Environmental impact of trekking in Trans-Himalayan ecosystems – a study of a highly visited trail in Ladakh

Dorje Dawa & Davide Geneletti

Abstract

In many Himalayan regions, the growth of mountain tourism is posing a threat to the fragile ecosystems. This study describes and assesses the impact of trekking and its related activities in the Markha Valley hosting the most promoted trekking trails of Ladakh (Indian Himalaya). A Geographical Information System (GIS) database was prepared and to analyze and model the relationship between tourism stressors (e.g. waste disposal, camping sites) and sensitive environmental receptors (e.g. soil, wildlife, groundwater). The results showed that high-altitude pasturelands are most affected areas. Most critical activities are overgrazing, waste dumping and soil trampling.

Keywords: GIS, land cover, Markha valley, tourism

1 Introduction

In many Himalayan states and regions, mountain tourism has become an important source of income, contributing significantly to economic development. This poses a threat to fragile mountain ecosystems. Furthermore, one of the characteristics of mountain tourism is the high degree of seasonality causing human pressures to concentrate in a relatively short period. This is particularly critical in high altitude ecosystems, where tourist access is essentially restricted to the summer months, which are also the peak period of biological processes, e.g. mating, vegetation growth, spawning (Droz & Dawa 2004). Due to significant rise in the popularity of trail use and high altitude mountain trekking, there has been a steep increase in trekkers over the last decade in many Himalayan states and regions (Chatterjea in press, Nepal and Nepal 2004). Supplementary factors like increase in leisure time, mobility, tourism promotion and increased income have also contributed to the increase of trekkers (Høyer 2000). In addition, the trail use is known as one of the fastest growing recreational activities (Lynn & Brown 2003).

Trekking as a recreative activity is mainly done in natural areas and protected areas (Chatterjea in press). Most protected areas in the developing regions of Himalaya lack adequate tourist infrastructures to receive a high flux of tourists, porters and pack animal (Singh & Mishra 2004). Some of the protected areas along the Himalayan belt have fragile ecosystems (Transhimalayan ecosystem) characterised by scarce vegetation, thin soils and low precipitation (Bhatnagar et al. 2006). For these reasons, trail use and its related activities are causing unusual and alarming impacts in the mountainous areas of developing countries, such as the Trans-Himalayan region.

This study describes and assesses the impact of trekking tourism and its related activities in the Markha Valley, which hosts the most promoted trekking trails of Ladakh, Indian Himalaya. Environmental impact of trekking has been a major concern in Ladakh, due to poor infrastructures (e.g. waste bins, accommodation, and toilets). The objective of this study is to understand the critical implications of trekking activities for the environment, particularly for natural ecosystems, wildlife, water, and soil. The study followed a stepwise approach:

1. A GIS database was prepared adapting data processing to high altitude ecosystems and complex mountain topography. Field work allowed the acquisition of information on environmental stressors (e.g. tourism flow, dumping sites and camping sites) and ground-truthing;
2. Scoping was performed to select environmental stressors and environmental receptors, and to identify potential impacts;
3. Stressors and receptors were mapped through GIS modelling (e.g. soil erosion susceptibility, soil fertility index, wildlife habitat composite index, runoff);
4. Environmental impacts were spatially described and then integrated into concise maps to identify most critical areas, as well as environmental components affected most.

This contribution presents an introduction to the study area (Section 2), the construction of the GIS database (Section 3), and an overview of the impact analysis (Section 4). A detailed description of the methods adopted for the impact assessment and the results obtained will appear in a forthcoming publication.

2 Study area

Ladakh has been experiencing anthropogenic development and its impacts since the Indo-Chinese war break out in 1962. In 1974, parts of Ladakh were opened for international tourism (Bhatnagar et a.l 2006). In 1972 and 1999, Indo-Pak war breakouts resulted in major developmental activities. During the last decade, pressure from military and tourism has affected some fragile ecosystems of Ladakh. Among the most critical impacts are overgrazing at campsites, tramping of soil and vegetation, wildlife disturbances, trail degradation, littering, off-road driving, and urbanisation in Leh, the capital city.

Markha Valley is situated within the Zaskar range, in the central sector of Ladakh, near to the main tourist hub centre of Leh (see figure 1). Since it opened for tourism in the early 90s, it has been one of the most visited trails in the Himalayan region. The trail offers a wide range of recreation, from cultural tours, trekking to mountain expeditions. The Markha Valley hosts the high-altitude transhimalayan protected area of Hemis National park (figure 1).

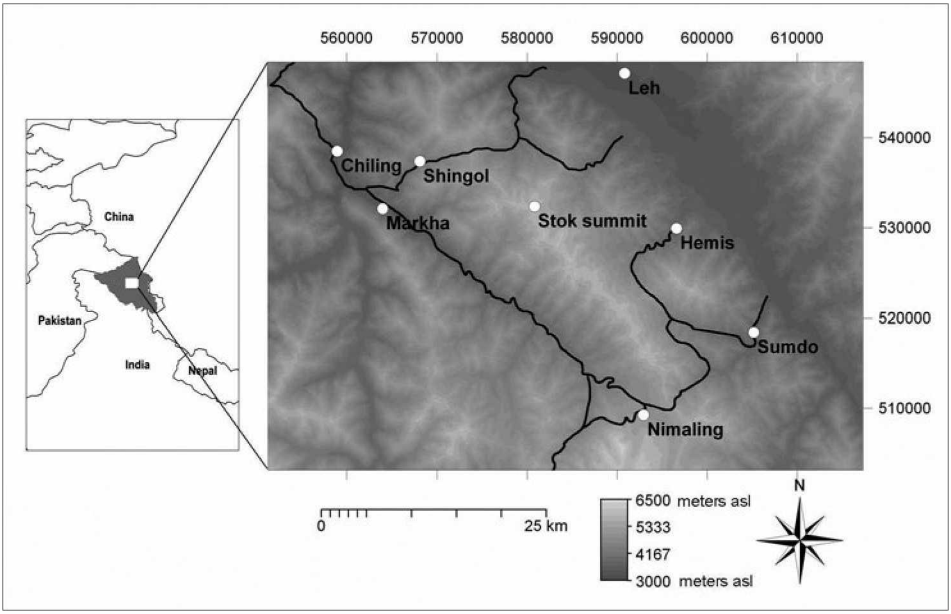

Figure 1: Location of study area.

3 Spatial database preparation

At the time this research was initiated, very few environmental data was available for Ladakh due to remoteness, security reasons, and lack of expertise. The Indian institute of remote sensing (IIRS) developed some of the basic databases of the region , but not all of these data were released for academic purposes. Joshi et al. 2006 developed a vegetation cover map for Ladakh when he carried out a transhimalayan floral biodiversity characterisation with global land cover facilities. Most other environmental studies focused on the regions' geology (Searle et al. 1990, Weinberg & Dunlap 2000, Jade et al. 2004). To generate a spatial database with a suitable scale for this study, basic GIS layers were processed from scratch, such as land cover, precipitation maps, Digital Elevation Model, soil fertility mapping, groundwater map, wildlife habitat, tourism, as shown in the following paragraphs.

3.1 Land cover classification

Ladakh depicts a land cover with scarce vegetation, predominantly with barren rock and barren soil, followed by snow and glaciers cover, patchy vegetation in the valley bottom and sparse bushes along the hilly region (Joshi et al. 2001). Low chlorophyll content, high mountain topography, uneven vegetation cover throughout the region and three image acquisitions made land cover classification particularly complicated. Therefore, classification of satellite images with supervised and unsupervised classification algorithms generated unsuitable results. Hence, a new method was adapted to generate the land cover for the region. Three indices were generated independently to discriminate vegetation, water and glaciers: the Normalized Difference Vegetation Index (NDVI) is based on a ratio of red values and the near-infra red values. This ratio proved high correlation with vegetation parameters such as green-leaf biomass (Rondeaux et al. 1995). Using this algorithm it was easier to discriminate the vegetation composition from the other classes, even though the chlorophyll content was low. NDVI images were generated, and with the help of visual interpretation values, adjusted and mosaicked. Later, a DEM was used to better identify agriculture, riparian vegetation, grassland, and wetlands (figure 2).

- The Normalized Difference in Snow Index (NDSI) was used for mapping snow and glaciers (Sidjak & Wheate 1999). Glaciers and snow cover most of the peaks ranging from 5,500–6,000 metres a.s.l. in the region. Spectral band 2 and band 5 were used to discriminate the snow cover using the formula:
- NDSI = (band2−band5) / (band2+band5) (Sidjak & Wheate 1999).
- Later DEM was used to counter check the snow elevated peaks (figure 2).
- Water was extracted with the help of the static water system index (Bo Cai 1995) easily discriminating most of the static aquatic systems like lakes.

Eventually, all the indices were aggregated and overlaid to produce a land cover map for the study area. Barren rocks and barren soils were classified within the unclassified area through visual interpretation.

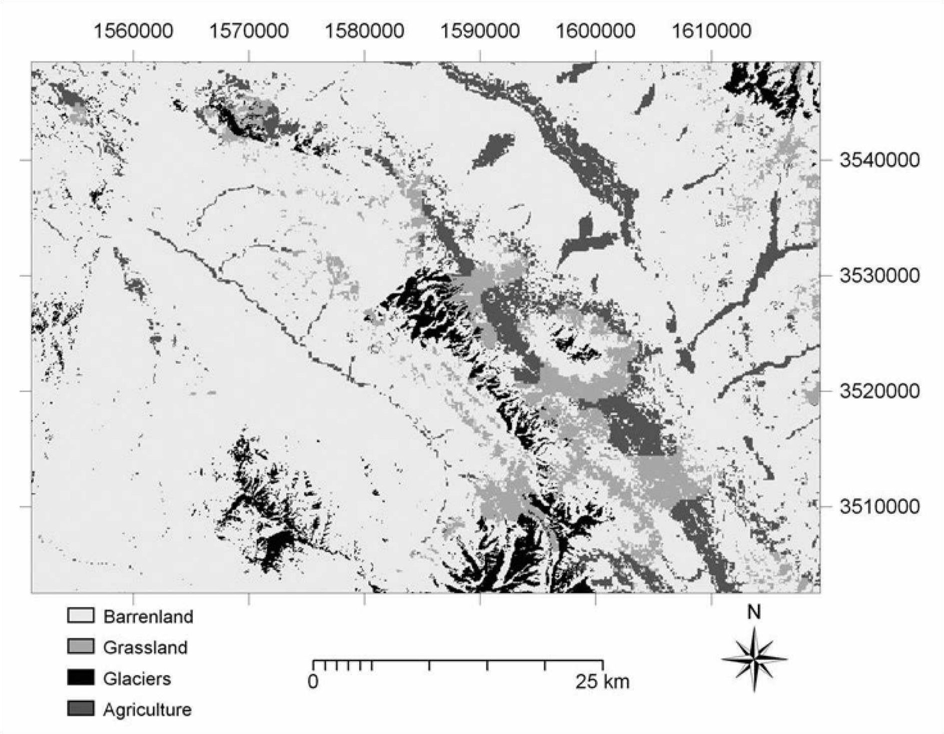

Figure 2: Land cover map of the study area.

3.2 Climatic and topographic data

A complete spatial representation of surface climate is now available with global coverage on internet data servers (New et al. 2002). These climatic datasets include seven global meteorological variables, namely precipitation, wet day frequency, temperature range, relative humidity, sunshine duration, ground frost frequency, and wind speed. This dataset is an average measurement from 1961 to 1990 having a resolution of 0.5° latitude/longitude. From importing the available data in a GIS and interpolating them using the DEM, a precipitation map was developed. This map allowed estimating the precipitation at the main stopovers of the Markha trail.

The freely available 90 m resolution DEM obtained from SRTM data were used. SRTM is a radar interferometry dataset derived from the Endeavour (shuttle radar topography machine). A typical characteristic of unedited SRTM DEM is the presence of numerous voids. These voids originate from the shadowing, layover, atmospheric disturbances or other radar specific causes. Thus some parts of the DEM show speckled with negative elevation values. To overcome this obstacle, values from other existing DEM with coarser resolution were used to fill up the void. Once the values were filled up, the resulting maps were filtered. In total 12 tiles of SRTM DEM data were used to cover the whole study area.

3.3 Soil and wildlife data

Soil fertility mapping was carried out by classifying the available soil map with two parameters: soil type and texture. Soil type ranking order was derived from USDA soil classification while soil texture ranking order was derived from soil texture classification triangle.

The Wildlife Institute of India provided habitat maps of six large herbivore endangered species. There were six IUCN red listed species, two critically endangered species, one highly vulnerable and three least concerned species. Latter these habitat maps were aggregated to generate a habitat composite index by overlaying the distribution maps and assigning weight to each vulnerability class.

3.4 Tourism flow data

During fieldwork in summer 2006, tourism data were collected including tourist inflow, porter inflow, pack animal, lodgements, GPS location of camp site and dump site along the trail, campsite area, and dumped quantity waste assessment. A total inflow of almost 8,000 tourists, 2,000 accompanying people and 6,000 pack animals were reported during the high seasonality of June to October (Table 1). This figure is in stark contrast to the 600 inhabitants of the Markha valleys solely dependent on agriculture and pastoralism.

Table 1: Tourism inflow estimates.

Months	Tourists	Pack animals	Porters
May	450	360	180
June	750	600	300
July	2,400	1,920	960
August	3,000	2,400	1,200
September	750	600	300
October	450	360	180
Total	7,800	6,240	3,120

4 Preliminary impact analysis and conclusions

The environmental impacts were assessed through building up a scoping matrix, which represents the preliminary process in environmental impact assessment (EIA) to recognise environmental stressors and potential environmental receptors, and their spatial distribution. This process is significant in understanding the major environmental components vulnerable to stressors. In this study, major stressors were

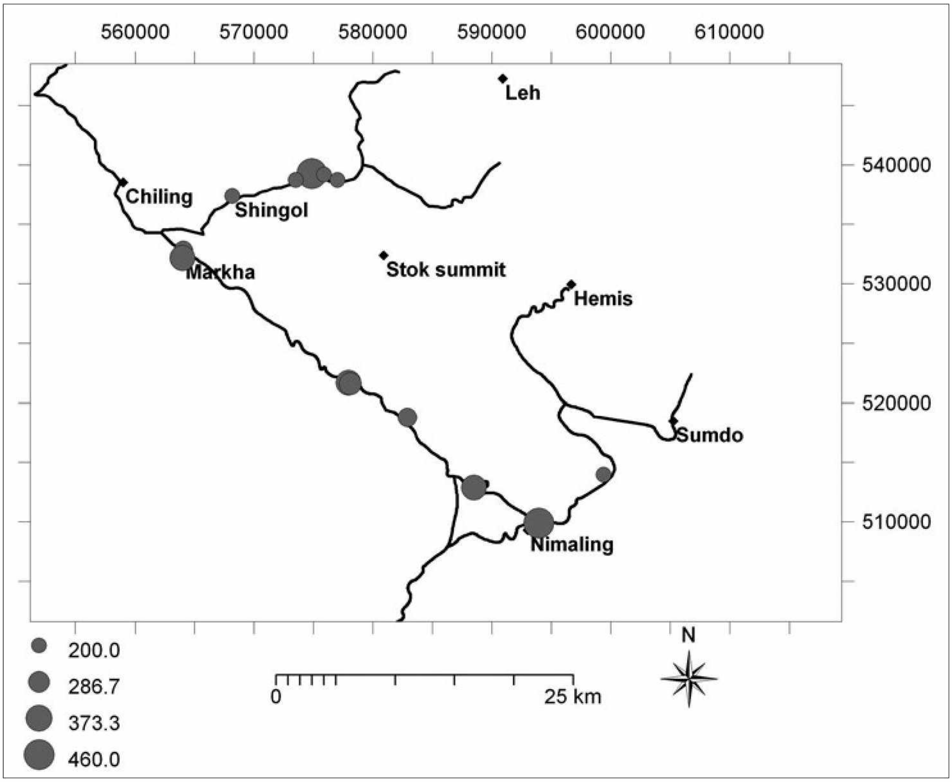

Figure 3: Dumping sites mapped along the Markha trail (dot size is proportional to estimated amount of waste in kilogram/tourist season).

recognised as dumping of waste along the trail, heavy inflow of human and pack animals and camping sites. Dumped material, for example, was assessed along the trail recognising that an average of 300 kilogram of waste material is dumped at several stopovers during each season (figure. 3).

The adverse impacts of stressors were overgrazing, soil erosion, groundwater pollution, trail degradation, habitat fragmentation, and habitat disturbance. GIS modelling was applied to spatially represent and assess each impact. For example, overgrazing by pack animals was assessed by first mapping grazing patterns of large herbivore mammals at sub-watershed level. Subsequently, areas prone to overgrazing were identified by considering slope and water distance, which are the major contributing factors for grazing in large herbivore animal (Ganskopp et al. 2004). These data were integrated with field data of pack animal inflow and grassland to exhibit the grasslands affected most by overgrazing (figure 4). Likewise habitat fragmentation and soil erosion were spatially assessed (Geneletti 2002, Saavedra 2004).

The study showed that high altitude pasturelands, fragile habitat components, and soil are most affected. The most critical activities are overgrazing, solid waste dumping along the trail, wildlife habitat disturbances and soil trampling. The study aimed

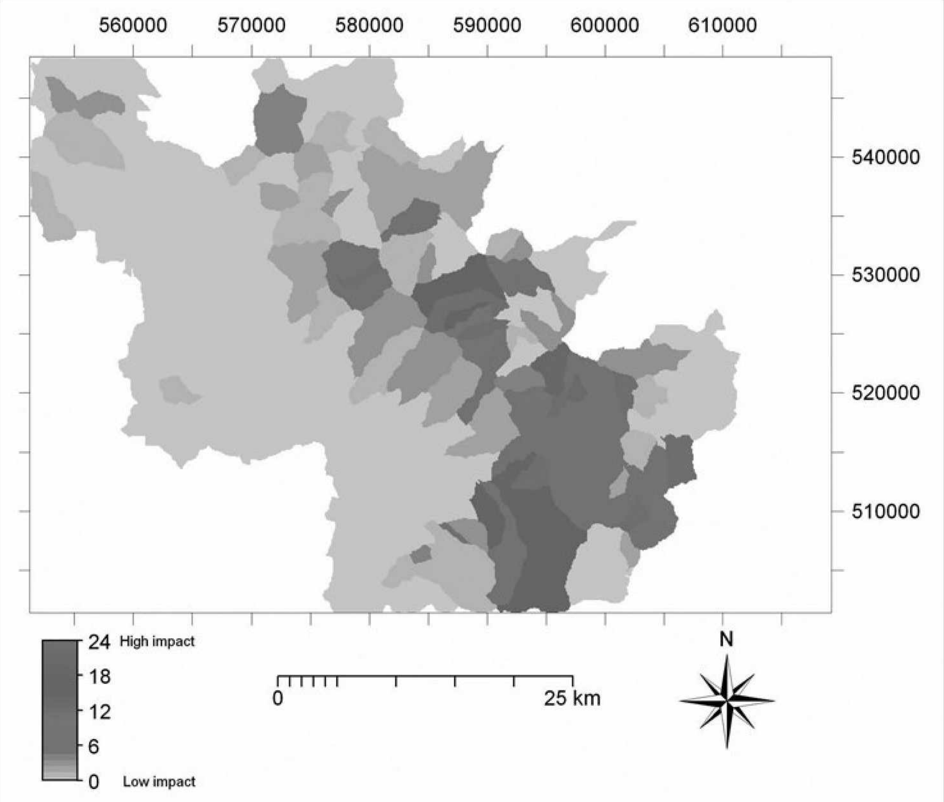

Figure 4: An example of impact map at sub-watershed level: overgrazing by pack animals (simplified legend for b/w representation).

at supporting decision-making in natural resource management, and particularly in the regulation and planning of tourism activities and infrastructures. The method is now being extended so as to model the impact of all operated trekking trails in the region of Ladakh.

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References

Bhatnagar, Y.V., R. Wangchuk, H.H.T. Prins, S.E. Van Wieren & C. Mishra 2006, "Perceived Conflicts Between Pastoralism and Conservation of the Kiang Equus kiang in the Ladakh Trans-Himalayas India", *Environmental Management 38,* 934–941

Bo, C. 1996, "NDWI – A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water From Space", *Remote Sensing of Environment 58,* 257–266

Chatterjea, K., (in press), "Assessment and demarcation of trail degradation in a nature reserve, using GIS: case of Bukit Timah Nature Reserve", *Land degradation and development*

Droz, H.B. & S. Dawa 2004, *Biodiversity of Ladakh: Strategy and action plan.* LEDeG, Sampark

Ganskopp D., R. Cruz & D.E. Johnson 2000, "Least-effort pathways? A GIS analysis of livestock trails in rugged terrain", *Applied Animal Behaviour Science 68,* 179–190

Geneletti, D. 2004, "Using spatial indicators and value functions to assess ecosystem fragmentation caused by linear infrastructures", *International journal of Applied Earth Observation and Geoinformation 5,* 1–15

Høyer, K.G. 2000, "Sustainable Tourism or Sustainable Mobility? The Norwegian Case", *Journal of Sustainable Tourism 8,* 147–160

Jade, S., B.C. Bhatt, Z. Yang, R. Bendick, V.K. Gaur, P. Molnar, M.B. Anand & D. Kumar 2004, "GPS measurements from the Ladakh Himalaya, India: Preliminary tests of plate-like or Continiuous deformation in Tibet", *Geological Society of America 116*, 1385–1391

Joshi, P.K., G.S. Rawat, H. Padilya & P.S. Roy 2006, "Biodiversity Characterization in Nubra Valley, Ladakh with Special Reference to Plant Resource Conservation and Bioprospecting", *Biodiversity and Conservation 15,* 4253–4270

Joshi, P.K., S. Singh, S. Agarwal, P.S. Roy 2001, "Land cover assessment in Jammu & Kashmir using phenology as discriminant – An approach of wide swath satellite", (IRS–WiFS), *Current Science 81*, 392–398

Lynn, N.A. & R.D. Brown 2003, "Effects of recreational use impacts on hiking experiences in natural areas", *Landscape and Urban Planning 64, 77–87*

Nepal, S.K. & S.A. Nepal 2004, "Visitor Impacts on Trails in the Sagarmatha (Mt. Everest) National Park", *Ambio 33,* 334–340

New, M., D. Lister, M. Hulme & I. Makin 2002, "A high-resolution data set of surface climate over global land areas", *Climate research 21,* 1–2

Rondeaux, G., M. Steven & F. Baret 1995, "Optimization of Soil-Adjusted Vegetation Indices", *Remote Sensing of Environment 55,* 95–107

Saavedra, C. 2005, "Estimating spatial patterns of soil erosion and deposition in the Andean region using geo-information techniques: A case study in Cochabamba", (PhD thesis, Wageningen University), Wageningen

Searle, M.P., K.T. Pickering & D.J.W. Cooper 1990, "Restoration and evolution of the intermontane Indus molasse basin, Ladakh Himalaya", *Tectonophysics 174,* 301–314

Sidjak, R.W. & R.D. Wheate 1999, Glacier mapping of the Illecillewet icefield, British Columbia, Canada, using Landsat TM and digital elevation data, *International Journal of Remote Sensing 20* 273–284

Singh, R.B. & D.K. Mishra 2004, "Green Tourism in Mountain Regions – Reducing Vulnerability and Promoting People and Place Centric Development in the Himalayas", *Journal of Mountain Science 1,* 57–64

Weinberg, R.F. & W.J. Dunlap 2000, "Growth and Deformation of the Ladakh Batholith, Northwest Himalayas: Implications for Timing of Continental Collision and Origin of Calc-Alkaline Batholiths", *The Journal of Geology 108,* 303–320

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