

ENVIRONMENTAL IMPACT ASSESSMENT OF DYNAMIC ANTHROPOGENIC ACTIVITIES IN MAMLAY WATERSHED OF SIKKIM HIMALAYA — A REMOTE SENSING APPROACH

by

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ABSTRACT

Anthropogenic activities on watershed levels has been the cause of mounting developmental pressures on natural resources and an environmental impact assessment using remote sensing for the period 1988-1992 was performed. It was possible to infer both positive and negative impacts for a basic resource unit like a watershed in an ecologically fragile Himalayan region. The significant parameters were derived and their inter-relationships discussed in this paper which should help in choosing the development priorities and micro-level planning for an environmentally sound and sustainable development of such regions.

1.0 Introduction

Sikkim is a small Himalayan State of India falling in the Eastern Himalaya. It encompasses a mountainous terrain with rugged topography covering an area of 7,096 km². The mountains of this state rise in elevation northwards with high serrated, snow capped spurs and peaks culminating in the Mount Kanchenjunga (8,585 m amsl). The southern Sikkim is more open, lower and fairly well cultivated. The whole of the State almost entirely falls within the upper Teesta river basin, the main tributary of which is the Rangit River.

The growing emphasis on micro-level planning and sustainable development of mountain environments necessitates detailed studies of a basic resource unit like watersheds (Sharma *et al.*, 1992) in terms of their natural resources, trends of exploitation and environmental impacts. Satellite-based remote sensing inputs should serve as a key element to initiate integrated sustainable development at micro-level (Rao, 1994). Such an approach is also useful for periodic monitoring of these aspects, particularly in difficult and inaccessible mountain terrains (Krishna *et al.*, 1994).

The synoptic and repetitive coverage of satellite remote sensing with good spatial and temporal resolutions has facilitated such works to a good extent when combined with collateral information and groundtruth of the interpretations (Nagarajan *et al.*, 1994). Therefore, to get an insight into the rational utilization of natural resources for optimum production, minimum disturbance to the ecosystem and better micro-level planning, this environmental impact assessment was undertaken.

2.0 The study area

This study was carried out in the Mamlay watershed of the South district, Sikkim (Figure 1). The watershed falls between 27°12'3"N to 27°14'16"N latitudes and 88°19'2"E to 88°23'30"E longitudes covering an area of 30.09 km². The Mamlay watershed covers a good profile of altitude, ethnoculture, land use and also, wide ranging agricultural practices and forest types in varying gradients of altitude (Sharma *et al.*, 1992). Moreover, this is an anthropogenically vibrant Himalayan watershed with predominant agriculture and agro-forestry activities. The population of this watershed is about 4,000, of which 95 per cent is concentrated in lower and middle hill slopes and 5 per cent in upper hill slopes.

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2.1 Geology

The Mamlay watershed is part of the Rangit tectonic window within the central crystallines of the Sikkim Himalaya. The area is characterised by folded structure and the significant thrusts here are Sikkip and Tendong. Two major rock formations, namely the Damuda and Daling, are found here (Bose, 1989) showing different levels of weathering and erosion. The harder granites, gneisses, dolomites, sandstones and quartzites occupy the hill tops and high slopes of ranges while the softer slates, phyllites, shales and schists occur on lower hill slopes and valleys.

2.2 Topography

The elevation range of the watershed is 300 m to 2,650 m. The topography becomes rugged from east to west. Some landslips and gullies are also observed. Physiographically, the watershed is divided into three geomorphic units: (a) lower hill slopes (< 1,000 m), (b) middle hill slopes (1,000-2,000 m) and (c) upper hill slopes (> 2,000 m). The middle hill slopes occupy 50 per cent of the area, lower hill slopes 40 per cent and upper hill slopes the remaining 10 per cent. The slopes show, on average, a range of 30° to 40°.

2.3 Drainage pattern and texture

The watershed is in the catchment area of Rangit River and has five perennial streams within it. The drainage pattern is dendritic. This has developed due to the presence of rocks of more or less uniform resistance and implies, geologically, a notable lack of structural control.

The drainage texture shows a drainage density value of 2.62 and a stream frequency value of 3.06. The texture in general is coarse showing a large number of surface drainage lines indicating impermeable bed rocks.

2.4 Forest cover/vegetation

The watershed has reserved forests which are mostly natural. Forests are also seen in private holdings especially in areas of cardamom cultivation. The per cent ratio of natural forests to the private holding forests is 67.33. These are classified into: (a) sub-tropical natural forest and (b) temperate natural forest. According to Sharma

et al. (1992), out of all tree species of this watershed, 38 species are used for timber including nine high quality species and 38 species as fodder, 16 of which are considered of high fodder value. As much as 69 species are mainly used for fuel wood.

2.5 Agriculture

A considerable area of the watershed is under agriculture which includes horticulture and agro-forestry sub-systems. The upland farming system with bench terraces and slopy land with no terraces is most common here. The common crops include maize, pulses, cereals, ginger, orange and large cardamom.

3.0 Objectives

The environmental impact assessment of the dynamic anthropogenic activities within the watershed was attempted using Indian Remote Sensing satellite (IRS-1A/1B) data acquired in November 1988 and November 1992, SPOT satellite data in November 1990, collateral data from Survey of India topographic sheets and ground-truth surveys. The assessment was done using the information generated on the varied terrestrial features as land covers.

4.0 Methodology

IRS-1A/1B LISS II geocoded false colour composites (FCCs) of bands 2, 3 and 4 of November 1988 and November 1992 together with SPOT-1 (HRV-1, MLA) geocoded FCC of November 1990 were visually interpreted using standard techniques (Sabins, 1987). Plate 1 shows FCC scenes of corresponding years covering the watershed. The schematic steps of the study are:

The interpretation of multirate satellite data led to the generation of specific land cover themes. The topographic sheets were used during ground-truth field visits which were carried out for identifying ground control points (GCPs) and minimizing the shadow effects of the hills by ground verifications of the questionable features. This was done in accordance with the multistage sampling technique for terrain studies (Pachauri and Krishna, 1984, and Krishna, 1984). The satellite scenes used were of 1:50,000 scale leading to ease of interpretation aided by an optical reflecting projector for enlargements of the initially inter-

puted maps and replotting using a light table with a coordinate measuring system. The maps thus prepared are shown for the years 1988, 1990 and 1992 respectively in Figures 2a, b and c.

Land cover statistics were generated using a high precision digital planimeter. Table 1 shows

the percentage of land cover types for the different years in terms of forest land, agricultural land, built-up land, rock outcrops, waterbodies/streams and mass wastings/landslides at level I and their sub-classes at level II. The major land-cover (level I) changes are shown in Figure 3 for the years 1988-1992.

Table 1. Environmental impact assessment of anthropogenic activities within the Mamlay watershed

Level/ Serial No.	Land cover types	Data interpreted and quantified (in per cent)			Impacts	Remarks
		IRS 1A LISS-II FCC 1988	SPOT-1 MLA FCC 1990	IRS 1B LISS-II FCC 1992		
I ₁	Built-up land	2.12	2.99	2.12	Not much	Due to the comparatively lower spatial resolution of IRS scenes, only significant cluster settlements were interpreted whereas SPOT gave more detailed information.
I ₂	Agricultural land					
II _{2.1}	- Rainfed land	13.80	18.58	21.83	Increasing over the years in all the categories at level II.	
II _{2.2}	- Irrigated land (Khet)	1.23	1.29	1.33		
II _{2.3}	- Orange Orchard	0.40	0.42	0.53		
I ₃	Forest land					
II _{3.1}	- Dense mixed forest	27.60	25.51	21.66	Decreasing forest resources which may also lead to loss of wildlife and increased soil erosion.	
II _{3.2}	- Open mixed forest	40.34	35.96	35.10		
II _{3.3}	- Sal forest	0.46	0.42	0.34		
II _{3.4}	- Degraded forest	2.19	2.36	2.88		
II _{3.5}	- Scrub land	5.22	5.34	6.97		
II _{3.6}	- Forest blanks	0.33	0.35	0.40		
I ₄	Rock outcrops	5.64	6.00	6.04	Not much as there is no evident mining or quarrying activities here.	No trend can be suggested and figures projected here should be considered as the status as interpreted from 1990 SPOT scene.
I ₅	Mass wastings/landslides	0.00	0.06	0.20	Increasing and found to occur on rainfed land indicating poor farming practices without precautions for such calamities.	
I ₆	Water bodies/streams	0.67	0.73	0.60	Not much as there is no evident stream manipulation practice.	No trend can be suggested and 1990 SPOT data can be considered as the status of waterbodies here.

5.0 Results and discussion

The quantitative data for the different years on a thematic basis as contained in Table 1 and Figure 3 indicates the following:

Forest land as level I category includes dense mixed forest and open mixed forest, and sal (*Shorea robusta*) mixed forest at level II which shows a decrease from 1988 to 1992. Degraded forest, scrub land and forest blanks at level II show an increasing trend. Therefore, the overall impact is progressively decreasing forest resources which also implies loss of wildlife and valuable tree species and increased soil erosion in the area.

Agricultural land as level I category includes rainfed land and irrigated land, and orange orchard at level II. All of these show a progressively increasing trend. The net impact is positive in terms of the socio-economic development of the inhabitants of the watershed. However, at the same time, it is significant to note that this may be due to the encroachment of forested land by increasing agricultural activities. Therefore, it seems appropriate to draw a correlation between forested land and agricultural land to examine the relative impacts.

Built-up land does not show much variation. This is partly due to the scattered nature of the settlements and to the more limited spatial resolution of IRS (36.25 m). The SPOT scene, with its greater spatial resolution (20 m), was more useful in interpreting a more realistic area coverage of this land cover class which corresponds to 2.99 per cent of the watershed area. This category is perceived to increase with the growing population.

Rock outcrops do not show much impact as there are no evident mining or quarrying activities except for local level quarrying of rocks for road metals and building materials. As an economic mineral, coal seams occur here but mining is not done. The area coverage of rock outcrops was delineated more precisely using the SPOT imagery and the data thus obtained was considered more accurate for this land cover class which corresponds to 6 per cent of the watershed area.

Processes of mass-wastings such as landslides are not so alarming in the watershed but

a progressive trend is observed which needs to be monitored and mitigated. No landslides were observed in 1988, but an increasing trend in landslide occurrence was noticed in 1990 and 1992. During field visits, it was observed that landslides occurred on rainfed land under upland farming practices contributing to the high run-off and erosion rates. The agricultural areas show a high rate of landslides, apart from barren and sparse vegetation growth. This also indicates unsystematic and poor drainage in farming practices which should be improved to avoid such calamities in the future. Change over from traditional crop cultivation to cash crop cultivation also contributes to aggravation of the problem.

In respect of waterbodies, the IRS imageries, due to their limited resolution, gave information as per inferences drawn from the traces of streams whereas SPOT imageries provided a much better delineation. Therefore, the percentage area cover of 0.73 per cent drawn from SPOT imagery for the year 1990 is considered the status as of that date. Such a small percentage of area classified in this category indicates water-filled stream channels which, in the month of November are relatively dry. The field visits suggest not much manipulation by the inhabitants in the surface water bodies. Therefore, not much negative impact is inferred.

6.0 Conclusion

The environmental impact assessment of dynamic anthropogenic activities over the years within the watershed derived from multi-temporal satellite data depicts the overall trends of development with their consequences as listed below:

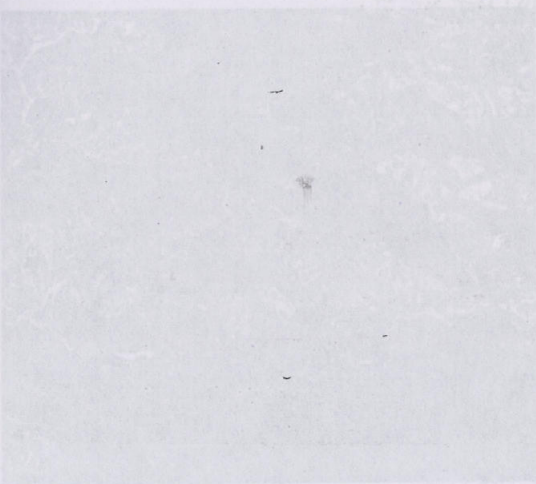
- (1) Change in land use from forest to agricultural land;
- (2) Change in land use within agricultural land from one crop to another;
- (3) Change in land use from forest to non-forest as a consequence of other activities such as logging, fuel-wood and fodder collection.

These have components of positive impacts requiring their appraisal as well as negative impacts for immediate attention to environmental conservation and sustainable development for such eco-

logically fragile Himalayan regions. The further scope of such a study can be outlined as analyzing the relationship between population and land use from existing data, land-use dynamics which shall predict change in future land use with increasing population on watershed levels for the Himalaya. Digital image processing of remotely sensed data should also be carried out for a finer detailing of the terrestrial features for such purposes.

References

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(a)



(b)



(c)

Plate 1. False colour composites (a) IRS 1A LISS II, 1988 (enlarged), (b) SPOT-1, HRV-1, MLA, 1990 (reduced) and (c) IRS 1B LISS II, 1992 (reduced)

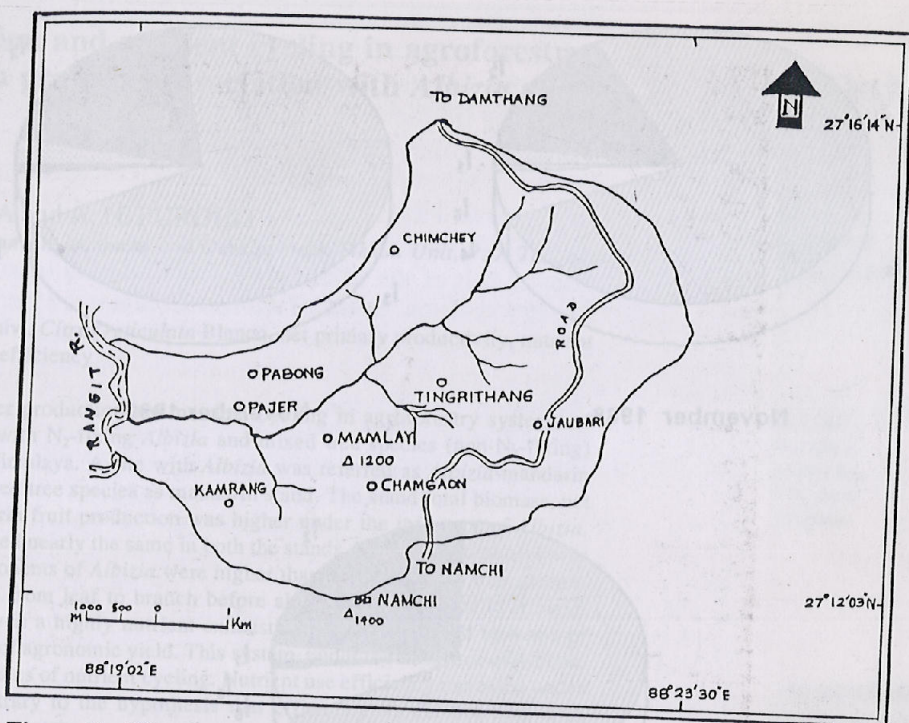


Figure 1. Mamlay watershed of South Sikkim

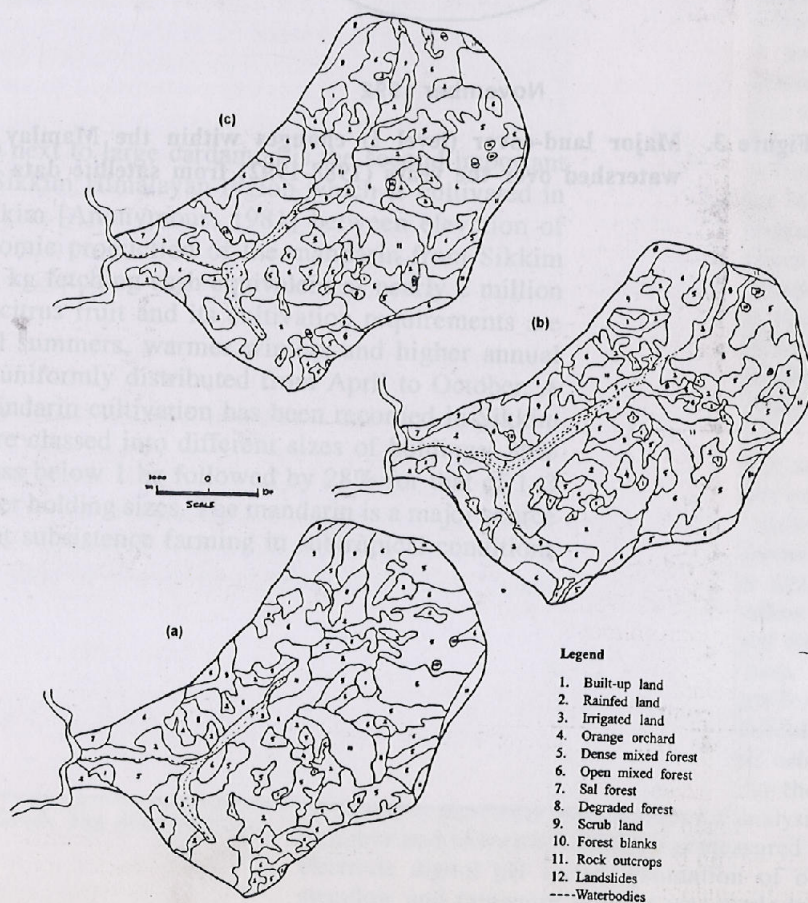


Figure 2. Land-cover types for (a) 1988, (b) 1990 and (c) 1992

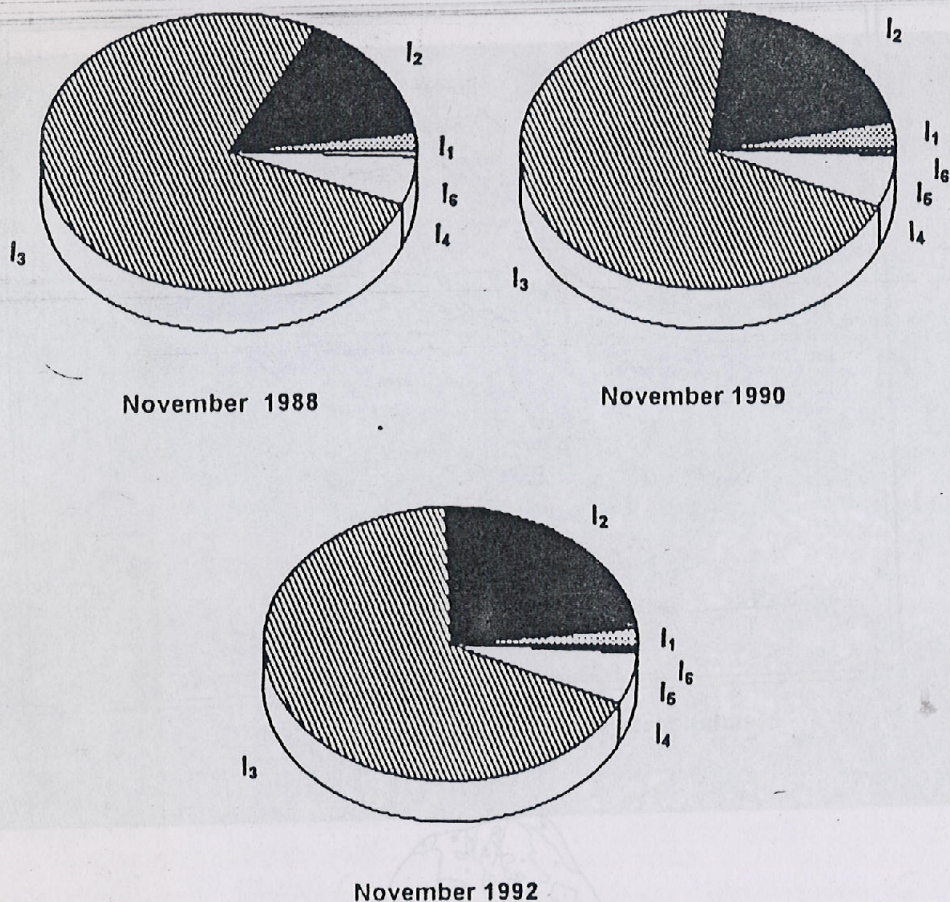


Figure 3. Major land-cover (level I) changes within the Mamlay watershed over the years (1988-1992) from satellite data