and sediment accumulation in the Mekong increased between 1998 and 1999.



(a). Date of the image: 8 January 1996.

(b). Date of the image: 5 February 1999.



(c). Changes in land use and river forms between 8 January 1996 and 5 February 1999.

Figure 2. SPOT images of 1996 and 1999, and the changes between the two years.

3.4. Seasonal changes

We found 8 images of the same scene for 1998: 7 January, 18 February, 8 March, 24 April, 16 May, 27 August, 25 October and 12 December. This allowed us to monitor seasonal changes on the slopes and in the river for the whole year. Up to April the direction of change is one-directional. Cleared fields have the same spatial distribution, the river level falls steadily, sandbars grow, bedforms are exposed, the river reverts to a low level channel, and the colour of the water changes probably indicating progressively less concentration of suspended load. By May, the river stage is slightly higher which could be due to short rain showers and summer snowmelt water arriving from the Tibetan Plateau. By August, the wet monsoon is well set and the stage is high in Mekong submerging most bars and transporting considerable amount of suspended load. The edge of the cleared land indicates progressive vegetation encroachment. By October, new vegetation has covered most of the cleared patches. The river stage is still high but the colour indicates a possible drop in sediment concentration. By December, the slopes are again marked with cleared patches, most of which are in their old location but several new areas have emerged and several old patches are now vegetated. The river stage is dropping and the bars resemble their location of previous January. It is likely that most of the erosion of and sediment transfer from cleared land happens during the early part of the southwest monsoon with the onset of heavy rains. With the establishment of a vegetative cover, the process of erosion slows down, although sediment already in the tributaries and the Mekong will continue to be efficiently transported downstream for the rest of the wet season. The sediment begins to be stored in the Mekong at the falling stage of the annual hydrograph and in places listed above.

4. CONCLUSIONS.

This is an exercise in optimising information retrieval from satellite images using only visual interpretation and simple computer-based analysis. We are trying to build a bridge between geomorphologists, environmental managers and remote sensing users. We may reach the following conclusions from this study on the middle Mekong Basin.

1. A very large area can be quickly mapped for (a) geomorphological characteristics and (b) environmental analysis.
2. Such mapping indicates areas that are vulnerable to future development projects and choice of techniques for environmental amelioration.
3. Even visual interpretation provides a reasonably accurate picture of landforms and ongoing processes. Visual interpretation therefore can be used at least for a reconnaissance study. This is particularly useful for large areas and difficult terrain.
4. An enormous amount of information currently remains stored in the archived images. These can be used for (a) time-based analysis and (b) a conceptual model for seasonal changes.

We have carried out this work with 20-m resolution multispectral SPOT images. The level of the analysis can be extended considerably by near-synchronous field visits and hydrological measurements. Application of images with higher resolution, such as IKONOS, should provide an interpreter with far superior resources and a more in-depth study.

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