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Potential of satellite based sensors for studying distribution of archaeological sites along palaeo channels: Harappan sites a case study

M.B. Rajani [a,*], A.S. Rajawat [b]

[a] National Institute of Advanced Studies (NIAS), Indian Institute of Science Campus, Bangalore 560 012, India
[b] Space Applications Centre (SAC), Ambawadi Vistar P.O., Jodhpur Tekra, Ahmedabad 380 015, India

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ABSTRACT

A large number of remote sensing based studies have shown evidence of a prominent river system, which has become buried under sand cover of Thar Desert sometime during late Holocene. This major river has been identified as *Sarasvati*, a legendary river mentioned in ancient Indian texts. This region is rich with archaeological sites of Harappan civilization (2500–500 BC). The present study has utilised digital image processing and enhancements techniques on multisensor satellite data followed by field investigations to reconfirm known traces and detect hitherto unknown traces of palaeochannels of Sarasvati river through parts of Indus alluvial plain in Thar desert. Potentials of IRS-P4 OCM (Primarily an Ocean Color Sensor, with eight narrow spectral channels, high radiometric resolution of 12 bits and large swath of 1420 m) could be exploited for the first time to detect hitherto unknown traces of palaeochannels of Sarasvati river through sand dune topography of Thar desert in parts of Western Rajasthan in India and adjoining parts of Pakistan by applying Principal Component Analysis technique. Pattern of palaochannels indicate westward migration of the Sarasvati river in parts of Indus alluvial plain. Database of more than 1000 archaeological sites compiled from various published sources, prepared in GIS environment could be utilised to understand their relationship with identified courses of the Sarasvati palaeochannels. Through this study it was found that there is a large spread of Mature Harappan (2200–1700 BC) sites along the palaeochannel of the Sarasvati and its tributaries in north-west India, but late Harappan (1700–1500 BC) sites are limited to further west in adjoining regions of Pakistan indicating that the shift of cluster of settlements have followed the pattern of river migration towards west. Digital terrain modelling by superimposing archaeological sites on SRTM DEM along with draped satellite data (Resourcesat-1 AWiFS and IRS-1D LISS-III) has helped in identifying geomorphological guides for archaeological investigations such as presence of relict natural levees seen as raised mounds and coincidence of known archaeological sites over them. It is suggested that other relict natural levees or raised mounds adjoining the identified palaochannel courses may be taken up for further archaeological exploration.

1. Introduction

The region of northwestern India (covering the states of Punjab, Haryana, Gujarat and Rajasthan) and flood plains of river Indus and its tributaries in Pakistan is geographically diverse, geologically active and rich in archaeological sites of the Harappan civilization (2500–1500 BC). In the past few decades a large amount of work has been carried out to map palaeochannels in this region using multi-sensor satellite data and to understand their migration and evolution (Ghose et al., 1979, 1980; Pal et al., 1980; Sood and Sahai, 1983; Ramasamy et al., 1991; Rajawat et al., 1999a,b, 2003; Rajawat, 2005). These studies have shown evidence of a prominent river system, which has become buried under the sand cover of Thar Desert sometime during late Holocene. This major river has been identified as *Sarasvati*, a legendary river mentioned in ancient Indian texts including the *Rigveda* (Griffith, 1889: 6.62,2–13). The Sarasvati river is inferred to flow from Himalayas to Arabian Sea through present states of Punjab, Haryana, Rajasthan, and, in Pakistan, Bahawalpur and Sind.

Fig. 1 shows IRS-1C WiFS mosaic providing a synoptic view of the study area covering Indus basin and the Thar desert. Large

* Corresponding author. Tel.: +91 80 22185140; fax: +91 80 22185028.
E-mail addresses: rajanihf@gmail.com (M.B. Rajani), asrajawat@sac.isro.gov.in (A.S. Rajawat).

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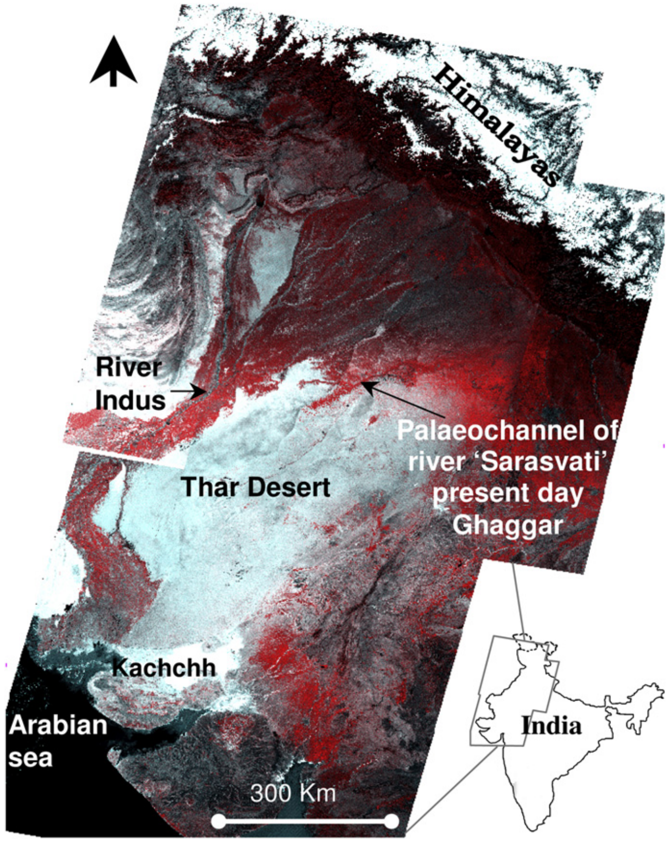

Fig. 1. IRS-1C WiFS mosaic providing a synoptic view of the stud area covering the Indus basin and the Thar desert.

portion of the study area appears as light bluish to white tone due to the presence of aeolian sand. However, the synoptic cover in this data distinctly shows the pattern of palaeochannels in north-western India and adjoining parts of Pakistan. Present day dried Ghaggar bed is identified as palaeochannel of the river Sarasvati.

The present study aimed to analyse multisensor satellite data using digital interpretation techniques in conjunction with Geographical Information System (GIS) to reconfirm as well as identify hitherto unknown palaeochannels in the Indus basin in particular Thar desert and correlate with spatial distribution of Harappan settlements. The study also aimed to utilise 3 D View of the terrain using SRTM DEM in conjunction with enhanced satellite data to identify geomorphological guides for archaeological exploration.

2. Materials and methods

Multisensor satellite data was used for the study. The salient characteristics of satellite data utilized in this study are listed in Table 1. Image processing software primarily used for this study is ERDAS IMAGINE and ENVI. First of all geometric corrections were carried out using Ground Control Points (GCPs) from corresponding topographical maps for AWiFS, WiFS, OCM and LISS-III data. Digital mosaic was made using AWiFS and WiFS data and SRTM DEM data for the entire Indus basin and the Thar desert region. First of all, attempt was made to identify known palaeochannels of the Sarasvati river on the basis of published sources based on the following interpretation criteria: (i) drainage channel like shape, (ii) usually vegetated regions, (iii) regions normally associated with moisture, (iv) presence of fluvial sediments, (v) low depression areas, (vi) association with abandoned fluvial landforms, (vii) association with lineaments and (viii) absence of drainage on topographical maps. Subsets from Resourcesat-1 AWiFS and IRS-P4 OCM were made for the northern (northern parts of Rajasthan and adjoining regions) as well as the southern parts (deltaic region in the Rann of Kachchh). It was observed that among various digital image processing techniques, Principal Component Transformation technique provided distinct patterns of palaochannels. PC transformation was carried out for subsets of Resourcesat-1 AWiFS and IRS-P4 OCM data. Various combinations of PC images were used for generating colour composites and based on the clarity of palaeochannel patterns, optimum combinations were chosen. These were further enhanced by contrast stretching.

Principal components analysis (PCA) was used as a method of data compression. It allowed redundant data to be compacted into fewer bands – that is, the dimensionality of the data was reduced. The bands of PCA data are non-correlated and independent, and are more interpretable than the source data. In the PCA most of the variance in multispectral data is compressed into the first few PC images, noise is generally relegated to the less-correlated PC images. Spectral differences between materials may become more apparent in PC images than in individual bands.

The PC transformation is used to decrease the amount of correlation between bands of data and maximize the differences between bands. In most images the transformation content of adjacent bands is nearly identical (highly correlated). A three-dimensional plot of reflectance values in three bands (displayed as red, green, and blue, and known as "RGB" space) would generate as ellipsoidal cluster of points. The tightness of this cluster is an indication of the redundancy of the datasets. The PC transformation generates a new set of orthogonal (uncorrelated) axes in space such that the principal axis is oriented through the long dimension of the ellipsoid, and the secondary and tertiary axes define correspondingly smaller distributions or densities of data points. This transformation can be performed on any number of channels and will generate axes in n-space where the n axes correspond to the number of input bands. Generally speaking the first principal component contains the brightness information of the image, the second, third, etc., components contain progressively less information and the last components tend to contain first the systematic and then the random noise in the image. One can create a color image using any three components. Usually the first three components are used. The second and the third component reveal subtle difference in surface materials.

Contrast enhancement modifies the gray scale to produce a more interpretable image. One is required to inspect the original histogram and then determine the elements of the scene that are of greatest interest. Then one chooses the optimum stretch for his requirements. The purpose of a contrast stretch is to:

Table 1
Salient characteristics of satellite data utilized for the study.

Resolutions	Resourcesat-1 AWiFS	IRS-P4 OCM	IRS-1C/1D WiFS	SRTM DEM
Spectral channels (nm)	B1 520–590 B1 620–680 B2 770–860 B3 1155–1700	B1 402–422 B2 433–453 B3 480–500 B4 500–520 B5 545–565 B6 660–680 B7 745–785 B8 845–885	B1 620–680 B2 770–860	
Spatial (m)	56	360	188	90 m
Swath (km)	740 (from two cameras)	1420	780	–
Quantisation (bit)	10	12	8	