Transactions on Ecology and the Environment vol 50, © 2001 WIT Press, www.witpress.com, ISSN 1743-3541

Remote sensing of fluvial landforms in the Lar basin, Iran

K. Solaimani
Department of Watershed Management, Mazandaran University, Iran

Abstract

The Lar River basin in northern Iran is 780 km^2 in area, and reaches a maximum elevation of 5671m. It has a semi-arid climate and contains mountainous terrain, dissected by deep river valleys. The Lar valley has been dammed near Polour to provide a water supply for Tehran. The reservoir created by this dam is subject to sedimentation as bedload and suspended load is delivered from throughout the catchment. It is also subject to leakage due to being partly constructed on limestone terrain. To assist in management of the reservoir, information is required about erosion and sediment transfer processes in the basin. Field studies of these processes are made difficulty by the nature of the terrain and the basin size. A range of remotely sensed data types was thus to describe the landforms and vegetation of the basin, and subjected to field checking. In particular, stereoscopic images from the KFA-1000 platform and SPOT (XS) images were used. Quantitative assessment of the areas and thus volumes of this active erosion was difficult because of the range of sizes of features involved and the difficulty of measuring their depths. However, within each tributary valley, river terraces have been deposited which enable volumes of potentially mobile fluvial sediment to be identified. A geomorphological map based on aerial photographs and field checking suggested a total terrace area of 6.4% of the basin. The same area estimated from KFA-1000 images was 5.6%, and other data sources (SPOT, Landsat TM) gave appreciable under-estimates. Combining the information from the different data sources thus enables an overall assessment of erosional and depositional fluvial features to be made. This suggests that while, under present-day conditions the Lar reservoir may take c.5ka to in-fill with sediment, there is abundant temporarily stored and easily remobilised material within the catchment which could significantly decrease this life expectancy given relatively small changes in climatic conditions.

1 Introduction

Soon after remote sensing data became available, geomorphologists began using the images as a means of anticipating what they might encounter in the field and to plan the field campaigns. This quickly led to using remote sensing data as a basis of interpretation in their own right. During and following World War II in the 1940s and 1950s, the term landform came to mean (Belcher, et al. [1]; Way, [2]) the perceived covarianceís associated with landscapes that, when developed under similar conditions, exhibit similar "visual" patterns which allow their recognition on aerial photographs. Geomorphologists have been studied drainage patterns and their relationship to terrain conditions (Gregory and Walling, [3]). Several other works have documented the implicit influences of different rock properties and structures upon topographic relief (Yatsu, [4]; Sparks, [5]; Twidale, [6]; Day, [7]). In general, drainage density in eroding rock landscapes is a function of rock resistance to weathering, relief, and climate. Shales have drainage textures that are a relection of both topography and climate. Higher relief will generate a finer textured drainage. The relationship with climate is more complicated. It is the amount of protective vegetation cover (which can be correlated to temperature and precipitation) that significantly controls erosion and drainage density.

In general, drainage density indicates the prosity and permeability of the underlying material. Materials with good permeability generally have a medium to coarse drainage density. Such materials include sandstones, terrace geravels, limestones, talus slopes, volcanic ash, beach and dune sands. Any precipitation that falls on these materials either infiltrates it or is carried off in a sparse network of surface drainage. The end members of these materials are extensive dune sands and karsted limestone plains, which may have no integrated surface drainage. Drainage channel patterns give clues about the associated geology. Braided channels indicate easily erodiable, coarse-grained materials. Meandering channels suggest medium to fine-grained materials. Narrow, relatively straight drainage courses suggest resistant materials. Abrupt changes in channel pattern or drainage patterns indicate changes in geologic conditions. Most changes in channel type indicate changes in the materials that make up the bank.

2 Methods

There was considerable activity by Latham [8] and Simpson [9], Lillesand and Kiefer [10] and Twonshend [11]. The application of remote sensing is increasing all the time, but is especially valuable in the initial reconnaissance stage of terrain analysis. Remote sensing shown its greatest value where fieldwork was difficult. In this research KFA-1000 images, aerial photographs, Digital Landsat TM and SPOT data were used for stereoscopic and digital image analysis. The remote sensing interpretation of the geomorphological changes of the study area formed a part of an extensive investigation in the field. Therefore field investigation of landforms was an important part of this work. The field investigation techniques were developed and modified over three months in

1999. The selection of field sites follows those used for remote sensing techniques to allow direct comparison attempt.

3 Landforms on sedimentary rocks

Sedimentary rocks in the Lar basin consist of material deposited by or from surface water and weathering. Consequently, they are layered, and in most instances, the layers were initially nearly horizontal. The volumes of rocks that ice and wind have deposited are far smaller than those that accumulated in aqueous environments. However, the wind and ice deposits have specific characteristics that are important to understanding geologic history and also have engineering and economic implications. Although nearly flat-lying at deposition, subsequent deformation and large scale solution collapse may subtly or profoundly change the geometric configuration and orientation of the horizontal layers, by bending, tilting, folding, and breaking them. Uplift and deformation also produce pervasive fracturing. The more brittle units preserve these fractures as discrete fabric elements. At or near the surface, these features become the loci of more intense weathering and erosion, which can impart a distinct pattern to the landscape.

Sandstone is a clastic sedimentary rock consisting of angular to rounded sand grains that are consolidated and cemented by various minerals. In many area (e.g. Chehel Cheshmeh, Marghehsar-Kuh and northern parts of the basin) it occurs interbedded with other sedimentary rocks but many form depositional packages hundreds of metres thick. Sandstones are waterlaid sediments in the Lar basin. Most sandstones which accumulated in the near-shore zone of the former Lar lake or in stream or river channels.can be traced on Shemshak formation (Jurassic). Sandstones exhibit rare vegetable remains, which are referable to: *Pachypteris shemshakensis* Barnard, and Podozamites cf. *schenki* Heer (Barnard, [12]). The total thickness of the Shemshak Formation is about 1000m. Sandstones are classified according to textural and lithologic compositions as well as cementing agents. Coarse sandstones grade into conglomerates; fine sandstones grade into sandy shales, siltstones and mudstones. Cementing agent bind the particles during lithification, and the composition of the cementing agent influences the rock's resistance to weathering and erosion. Most sandstones are resistant rocks regardless of climatic setting. This is reflected by the amount of variation in drainage density in different settings of topographic relief or climate change. Most surfaces are light coloured with some banding and sparse natural vegetation cover. These rocks develop little soil in the Lar basin because wind and water erosion remove particles and deposit them elsewhere. The spectral characteristics of this formation on KFA-1000 images and gray SPOT images show that the slopes of pure sandstone are generally light-toned, but the overall spectral response over the formation can be highly variable, depending upon the presence of other minerals, weathered soil cover, vegetation and structural orientation (Figures a and *b*).

Shale is a general term for lithified fine grained muds that are fissile, meaning they break along planes. Shales are the most common sedimentary rock, covering about half of the earth's landsurface. Black shale with sandstone can be fined in the Lar, Sefid-Ab and Dalichai upstream with coal streaks and many plant remains. Because of their low permeability and compactness, most area in the Lar basin have high surface runoff. Therefore this characteristics greatly influenced and controlled the rates and intensity of weathering and erosion processes in study area. In most places, the rock is really hard enough for joints and faults to expressed in the study area, though larger joints and faults my be discenable in some locations. In some areas, shale terrains develop a badlands topography with a fine-textured dendritic drainage pattern (KFA-1000 image).The vegetation cover is sparse but in some area appear banded on hillsides reflecting differences in soil moisture (Figures a and b).

Limestones are widely distributed in the Lar basin. Limestone landforms cover approximately 7% of the exposed earth's land surface which is covered about 20% of the study area and exhibit different colours, depending amount and type of contained impurities. The surface pattern consists of short stream segments that end at surface depressions. Acidic waters seeping along joined and bedded planes dissolve the rock to form sinkholes and subterranean channels (e.g. between Dalichai and Sefid-Ab; Figures a and b). The number of holes has significantly increased after construction of the artificial dam, and they are able to deliver water and sediments to the Lar River via subsurface channels. Two mentioned sinkholes were detected on KFA-1000 and aerial photographs and field inspection in July 1994 and June 1999 which give flowing formation:

Table 1: Geometric changes of sinkholes (1994-99).

Sinkhole number	Year	Diameter/m.	Depth/m.
1	1994	27.7	15.5
	1998	58.6	10.8
2	1994	16.9	12.3
	1998	26.3	9.5

4 Channels morphology

Drainage patterns of the main streams in the Lar basin can be clearly identified from the imagery. Meandering between the Lar/Khoshkehlar junction and Gozaldarreh station and a distributory pattern consisting of several channel branches that originated from the same source appears close to Lar lake between Kamardsht and Gozaldarreh. In the Lar downstream after Kamardasht, lower stream gradients produce braiding on the flood plain. In same area before Gozaldarreh a braided pattern is controlled by the load carried by the Lar and marked by a shallow channel separated by islands and channel bars. Figures *(a)* and *(b)* from Landsat and SPOT 3 band composite images show the channel morphology of the Lar tributary. The landforms associated with fluvial erosion in the Lar are gorges and V-shaped valleys, which are identified on stereoscopic KFA-1000 (Lar down stream after Dam and the middle part of Dalichai). Typical depositional landforms including fans, alluvial plains, natural levees, river terraces and meander scars, can all be seen in the Lar sub-basin on stereo view of KFA-1000 and aerial photographs.

Transactions on Ecology and the Environment vol 50, © 2001 WIT Press, www.witpress.com, ISSN 1743-3541

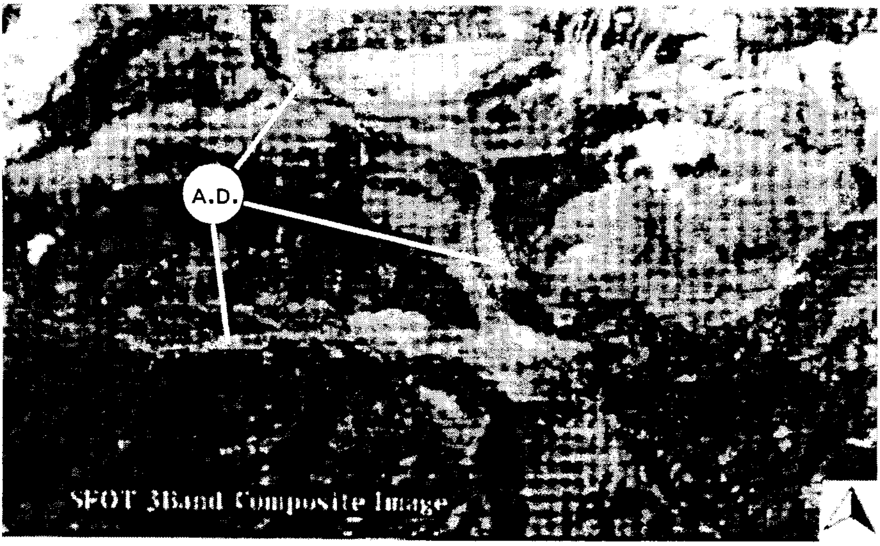

Figure a: Spot 3B composite of the Lar upstream,
A.D. = ancient deposits shown in lighter areas
Dark lines in river channels are recent deposits

Figure b: Landsat TM 3B composite (1,3 & 7) of the Lar downstream,
Dark line in river channels and also on slopes shows recent deposits

5 Conclusion

An important application of remote sensing data is in detection of dynamic features, such as changing in planform and migration of the rivers and delineation of paleochannels. Sediment transport from the erodiable surfaces upstream and also from river banks in the middle and downstream is widespread and in some areas of the Lar and Khoshkelar, deflects stream flows. Surface erosion has created landforms much larger than a pixel size in the Lar basin such as areas of bare soil, alluvial deposits and rills. Therefore detection of surface changes was impossible by means of their brightness values alone and indirect evidence was used such as larger scale data and field checking. Both of Landsat and SPOT data were the most useful especially in 3 band colour composite images (Fgures a and b), and also the maximum likelihood method for detection of landforms in the Lar basin.

References

[1] Belcher, D.J., Liang, T., Costello, R.B., Fallon, G.L., Hodge, R.J., Ladenheim, H.C., Lueder, D.R., and Mollard, J.D. A photo-Analysis key for the Determination of Ground Conditions. Cornel University. Land Form Series Technical Report No. 3, 6 volumes. Prepared for U.S. Office of Naval Research, 1951.
[2] Way, D.S. *Drainage density: a function of rock poroperties, relief, and climate.* Ph.D. dissertation, Clark University, Worcester, Massachusetts, 1982.
[3] Gregory, K.J. and Walling, D.E. Drainage basin form and process. New Yourk: Halstead Press, 1973.
[4] Yatsu, E. *Rock Control in Geomorphology.* Tokyo: Sozosha, 1966.
[5] Sparks, B.W. *Rocks and Relief.* St. Marlin's Press. New York, 1971.
[6] Twidale, C.R. *Structural Landforms.* Australian National University Press, 247p., 1971.
[7] Day, M.J. Rock hardness and landform development in the Gunong Mulu National Park, Sarawak, E. Malaysia. in Earth Surface Processes and Landforms, vol. 6. P. 165-72, 1981.
[8] Latham, J.P. Remote sensing of the environment. *Geogr. Rev.* 56, 288-91, 1966.
[9] Simpson, R.B. Radar, geographical tool. Ann. Assoc. *Am. Geogs* 56, 80-9, 1966.
[10] Lillesand, T.M. and Kiefer, R.W. *Remote sensing and image interpretation.* John Wiley and Son. New York, 1994.
[11] Townshend, J.R.G. (ed). *Terrain analysis and remote sensing.* London: George Allen & Unwin, 1981.
[12] Barnard, P.D. Flora of the Shemshak Formation. *Ital. Paleont. Strat.,* 71(4), Milano, pp. 1123-1168, 1965.