Satellite image and India's past

M.B.Rajani[1] and K.Kasturirangan[2]

[1]NIIT University (NU), Neemrana, Alwar District, Rajasthan - 301705, India. Email: rajaniphd@gmail.com

[2]National Institute of Advanced Studies (NIAS), IISc Campus, Bangalore 560012, India

Abstract:

Since 2005 research in the field of remote sensing and GIS applications for archeology has been conducted at the National Institute of Advanced studies (NIAS), Bangalore. Specific investigations on several case studies have been undertaken. This article will elaborate on the nature of this technology and its use to archaeology, the status of research in this field internationally and the role of our country in it, infrastructure and expertise requirements, and then it will briefly describe specific case studies and results of the investigation.

An Overview Of Contemporary Advances In The Use Of Space Techniques For Archaeological Exploration:

In the human history, one of the earliest breathtaking views of our earth from space must be the rising Earth seen by Apollo 8 astronauts in 1968 as they came from behind the Moon. This is a landmark event in earth observation from space. Though one already knew that earth would look blue from outside, the image that Apollo 8 astronauts saw and photographed graphically shows earth as a lonely object looking like a tiny blue marble against the dark background of space. Until then, how earth would look from outside was a concept or an idea and left to people's imagination. But an image allows one to visually perceive what was till then a concept. This perception brings life into the concept and allows one to quickly understand the subject or its condition better. It is a spectacular experience to see a whole body of information projected in the form of one visual. Such a picture clarifies many conceptions about the area that may have been disconnected and distorted in one's mind. Several later observations by astronauts on space flights, or scientists analysing earth's images taken from space have reported with excitement seeing the Great Wall stretching across the mountains of China and the Great Pyramid adorning the Giza plateau west of river Nile. In case of archaeological sites, apart from seeing features that depict some object or phenomena, it also displays another dimension: time. Time in human history, showing something that was!

Launch of Sputnik on October 4th 1957 heralded a new era for the mankind by throwing open the access to the vantage point of space. Over the last more than 50 years space has opened up new vistas in communication, broad casting, remote sensing for earth resources survey, navigation and position fixing, meteorology, as well as space exploration for scientific investigation (Kasturirangan et al. 1998). One of the key developments in this connection is the advent of remote sensing, a capability to image the earth from space. This has opened up several new possibilities of understanding earth's land, ocean and atmosphere. The present article specifically addresses application of space based imaging for archaeological research. But applying satellite image for archaeology is not simple. As Sever and Wiseman (1985), early scholars of remote sensing archaeology very pertinently recognised, that for a successful application knowledge of archaeology alone is not sufficient: In their words "Successful application of this technology requires an integrated approach. A knowledge of the specialized field of interest, such as Pre-Columbian Maya architecture, is not adequate. In using remotely sensed data one must integrate aspects of ecology, radiation transfer mechanisms, atmospheric physics, computer science, mathematics, and sensor technology -- in addition to one's area of archaeological expertise -- in order to be successful". To this list, the present author would add mapping/cartography as this is essential for integrating multiple layers of geo-spatial information using Geographical Information System (GIS).

With the initiation of Landsat series of earth observation satellites by NASA in 1972, the earth could now be viewed through various bands of the electromagnetic spectrum as a patchwork of many colours. Researchers gradually realised that these images were of value to many disciplines including archaeology. Aerial and space photography for archaeological purposes have had dramatic success in many parts of the world (Ben-Dor et al.1999, Challis et al. 2004, Holcomb 2001, James 1995, Kouchoukos 2001, Pope 1989, Trumpler 2005, Williamson 2002, Tripati 2005). The book *Remote sensing in archaeology* (2007) edited by James Wiseman and Farouk El-Baz, is one of the first volumes of its kind in this emerging field. It is a collection of articles that deal with remote sensing techniques, from ground, air and space, being used for archaeological exploration, with authors and case studies from around the world.

The book *Satellite remote sensing for archaeology*, authored by Sarah Parcak presents case studies from Asia, Central America, and the Middle East, including Xi'an, China; Angkor Wat, Cambodia and Egypt's floodplains (Parcak 2009). This book provides a detailed survey of the history and development of the field through chronological review of publications, connecting satellite remote sensing in archaeology to broader developments in remote sensing technology, archaeological method and theory, cultural resource management, and environmental studies. The book also discusses all of the major conferences in the field of remote sensing archaeology held world wide, starting from the first conference sponsored by NASA in 1984 called "Remote Sensing and Archaeology: potential for the future". In October 2004, the 'First International Conference on Remote Sensing Archaeology' was organised by the Chinese Academy of Science in Beijing and hosted by the Joint Laboratory of Remote Sensing Archaeology (JLRSA). In that context, an international team of experts was created in order to promote multidisciplinary activities of remote sensing archaeology in the entire world. In December 2006 the 'Second International Conference for Remote Sensing Archaeology' was held in Rome, Italy, at the National Research Council. The third conference in this series was held in India at Tiruchirappalli, jointly organised by Bharathidasan University, University of California, Merced and Berkeley, University of Siena (Italy) and by the

REACH Foundation, Chennai. Around 70 papers were presented in this conference covering the many topics:

- Aerial archaeology;
- 3D remote sensing: technologies and archaeological interpretation;
- Close-range aerial photography;
- Ground-based sensing archaeology;
- Integrated remote sensing technologies for the interpretation of landscape ecosystems;
- Issue of archaeological interpretation of remote sensing data;
- Cyber archaeology and 3D landscapes visualization through the time;
- Issues of quality framework in archaeological remote sensing;
- Experience of archaeological remote sensing from commercial sector;
- special session was devoted to huge projects on digital cultural atlases and National and Trans-national projects on historical GIS.

There have been earlier initiatives in India to promote use of remote sensing for archaeology. In the past few decades, large amount of work has been carried out to map palaeochanels in northwest India using multi sensor satellite data and understand their migration and evolution. These studies have shown evidence of a prominent river system, which has become defunct and buried under sand cover of Thar Desert sometime during late Holocene. This major river has been identified as '*Sarasvati*', a legendary river mentioned in many ancient Indian texts and epics. Also hundreds of sites belonging to Harappan civilazation are to be found on the banks of these palaeochannels. National Remote Sensing Cente (NRSC) Hyderabad, conducted a training programme to introduce remote sensing technology and applications to archaeologists from all over India in March 2000. A special issue on archaeological applications of remote sensing was published by the bulletin (June 2001) of NNRMS (National Natural Resources Management System), Department of Space, Government of India. This issue comprised of fourteen articles covering methods for detection of sites and palaeochannels. More recently a major project of preparing GIS database of Hampi in Karnataka was undertaken by RRSSC-B (Regional Remote Sensing Service Centre, Bangalore). A group of scientist in NRSC have used optical remote sensing imagery to map ruins in and around the Buddhist site of Nalanda in Bihar (Kamini et al. 2007).

In 2007, representatives of two Italian research institutes (IMAA, and IBAM) of the National Council Research (CNR) created the EARSeL (European Association of Remote Sensing Laboratories) Special Interest Group (SIG) on Remote Sensing for Archaeology and Cultural Heritage (Re.Se.Ar.C.H.). The SIG was formally launched in June 2007 at the annual EARSeL Symposium held in Bozen. Since then, the group has tried to foster interaction among archaeologists, scientists and managers interested in using remote sensing data (from ground, aerial and satellite) and Information Technologies to improve traditional approach for archaeological investigation, protection and management of Cultural Heritage. In the context of the EARSeL Re.se.Ar.C.H. activities, the 1st International Workshop "Advances in Remote Sensing for Archaeology and Cultural Heritage Management" was held in Rome from 30 September - 4 October 2008. The deliberations of this conference is discussed in some detail herewith because of active participation by the author of this thesis in the conference and also the discussions in this conference highlighted many salient points regarding the state of the field in a global context and problems in pursuing research in this field for scholars coming from relevant fields.

During the four days of the workshop around 100 papers were presented and discussed by over 244 authors (109 registered participants who attended the workshop) coming from 25 different countries. A variety of issues, applications and study cases emerged from the papers. The Proceeding (Lasaponara and Masini, 2008) book includes 93 papers divided in 9 sections which focus the following topics:

- Satellite imagery for archaeology: data processing methods and study cases;
- Aerial archaeology from the historical photographs to multispectral and hyperspectral imagery;
- Active airborne and satellite sensors (lidar, SAR): Data processing and applications;
- Sub-surface reconstruction based on GPR, magnetic and electrical tomography for archaeological research;
- 3D visualization and Virtual reconstruction of landscape and sites;
- RS and GIS based method application for cultural heritage management and documentation;
- Landscape archaeology and palaeo-environmental studies based on remote sensing, GIS and ICT;
- International Archaeological missions as outstanding ‘laboratories’ of archaeological Science

Indian representation in the workshop constituted of five papers that were presented and also published in the proceedings. Out of which four papers are an out come of collaboration between National Institute of Advanced Studies, Bangalore, and various centres of ISRO (SAC, ADRIN, NRSC, IIRS), together with discussions with archaeologists from Department of Archaeology and Museums, Mysore.

At the concluding session of the conference a summary of the performance of the conference was discussed together with emerging points indication the current state of this subject, its advantages and limitations. One of which is the huge technological disconnect between the understanding of practitioners of conventional methods for archaeological studies and remote sensing experts. Some of the questions emerging from this workshop are: Is the modern remote sensing an answer to the questions of conventional archaeology? There seems to be a gap between archaeologists and technical experts in particular remote sensing. Is there a technological over kill? Or should the technological mission be better communicated? How to bridge the gap? One of the important points arising from workshop is that some have found that even very high resolution is not enough for archaeological application. At the same time, others have demonstrated usefulness of medium and coarser resolution for same application. Therefore, what would be an optimal spatial, spectral and temporal resolution for archaeological application is subject to further discussion and research.

It is important to remember that remote sensing may not answer all questions that are asked in conventional practice. There may be questions that one has not been able to ask so far due to limitations in technology. Remote sensing may provide opportunity to pose new questions.

Infrastructure And Inter-Institutional Framework Adopted For The Present Study:

India is very rich in its cultural heritage. It houses thousands of archaeological sites spread across the whole country. It also has a large archaeological community involved in diverse activities connected to heritage preservation and research. A new tool like remote sensing and GIS has high potential for objectives of the ongoing work of the archaeological community. These tools and methods help in establishing certain facts about the sites that may not be possible to achieve from other conventional methods. However these techniques and tools are not fully exploited so far as their use for archaeological research in India is concerned. Further even in the global context this direction of research is in the early evolutionary stage as is evident from the details of earlier review. Application of remote sensing involves several diverse activities and calls for expertise in many disciplines. In order to accomplish all the objectives of the present study a unique network involving specific interfaces between several institutions was developed. To be more specific, the acquisition and pre-processing of the imageries is done by NRSC of the Department of Space (DOS), the image processing and analysis algorithms are either available as open source or with institutions who develop it for their purpose, and, planning and exploration for data collection at ground level in archaeological sites calls for support from Archaeological department. These are three important category of Institution that feature in this kind of work.

One of the early steps in this connection was the setting up of an image-analysis and GIS system that involved specification of capabilities in terms of hardware and software. As a part of present work reported in the thesis an agreement was reached with DOS to support such facility at National Institute of Advanced Studies (NIAS). Coming to the other dimension of the present work involving acquisition of remote sensing imagery the necessary interfaces were developed. NRSC archives and distributes IRS (Indian Remote sensing Satellites) images and also archives data from other satellites. The archive catalogue for which is available online (http://www.nrsc.gov.in/). For acquiring imagery one has to become familiar with the methodology of providing the necessary specification in order to define the geographical coordinates of the study area, choice of satellite/sensor (which will be governed by the spatial and spectral resolutions required for the study) and date/season of preferred observation. Once such specifications are given, the interactive website lists all the images that conform to the given requirements. Among the available images, suitable ones can be selected whose satellite/sensor, path, row and date have to be noted and quoted for ordering it from the Data Centre. After acquiring standard data on CD-ROMs most of the analysis were conducted in the facility at NIAS. A few specialized techniques in image processing, interpretation and analysis were realised through interface with outside institutions including Space Applications Centre (SAC), Advanced Data Processing Research Institute (ADRIN) and Indian Institute of Remote Sensing (IIRS).

Parallel to these activities regular interaction was made with archeologists in the Department of Archaeology, Karnataka, particularly for planning and execution of field visits to Talakadu for verification and GPS survey. Lastly, some of the sites also needed some unique inputs from historians for interpreting the data.

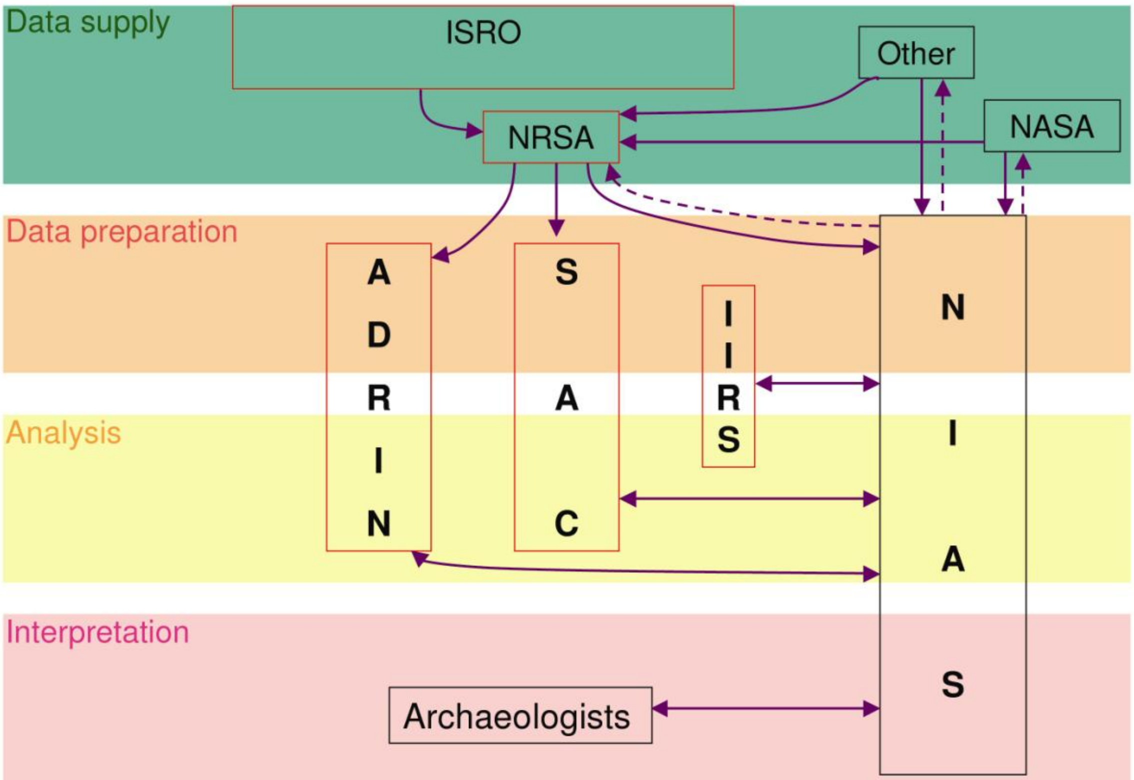

Figure-1: Inter Institutional Interfaces

Above is a brief description of the network and interfaces involved in the execution of this research, which is illustrated in Figure-1. It also describes a model that can be adopted for future projects.

Case Studies:

The work on the present case studies focused on the use of space technology to explore archaeological sites from the point of view of the advantages it provides such as synoptic view, multi-spatial, multi-spectral and multi-temporal resolutions. Further the work involved integrating these outputs from the analysis of the space imageries with results of conventional archaeological investigations. Such a unique approach enabling:

- Spatial relationships between known areas of the site with adjacent unknown area
- Investigate the dynamic changes in a particular site induced by natural or anthropogenic causes and in different time scales.
- Detect subtle features not identifiable in single wavelength bands.
- Evaluate the topographical features to understand cultural aspects.
- Ultimately create a GIS for the site enabling the integration of spatial and non-spatial data for visualization

The sites have been categorized into three broad classes depending on characteristics dictating specific choice of imagery and analytical tools to understand the unique features of the sites not discernable by conventional approaches.

The first category of case studies deals with detection of vegetation marks revealing archaeological features. Bengaluru, Belur, Halebidu and Somanathapura were chosen as their historical accounts mention presence of fort/wall or moats which at present cannot be detected by conventional exploration. This study has for the first time identified in these sites circumscribing moats indicating the boundary of the site, which could be detected through patterns formed by vegetation (Rajani 2007, Rajani and Settar 2010). It was also found that such signatures are prominent in medium spatial resolution (5.8m) multispectral images especially with a combination that include infrared band. Vegetation patterns of a much larger feature, i.e. palaeo-channels of river Sarasvati, which is of interest to archaeology, could be detected on coarse resolution image (~56m to 360m) covering a large swath. This work was further extended using GIS, to map Harappan site-distribution along the channel by overlaying locations of sites of two different periods. This study for the first time has established that the shift of cluster of settlements is in the same direction as the established shift of river migration (Rajani and Rajawat 2011). It would not have been possible to draw this conclusion using conventional approaches of archaeology.

The second set of case studies is based on using 3D models for sites in undulating areas. Badami was chosen as representative of such sites. This work suggested that Cartosat-1 data produced the best DEM compared to two other methods; however the other methods were also analysed because these can be employed if stereo data is not available or not accessible in some cases. This work also demonstrated application of 3D visualization, virtual fly-through and visibility analysis for archaeology which is of importance for Cultural Resource Management (Rajani et al 2009). The study on Mahabalipuram led to understanding the implication of sea level changes on coastal archaeological sites. DEM was used to generate 3D landscape of this area and simulate flooding at raised sea levels. Coastline and adjacent seven monuments as illustrated in an old map dated 1670 AD were compared with 3D model generated using recent satellite imagery. This study provides an alternative explanation for the mystery of the name Seven Pagodas for this site by identifying seven temples that constituted this term, which were marked on the old map (Rajani 2009).

In the third case the composite approach from methods used in first and second sets led to studying a single site Talakadu applying several techniques, which included optical data of multiple dates, microwave data, stereo data and also ground truth. The main outcomes of this study are identification of four features including a canal that irrigated the old township, the command area of the canal, a reservoir and a bund or fortification that protected the site on its west (Rajani and Patra 2009). Radar data detected a palaeo-channel showing an older course of the river (Rajani et al. 2011), and DEM of this area allowed topographical and flooding analysis giving an overall understanding of the terrain. This work has adopted a unique approach by analyzing imagery of multiple spatial resolutions, different spectral bands and many dates for the same site, which called for accurate georeferencing of all the imagery. This study further highlighted the importance of georeferencing without which analysis of multiple image layers would not be possible. Moreover the extensive use of GPS further reiterates the importance of common georeference. The GPS tracking during ground visits has shown a new way of recording archaeological expedition which can help making field notes in a less laborious and more accurate manner.

Conclusions:

Extensive investigation of this multitude needs different kinds of facilities and expertise in several areas. This effort therefore called for developing appropriate interfaces between Space Research organizations, archaeological Department and academic Institutions. The model, as adopted in the present study to deal with such a multi-dimensional activity, required developing and establishing institutional framework having both scientific and procedural interfaces. Any extension of such a type of work as reported here, to integrate space capabilities with conventional archaeological procedures for a National operational programme, can benefit from the present experience.

The presented techniques for each case study are only some of the many possibilities that remote sensing technology has to offer for archaeology. These studies can be further developed by using higher spatial resolution, and observation in varied spectral regions like middle infrared, thermal and microwave bands and also hyperspectral imagery. The underlying role of spatial spectral, temporal, radiometric resolutions have to be understood for which remote sensing will have to be applied more widely. Adequate usage and application is dependant on RS data availability and data policy, which is an important issue. In this connection, India’s impressive constellation of Remote Sensing satellites could be a potential source for data. Out of this data, an interesting India image portal called Bhuvan has been created which could be of interest to future work in archaeology. Further, the systems operated by France, Germany and United States of America are other important sources. Many other countries have also built and orbited Remote Sensing satellites with capabilities whose value for archaeology have to be evaluated. One cannot overlook the capabilities of Google Earth that provides high definition cartographic information on Internet free of cost, available for anybody to use for any purpose. There is a need for international framework for data availability for archaeology and heritage research. The abundance of heritage wealth in the world calls for dedicated mission for archaeological study, which can be justifiably planned only when archaeological signatures are recognized with greater confidence, resulting from wider and larger usage of remote sensing data for archaeological application. Space based remote sensing can be further extended to geophysical methods such as GPR and magnetic survey. All these methods add new dimensions to archaeological studies opening up new vistas of investigation and exploration to put archaeology on a strong scientific and technological footing.

There is an inherent urge in human beings to want to know our past; the extent of historical research holds testimony to this. But there is much about our past that still remains a mystery. This may be because of lack of evidence or lack of tools to access the evidence. With the emergence of new technology certain new tools also emerge. If more researchers in fields such as archaeology recognize the role that remote sensing can play in their research, these methods can be adopted in a much larger scale than what we witness today. The present work unambiguously establishes that for facilitating better understanding of human history and history of human impact over the environment, remote sensing technology could offer an innovative and potentially powerful route to one more area of research – the science and art of archaeology.

Some scholars working in the field of archaeology have raised issues related to the impact of conventional techniques of archaeological exploration in the context of preserving the integrity of the sites under study. In their view, the very process of manual and invasive methods of excavation may not be the best approach in the identification, study and preservation of archaeological sites. This is one more perspective in which one can assess the utility of the modern remote sensing particularly its non-invasive character. However, much needs to be done in terms of developing the capabilities of remote sensing and the relative exploratory methodologies so that it can become a viable alternative to replace invasive methods totally. Perhaps the possible limitations in such a strategy could make it not possible to completely replace the conventional techniques by alternate non-invasive approaches. For the time being, it can be safely concluded that remote sensing techniques at best can prove to be an effective complementary and supplementary technique to the conventional methods of exploration in archaeology.

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References:

Ben-Dor, Eyal, Juval Portugali, Moshe Kochavi, Michal Shimoni, Lipaz Vinitzky, ‘Airborne thermal video radiometry and excavation planning at Tel Leviah, Golan heights, Israel’, *Journal of field archaeology*, vol. 26, no.2, (Spring, 1999), pp. 117 - 127.

Challis, Keith, Gary Priestnall, Adam Gardner, Julian Henderson, Sarah O’Hara, ‘Corona remotely-sensed imagery in dryland archaeology: The Islamic city of al-Raqqa, Syria’, *Journal of field archaeology*, vol. 29, no.1-2, (Spring, 2002 – Summer, 2004), pp. 139-153.

Holcomb, Derrold W., 2001. ‘Imaging Radar and archaeological survey: an example from the Gobi desert of southern Mongolia’, *Journal of field archaeology*, vol. 28, no.1-2, (Spring-Summer) pp.131-141.

Jamie James, 1995. ‘Shuttle Radar maps ancient Angkor’, *Science*, vol. 267, no. 5200, (Feb, 17) p. 965.
Kamini, J., Kulkarni, Malatesh, Raghavaswamy, V., Roy, P.S., and Mishra, P.K., 2007. ‘CARTOSAT-1 views the Nalanda Buddhist ruins’ *Current Science*, vol.93, no.2, 25 July, pp.136-138.

Kasturirangan, K., Murhty, Sridhara K.R., Rao, Mukund, Srivastava, S.K., and Hegde V.S., 1998. ‘Expanding the use of space technology applications – opportunities and constraints in making it happen’, UN/IAF Workshop on expanding the user community of space technology applications in developing countries, Melbourne, Australia.

Kouchoukos, Nicholas, ‘Satellite images and near eastern landscapes’, *Near eastern archaeology*, vol. 64, no. 1-2, Mar.-Jun., 2001), pp. 80-91.

Lasaponara, R., Masini, N. (Eds,) 2008. Proceedings of Workshop on Advances in *Remote Sensing for Archaeology and Cultural Heritage Management*, Aracne editrice S.r.l., Rome.

Parcak, Sarah H., 2009. *Satellite remote sensing for archaeology*, Routledge, London and New York.

Pope, Kevin O., Bruce H. Dahlin, ‘Ancient Maya wetland agriculture: New insights from ecological and remote sensing research’, *Journal of field archaeology*, vol. 16, no.1, (Spring, 1989), pp. 87 - 106.

Rajani M.B., and Patra, S.K., 'Application of satellite image processing techniques for Talakadu, a unique archaeological landscape in India', *PHOTO-INTERPRETATION*, ESKA, Paris, France, 2009-4 (volume 45)

Rajani M.B., and Rajawat A.S., 'Potential of satellite based sensors for studying distribution of archaeological site along palaeo channels: Harappan sites a case study' *Journal of archaeological sciences*, Elsevier, 2011, DOI:10.1016/j.jas.2010.08.008

Rajani M.B., Bhattacharya, S., and Rajawat A.S., ‘Synergistic Application of Optical and Radar Data for Archaeological Exploration in the Talakadu Region, Karnataka’, *Journal of the Indian Society of Remote Sensing*, Springer, 2011, DOI: 10.1007/s12524-011-0102-6

Rajani, M. B., "Space based remote sensing applications for archaeology", Proc. SPIE 7651, 76511O (2009); doi:10.1117/12.855565

Rajani, M.B., ‘Bangalore from Above: An Archaeological Review’ *Current Science* 93(10): 2007, 1352-53

Rajani, M.B., and Settar, S., ‘Application of multispectral remote sensing imagery in detection of ancient forts in South India’ In Stefano Campana, Maurizio Forte and Claudia Liuzza (Eds.), BAR –S2118, 2010 Space, Time, Place *Third International Conference on Remote Sensing in Archaeology, 17th-21st August 2009, Tiruchirappalli, Tamil Nadu, India*, ISBN 978 1 4073 0659 9, pp.123-127.

Rajani, M.B., Patra S.K., and Verma, Mamta 'Space observation for generating 3D perspective views and its implication to the study of the archaeological site of Badami in India' *Journal of Cultural Heritage*, Elsevier, Volume 10, Supplement 1, December 2009, pp. e20-e26. DOI: 10.1016/j.culher.2009.08.003

Sever, Tom, and Wiseman, James, 1985. *Remote sensing and archaeology: potential for the future*, report on a conference, March 1-2 1984, NSTL Mississippi.

Tripathi, Alok, Ed., *Remote sensing archaeology*, Sundeep Prakashan, New Delhi, 2005.

Trumpler, Charlotte, ed., *The past form above*, Francis Lincoln Limited, London, 2005.

Williamson, Ray A., Winston Hurst and Michael Jeffe, *Satellite remote sensing for archaeology and historic preservation: mapping the ancient trails of southeast Utah*, (ESA SP-515) 2002.

Wiseman, James, and El-Baz, Farouk, (Eds.) 2007. *Remote sensing in archaeology*, Springer, New York, USA.