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Remote Sensing Study of the vicinity of a UNESCO World Heritage Site in Maharashtra using Multi – Temporal Satellite Imagery

Pranita Shivankar[1*], Dr. Devashree Hardas[2], Dr. Prabodhachandra Deshmukh[3], Arun Suryawanshi[4]

[1](Dept. of Physics, RTM Nagpur University, Nagpur, India),

[2](Dept. of Physics, Priyadarshini Indira Gandhi College of Engg., Nagpur, India),

[3](Ex-Reader, Dept. of Physics, RTM Nagpur University, Nagpur, India),

[4] (Regional Remote Sensing Center, Nagpur, India)

ABSTRACT: *India has been actively working in close co-operation with other international agencies e.g. ICOMOS (International Council on Monuments and Sites), IUCN (International Union for the Conservation of Nature and Natural Resources), ICCROM (International Centre for the Study of Preservation and Restoration of Cultural Property) etc. In the country, there are 27 World Heritage Sites out of which 22 are cultural sites and 5 are natural sites. The present research work involves a study of the neighborhood of an eminent Cultural World Heritage Site in India 'The Ajanta Caves' which is inscribed by the UNESCO in 1983 and it is a protected monument under the Archaeological Survey of India (ASI).*

The Ajanta Caves (Latitude: 20°32'N, Longitude: 75°45'E), recognized as one of the most spectacular, sublime and historic aesthetic mural creations in the world are situated in Aurangabad District of the Maharashtra State in India. This site consists of a group of 30 rock-cut cave monuments which contain a number of fascinating paintings and sculptures considered to be masterpieces of art and some frescos. The caves were built in two phases; the first had started around the second century BCE and the second phase in the fifth and sixth centuries. The first was the construction of sanctuaries (known as chaytia-grihas) in the canyons of the Waghora River, probably under the patronage of the Satavahana dynasty. Most of the creative work took place over a short time period from 460 to 480 CE, during the reign of Emperor Harisena of the Vakataka dynasty.

In this project, remote sensing techniques are employed to acquire multi-temporal data through satellite imagery with adequate resolution, the analysis of which reveals the vicinity of the eminent archaeological site. The analysis and digital interpretation of this data gives a fairly accurate estimation of the changes in the peripheries of the caves. The objective of this study is to explore the influences of urbanization to essentially develop approaches to protect and preserve the precious archaeological site.

KEYWORDS: *Digital Interpretation, ICOMOS, Remote Sensing, UNESCO, World Heritage Site.*

1. INTRODUCTION

Ajanta Caves are situated at a distance of 107 km north of Aurangabad, the district headquarter[1]. The caves attained the name from a nearby village named Ajanta located about 12 km[2]. These caves were discovered by an Army Officer in the Madras Regiment of the British Army in 1819 during one of his hunting expeditions[3]. Being declared as protected monument under Ancient Monuments and Archaeological Sites & Remains Act, 1958, the Caves are maintained by the Archaeological Survey of India[4]. The caves include paintings and sculptures described by the government Archaeological Survey of India as "the finest surviving examples of Indian art, particularly painting", which are masterpieces of Buddhist religious art. The caves were built in two phases starting around the 2nd century BCE, with the second group of caves built around 400–650 CE according to old records, or all in a brief period of 460 to 480 according to the recent proposals of Walter M. Spink. The site is a protected monument under supervision of the Archaeological Survey of India since 1983, as these Caves have been declared by UNESCO a World Heritage Site.

Spectral remote sensing has been used in a variety of applications, including archaeological investigations worldwide. Remote sensing data and image interpretation are used as major tools in investigating natural formations and man-made structures[5,6,7,8,9,10,11]. For this purpose, the raw and processed satellite data can be well interpreted by digital image processing and interpretation techniques. The supervised classification methods of image processing are applied to identify and compare the rate of changes in the study area and the results of images are compared with field data[12].

In the present study, the multi-temporal change detection analysis has been done around the region of caves. In this project, remote sensing techniques are employed to acquire spatial, multi–spectral and multi–temporal data through satellite imagery with adequate resolution to reveal the vicinity of the study area of Ajanta Caves over ~36 km radial distance. The analysis and digital interpretation of this data is supported by field survey to procure the adequate requisite ground truth information to obtain accurate estimation of the changes in the area. The scanning of the temporal images in this study is useful to monitor the changes in the peripheries of the cultural heritage.

2. MATERIALS AND METHODS

2.1 Study Area: The Ajanta Caves (Latitude: 20°32'N, Longitude: 75°45'E) are situated in Aurangabad District of the Maharashtra State in India. The study area covers approximately 16 km radial distance from the centre. The Caves at Ajanta were recognized as one of the most spectacular, sublime and historic aesthetic mural creations in the world. Figure 1 shows the location of the Ajanta Caves in Maharashtra state.

Figure 1: Location of the study area

2.2 Data Used

i) Satellite Data: Landsat TM (October 1989) and Landsat ETM+ satellite images of the year (October 2000) were obtained from NRSC (National Remote Sensing Centre), Hyderabad, India. These images were employed for digital image processing. In the present study, the satellite Landsat 7 which carries an ETM+ (Enhanced Thematic Mapper) has been used which has same spectral bands as that of TM+ (Thematic Mapper). But ETM+ has one additional panchromatic sharpening band of 15m.

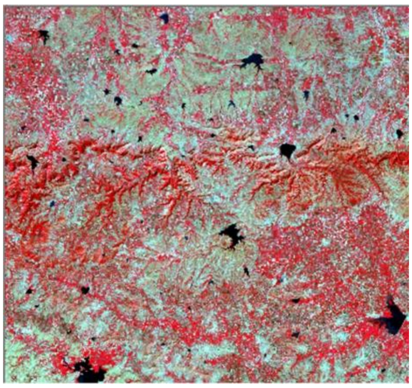
ii) Software used: ArcGIS 9.3 and ERDAS Imagine 9.0, ERDAS Imagine 10 were used to process and analyse the input parameters. All the rectified and georeferenced datasets were interpreted for classification by Prime Win software version 1.2 and correlated to identify spatial changes.

iii) District Maps: Relevant district maps of Aurangabad District provided by GSI (Geological Survey of India), Nagpur were used for boundary generations. The facilities of Geoinformatics Laboratory of Regional Remote Sensing Service Centre – Central (RRSSC), Nagpur were used for data generation, integration, processing, classification and interpretation.

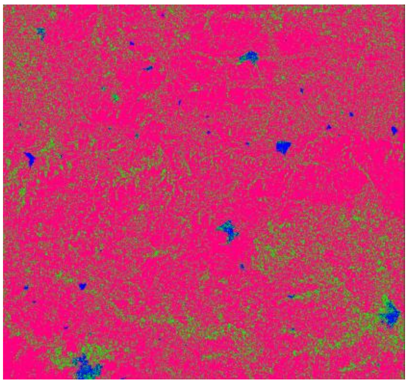
3. RESULTS AND DISCUSSION

Comparison of Classification Results

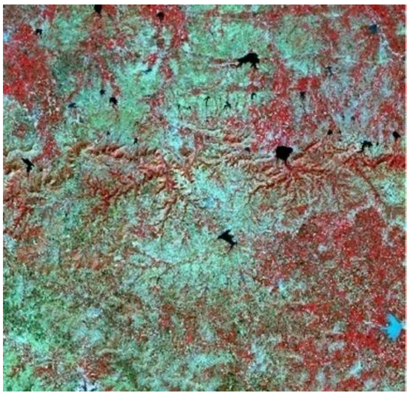
From figure 2, the results of classification for the two different times show that all the classes of the study area have changed during the period of 1989 to 2000. Table 1 show the transitions based on the comparison of the result of classification for 1989 and 2000.



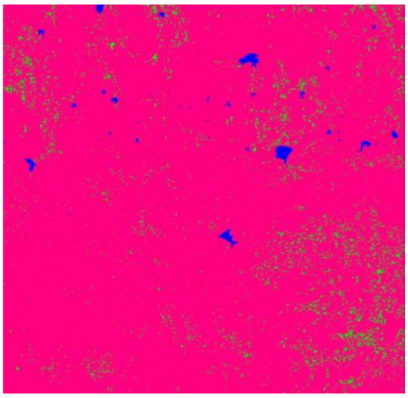
FCC image of the year 1989



Classified image of the year 1989



FCC image of the year 2000



Classified image of the year 2000

Legend

Waterbody

Dense Vegetation

Open Land

Figure 2: Satellite image interpretation

Table 1: Classification Statistics of different land cover found in different years

Sr. No.	Class	No. of pixels		Percentage	
		1989	2000	1989	2000
1	Waterbody	9311	6889	0.77%	0.57%

2	Dense Vegetation	238047	47591	19.77%	3.95%
3	Open Land	955742	1148620	79.37%	95.39%
4	Null	1060	1060	0.09%	0.09%
Total ground points		1204160			

Water Body
There is marginal variation in the area under water bodies in the study area. In the year 1989, the total area under water bodies was 0.77% of the total area while in the year 2000; the total area under water bodies was 0.57% (Table-1 & Figure 2). It means Water level has decreased during the period of year 1989 to 2000 by 0.20%. As per visual interpretations, there are so many water bodies which are destroyed in the recent years. This change is possibly due to increase in the temperature of earth surface due to phenomenon of global warming in the recent past.

Dense Vegetation
It is observed that the class dense scrub has decreased successively from 1989 to 2000. It has decreased by 15.82% (Table-1 & Figure 2). It may be due to deforestation or increase in barren land which decreases the percentage of dense scrub in the study area.
There has been also the reduction in agricultural area in the past 11 years between the year 1989 to 2000. This is primarily to meet the needs of industries and settlements due to the increase in the population of the study area. Recent Satellite imagery and google earth images clearly shows the dense settlement regions in the neighborhood of Ajantha caves. The considerable percentage in reduction of dense vegetation also can be attributed to the increase in the farming activities in the study area. The changes in density of crops throughout the span may be due to transformation of some part of agricultural land into open land because of reduction in water table of the area under study.

Open Land
Open land consists of different arable lands left un-cultivated as seasonal/temporary fallow for less than a year and as permanent fallow up to 5 years or more because of diverse reasons. It also includes land devoid of vegetation and accelerated erosion. Area under open land has increased by 16.02% from 1989 to 2000 (Table-1 & Figure 2). It implies that the quantum of land degradation has increased significantly with the passage of time. Thus a proper land management program is urgently required for the area otherwise it will expand at an alarming rate and may be possible that the area will convert into settlements which will pose a serious challenge in future to the world heritage site.

4. CONCLUSION

The present study brings out the significance of the utility of remote sensing techniques for Multi-temporal analysis of a World Heritage Site. It reveals changing pattern of land use/land cover in the study area over the span of 11 years. The analysis of land use/land cover through satellite imagery of the study area provide significant clues for the future planning of the area.

In this paper, using Landsat TM and ETM+ images from 1989 to 2000, land use changes in and around Ajanta Caves were evaluated and analysed. Landsat satellite has applications potential in a wide range of disciplines such as agriculture, inventory of forest resources, geography, geological mapping and water quality analysis. Therefore the study finds that these datasets are useful in delineation of various thematic maps. Monitoring of the peripheral changes in and around the site becomes easier with the help of remote sensing technique. The corrective measures can be taken to avoid the damages to the site which is otherwise not possible using any other technique. For classification of the images, Maximum Likelyhood Classification method was applied using Prime Win Software version 1.2. In addition, ArcGIS version 10 and ERDAS Imagine 9.0 were used for georeferencing of the images.

The multitemporal satellite data, greatly enhanced the detection and delineation of various physiographic units. With the help of Google earth images from the year 1985 to 2013, it is observed that the urbanization is increased around the peripheral region of the site. The results of the study revealed that during the year 1989 to 2000, the significant expansion in the open land is observed. So, we may conclude that human activities are increased in the region closer to the precious site. In case of lack of improper planning, the increased human activities may lead to the degradation and eventually destruction of the archaeological landscape, which is a treasure of culture and heritage of human existence. Results can be further improved by using high resolution satellite imagery of the area where the settlements exist. It will further help to forecast the human impacts and rate of change of urbanization within the peripheral study area.

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* *correspondence (e-mail:* pranitashivankar19@gmail.com*)*