Land-use Change in the Lake Inle Catchment, Myanmar: Implications for Acceleration of Soil Erosion and Sedimentation

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Kyoto Working Papers on Area Studies No.26
(G-COE Series 24)

February 2009

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The publication of this working paper is supported by the JSPS Global COE Program (E-04): In Search of Sustainable Humanosphere in Asia and Africa.

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Land-use change in the Lake Inle catchment, Myanmar: Implications for acceleration of soil erosion and sedimentation

Takahisa Furuichi*

Abstract: This study analyzes land-use change of a lake catchment, Myanmar, using Landsat MSS data in 1973, Landsat TM data in 1989, and ALOS AVNIR-2 data in 2008. Results of the analysis are integrated with a former study that examined sediment movement in the catchment. Results show that land-use of the catchment has not been significantly changed since 1973, while the former study suggests that sedimentation rates are likely to have been accelerated in the last 50 years. These results of the two studies indicate that acceleration of the process is not always related to land-use change at a catchment-scale. Extension of gully networks is the best explanation for likely acceleration of sedimentation in the sinks, so that of soil erosion in the catchment.

Key Words: land-use, NDVI, soil erosion, catchment scale, Myanmar

1. Introduction

Soil erosion and downstream sedimentation are serious environmental issues in Southeast Asia (ADB, 2002). Myanmar is no exception; soil erosion and sediment transport in the country appear to be higher than the Southeast Asian average (Furuichi, 2007). The catchment of Lake Inle, located in the central eastern part of the country, has long been reported to be facing severe soil erosion and sedimentation. This is of both local and national concern given its significance to the economy, environment, and culture (*The Myanmar Times*, March 27 – April 2, 2006). To have catchment-scale assessment of soil erosion, sediment transport, and sedimentation processes, Furuichi (2007) constructed sediment budgets of the Lake Inle catchment through identification of sediment sources, estimation of sedimentation rates, and quantification of sediment flux. One of subsequent research interests is land-use analysis of the catchment because land-use change generally affects rates of soil erosion, sediment transport, and sedimentation.

This study analyzes land-use change in the Lake Inle catchment, and results of the analysis are integrated with the former study. The integration of the results provides an important view on nature of the soil erosion process at a catchment scale.

2. Study area

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The Lake Inle catchment is part of the Salween River basin (the lake's center is at 20º30'N and 96º55'E) and is near the western edge of the Shan Plateau (Figure 1). The catchment of Lake Inle is approximately 3,800 km^2 and its total relative relief is about 1,200 m (Figure 2).

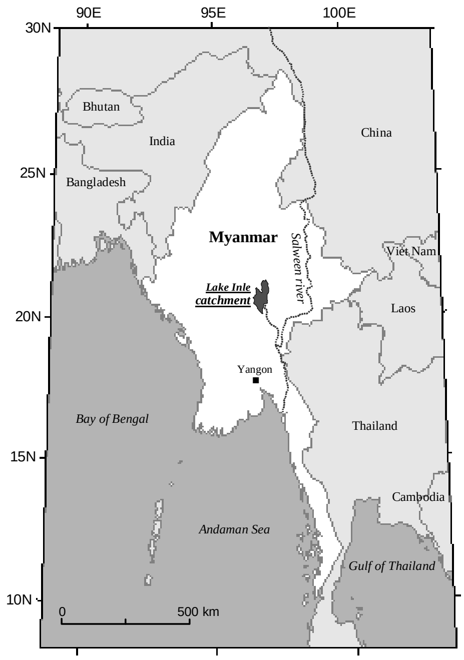

Figure 1: Location of the Lake Inle catchment

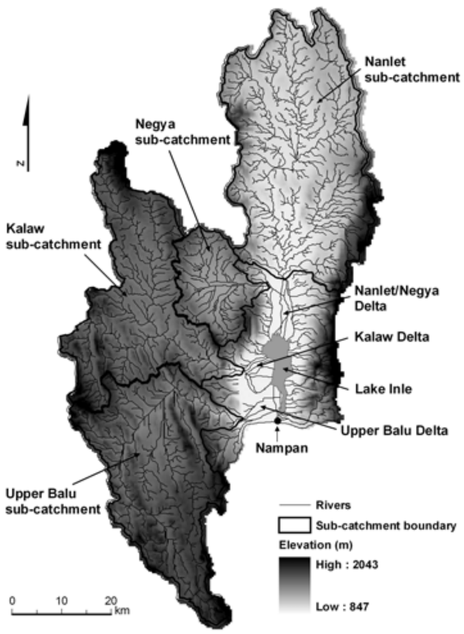

Figure 2: Topography, hydrological networks, and sub-catchments of the Lake Inle catchment. Hydrological networks were drawn using SRTM-3 DEM data and modified based on topographic maps.

The south-west monsoon brings most rain to the country, and the Lake Inle catchment receives annual rainfalls between 1,000 and 2,100 mm, depending on the location in the catchment. Generally, there is more rainfall at higher altitudes in the catchment.

Karamosia (2001) reported that agricultural land, forest with sparse canopies[1], and grassland account for 35%, 30%, and 22% of the catchment, respectively (Table 1). Forests with dense canopies remain only on 6% of the catchment. River floodplains where sufficient water can be secured are used for paddy fields, and slopes and river floodplains where water resources are limited are used for croplands. Consequently, sub-catchments that have broad river floodplains, namely the Nanlet and Negya sub-catchments (Figure 2), have a wider distribution of paddy fields than the others (the Upper Balu sub-catchment also has paddy areas in the middle plain). Mountain slopes are cultivated occasionally up to the tops of the mountains. Shifting cultivation exists on mountain slopes, but information on spatial extension or cycles of land-use was not obtained. Grazing also exists largely for raising cattle for agricultural use, but goat grazing is not seen.

Table 1: Land-use in the Lake Inle catchment

Land-use	%
Agriculture land	**35**
Forest with sparse canopies	**30**
Grassland	**22**
Others	**7**
Forest with dense canopies	**6**

Data from Karamosia (2001)

3. Method

Three sets of satellite images were used for land-use analysis:

(1) Landsat MSS images (60 m in resolution) on 10 January 1973 (2 scenes);

(2) Landsat TM images (30 m in resolution) mainly on 10 February 1989[2] (4 scenes); and

(3) ALOS AVNIR-2 images (10 m in resolution) on 16 January 2008 (2 scenes).

[1] Karamosia (2001) did not provide definition of the forests with sparse canopies and dense canopies.

[2] Four images were necessary to cover the whole catchment. Two images, that cover most of the catchment, were taken on 10 February 1989, while other two images, that cover much smaller areas, were taken on 16 January and 17 February 1989.

Analysis was made by producing false color images and calculating normalized difference vegetation index (NDVI). NDVI is a widely used index for identification of vegetation cover. It employs characteristics of green leaves that strongly reflect near infrared electromagnetic wave and absorb red wave.

False color images were complied using following bands of images:

- Landsat MSS images: bands 7, 5, 4
- Landsat TM images: bands 4, 3, 2; and
- ALOS AVNIR-2 images: bands 4, 3, 2.

NDVI was calculated from the following formula:

$$\mathrm{NDVI} = \frac{\mathrm{band(nir)} - \mathrm{band(red)}}{\mathrm{band(nir)} + \mathrm{band(red)}} \quad ,$$

where band(nir) and band(red) are intensities of bands in near infrared and red, respectively. For each data set, bands used for NDVI are as follows:

- Landsat MSS images: bands 7 and 5;
- Landsat TM images: bands 4 and 3; and
- ALOS AVNIR-2 images: bands 4 and 3.

Data is analyzed in the procedure shown in Figure 3. Band correction applied in this study is conversion of intensities in the fixed scale (0-255) into raw intensities. Band correction will be discussed in a later section.

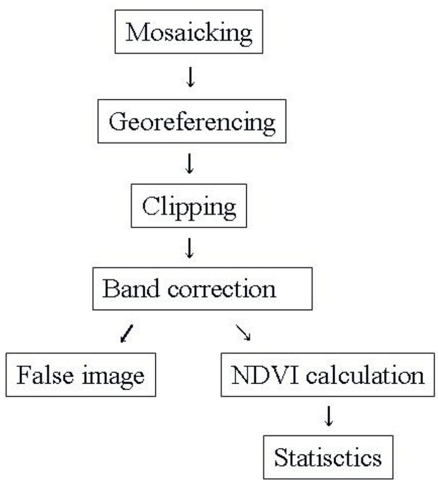

Figure 3: Procedure of satellite image analysis

4. Results

False color images

False color images produced using the data sets are shown in Figure 4. Two characteristics are identified. First, vegetation in the catchment had been already cleared extensively by the time of 1973. Second, vegetation cover generally decreased from 1973 to 1989, but slightly increased from 1989 to 2008, although differences of resolution (MSS: 60 m, TM: 30 m, and AVNIR-2: 10 m) may have affected the color expression.

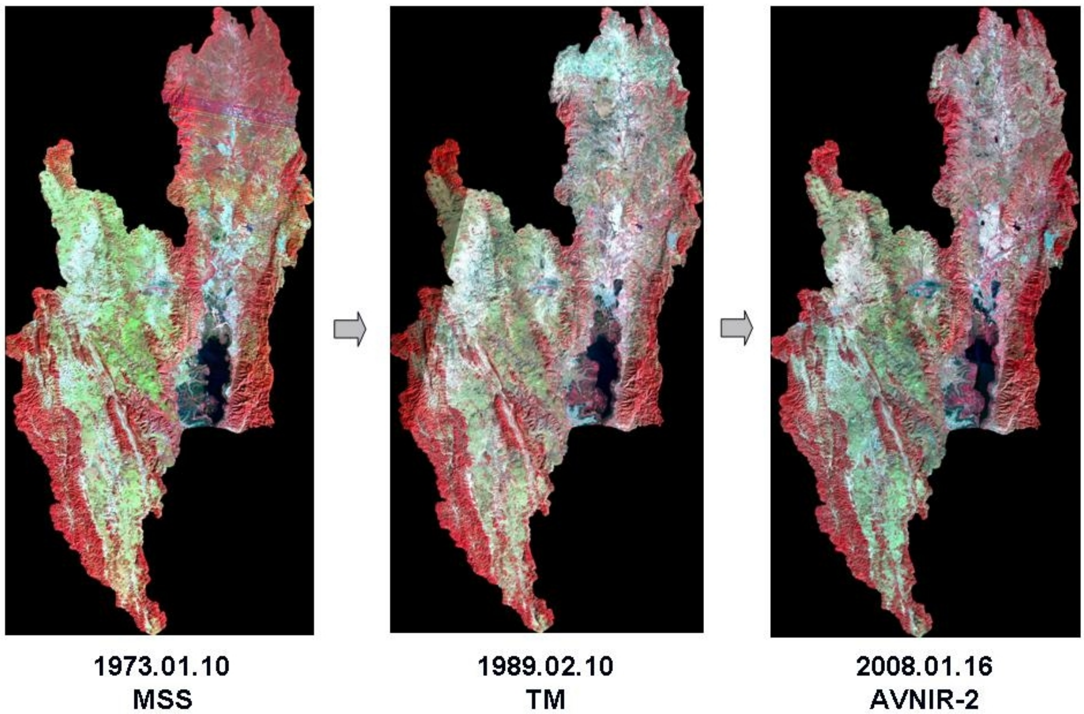

Figure 4: False images of the Lake Inle catchment at three time stages. The data sets used are Landsat MSS (1973), Landsat TM (1989), and ALOS AVNIR-2 (2008). Areas of reddish color are covered with vegetation.

NDVI

NDVI is calculated for each data set, which is illustrated in Figure 5. As a rough estimate, areas of minus values are displayed as red colors, those close to zero as green colors, and those of plus values as blue colors. In general, dense vegetation shows between 0.3 and 0.8 in NDVI (blue colors), and soils take around 0.1 to 0.2 (green colors). Results of the calculation indicate similar characteristics of the false images. Dense vegetation cover is observed only in limited areas in 1973. Slight, gradual increase can be found from 1973 to 1989, and also from 1989 to 2008; however, use of extensive areas most probably for agriculture has not been changed since 1973.

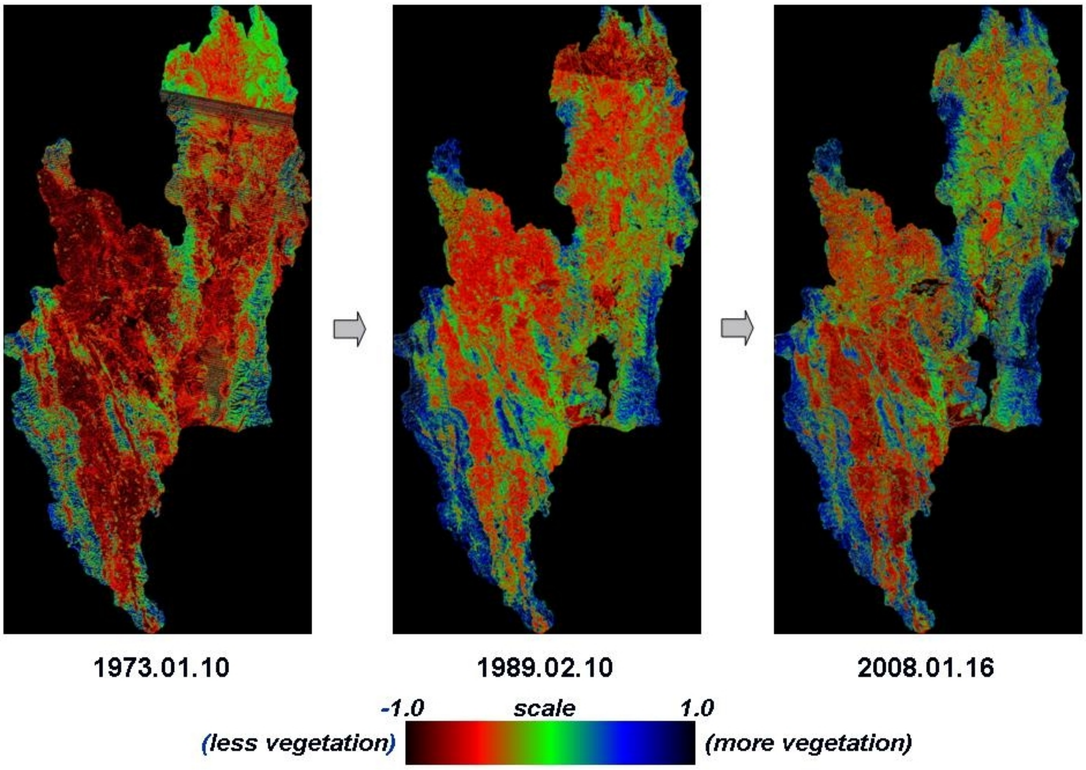

Figure 5: NDVI of the Lake Inle catchment at three time stages. Data set used is same as those in Figure 4.

Figure 6 shows frequency distribution of NDVI for the three data sets. Distributions of 1989 and 2008 largely overlap and highest frequencies are found between 0.0 and 0.2, suggesting soils are exposed in the majority of the areas of the catchment. Plots of 2008 have wider distribution to the plus, indicating increase of dense vegetation from 1989 to 2008. Distributions of the 1973 data set (bands 6 and 7 were used as near infrared band for the calculation) have considerable difference from those of 1989 and 2008, which suggest direct comparison of the 1973 result with others is inappropriate.

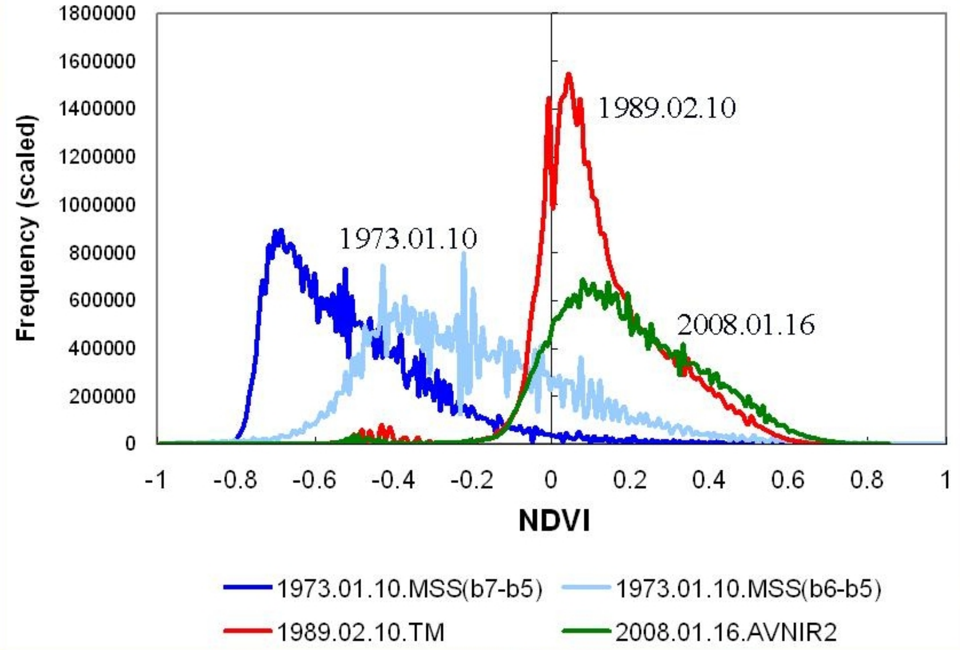

Figure 6: Frequency distributions of NDVI for the data sets of the three time stages. For the 1973 data set, NDVI calculated by bands 6 and 5 is also displayed as an alternative.

5. Discussions

Factors affecting band signals

Several atmospheric and ground factors possibly affect remotely-sensed signals. Major effects widely known are atmospheric effects, cloud effects, soil effects, and anisotropic effects. Use of different sensors also induces additional effects to consider: resolution effects and spectral effects. While, in particular, the shift of frequency distribution of 1973 data (Landsat MSS) is likely to be caused by some of these effects, this study has not properly performed corrections for these effects. Improvement of data manipulation is remained for future study.

Disagreement between changes of land-uses and sedimentation rates

Despite the insufficiency of signal corrections, it still can be interpreted that overall land-use in the catchment has not been significantly changed since 1973. Furuichi (2007) examined temporal changes of sedimentation rates in three types of sink (river mouth, marsh, and delta) and found higher sedimentation rates over the last 50 years compared to those in the previous period. Furuichi used both OSL and ^{137}Cs dating methods which are not typically suitable for dating sediments deposited within the last 50 years, and therefore changes in sedimentation rates in the last 50 years were not quantitatively examined. However, field observation and hearing from villagers suggest that sedimentation rates are likely to have been accelerated even within the last 50 years. If this is the case, sedimentation history disagrees with land-use history because accelerated sedimentation rates are generally a consequence of acceleration of soil erosion rates, which is often caused by land-use change (i.e. deforestation), particularly in the case of mainland Southeast Asia.

This disagreement tells us an important nature of soil erosion and its relationship with land-use change, that is, soil erosion is a very site-specific process (Forsyth and Walker, 2008). The disagreement suggests that acceleration of sedimentation cannot be attributed to change of catchment-scale land-uses. Given the catchment land-uses have not been significantly changed, that is, significant change in soil erosion from a slope is unlikely, acceleration of sedimentation seems to be caused by soil erosion intensified in the areas close to and connected to the stream network. Comparison of gully networks in the catchment between 1983 (aerial photos) and 2004-2006 (field observation) reveals that the gully networks are extended in the catchment between the two time stages. Considering that gullies are a sediment source which directly, efficiently supplies sediments to the stream network, increase of gully erosion is likely be the significant cause of acceleration of sedimentation in the sinks.

6. Conclusion

With data correction required to remove a series of effects from band values measured, satellite images provide considerable benefit in land-use analysis. Although there is necessity to refine the present data set in the satellite image analysis, it is still clear that overall land-use in the Lake Inle catchment has not been significantly changed since 1973. If understood in the common context in mainland Southeast Asia, this result of land-use history in the catchment disagrees with the likely change in sedimentation rates in the sinks. The disagreement suggests that soil erosion is a site-specific process and that acceleration of the process is not always related to land-use change at a catchment-scale. Extension of gully networks is the best explanation for likely acceleration of sedimentation in the sinks, so that of soil erosion in the catchment.

Acknowledgements

The author is grateful to Osamu Isoguchi of Japan Aerospace Exploration Agency for providing advice on analysis of remotely-sensed data. This study is supported by Grant for Next Generation Research Initiative (FY2007) under the Global COE Program "In Search of Sustainable Humanosphere in Asia and Africa", Center for Southeast Asian

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