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Reconstruction of contested landscape: Detecting land cover transformation hosting cultural heritage sites from Central India using remote sensing

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ABSTRACT

Central India hosts one of the largest repositories of archaeological sites in the world having a semi-arid climate and distinct eco-geography which is prone to rapid change due to human activities. This paper discusses the changes in land use and land cover for the past twenty-three years in the region altering the rich cultural heritage, revealing by the presence of numerous painted rock-shelter sites in the region. The land cover and land use changes in terms of deforestation, urban growth and development and sandstone mining have been evaluated in the present study. Some of the above-mentioned parameters have been quantified using remote sensing and GIS data by peeping into the past and the present demonstrating sufficient practical and scientific value for the present work. The use of landsat satellite data of appropriate spectral and spatial resolution are imperative in this research where two supervised classificatory schemes viz. MLC (maximum likelihood classification) and SVM (support vector machine) are implemented for image classification. Landsat images of the years 1989, 2000 and 2011 have been processed to detect the current and historical changes of cultural heritage sites in its structural and spectral aspects in one of the remote regions of central India that matched the ground truthing from the present day survey and field work. The techniques provided differential results and in terms of accuracy SVM performed better than MLC while detecting natural and archaeological change estimation of the contested landscape of rock art. The change analysis suggests the gradual and steady destruction of natural and cultural wealth of this area leading to complete fragility. The deforestation led to the exposure of painted sandstone rock-shelters with in situ archaeological deposits. In the recent past intensive sandstone mining till the present years is obliterating unique cultural heritage sites in this region of Central India. Finally, a set of guidelines has been recommended to employ good policies to align heritage conservation and development on the right track to promote sustainable land use cost-effectively.

Introduction

The rock art of Central India is rich and diverse in its thematic, techno-stylistic and chrono-stylistic components. The districts of Mirzapur and Rewa of the states of Uttar Pradesh and Madhya Pradesh host some of the main archaeological records in terms of painted rock-shelter sites in Central Indian context. Intricate colour composition and superimpositions of prehistoric paintings forms the corpus of prehistoric sites in this part of India, revealing great heritage value on its own. However the landscape of archaeology has been contested (Bender et al., 2008; Leavy et al., 2007; Ouzman, 1998, 2001), shedding variable amount of light on the presence of different culture areas within the same eco-geography where a vast array of disciplines play a combinatorial role to understand the true nature of land use/land cover change. Archaeology, anthropology, geomorphology, remote sensing, geographical information system, exhaustive field survey, discovery of new sites and cataloguing of the landscape modification through foot survey, all play their respective roles to delineate the mode of land use in the recent past and in the present altering the precious cultural and natural resources of the area leading to an irreversible change and collateral loss. The ecosystem of the area is highly disturbed due to the man-made changes, damaging the landscape of the art and landscape of the natural resources. The deforestation activity is damaging the forest cover affecting the forest-products and ecology. On the other hand, both steady sandstone mining and weathering are damaging precious rock art. Quarrying activities of semi-precious minerals and ornamental rocks are altering the stratigraphy of the primary context sites, where the archaeological assemblages are getting

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mixed. This research has been able to detect all the changes by means of present day field survey and satellite data from the past twenty-three years deploying two different algorithms classifying the data. The novelty lies in the detection of simultaneous natural and cultural heritage change through different classification schemes where one performs better than the other providing richer information about the increasing fragility of the area invoking urgent need to come up with policy recommendations to protect the archaeological landscape from a perpetual damage.

Rock art research in the said area of Mirzapur and Rewa is very well known from the second half of the nineteenth century, when British officers Carlleyle and Cockburn (Cockburn, 1894, 1899) did their initial surveys and discovered very many rock-shelter sites. After their discovery other scholars gradually made significant contribution in Indian prehistory, particularly in rock art and archaeology both before and after the independence (Misra, 1998; Pal, 1981; Varma, 1981, 2008; Verma, 1984). Recent works in the district of Mirzapur confirmed the presence of additional sandstone rock-shelters (Chakrabarti, 2001; Chakrabarti and Singh, 1998; Gupta, 2004; Misra, 2003; Misra and Pal, 2002; Pratap and Kumar, 2009; Tewari et al., 1999). In the applications of remote sensing for archaeological purposes land use/land cover changes (LULC) have gained considerable momentum and interest. Additionally it is linked with climate change which is one of the primary aspects of research in global archaeology and environmental sciences (Gupta and Srivastava, 2010; Lambin et al., 2003; Riebsame et al., 1994; Srivastava et al., 2012b; Walker et al., 1999). The predictive modelling and reasoning in land use/land cover rely on the ancient past, recent past, present and future land use patterns and systems (López et al., 2001; Munroe and Muller, 2007; Pijanowski et al., 2002; Veldkamp and Lambin, 2001). A better knowledge of past landscape alteration provides opportunities for optimum predictive modelling with enhanced resolution (Brown et al., 2005; Pocewicz et al., 2008).

LULC change is gradually becoming popular in archaeological sciences. Using this concept aided with different algorithms now, it has been possible to quantify cultural loss and damage of surface archaeology in a given landscape using high profile satellite data. LULC can be quantified based on parametric and non-parametric classifiers, where parametric classifiers assume a normal distribution for the entire dataset (Seto and Kaufmann, 2005). MLC, as one of the supervised classification techniques is widely used by several scientists that assigns a pixel to the class and finally show the output according to the mean and covariance of each class (Patel et al., 2012a,b; Richards and Jia, 2006). SVM, while calculating land use/land cover changes, being non-parametric does not reveal any inclination towards strict statistical paradigms, and deploy interconnected heuristic algorithms and regression analysis to identify change. SVM theory was introduced by Vapnik and Chervonenkis (1971) and subsequently detailed by Vapnik (2000). SVMs apply several types of kernels like linear, polynomial, sigmoid, Gaussian to name a few to include non-linear decision boundaries in the actual corpus of data (Islam et al., 2012a). SVMs determine the optimal separating hyperplane (OSH) between two classes applying Lagrange multipliers along with quadratic programming methods using training samples to testify the test data sets (Pal and Mather, 2004). SVMs have several applications in various disciplines (Hong et al., 2008; Lau and Wu, 2008). Currently SVMs are being used widely for remote sensing and target detection (Foody and Mathur, 2004a,b; Mathur and Foody, 2008a,b). Remote sensing allows estimating of land use/cover change accurately in a given region which is vital in archaeological sciences (Herold et al., 2002; Yuan et al., 2005). Scientists all across the world have contributed to enrich this avenue of inquiry (Jaiswal et al., 1999, 2003). A few techniques dealing with land use/cover change detection have been built, summarized and scrutinized in the recent decades (Lu et al., 2004; Singh, 1989). Two basic premises exist in land use/cover change detection having direct relation with pixel to pixel comparison and post classification comparative methods (Dewidar, 2004; Mukherjee et al., 2009), comparing two or more distinctly classified images of discordant dates (Serra et al., 2003; Shalaby and Tateishi, 2007). This method is widely used and most common for change detection analysis (Lillesand et al., 2004).

Proper understanding of the recent and historic changes of the archaeological record might assist to construct contingency plans and management strategies to protect the archaeological heritage of a vulnerable area. This is why in today's world land use/cover change detection has a global impact for environmental, geographical, archaeological, anthropological, cultural resource management and ecological sciences (Abd El-Kawy et al., 2011; El-Asmar and Hereher, 2011; Kaimaris et al., 2011; Lambin and Meyfroidt, 2010, 2011). Two supervised techniques are applied to understand the land use/cover changes of the said timeframe, particularly tracing the effects of socio-cultural pressure changing the natural landscape first, which is ultimately gradually destroying the cultural resources of the region that could harness a considerable amount of monetary profit to the government if properly utilized, preserved and managed. Support vector machine performed better than maximum likelihood classification depicting land use/cover changes properly in the districts of Rewa and Mirzapur. MLC revealed a mix of planned agriculture in the region with some forest plantations in the year of 1989, which diminished by 2000. By 2000 most of the sandstone units and forest canopy got exposed suggesting rapid deforestation including sandstone mining and lastly in 2011 agricultural land got restricted to a limited region with occasional forest cultivation leading to the complete exposure of sandstone formation hosting painted shelters with archaeological deposits. On the contrary SVM technique (Buddhiraju and Rizvi, 2010; Richards, 2012; Tarabalka et al., 2010) have been able to predict a different perspective altogether. Hence, the foremost objectives of this study will focus on detecting LULC changes using remote sensing and to define the patterns in historic and recent changes of archaeological hence contested landscape. The accuracy of land use, image processing, classification and change detection has been well obtained by the application of MLC and SVM, two state of the art algorithms. Socio-cultural causes of landscape change in the given region and its future implications for the cultural and natural resources will be determined tracing the man and environment relationship within the area affecting land system science altering choices and decision making of the people in the region, both in the present and future. Finally, preliminary measures regarding policy recommendations would be included providing information on the loss of cultural and natural heritage paving a way towards the loss of national identity.

Materials and methodology

Study area

The study area within the Central Indian context falls in the districts of Mirzapur and Rewa and the borderland of the two neighbouring districts. Rewa district (24°19′–25°12′ N and 81°02′–82°19′ E) is located in the state of Madhya Pradesh while Mirzapur district (23°52′–25°32′ N and 82°07′–83°33′ E), is located in the state of Uttar Pradesh (Fig. 1). Both are renowned for their archaeological and heritage value along with natural resources. Mirzapur has an area of 4522 km^2 while Rewa district covers a total area of 6240 km^2. Rewa being one of the northern districts of M.P., shares border with the Mirzapur district of U.P. in the northwest, north and northeast. It is bordered by Sidhi and Satna districts of M.P. in the South and West (Cunningham, 1885;