INTERPRETATION AND USE OF LANDSAT IMAGERY FOR RESOURCE PLANNING IN THE HIMALAYA

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INTRODUCTION

The Indian Himalaya and Its Resources

The Indian Himalaya, with widths varying from 250 to 300 km, extend for about 2500 km from west to east and cover an area of 594,427 square kilometers, representing nearly 18 percent of the total area of the country (Table 1). Forests are reported to cover as much as 53.2 percent. Starting from about 300 meters altitudes rise with 92 peaks over 8000 meter above sea level. The major North Indian rivers rise here. The natural resources of soil, water (and snow), vegetation, minerals, energy sources and terrain are interrelated and changes affecting one have repercussions on others. The resources range from renewable to practically non-renewable,but none is unlimited and theii use and conservation entail rational planning.

The Himalaya are geologically young and the environment is fragile. The extremes of climate, topography, relief, aspect and slope are some of the natural factors beyond human control (although slope can be modified to some extent) which have disturbed and damaged the environment and ecosystem. Unplanned land use, cultivation on steep slopes, overgrazing of pastures and wastelands by excessive but underfed livestock, shifting cultivation (mainly in Eastern India), lopping of broad- leaved species, road construction, mining and quarrying, over- exploitation of village or community forests, are a a few factors which have further accentuated ecological degradation. Erosion of topsoil is resulting in decreased production, not only where the soil has left, but also where it is deposited during floods. Speedy silting and sedimentation of reservoirs is a cause for alarm. Landslides and rockfalls are common and wind erosion takes place in the inner dry valleys. Springs are drying up and glaciers are reported to be receding.

The density of population per hectare of cultivated plus habitable land, which gives a more realistic picture than one based on the total geographical area, shows densities three to four times higher than in the plains. The resource base itself is gravely endangered, with land and forests most affected due to overpopulation and overstocking of livestock. Agricultural practices in rainfed, and particularly in unterraced, fields have been responsible for widespread and serious loss of topsoil, and agricultural nutrients have been depleted. The situation is getting worse in shifting cultivation (*Jhum*) areas.

Consequences of forest cover depletion and overgrazing are extremely serious. The three main categories of forests are reserved, village or community (protected/panchayat), and private

Table 1. Area and Population of the Indian Himalaya by State

S. No.	State	Geographical area (Km ^{2})	Reporting area (Km ^{2})	Forest %	Net area sown %	Population 1981	Rural %
1.	Jammu and Kashmir	2,22,236	45,230	61.4	15.6	5,987,389	78.9
2.	Himachal Pradesh	55,673	50,760	54.8	10.8	4,280,818	92.4
3.	Uttar Pradesh (8 hill districts)	51,112	48,800	46.7	17.1	48,835,712	80.9
4.	Sikkim	7,299	7,299	36.0	N.A	316,385	83.9
5.	West Bengal (Darjeeling)	3,075	3,110	38.1	32.1	1,016,177	85.7
6.	Assam	78,523	15,220	22.1	3.5	15,902,826	N.A
7.	Meghalaya	22,489	22,489	8.3	7.2	1,335,819	81.9
8.	Tripura	10,477	10,477	60.1	22.9	2,053,058	89.0
9.	Mizoram	21,087	20,920	62.0	1.9	493,757	75.3
10.	Manipur	22,356	22,110	27.2	6.3	1,420,953	73.6
11.	Nagaland	16,527	13,510	19.7	4.4	774,930	84.5
12.	Arunachal Pradesh	83,573	56,440	91.3	2.0	631,839	93.4
	Total:	5,94,427	38,206	53.2	9.7	43,049,663	

(Source-Planning Commission Task Force Report March 1982)

(Table 2). Village forests for the most part are no longer able to meet the needs of the people, and have turned into scrub and grassland. Overgrazing impedes regeneration, and fires to promote growth of grass also destroy young plants. As wood production decreases, people (mostly women and children) have to go farther from home for collection of firewood and fodder. Yet, firewood is and will continue to be the main energy source for the majority of the population.

The People and Their Needs

The region is a contact zone between the Indian subcontinent, the Tibetan Plateau and the Central Asian Mainland. This has had a profound effect on the sociocultural institutions of the people, their conditions of life and resource base on which they depend. The population of the region is about 43 million (Table 1) with a large number of ethnic groups at various stages of development, having very little in common. The sociocultural diversity and the differences of the natural resources and environments are so great that no uniform pattern of development can be adopted.

The basic human needs, apart from air, water and shelter, are food, fuel, fodder, fertilizer and fibre. Food supply in the region has to be supplemented from the plains because of the climatic conditions and limited availability of agricultural land in the mountains. Except in a few urban areas, wood and very small quantities of charcoal are the only source of fuel. Reported firewood production figures are misleading, as these do not include fuelwood removed free from the forests by the local people, for which no records are kept. However, the available export figures and estimated consumption of fuelwood are given in Table 3.

Energy needs of the people can only be met by regenerating the existing forests and creating man-made biofuel plantations or energy farms. With proper selection of species, this willresult in increased fodder and manure production. The species selected need to have, among others, the following properties: is fast growing; has high calorific value and highcropping potential; increases soil fertility; has leaves suitable for fodder and fertilizer; is suitable for watershed management and conducive to the general shaping of the environment.

Resource Planning Objectives in the Himalaya

The general objectives are to:

- Arrest and, as far as possible, reverse man-made ecological degradation (Protective)

- Rehabilitate badly eroded watersheds (Regenerative)

- Reduce soil erosion and water run-off to the maximum possible extent

- Conserve, maintain and improve tree growth and ground vegetation

Consistent with these goals are:

- To maximize production from all sources by afforesting denuded areas and wastelands adopting scientific land use and agronomic practices, improving and reducing livestock and adopting rotational grazing and controlled lopping

- To meet the fuelwood and fodder requirements of the people

- To develop and utilize non-conventional energy sources

Resource management in the Himalaya affects the downstream areas also. Since the effects follow natural rather than

Table 2: Statewise Forest Area of the Indian Himalaya by State (1981-82)

State	Forest Area (Sq. Km.)						
	Reserved	Protected	Unclosed	Others	Total	Encroach- unclosed Sq. Km.	Shifting Cultivation
1. Jammu and Kashmir	21,886	-	-		21,886	54	-
2. Himachal Pradesh	1,825	17,129	730	1	21142	167	-
3. Uttar Pradesh	23,720	10,070	20		34040	145	-
4. Sikkim	2,240	580,	-		2820	-	-
5. West Bengal	700*	426*	-	1,183*	143*	-	
6. Assam	17,074	-	2,759	10	30,708	1,312	4,900
7. Meghalaya	706	12		7	8,510	112	4,560
8. Tripura	3,862	2,058	-		5,920	15	1,360
9. Migram	6,312	1,647	5,240	3	16,629	-	4,800
10. Manipur	1,377	4,171	9,606	15,154	-	3,000	
11. Nagaland	286	518	210	1	2,876	10	6,570
12. Arunachal Pradesh	11,830	206	39,357		51,540	342	2,812

For entire state, as figures for hills districts alone not available.
(Source INDIA'S FORESTS 1984-FRI)

artificial boundaries, it is best to adopt watersheds as the units of integrated resource planning, monitoring and evaluation. This is true even in the case of rural energy planning, which has to consider the needs of the scattered inhabitants within a physical unit of land.

Resource Information Required

As the available knowledge and data base for the Himalaya is limited, fragmented, dispersed, sometimes outdated and on the whole, less than adequate, surveys are needed for:

- Water resources for human consumption, irrigation, power generation
- Snow for overall water resource assessment
- Soils (distribution, composition characteristics, degree of soil erosion and genesis of the various soil types) for determination of land capability or land use potential
- Vegetation (composition, distribution and degree of depletion of forests for rural energy

Table 3: Statewise Fuelwood Export (1980-81) and Estimated Annual Fuelwood Demand-Indian Himalaya

State	Fuelwood (000m) Exported	Estimated demand
1. Jammu and Kashmir	130	2994
2. Himachal Pradesh	134	2140
3. Uttar Pradesh	1041	2418
4. Sikkim	15	158
5. West Bengal	502*	2505
6. Assam	96	9951
7. Meghalaya	1	668
8. Tripura	174	1026
9. Mizoram	NA	247
10. Manipur		
11. Nagaland	NA	387
12. Arunachal Pradesh	24	316

Note: 1. Production figures are taken from FRI publications and these do not include firewood collected by local people.

2. Demand of fuelwood is calculated @ of 2.5 m 3 (1562.5 kg) per annum.

* For whole state

planning and for overall development, monitoring of changes, extent of pastures and wastelands, quantity of fodder and biomass produced)

- Mineral and fossil fuels (geological and geophysical mapping and exploration)

- Energy (geothermal, hydroelectric and meteorological data such as wind velocity, in addition to other renewable energy sources

- Crop (prediction of crop yield)

In the context of rural energy planning it is necessary to identify:

- Energy deficit areas

- Potential biofuel or energy plantation areas

- Sites for microhydel installations

- Sites for other non-conventional energy development

SURVEY AND DATA COLLECTION

Having decided upon the target area (e.g. energy deficit area), significant characteristics and parameters for which data are required may be noted. Technique and frequency of measurements, optimal level of spatial detail and sampling design, if necessary, are then decided upon. Available data from existing sources (such as Survey of India topographic maps, land records and forest working plans) is collected before undertaking new ground, air or satellite surveys. Ground surveys are the only method for detailed project work for very small areas but may not be practical for inaccessible and snowbound areas. Field checks are necessary for interpreted details and ground truth data is essential for interpretation of Landsat Imagery. Due to difficulty of timely procurement and high relief displacement, use of aerial photographs in the region will never have large-scale feasibility. At present, the only possibility is to use the Landsat Imagery as much as possible, supplemented with ground surveys of selected sample or priority areas.

THE LANDSAT SYSTEM

Satellites, Sensors and Imagery

The basic facts regarding the Landsat system are well known and need not be repeated. From the original video tape of satellite telemetry, the processing computers produce four different black and white corrected images on film, each of a 185 by 185 km scene, corresponding to the data registered on one of the four MSS bands. However, the 64 levels of intensity on the original tape are reduced in a black and white film to between 10 and 15 shades or levels of grey, which is the limit to which the human eye can distinguish. The grey levels for the same object often differ from band to band. By combining imagery of two or more bands, False Color Composites (FCC) are produced. Imagery (including the Thematic Mapper products for certain selected scenes) is available from the National Remote Sensing Agency, Hyderabad (NRSA). The Indian Himalaya are covered by about 46 scenes.

Arranged in order of increasing cost and sophistication, various methods of extracting information from remote sensing data are:

- Manual interpretation of standard photographic image - This is simple and uses inexpensive instruments. Photo enlargement and diazo processing are very useful.

- Manual interpretation aided by photographic enhancement - Image enhancement is a process of departing from the fidelity of an image so as to enhance particular features of interest by bringing out boundaries or edges of surface features. This is done by superimposing several images of the same scene taken on different dates or by assigning different colors to specific density ranges or slices. Zoom transferescope, color additive viewers and microdensitometers are used.

- Manual interpretation of special digitally enhanced photographic products

- Digital analysis of the Computer Compatible Tapes (CCT)- The digital data can be interpreted and analyzed. Though most expensive, it permits utilization of total information content of the original data and results can be in a variety of visual forms: statistical tables, graphs, digital maps, histograms, map overlays, annotated imagery or thematic maps.

Special Characteristics of Landsat Imagery and Data

Satellites have been the most prolific source of data since July 1972. The sensed data is available in digital form, permitting large data to be processed rapidly by computer to produce resource information desired for large areas in a relatively short time. Important data is obtained in infrared region which is beyond the range of camera systems. Thematic Mapper products are now available for selected scenes.

Resource	Capability of Landsat Regarding Imagery			Limitations
	Identification	Monitoring	Planning	
Water and Snow	Yes	Yes	Yes	Depth and quantities not available directly and dry streams can escape detection. For detailed project work of small areas, photographs are more useful.
Watershed Boundaries	Yes	Yes	Yes	Very, very small watershed boundaries cannot be delineated.
Geologic Survey	Yes	Yes	Yes	Adds one more dimension for understanding of mineral genesis.
Soils	Yes	Yes	Yes	Aerial photographs are useful for detailed work.
Land Use	Yes	Yes	Yes	Aerial photographs are useful for detailed work.
Forest and Vegetation	Yes	Yes	Yes	Aerial photographs are useful for detailed work.

The Imagery from a space platform has three very distinct and unique characteristics:

- The synoptic view coupled with uniform solar illumination from a near vertical perspective make it particularly useful for cartographic purposes, recognition of geologic features and vegetation patterns.
- Repetitive coverage provides an unequaled opportunity to monitor dynamic phenomena, such as changes in vegetation cover, hydrology, snow, land use, etc. Multi-date images can lead to more exact identification of static resource features.
- Uniformity, due to sun-synchronous orbit, makes it possible to have

image mosaics on a continental or country scale, and the overlay of scenes taken on different dates permits precise comparison.

USE OF LANDSAT IMAGERY

Remote sensing techniques provide the most rapid and cost- effective method for the inventory and monitoring of resources and land use over extensive areas (to be covered in low detail) together with detailed study of selected areas. The capabilities and limitations of Landsat data are given below. For best results, Computer Compatible Tapes analysis is necessary.

APPLICATION OF LANDSAT IMAGERY FOR RURAL ENERGY PLANNING

Identification and Mapping of Priority Areas

Generally, populated areas which are more than a reasonable walking distance away (say 5 km) from existing forests can be considered energy deficit areas. On band 5 (old) Landsat Imagery one can easily identify and map the existing forests: good (stratum 1.1) as well as degraded (stratum 1.2) Excluding snow- covered areas and alpine pastures, whatever non-forest area is seen on the imagery is an area of human and livestock concentration (Stratum II).

The present firewood supply to Stratum II areas is from the nearest existing forests of strata 1.1 and 1.2, and location of these strata clearly brings out the zone in which there is paucity of firewood. These can be mapped on scales varying from 1:250,000 to 1:1,000,000 depending upon the extent of area covered. As an example, if one were to consider the entire U.P. Himalaya, a 1:1,000,000 scale would be quite appropriate, while for a watershed of about 16,000 to 20,000 ha, 1:250,000 scale would serve the purpose. Once the location of villages with their population figures is marked on such maps (together with pilgrim routes and tourist spots), the position of areas where concentrated efforts are required can be more than clear to any energy planner. With edge-enhanced imagery and Computer Compatible Tapes analysis, more detailed information can be obtained.

Planning for Biofuel or Energy Plantations

Apart from availability of funds, the main constraints for any such program are the availability of suitable planting areas and people's willingness to cooperate. With the help of a map prepared at the identification stage, an estimate of potential planting areas may be obtained. With a similar study in the U.P. Himalaya, the estimated plantable area came to about 9,000 square kilometer. For 15,000 villages in the region, average planting area thus available per village is 60 ha. Planting can be done over 15-20 years, so that local people do not find difficulty parting with their grazing grounds and are able to get increased grass supply from closed areas. Similar estimates are possible for each watershed or sub-watershed. Forest and other relevant land use categories can be mapped for detailed work. Together with this planting, proper regeneration and controlled harvesting of existing forests, and protection and improvement of degraded forests, has also to be planned. Satellite imagery can be a useful tool in deciding the species to be planted if the planner is familiar with the terrain and locality factors.

Preliminary Selection of Microhydel Locations

The map prepared earlier can be supplemented by an overlay of the drainage system which can be mapped from Landsat Imagery (old Band 7). Land forms are quite clear on the imagery and with knowledge of local terrain one can select streams and a number of likely points for microhydel location, corresponding to the concerned priority area. Final choice has, however, to be made after ground survey. Since heights are not seen directly on the imagery, aerial photographs, if available, can serve the purpose better. If, however, the siting for microhydel has already been done, its location can be marked on imagery and an integrated overview of the situation, especially with respect to the likely impact on the environment, can be studied and examined. This is particularly true for big dams and hydel projects.

Development of Other Non-Conventional Energy Sources

Landsat Imagery clearly brings out the location of ridges and high points with which meteorological data on wind velocity can help in selection of windmill sites. Similarly, for solar energy installations one can select the sunny aspects and locations where maximum sunlight is likely to be available. However, use in all such cases relies on other available tools like aerial photography, topographic maps, and ground survey reports, and will depend upon the ingenuity and experience of the user.

CONCLUSION

Availability of Landsat Imagery, including Thematic Mapper products, has opened up vistas especially for integrated, multi-disciplinary and innovative resource and energy planning. In view of the environmental and ecological degradation, this is an urgent priority for the Himalaya. Interpretation of imagery and mapping can be done by experts in very little time. This gives a distinct advantage. Aerial photographs also afford this possibility and in some situations prove better, but in that case a much larger number of prints have to be handled and transfer of interpreted details onto base maps poses a serious problem due to extremes of altitudinal variations.

Maps with full details of extensive areas such as river systems, land use energy deficient areas, and potential plantable areas, are extremely difficult to obtain with much accuracy, if not impossible, by any other method. If Landsat Imagery were not available, the U. P. Himalaya Watershed Management project could not have been conceived as it was, or have had the impact it has had in the development of fuel and fodder plantations. Such work, however, needs active participation of fairly senior level of planners/users. Also, one has to keep abreast of the latest developments in the field which are rapid and levant for rural energy planning. A great deal of work has yet to be done to fully exploit this potential.

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