Journal of the Korean Society of Remote Sensing, Vol. 10, No. 1, 1994

An Analysis of Shifting Cultivation Areas in Luang Prabang Province, Lao PDR, Using Satellite Imagery and Geographic Information Systems

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(1994년 5월 30일 받음 ; 1994년 6월 10일 수리)

위성영상과 지리정보시스템을 이용한 라오스 루앙프라방 지역의 화전지역 분석

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Abstract

By Using MOS-1 satellite image(taken on 24 April 1990, after slash and burn), Shifting cultivation areas were estimated for the sub-basin area. In tropical region to analyse the correlation between shifting cultivation rate and bifurcation rate network which was calculated from topographic map, PC Arc - Info and IDRISI GIS software were used. As the distribution rate of shifting cultivation increases, the bifurcation rate is high. From the correlation analysis between the shifting cultivation and drainage network, it was found that shifting cultivation leads to land degradation and head erosion at the stream valley. To prevent such problems, it is necessary that shifting cultivation areas should be converted to permanent paddy fields.

요 약

삼림을 베어서 태우고 난 직 후의 라오스 북부 화전지역의 MOS-1 위성영상을 처리하여 유역분지 단위로 화전지역의 면적을 산출하였으며, 지형도상에서 얻어낸 하계망과의 상관관계를 분석하기 위하여 PC Arc - Info의 GIS software를 이용하였다. 그 결과 화전

의 분포비율이 높은 유역분지에서는 1차수하천의 분기율도 높게 나타남을 알 수 있으며, 라오스에 있어서 화전이 지표의 침식과 토지의 황폐화를 초래하여 여러가지 환경문제를 유발시키는 원인이 된다는 것이 규명되었다.

Introduction

Lao People's Democratic Republic (PDR) is one of the "least developed countries" from the standpoint of the United Nations definition. It is a landlocked country with an area of 236,800km^2 . Tropical forests in mountaineous region occupy two-thirds of the territory. The mountains are inhabited by various hilltribe groups practicing slash-and-burn agriculture, while the lowland alluvial plains along the Mekong River and other paddy fields are worked by ethnic peasants(Martin Stuart, 1986).

According to World Bank survey, per capita income(GNP) of Laos in 1988 is US$180. The primary industry is agriculture, which accounts for 65 per cent of GNP, of which 10-15 per cent is drived from forest products. The predominant crop is rice, which takes up more than 80 per cent of the cultivation area. About 40.7 per cent of national rice production is produced under rain-fed conditions in the uplands through shifting cultivation (Nukone and Khennavong, 1991).

The major problems faced by the government is converting shifting cultivation to permanent croplands because of food deficit. Forest destruction and land degradation have resulted from shifting cultivation. Thus, a more detailed analysis of the shifting cultivation areas, through the use of spatial data or satellite imagery and GIS, is needed. However, local governments have no computer facilities and technical capability to use remote sensing and GIS technology.

Shifting cultivation dominates in northern Laos, is practiced by an estimated 1 million people; and accounts for about 40% of the country's rice area but only 20% of national rice production, officially reported average upland rice yield was 1.3ton/ha for 1983-1987 (Fujisaka, 1991). Luang Prabang Province, the subject of this study, is located in the northern mountain region of Lao PDR and has an area of 18,625km^2 with elevation range from 500m to 1000m. Its forest cover is only 10 per cent, compared to the national forest coverage of 47 per cent in 1981(Collins, Sayer and Whitmore, 1990).

The Objectives of this study are to ; (a) Prepare a land cover/use map showing district boundary, and particulary the shifting cultivation area per district with the use of a

digital processing system and Geogrphic Information Systems; and (b) Analyse the shifting cultivation in relation to drainage network properties.

Data Collection

To analyse the drainage and shifting cultivation areas, topographic maps of 1:100,000 scale were used. The land cover classification map was produced by classifying MOS-1 imagery taken on 24 April 1990. PC Arc-Info software was used to analyse the data. For ancillary data, aerial photos(taken on 24 November 1982) and Landsat imageries(taken on 24 January 1973 and 31 December 1975) were used. To collect ground samples, three fields works were carried out during 1992, 7 -1994, 8.

An Analysis of Shifting Cultivation Areas

1. Image Processing

Luang Prabang Province is covered with nine satellite scenes and they were collected at different seasons. Because of the limited capacity of computer system and seasonal differences, the southern part of Luang Prabang Province was selected for the shifting cultivation analysis. A color composite was completed with 4/2/1 bands of MOS-1 satellite image and geometric correction was also accomplished on UTM coordinate system. On that image, district boundary layer was overlayed(Fig. 1).

Eight land cover categories were classified by supervised classification method : village, paddy field, forest A and B, shifting cultivation, barren land, and water A and B. Two to nine training areas were selected in each class. Forest types were divided into A and B, in which forest A is on shadow sides and forest B is on sunny slopes. Water A means Mekong River that was distinguished from turbidity water B of tributaries. Paddy field area covers a large area because the rock crops of mountainous area were slightly included(Fig. 2).

Fig. 3 was made by overlaying the shifting cultivation layer and district boundary layer. With this layer, it was possible to estimate the size of shifting cultivation area for each district using Arc-Info software.

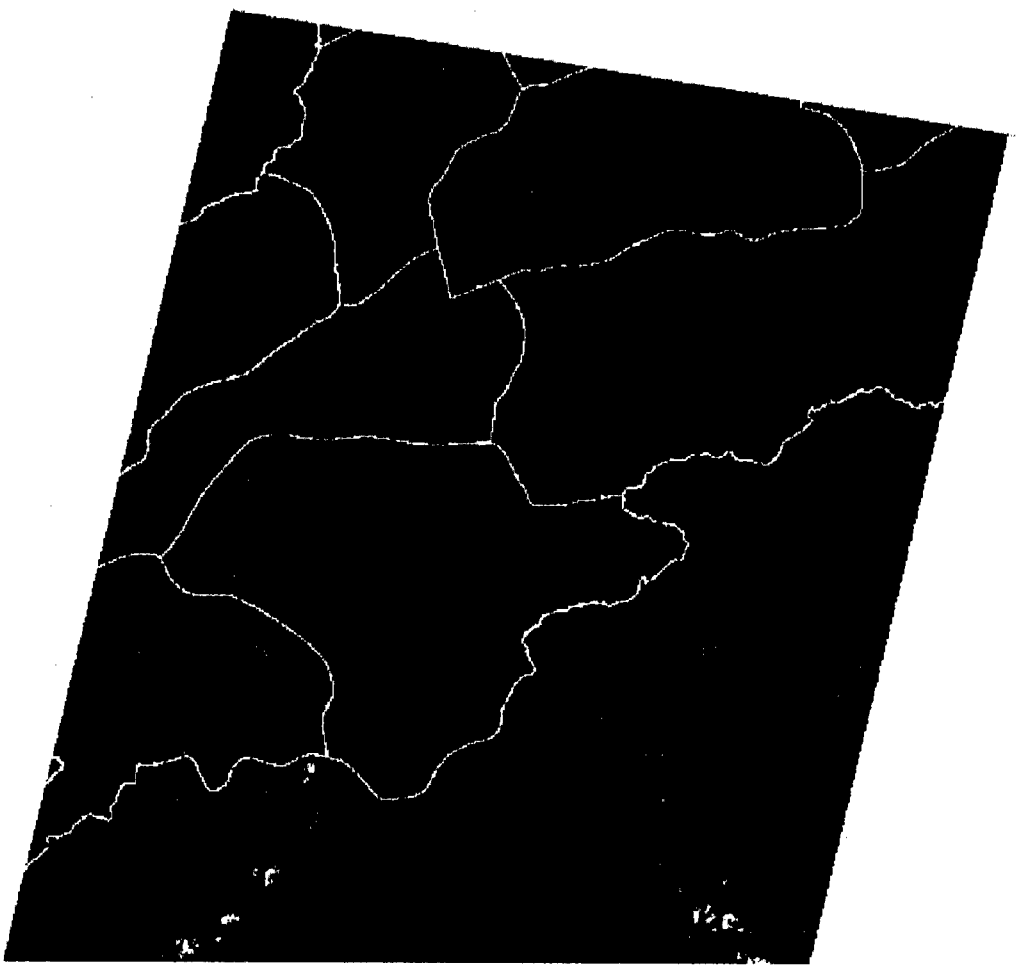

Figure 1. False color composite with district boundary of Luang Prabang Province, Lao PDR.

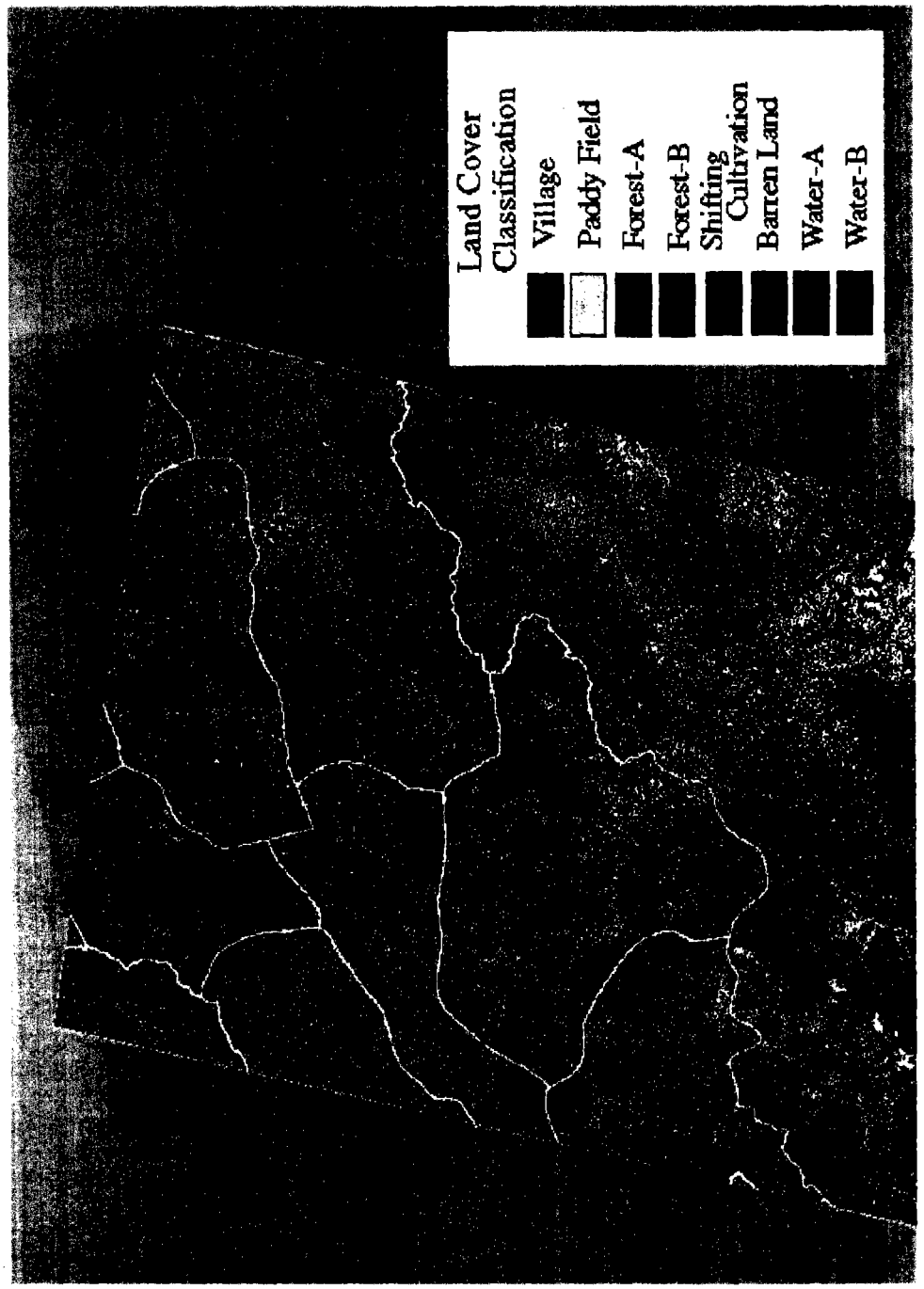

Figure 2. Land cover classification of Luang Prabang Province, Laos.

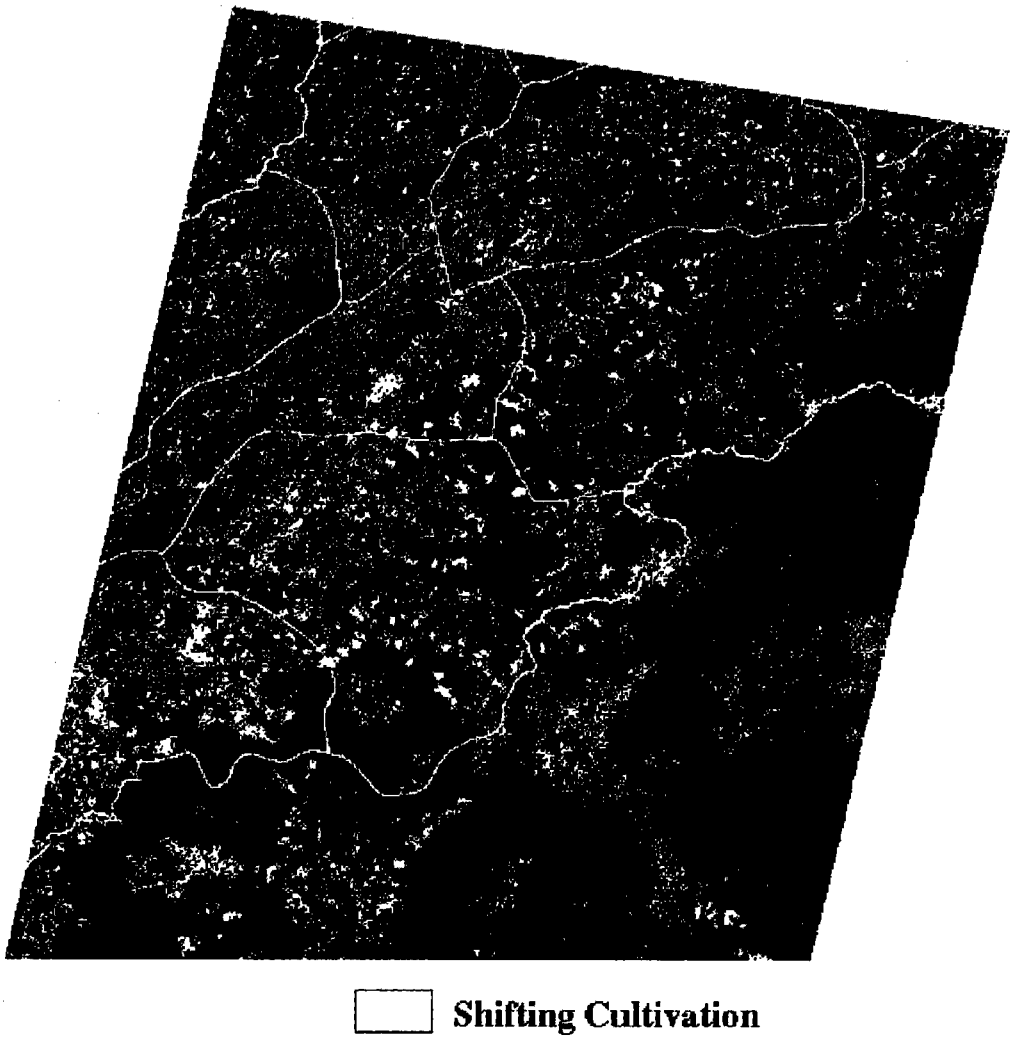

Figure 3. Shifting cultivation areas of Luang Prabang Province, Laos.

The cycle of shifting cultivation is a sequence of slashing(March), burning(March - April), seeding(May - June), two or three times of weeding(July - October) and harvest (November - December) during a period of time. The MOS-1 imagery(23 April 1990) was taken just after burning, therefore it was very easy to distinguish between shifting cultivation and fallow or forest which was the surrounding healthy vegetation. However, the subject area of this study, the southern part of Luang Prabang Province included only one district of Xiang Ngeun. So it was impossible to analyse the shifting cultivation area for each district unit. In this study, therefore, the analysis of the shifting cultivation and drainage network was performed on each of the twelve sub-basin areas of the Mekong River and its tributaries (Fig. 4).

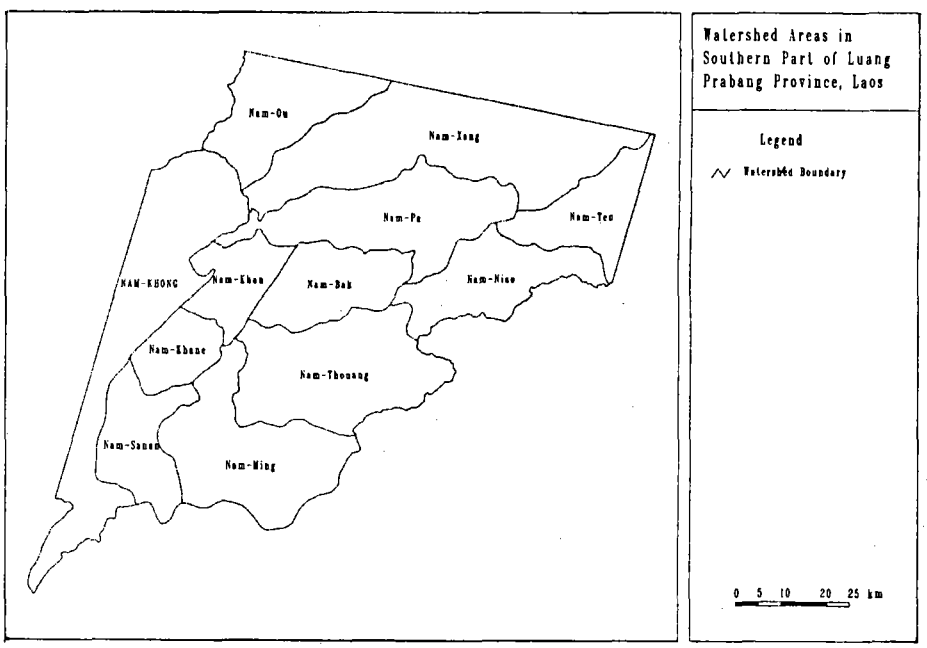

Figure 4. Watershed areas in southern part of Luang Prabang Province, Laos.

2. Analysing the Relationship of Shifting Cultivation and Drainage Network

Thematic data layers were constructed for district and drainage basin boundaries, drainage network, and distribution of shifting cultivation. Distribution map of shifting cultivation for each basin was prepared through vecterizing using IDRISI software from the land cover classification image. Output image from the above processing was overlayed with the sub-basin data layer(Fig. 5). Using this layer, it was possible to estimate and analyze the characteristics of shifting cultivation such as area, distribution rate and average area of each basin(Tab. 1). A choropleth map was completed from distribution rate of shifting cultivation in each basin that was presented by three levels showing rate of shifting cultivation area and total area. It showed that the basins of Nam Niao, Nam Ming and Nam Khane had a high ditribution rate, and that the Nam Ou, Nam Teu, Nam Pa and Nam Bak basin areas were low.

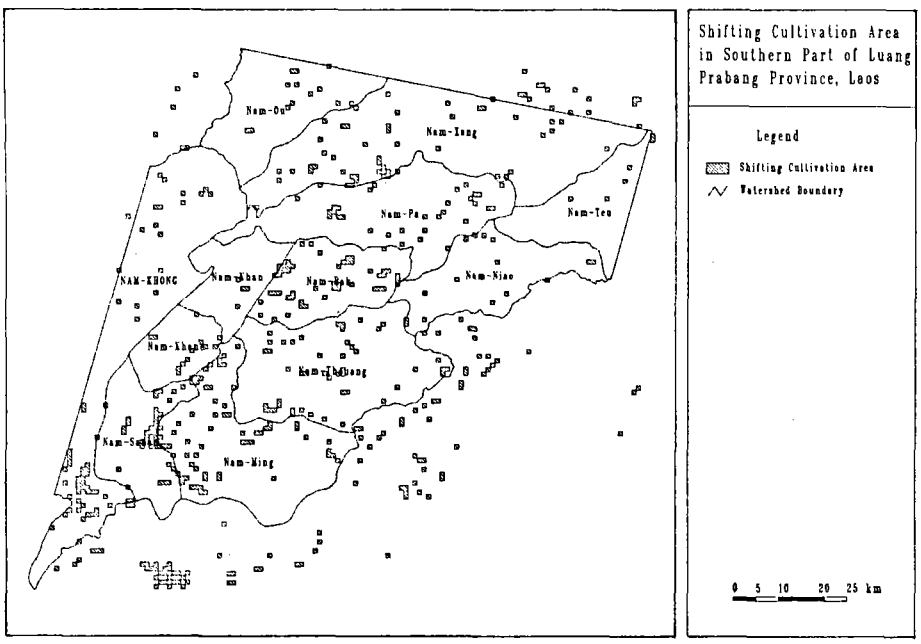

Figure 5. Shifting cultivation areas in southern part of Luang Prabang Province, Laos.
Table 1. Shifting cultivation areas in Nam KHONG watershed.

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watershed	total area (km^2)= A	S.C.Area (km^2)= B	rate(%) (B/A x 100)
Nam Ou	55.4	1.3	2.27
Nam Xang	157.8	5.7	3.64
Nam Teu	53.0	0.5	0.98
Nam Pa	79.6	3.4	4.21
Nam Niao	52.4	1.4	2.60
Nam Bak	44.2	4.6	10.37
Nam Thouang	91.1	4.6	5.07
Nam Khan	32.1	0.6	1.73
Nam Khane	24.0	1.2	5.15
Nam Ming	82.2	6.3	7.61
Nam Sanan	67.5	6.2	9.15
Nam KHONG	274.6	14.2	5.17

Drainage networks were analysed by bifurcation rate(number of N stream order/number of N+1 stream order, in this study it was calculated 1st/2nd) drainage density and frequency. The bifurcation rate was calculated by taking into account stream orders based on a 1:100,000 topographic map covering the study area. It was considered that the original bifurcation rate in a large scale is higher than this value. For example, the Nam Khane basin area was presented as 4.8 in this study, but from an aerial photo of 1:30,000, in another study(JO, 1993) the bifurcation rate was calculated as 6.1. In this study, the average bifurcation rate was 4.65 which means it was higher than compared to the normal bifurcation rate of 4.0-4.3. Nam Niao(5.52) was highest in value and Nam Xang(5.17), Nam Bak(5.03), Nam Thoung(5.00) followed in sequence, Nam Ou lowest at 3.18. Additionally, drainage density and frequency were analysed.

Through the anaysis for each basin area, the correlation of shifting cultivation and bifurcation rate, it was clarified that a higher bifurcation rate meant a higher distribution rate of shifting cultivation and the same in opposite case of a lower level. Among twelve sub-basin areas, six areas, 50 per cent showed a high correlation, otherwise there was no high-low or low-high area.

Therefore, it could be considered that shifting cultivation promotes ground erosion and accelerates the development of a first order stream in steep slope mountainous area such as this one. Consequently, it was clarified that shifting cultivation leads to not only deforestration and land degradation but also head erosion of stream valley and increasing the beded loads of sedimentary materials which caused the problems in watershed management. In addition to this, rice productivity of paddy field will be decreased by accumulation of calcium which is main content of limestone by run-off through shifting cultivation area.

Summary and Conclusion

To solve growing problems of shifting cultivation that causes severe deforestration and soil erosion in Lao PDR, it is necessary to have an efficient method to analyze the spatial pattern and distribution of shifting cultivation. Because shifting cultivation is practiced in mountainous areas, it is very difficult to access and analyse its spatial pattern. Land cover classification map of the southern part in Luang Prabang Province was prepared by using remote sensing technigue and geographic information systems including satellite imagery, aerial photos and topographic maps. It was possible to analyse the shifting cultivation areas in relation to drainage network for each sub-basin area of Mekong River and its tributaries.

It was clarified that satellite imagery is very useful in undertakening research on shifting cultivation areas, especially inaccessible areas. GIS is an important tool for analysing spatial patterns and thematic layers.

From the correlation analysis of the shifting cultivation and drainage network, it was found that shifting cultivation leads to a high bifurcation rate and head erosion of the stream valley. By field survey, it can be found too many gullies on shifting cultivation area. From this study, it was first investigated that shifting cultivation is main factor of soil erosion and leads to food deficit of subsistence to Lao people. Therefore, it is desirable

that shifting cultivation areas to be converted as much as possible to permanent paddy fields.

When compared to aerial photography used for reference data, the use of satellite imagery presents some difficulties in identifying fallow and natural forest. For more accurate results, it is desirable to analyse the multi-temporal and sequential satellite imagery for one cycle(one to two year shifting cultivation and three to four year fallow) of shifting cultivation.

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