The need for a National Archaeological database

Ekta Gupta[1,*], Sonia Das[1], Kuili Suganya Chittirai Balan[1], Viraj Kumar[2] and M. B. Rajani[1]

[1]National Institute of Advanced Studies, Indian Institute of Science Campus, Bengaluru 560 012, India
[2]PES University, 100 Feet Ring Road, Banashankari Stage III, Bengaluru 560 085, India

India's economic development is evident in its industrial growth, extensive transportation network, and rapidly expanding cities, towns and villages. While this growth has numerous positive aspects, it also has the potential to cause irrevocable damage (directly or indirectly) to rich archaeological heritage of the country. The present study makes three contributions. First, it examines several archaeological sites where economic developmental activities have caused significant damage. Second, it demonstrates how the risk of further damage can be minimized using geospatial solutions to protect and manage such sites. Third, it conceptualizes a framework for incorporating spatial and non-spatial knowledge of archaeological sites into a National Archaeological Database. We propose that this national archive should be made publicly accessible under the Digital India programme, where it can assist decision makers (development authorities, state departments, etc.) and help citizens plan for future economic growth while preserving the fragile remnants of our past.

Keywords: Archaeological database, economic development, geospatial solutions, protection of heritage sites.

Introduction

STATE agencies routinely use geographic information system (GIS) and remote sensing (RS) technologies for managing assets and making decisions. One such effort has been initiated by the Ministry of Culture, Government of India, in collaboration with the Indian Space Research Organisation (ISRO) to create a national geospatial inventory of historical sites and monuments listed by the Archaeological Survey of India (ASI)[1]. For each site, the database includes spatial information representing the boundaries of the protected area (i.e. the monument), prohibited area (up to 100 m from the monument) and regulated area (up to 200 m from the monument)[2]. By making these data publicly available via Bhuvan geospatial portal, it is hoped that governmental agencies as well as citizens can take decisions related to land use in areas near archaeological sites in a timely and cost-effective manner[3]. For example, those who are planning activities such as construction or mining at a site can use a simple GAGAN-based smartphone application[4] to determine whether the site falls within a restricted or regulated area (further details about this facility can be found in Raj *et al.* in this Special Section). Similarly, relevant authorities can grant or deny approval for such activities by referencing this resource.

While such a resource clearly has value, there are at least two reasons why it is inadequate for decision-making. First, the process of identifying protected, prohibited and restricted buffer zones for each site often requires an understanding that is holistic – it includes historical, geographic, cultural, architectural and technical aspects. As an illustrative example, Figure 1 is a snapshot from Bhuvan of the Hoysala period site of Halebidu, showing the protected, prohibited and regulated areas around temple structures using 100 and 200 m limits. This simplistic demarcation excludes large parts of Halebidu, which is known to extend as far as the fort (according to the excavation report of 1930)[5] and the moat (identified through remote sensing analysis)[6]. Thus, judicious site management requires active collaboration among experts in archaeological departments, academia and other institutions, who are familiar with records and scholarship associated with each site. Second, the present resource is static (by design) and will therefore become outdated in the face of rapid development. To remain relevant, it is necessary to integrate this inventory with other spatial datasets maintained by governmental agencies in charge of transportation networks, industrialization, mining, housing and other large-scale development. This integration will also allow governmental agencies to regulate development near archaeological properties in accordance with these buffer zones. To ensure that all development (both state and private) respects these zones, it is crucial to allow the inventory to be inspected and updated by concerned citizens, journalists, etc. to reflect potential violations.

To address these limitations, the present article proposes that a National Archaeological Database (NAD) should be created under the Digital India programme[7]. This Government of India programme aims to 'transform India

*For correspondence. (e-mail: ekta.geo@gmail.com)

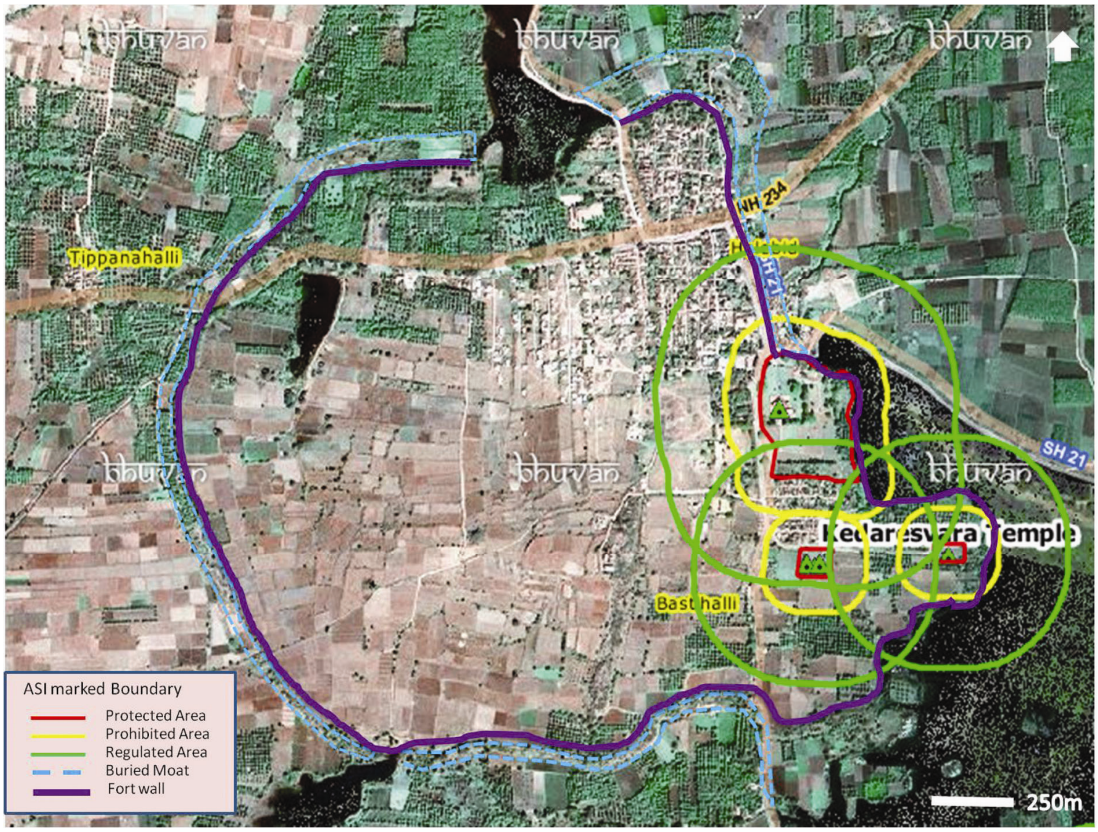


Figure 1. Screenshot from Bhuvan showing protected, prohibited and regulated area boundaries in Halebidu, Karnataka on which is superimposed features identified using remote sensing indicating larger fort and buried moat.

into a digitally empowered society and knowledge economy[4], by integrating electronic databases from several governmental departments to enable better decision-making. A framework is proposed for populating NAD with site-specific data (both spatial and non-spatial) under the guidance of experts, which will address the first limitation. The second limitation can be addressed by creating NAD at par with other databases under the Digital India programme, and by permitting crowd sourced updates to the database after suitable validation.

The article first discusses the importance of archaeological landscapes, and summarizes the use of RS and GIS technologies to capture relevant landscape information in electronic databases. It then provides several illustrative examples of damage or destruction to archaeological landscapes by a range of developmental activities. Lastly, it describes our proposed framework for creating NAD, integrating it with other databases under the Digital India programme, and concludes with a discussion on problems and challenges.

Archaeological landscapes, remote sensing and geographic information systems

Aston and Rowley[8] evocatively describe the landscape as 'a palimpsest onto which each generation inscribes its own impressions'. While these impressions are sometimes difficult to detect, the 2009 UNESCO guidelines highlight the potential of landscapes to inform us about the past[9]. The term 'archaeological landscape' usually includes not only the physical expanse of a site, but also the ecological, social and cultural processes in its spatio-temporal context[10,11]. Here, the term 'archaeological landscape' will be restricted to physical expanses containing tangible expressions of built cultural heritage. We now briefly review the ways in which RS and GIS technologies can be used to record archaeological landscapes in a digital form suitable for decision making using appropriate analytical tools.

Wheeler[12] emphasizes the richness of India's heritage: 'Go to any living village in India and you will find beneath it layer of vestiges of ancient civilization'. Despite the wealth of remains excavated by archaeologists, the ASI has acknowledged that much of the country's landscape remains *terra incognita*[13]. It is essential to identify and document surviving archaeological treasures as efficiently as possible, because they are vulnerable to deterioration or destruction in the face of rapid development.

RS technology can help archaeologists perform extensive reconnaissance surveys rapidly and for significantly lesser cost than traditional exploratory methods. Multispectral satellite data can detect palaeochannels, and

archaeological features such as moats, walls, roads, canals, ruins of old structures, etc. buried under vegetation can be often detected by unusual crop marks[6,14–16]. LiDAR and radar sensors have also been used to find sites in the Honduran rainforest, an ancient Mayan city in Caracol, Belize and undocumented cityscapes of Angkor in Cambodia[17–19]. (For more details, readers may refer to articles by Navalgund and Rajani, and Rajangam and Rajani in this Special Section.)

Detection is an important first step, but preservation efforts at archaeological sites can be effective only when they are protected by buffer zones, where developmental activities that are potentially harmful to heritage are prohibited or heavily restricted[20]. UNESCO has developed a detailed protocol for zoning, which includes the creation of heritage landscape protection zones, environment conservation zones, archaeological research zones and monument management zones[9]. This detailed level of zoning is not applied consistently to the 3600 sites listed as protected by the ASI (or even to all 29 properties in India inscribed on the UNESCO World Heritage List[21]), nor to the hundreds of sites that individual State Departments of Archaeology are responsible for. Undertaking such a task is challenging, but RS and GIS technologies have proved effective in assisting such efforts. For example, these technologies have been used to assess the vulnerability of a region to floods, coastal inundations, and other natural disasters, and to monitor illegal encroachment in sensitive areas. These tools can be useful in cultural resources management. For example, a visible line of sight for planetary and stellar observations is clearly necessary at a site such as Jantar Mantar. RS technologies allow inter-visibility analyses to be conducted on viewshed models for such sites, and can therefore ensure that adverse effects of developmental activities are minimized.

GIS technologies allow spatial data from multiple sources to be integrated into a single platform, where an interactive graphical user interface can be used to pose and answer complex queries to assist decision making. The spatial data can be stored in geometric or thematic form with any kind of information that has spatial context. Geospatial and geo-statistical analysis can be performed. GIS also facilitates the use of descriptive, predictive and prescriptive models with sets of spatial variables. Descriptive models involve suitability analysis (e.g. suitability analysis of construction of a dam near a heritage site), predictive models test the 'what if' scenario (e.g. prediction of urban growth and its consequences on heritage sites) and prescriptive models allow spatial decision-making to assess the different management actions (e.g. distance of factory emitting pollutants from a monument sensitive to pollution)[22]. For example, by integrating global datasets on location of Ashokan edicts, geology, population, climate, topography and other environmental parameters, Gillespie *et al.*[23] have identified 121 locations in the Indian subcontinent which hold possibilities for the hitherto undiscovered inscriptions to be found.

Impact of developmental activities on archaeological landscapes

The forces of liberalization, privatization and globalization have triggered large-scale developmental activities in India over the last few decades. Large tracts of land that either lay fallow or were used for non-mechanized agriculture over several centuries are now bearing the brunt of heavy machinery for projects such as expansion of transportation networks[24], formation of special economic zones (SEZs)[25], quarrying, etc. The Ancient Monument and Archaeological Sites and Remains (AMASR) Act prohibits all construction within 100 m of protected monuments, but there have been efforts to grant exceptions for projects deemed to be sufficiently in the 'public interest'[26]. Such judgements are necessarily subjective, and the developments triggered by making one such exception can easily strengthen the argument for granting further exceptions. Indeed, UNESCO has warned that 'the cultural heritage and the natural heritage are increasingly threatened with destruction not only by the traditional causes of decay, but also by changing social and economic conditions which aggravate the situation with even more formidable phenomena of damage or destruction'[27]. Spatio-temporal analysis of remote sensing data and historical records in GIS platform can reveal the extent of this damage, as illustrated in the following examples.

Sarnath

This site, where Buddha is believed to have first preached, is one of the four holy sites of Buddhism. The city is situated near the confluence of the Ganga and Varuna rivers in Uttar Pradesh. Cunningham[28] visited the site in 1835–36 and wrote about the initial excavations. Subsequent excavations have been carried out (some as recently as 2014)[29], and have uncovered monasteries, stupas (Dhamekh, Dharamrajika and Chaukhandi) and antiquities dating from the 3rd century BCE to the 12th century CE (ref. 30).

Although the stupas and other excavated structures are identifiable, there is no map demarcating the ASI property's boundary, nor are any boundary walls visible on satellite images. The Bhuvan inventory (retrieved on 22 April 2017) shows a protected area of 0.21 km^2 around the main excavated area consisting of the Dhamekh and Dharmarajika stupas, and a 0.09 km^2 area about 750 m south of this surrounding the Chaukhandi stupa. The

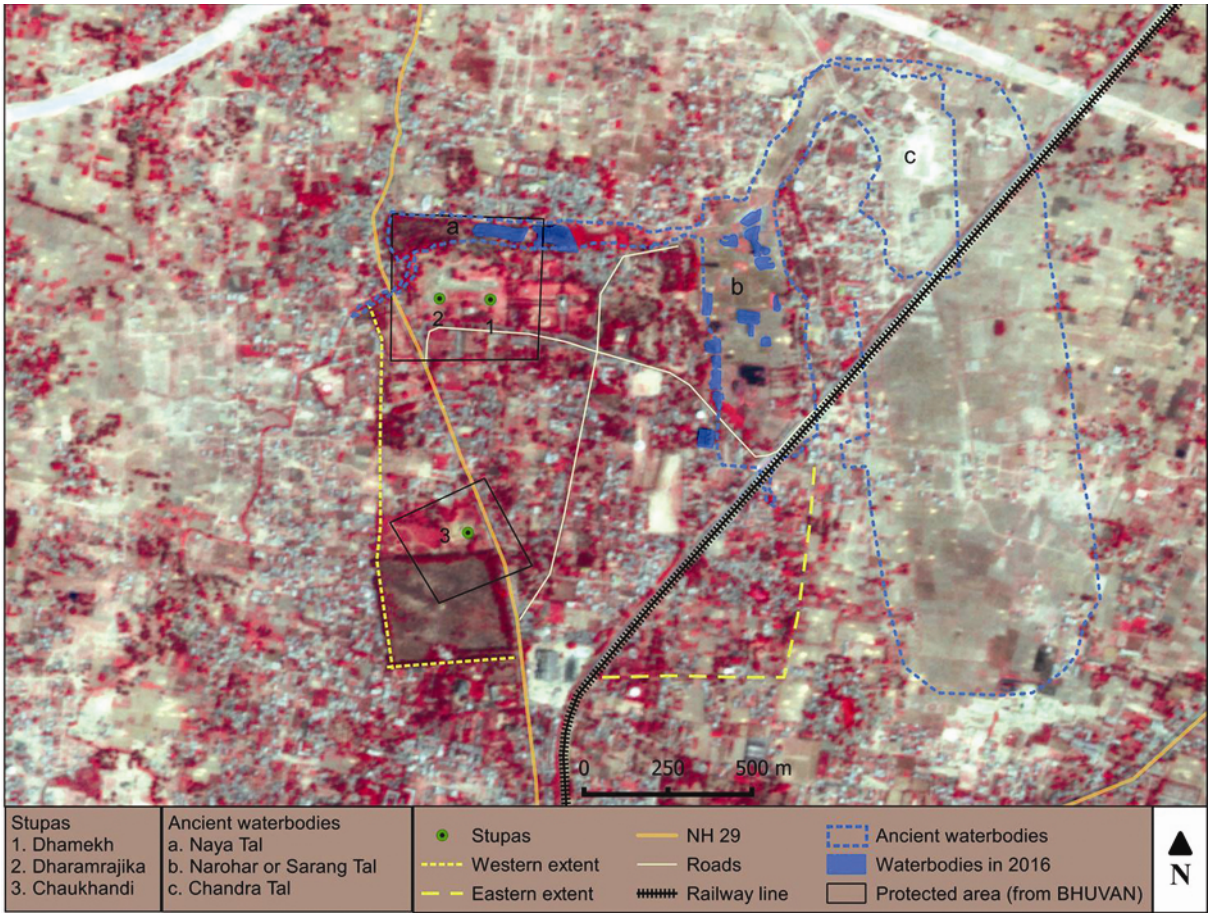


Figure 2. The protected archaeological site of Sarnath (as marked on Bhuvan; retrieved on 20 April 2017) and its vicinity showing the identified larger extent of site and water bodies as seen on satellite data (RESOURSESAT-2 LISS-4 data, 14 April 2016).

boundary of the protected area shown on Bhuvan cuts across roads, settlements, waterbodies, etc. Thus, there is no indication that developmental activities are being curtailed within the protected area.

Studies at other sites have revealed that regions of archaeological interest can extend significantly beyond protected areas[31]. Hence, this study used satellite imagery to examine the region surrounding the protected area. We identified crop marks indicating that the ancient settlement had a large rectangular layout (about 3.7 km^2), with sides oriented to the cardinal directions and flanked by waterbodies that are now dry (Figure 2). By georeferencing Cunningham's map[28], we found that the 1.4 km^2 area he surveyed in 1871 lies within the northern half of this rectangular layout. This archaeological landscape has been fragmented by the construction of a highway (NH-29) and a railway line from Varanasi to Gorakhpur. The site was disturbed by public works projects even in the 19th century, when 50–60 cartloads of stones from Sarnath's buildings were used to erect an iron bridge over the River Barna. Dozens of sculptures from Sarnath were thrown into the river to serve as a breakwater for the piers of another bridge[32].

Avati

This site, which is also known as Avathi or Ahuti, lies under the purview of the Directorate of Archaeology and Museums, Karnataka and is situated about 40 km north of Bengaluru in Devanahalli taluk. The site is known to have some prehistoric antiquity[33], but there is richer historic evidence. Ranabhaire Gowda, the first known chief of Yelahanka Nadaprahus, came from Yenamanji Puttur in Tamil Nadu and settled down in Avati. His sons founded Doddaballapur, Devanahalli and Chikkaballapur. It is believed that Kempe Gowda I, the founder of Bangalore, also belonged to this clan[34].

For this case study, multispectral data (IRS-P6 LISS 4) were used to identify a moat surrounding Avati hill that possibly demarcates the extent of the royal site, and a canal (identified using IRS and GeoEye data) surrounding Avati village (Figure 3). Apart from these landscape features, the Avati hill has many archaeological remains and 16th/17th century CE temples[35], which were geo-tagged during the field survey. The construction of a railway line and a highway (NH-7) has not only destroyed the actual area of construction, but has also disintegrated the

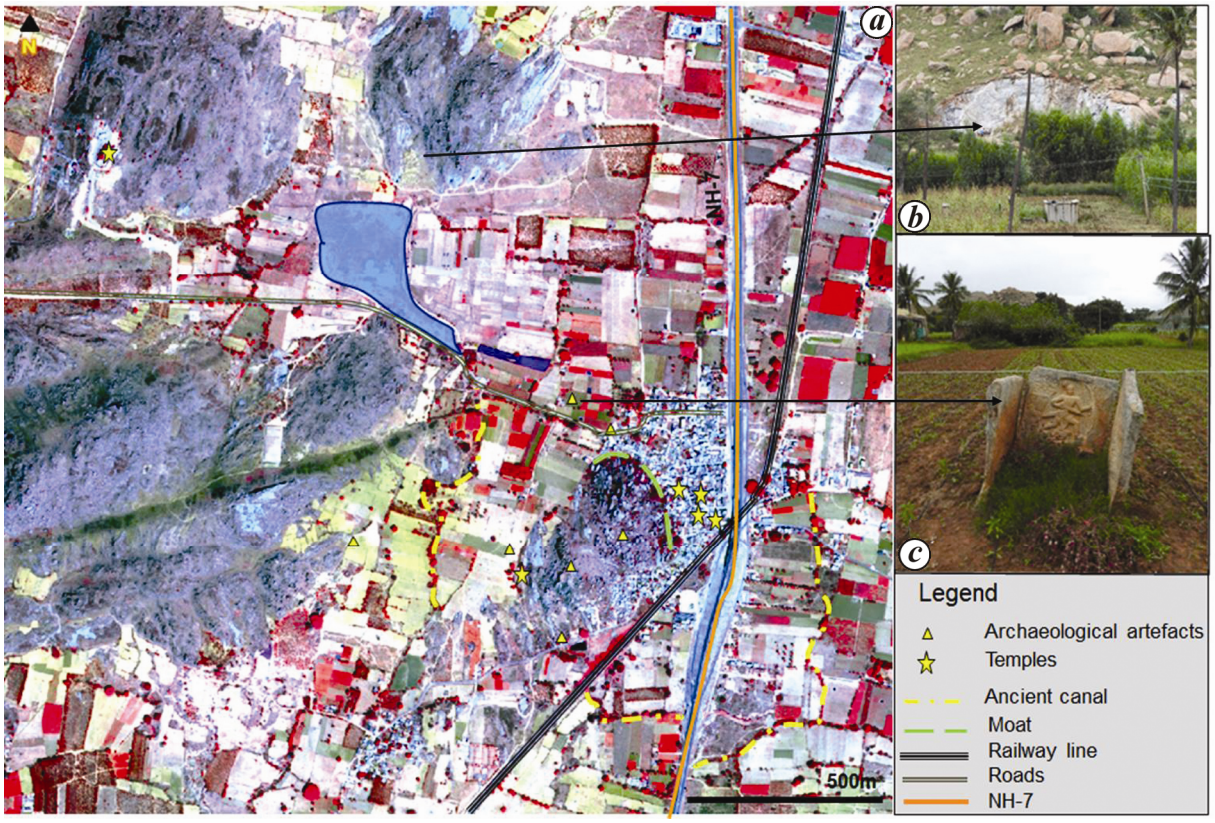


Figure 3. ***a***, Map of Avati showing distribution of archaeological artefacts, temples, water bodies and features (moat, canal) extracted from remote sensing (image: GeoEye-1; 7 April 2013). ***b***, Ground image of a hill being quarried. ***c***, A hero stone with inscriptions.

archaeological landscape by cutting across the canal network. It is likely that the proximity of the site to a major metropolis exposes it to significant pressure from real estate development.

Agra

For this case study, a comparative analysis was performed on the maps of Agra from three different time periods: a Mughal era painting made in 1720 CE for the Maharaja of Jaipur[36], a map from the British era (1868 CE)[37], and a Google Earth image (dated 27 February 2017). Some features from the Mughal era, including fort walls, gardens (Baghs) and canals survive today. Ebba Koch[38] has identified 44 such baghs along the banks of the Yamuna river by studying Mughal and British era texts, and through on-site identification of physical remains. By carefully geo-referencing the two earlier maps with the Google Earth image, the boundaries of most baghs on the inner (left) bank of the river are identifiable (Figure 4). The settlement was within the confines of the internal fort wall even in 1868, but the city has now sprawled well beyond this area. Identifying the extent of the ancient settlement in the context of the present city can assist in heritage management and planning subsequent growth.

The process of geo-referencing of such old maps, although laborious, can take advantage of the fact that newer constructions often follow patterns established by earlier settlements, particularly along canals, fort boundaries and major roads. This is not surprising, given the effort needed to alter such prominent features. It is telling that the greatest uncertainties in the identification task were at locations where large-scale modern constructions (major roads and the railway line) cut across the archaeological landscape. As at Sarnath and Avati, these constructions have not only destroyed archaeological evidence at the immediate site, but now act as a barrier, disintegrating and dividing the settlement.

Agra's most treasured heritage structure, the Taj Mahal, has also suffered from subsequent developmental activities. The mausoleum was built between 1631 and 1648 CE by Shah Jahan in the memory of his favourite wife Mumtaz[39]. The white marble structure is vulnerable to chemical weathering caused by industries, refineries and traffic pollution in the vicinity. After officially recognizing the extent of the damage, the Government of India has spent significant resources to protect the monument[40]. Other heritage sites such as Victoria Memorial in Kolkata[41], Belur Math in Howrah district[42] and Charminar in Hyderabad[43] have been similarly affected by pollution. These examples illustrate the need for

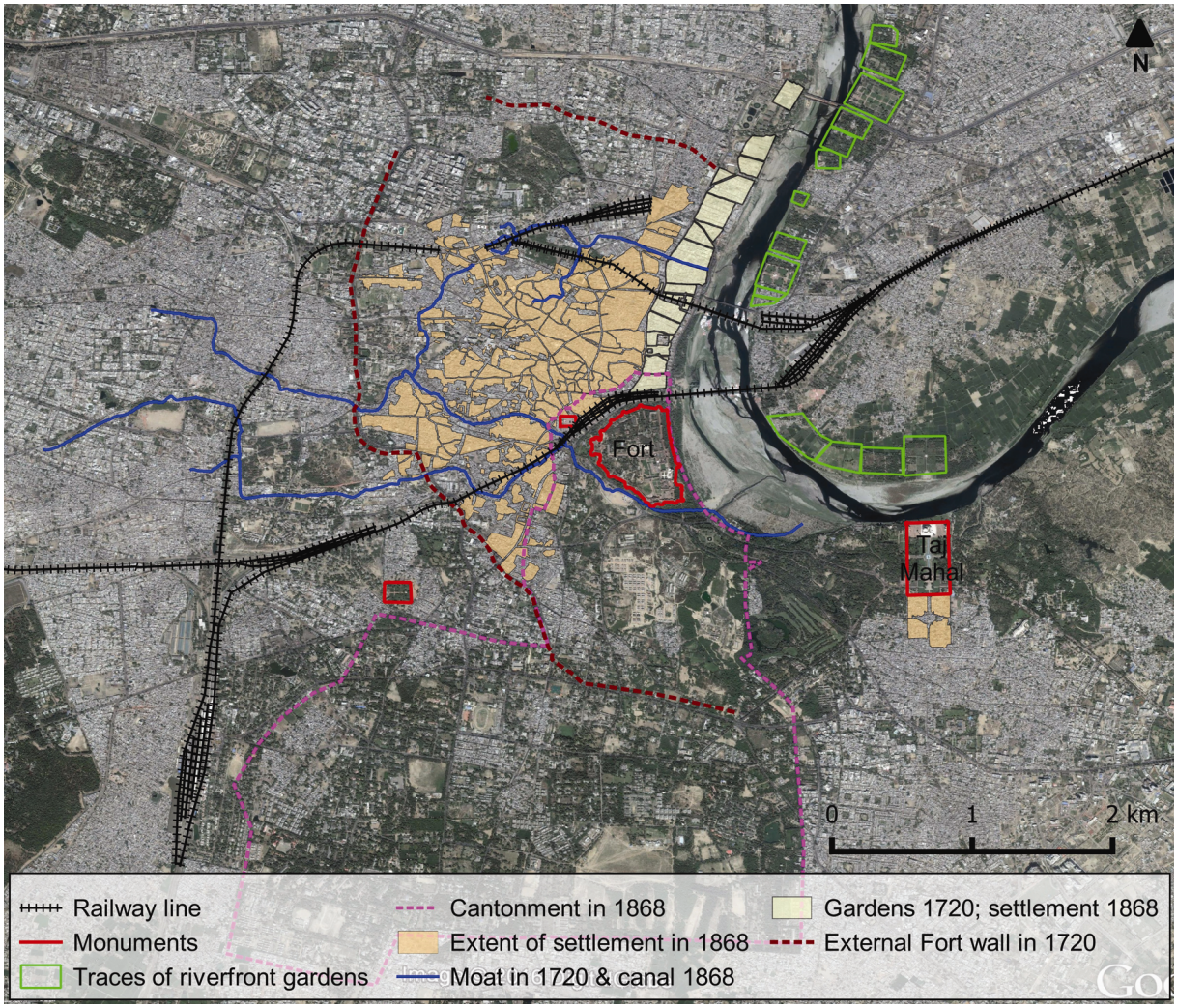


Figure 4. Landscape of Agra with land-use details as seen in 1720, 1868 and at present (Map data: Digital Globe 2016; 27 February 2017).

careful prior planning around heritage sites to avoid damage and costly repairs in the future.

Sanganakallu-Kapgallu

This is located 7 km northeast of Ballari city in Karnataka. In this site there are five large granitic hills, that were inhabited during the late prehistoric period dating from about 2200 to 1000 BCE. Among them, the large hill (Hiregudda) has a 1.5 km long dolerite dyke cutting through it in the north–south direction. Artefacts, habitation deposits, factory debitage, etc. dating from the Neolithic to the Iron Age have been documented from this site, and have thrown light on human cognitive, social, economic, ecological and geomorphic evolution. Such prehistoric sites are vulnerable to destruction and damage because they lack noticeable structures[44,45]. Menon[46] details the ravaging and vandalism of ancient structures at megalithic sites, as well as the clearance of 60 megaliths (recorded by A. Sundara in 1970s) near Aihole. This destruction sometimes occurs due to lack of awareness, and it is possible that quarrying the Choudamagudda hill at Sanganakallu was permitted because the importance of the site was unknown outside academic circles. Ravi Korisetter has been instrumental in halting the quarrying activity in this area, but the damage that has occurred is permanent (Figure 5). This highlights the need to disseminate knowledge about sites as widely as possible, especially within the communities near these sites.

Jantar Mantar

This observatory in Delhi is one of five built in the 1720s by Raja Jai Singh II of Jaipur (the other four are at Jaipur, Ujjain, Mathura and Varanasi). It contains world-class astronomical instruments constructed in masonry[47], but the opportunity to fully understand their contribution to astronomy is lost because the construction of skyscrapers around this site and the liberal use of Perspex glass on one of these structures have destroyed much of

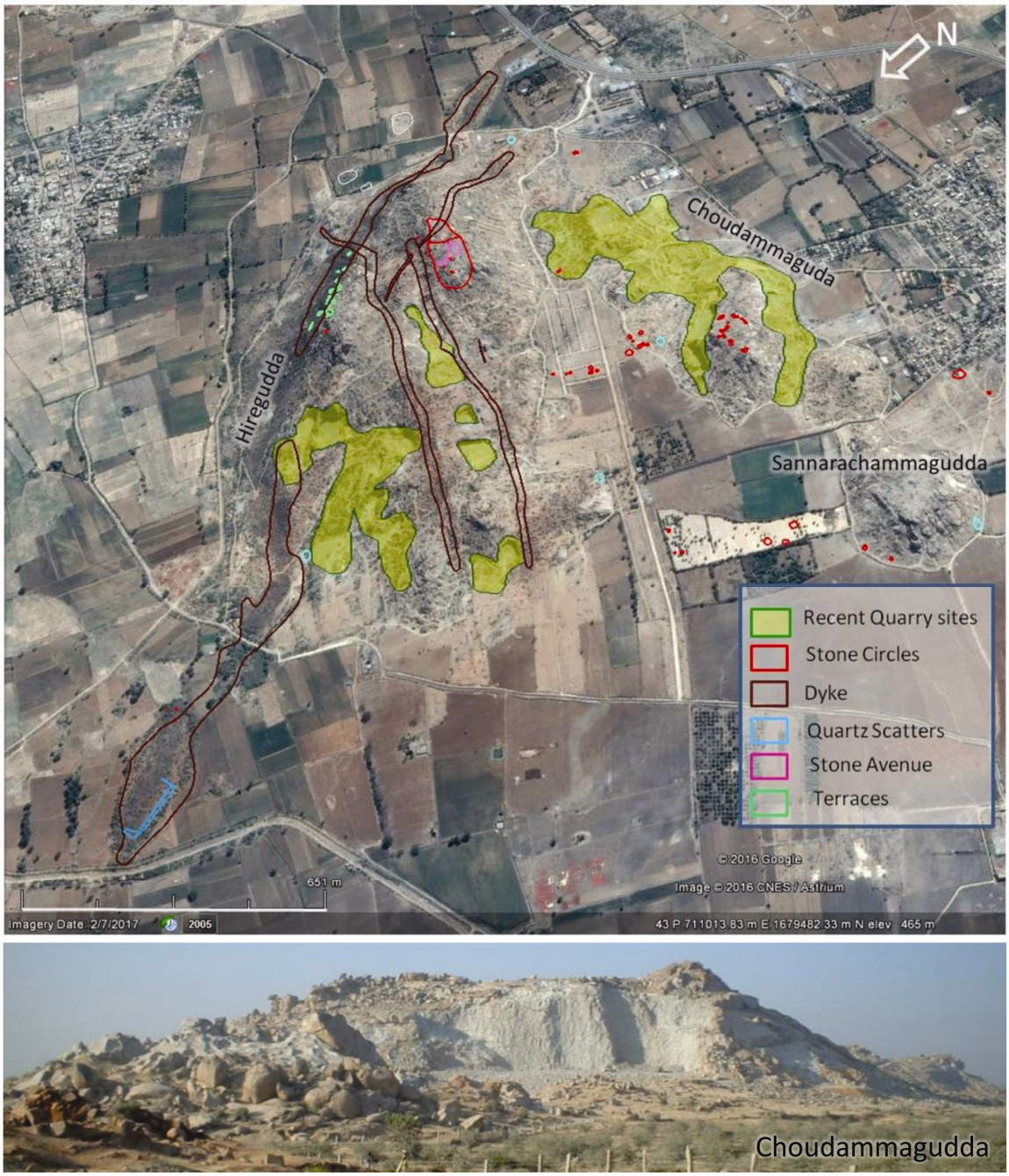


Figure 5. (Top) Map of Sanganakallu prehistoric site showing the spread of mining activities in the context of archaeological locations. (Bottom) Ground photograph showing quarried portion of the Choudamagudda hill (photo courtesy: Ravi Korisettar).

the functionality of these instruments[48]. This example illustrates the importance of site-specific demands, and the value of a single reliable resource accessible to site management authorities and development planners.

Chikkajala

This is located about 15 km from Bengaluru, and has been recognized as a prehistoric site where Megalithic tombs were discovered by Captain Branfil in 1881 (ref. 49). The primary structure is a fort/enclosure wall (estimated to be at least 200 years old) with a temple, tank, pillared pavilion and residential space within the 2 acre enclosure (Figure 6). A chronological sequence of four satellite images shows how the fort has gradually succumbed to development pressures (Figure 7). In 2004, NH-7 was a single carriageway, with the fort located at a safe distance. In 2010, the highway was expanded into a dual carriageway, with a service road abutting the

ill-fated fort. Thereafter, the National Highways Authority of India was granted permission to break a segment of the fort's outer wall to widen the highway and accommodate a flyover. The sequence of images clearly shows how rapidly the site became overgrown (damaging the temple, tank and other structures) once the outer perimeter was breached – an example of 'destruction in the name of construction'[50]. This is one among 92 sites across India that have either gone missing or have succumbed to rapid urbanization and infrastructure development[51].

Framework for creating the National Archaeological database

It is inevitable that developmental activities will partially or wholly destroy some of India's archaeological heritage. However, as illustrated in the previous section, this destruction is sometimes caused by developmental activities authorized without adequate awareness of the extent or value of archaeological heritage present in a region. Therefore, we believe it is imperative to create and maintain a NAD that identifies regions of archaeological importance, and that this authoritative resource be made available publicly and referenced in authorizing all developments. This will at least ensure that any decision to favour development over heritage preservation is taken with relevant facts available to both decision-makers and citizenry, as befits a healthy and vibrant democracy. The value that such a resource can provide is clearly illustrated by the challenge posed by Tipu's armoury in Srirangapattana, which was located close to the railway tracks (Figure 8). When the track-doubling project between Bengaluru and Mysuru was proposed, it would have been useful to make the public aware of the need to either demolish this historic structure, or to consider alternatives that would have raised costs. Instead, the project was sanctioned and later held up and the work was hindered for decades along this stretch, thereby raising its true cost. The proposal from the government for relocating the armoury came much later at significant additional expense[52], when it was too late to consider less expensive or less disruptive plans. The tools described earlier in the text can facilitate such dissemination and decision-making, and should therefore be utilized.



Figure 6. (Top) Interior of Chikkajala fort. (Bottom) To the right is a truncated wall along with the abutting road and flyover.

We now propose a framework for creating a NAD (Figure 9). It is first necessary to collate a variety of facts to obtain a holistic understanding of each site. These facts are primarily obtained from three sources: (i) ASI and archaeological departments of each state, which maintain archaeological records and related materials for the sites they manage; (ii) academic researchers in disciplines related to heritage management such as archaeology, history, geoarchaeology, geomorphology, remote sensing and GIS, and (iii) non-governmental organizations such as the Indian National Trust for Art and Cultural Heritage (INTACH), Indian Trust for Rural Heritage and Development (ITRHD), etc. which acquire and maintain records relevant to sites that may be unavailable elsewhere. Thus, our framework stipulates that members are drawn from all three communities to initiate site-specific management planning by demarcating the boundaries of areas to be protected based on the criteria defined by UNESCO[9]. This includes exploring the known extent of the site, tailoring zoning policies to any specific needs of the site, and demarcating zones accordingly. NAD will initially be populated with these spatial data, together with relevant non-spatial data and metadata. This community, consisting of representatives from the government, non-governmental organization and academia, will also be responsible for updating NAD as and when new facts come to light.

To ensure that NAD is kept up-to-date and used as a resource for planning all developmental activities, our framework specifies that this database should be integrated within the Digital India framework to ensure that it can be seamlessly inter-linked with geospatial data of other governmental agencies and departments. To achieve this, it is critical to maintain consistent standards in the accuracy and representation of spatial data. In the context of GIS standards, the National GIS (N-GIS) framework states that it cannot be a 'collection of whatever map/image data is available'[53] – a systematic GIS asset needs to be designed with layer/image definitions, feature definitions, schema definitions and created for the specific purpose of the N-GIS – which is seamless across the nation uniformly, standardized according to a N-GIS standard and constantly updated according to an update cycle.



Figure 7. Time-series Google Earth images of Chikkajala fort in the course of widening of National Highway 7.



Figure 8. ***a***, ***b***, Google Earth images of Tipu's armoury and railway track. ***c***, Ground photograph of armoury.

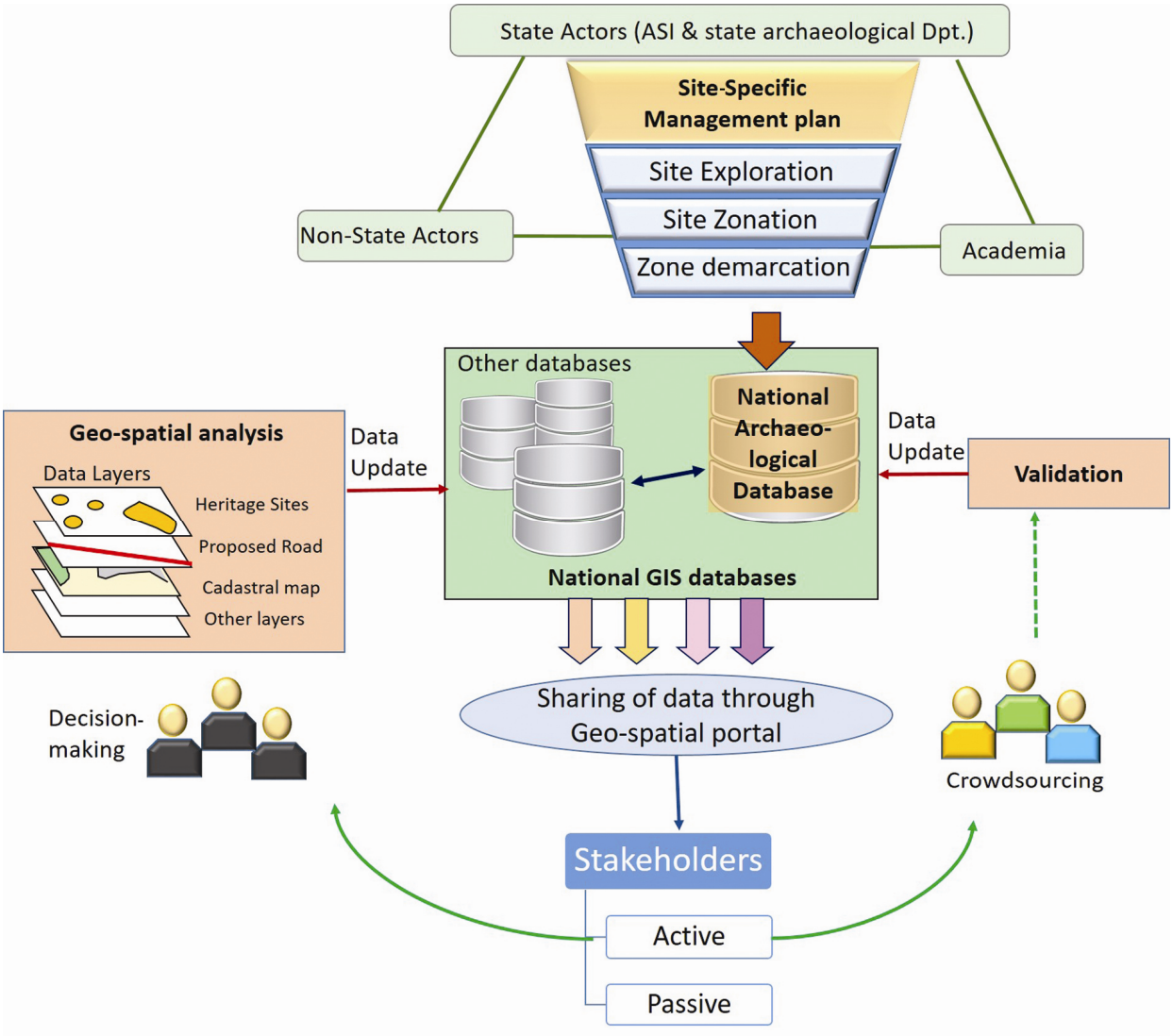


Figure 9. Conceptual diagram of the National Archaeological Database.

Therefore, it is necessary to develop detailed GIS data standards in line with N-GIS standards so that concerned departments can access these data seamlessly. Further, those data must be made available on a platform where multiple spatial datasets (road and railway transport networks, revenue maps, village and panchayat boundaries, etc.) can be integrated, visualized and analysed.

At present, Bhuvan seems to be the best platform that addresses these needs: it provides support for many kinds of geospatial data concerning India, and is based on standards stated by N-GIS.

Lastly, our framework proposes a public web portal to access data from NAD. This portal would serve two categories of stakeholders: passive users who query the database and take actions that do not lead to updates to NAD (e.g. tourists, or developers trying to determine whether a plot of land falls within a protected zone), and active users whose actions may indirectly lead to NAD updates. SMARAC (see Uday Raj *et al.* in this Special Section) offers 'government to citizen' functionalities that address the former category of users. The primary actors in the latter category are decision makers for various developmental projects, who will query NAD to determine the impact of these projects to nearby heritage (SMARAC provides 'government to government' functionalities to such users). If the project is permitted (perhaps with certain modifications), the necessary changes will be reflected in the inter-linked geospatial databases, and hence NAD will also be updated. Our framework also considers a smaller, but nevertheless vital active role for concerned citizens, journalists, etc. who wish to report inconsistencies between the ground reality at a site and the data present in NAD. (For instance, such inconsistencies would arise if unauthorized developmental activities were noted within buffer zones.) We now discuss the feasibility of this approach.

The use of volunteered geographic information (VGI) in the context of archaeology and site management is attractive because repeated field visits to acquire data are not feasible, and the availability of low-cost smartphones equipped with cameras, GPS and other sensors makes it possible to involve citizens in data gathering even in developing countries[54]. Such data may contain inaccuracies, including positional inaccuracies (e.g. caused by faulty GPS sensors), semantic inaccuracies (e.g. caused by misinterpreting features), temporal inaccuracies, etc. For archaeological purposes, such data typically require professional oversight before they can be used[55], although positional accuracy appears to improve as the number of contributors increases (analogous to Linus' law in the context of open-source software development)[56]. Despite these concerns, VGI has been used successfully in applications such as creating a 3D representation of a recently destroyed stone bridge[57] and examining a 6000 sq. km area for the tomb of Genghis Khan[58]. To harness this resource, our framework allows citizens to submit VGI for validation to the competent authority, who can update NAD as necessary. Actively seeking inputs from residents near a site has two additional benefits. First, the historical and archaeological data for the site can be enriched with knowledge from the local community, which may otherwise be unrecorded. Second, involving the community will raise awareness about the value of the site, and sensitize them to the need to balance site conservation and protection with development.

Discussion and conclusion

Remote sensing and GIS technologies have demonstrated their usefulness in the context of heritage management and conservation[59–61]. The ideas presented here are logical extensions of the collaborative effort initiated by ISRO and the Ministry of Culture. We have articulated the need to create a NAD as part of the Digital India programme, at par with other geospatial databases used by Central and State governmental agencies. We have also described a framework for seeding this database with relevant facts (drawn from a community of experts) and keeping it up-to-date.

It is important that this database should be consulted before authorizing any construction near archaeological sites, ensuring that past errors resulting in irreparable loss to heritage and escalating costs can be mitigated. In this context, it is useful to draw an analogy with our approach to the problem of female infanticide. It was only in 1991 that a data-driven approach was adopted, when the Census of India tabulated the sex ratios for the age groups '0 to 6' and '7 and above' separately for the first time[62]. Public access to these data triggered an informed debate about the large numbers of missing female children, and eventually led to policies to address this critical issue. We hope that making data about the extent and archaeological significance of each site publicly accessible will lead to similarly informed debates and policy decisions to minimize the impact of proposed developmental activities, while keeping the project costs acceptable.

The importance of cultural heritage is well stated in Article 3 of the Universal Declaration on Cultural Diversity (2001): 'Cultural diversity widens the range of options open to everyone; it is one of the roots of development, understood not simply in terms of economic growth, but also as a means to achieve a more satisfactory intellectual, emotional, moral and spiritual existence'[63]. This article has suggested an approach to make us aware of our archaeological heritage in terms of what we have lost, what we still have, and what we are in the process of losing. Armed with this information, we can take better decisions on balancing our country's growth with limited damage to its cultural assets.

1. National Remote Sensing Centre; http://bhuvan.nrsc.gov.in/governance/culture_monuments (retrieved on 1 August 2017).
2. Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act, 2010; http://asi.nic.in/minutes/Brief_note_on_the_salientfeature_of_AMASR_Act2010.pdf (retrieved on 5 September 2015).
3. Indian Space Research Organisation; http://www.isro.gov.in/isro-to-map-and-provide-management-plans-heritage-sites-and-monuments-of-national-importance (retrieved on 5 September 2015).
4. http://pib.nic.in/newsite/PrintRelease.aspx?relid=134061 (retrieved on 16 April 2017).
5. Annual report of the Mysore Archaeological Department for the year 1930. The Government Press, Bangalore, 1934.
6. Rajani, M. B. and Kasturirangan, K., Multispectral remote sensing data analysis and application for detecting moats around medieval settlements in South India. *J. Indian Soc. Remote Sensing*, 2013, doi:10.1007/s12524-013-0346-4.
7. Digital India: unleashing prosperity; http://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-tele-tech-2015-noexp.pdf (retrieved on 13 June 2017).
8. Aston, M. and Rowley, T., *Landscape Archaeology: An Introduction to Fieldwork Techniques on Post-Roman Landscapes*, David & Charles, 1974, p. 14.
9. An, H., Protocols for Best Conservation Practice in Asia: Professional Guidelines for Assuring and Preserving the Authenticity of Heritage Sites in the Context of the Cultures of Asia. UNESCO Bangkok, 2009; ISBN: 978-92-9223-242-9 (electronic version).
10. Wandsnider, L, Regional scale processes and archaeological landscape units. In *Unit Issues in Archaeology: Measuring Time, Space, and Material* (eds Ramenofsky, A. F. and Steffen, A.), University of Utah Press, 1998, pp. 87–97.
11. Rossignol, J., Concepts, methods and theory building: a landscape approach. In *Space, Time and Archaeological Landscapes* (eds Rossignol, J. and Wandsnider, L.), Springer Science & Business Media, 2013, pp. 3–11.
12. Wheeler, M., *My Archaeological Mission to India and Pakistan*, Thames & Hudson Ltd, 1976.
13. Archaeological Survey of India, National Policy on Archaeological Exploration and Excavation; http://asi.nic.in/pdf_data/Final_Draft_Policy_Expl_Excv-09_14.pdf (retrieved on 15 September 2015).
14. Parcak, S. H., *Satellite Remote Sensing for Archaeology*, Routledge (Taylor and Francis group), 2009.

15. Thomas, L. S. and Daniel, E. I., Landscape archaeology: remote-sensing investigation of the ancient Maya in the Peten rainforest of northern Guatemala. *Ancient Mesoam.*, 2003, **14**, 113–122; doi:10.1017/S0956536103141041.
16. Gupta, E., Das, S. and Rajani, M. B., Archaeological exploration in Srirangapatna and its environ through remote sensing analysis. *J. Indian Soc. Remote Sensing*, 2017; doi:10.1007/s12524-017-0659-9.
17. Arlen, F. C., Diane, Z. C. and John, F. W., Lasers in the jungle. *Archaeol. Arch.*, 2010, **63**(4); http://archive.archaeology.org/1007/etc/caracol.html (retrieved on 15 December 2016).
18. Lawrie, B., Beyond Angkor: how lasers revealed a lost city. *BBC News Magazine*, 2014; http://www.bbc.com/news/magazine-29245289 (retrieved on 15 December 2016).
19. Preston, D., Exclusive: lost city discovered in the Honduran rainforest. *National Geographic*, 2015, published online on 2 March 2015; http://news.nationalgeographic.com/2015/03/150302-honduras-lost-city-monkey-god-maya-ancient-archaeology/?utm_source=Facebook&utm_medium=Social&utm_content=link_fb20150302-news-hondurasexclusive&utm_campaign=Content&sf7754268=1 (retrieved on 16 December 2015).
20. Rajani, M. B., Patra, S. and Verma, M., Space observation for generating 3D perspective views and its implication to the study of the archaeological site of Badami in India. *J. Cult. Heritage*, 2009, **10**(Suppl. 1), e20–e26; https://doi.org/10.1016/j.culher.2009.08.003.
21. India – UNESCO World Heritage Centre; http://whc.unesco.org/en/statesparties/in (retrieved on 22 April 2017).
22. Bossler, J. D., Jensen, J. R., McMaster, R. B. and Rizos, C., *Manual of Geospatial Science and Technology*, Taylor and Francis, London, 2004.
23. Gillespie, T. W., Monica, L., Barron, S., Karla, K. and Rovzar, C., Predictive modelling for archaeological sites: Ashokan edicts from the Indian subcontinent. *Curr. Sci.*, 2016, **110**(10), 1916–1921.
24. Transport Research Wing. Basic road statistics of India 2011–2012, Ministry of Road Transport and Highways, Government of India, 2013; http://in.tool-alfa.com/LinkClick.aspx?fileticket=03johLzQkm4%3D&tabid=72&mid=486 (retrieved on 22 April 2017).
25. Chadchan, J. and Shankar, R., An analysis of urban growth trends in the post-economic reforms period in India. *Int. J. Sustain. Built Environ.*, 2012, **I**(1), 36–49.
26. Vishnoi A., Heritage Act may be amended to make way for public projects. In *Economic Times*, 30 September 2016; http://economictimes.indiatimes.com/articleshow/54593987.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst (retrieved on 4 January 2017).
27. UNESCO, Convention concerning the protection of the world cultural and natural heritage; http://whc.unesco.org/en/conventiontext/ (retrieved on 5 February 2017).
28. Cunningham, A., Archaeological Survey of India: Four reports made during the years 1862–63–64–65, Government Central Press, Simla, 1871, vol. 1, pp. 103–104; https://archive.org/details/report00cunngoog (retrieved on 12 November 2016).
29. Archaeological Survey of India, Sarnath; http://www.asisarnath-circle.org/EXCAVATION&EXPLORATION.htm (retrieved on 19 April 2017).
30. Archaeological Survey of India; http://asi.nic.in/asi_monu_tktd_up_sarnath.asp (retrieved on 19 April 2017).
31. Rajani, M. B., The expanse of archaeological remains at Nalanda: a study using remote sensing and GIS. *Arch. Asian Art*, 2016, **66**(1), 1–23.
32. Sherring, M. A., *The Sacred City of the Hindus: An Account of Benares*, Trübner and Co., London, 1868, p. 25.
33. Kamath, U. S. (ed.), *Gazetteer of Bangalore Rural District*, Government of Karnataka Publication, 1989, p. 795.
34. Rao, C. H. (ed.), *Mysore Gazetteer, Volume 5*, Government of Karnataka Publication, 1930, pp. 86–88.
35. Aruni, S. K., *Architecture and Sculptural Art of Yelahanka* Nadaprabhus (In Kannada), Bangalore University, 2007, pp. 42–44.
36. Koch, E., *The Complete Taj Mahal*, Thames and Hudson Ltd, London, 2012.
37. Map source, The Huntington Library, San Marino, California, Agra Cantonment, City and environs: season 1868–69, Call number 623665, Survey of India Map. http://hdl.huntington.org/cdm/printview/collection/p15150coll4/id/7094/type/singleitem (retrieved on 16 March 2016).
38. Koch, E., Taj Mahal: architecture, symbolism and urban significance. *Muqarnas*, 2005, **22**, 128–149.
39. UNESCO & WHC, World Heritage List, Taj Mahal, description, http://whc.unesco.org/en/list/252 (retrieved on 6 August 2015).
40. Rao, M. N. and Rao, H. V. N., Air pollution. Economics effects of air pollution. In *Air Pollution*, Tata McGraw-Hill, New Delhi, 1989, p. 77.
41. Sarkar, S. L., Bhadra, A. K. and Mandal, P. K., Investigation of mortar and stone deterioration in the Victoria memorial, Calcutta. *Mater. Struct.*, 1994, **27**(9), 548–556.
42. Belur Math endangered. In *Down to Earth*, 1994; http://www.indiaenvironmentportal.org.in/content/17602/belur-math-endangered/ (retrieved on 20 September 2015).
43. Rao, N. V., Rajashekhar, M. and Rao, G. C., Detrimental effect of air pollution, corrosion on building materials and historical structures. *Am. J. Eng. Res.*, 2014, E-ISSN: 2320-0847 p-ISSN: 2320-0936, 359–364.
44. Korisetter, R., Venkatasunnaiah and Fuller, D. Q., Brahmagiri and beyond: the archaeology of the southern Neolithic. In *Indian Archaeology in Retrospect, Vol. I: Prehistory – Archaeology of South Asia* (eds Setter, S. and Korisetter, R. M.), Indian Council of Historical Research, New Delhi, 2001.
45. Boivin, N., Brumm, A., Lewis, H., Robinson, D. and Korisetter, R., Technological understanding: exploring prehistoric soundscapes in South India. *J. R. Anthropol. Inst.* (*N.S.*), 2007, **13**, 267–294.
46. Menon, S. M., *Ancient Stone Riddles: Megaliths of the Indian Subcontinent*, Manipal University Press, Manipal, 2012.
47. Mukherji, S. A., Jantar Mantar lecture, September 2010; http://anishashekhar.blogspot.in/2010/10/jantar-mantar-lecture-september-2010.html (retrieved on 17 August 2015).
48. Masselos, J. and Gupta, N., *Beato's Dehli: 1857 and Beyond*, Penguin, UK, 2011.
49. Annaswamy, T. V., *Bengaluru to Bangalore: Urban History of Bangalore from Pre-Historic Period to the end of 18th Century*, Vengadam Publications, Bangalore, 2003.
50. Reddy, Y. M., 3,000-year-old site in Bangalore is history. In *Bangalore, DNA (Daily News and Analysis)*, 14 April 2012; http://www.dnaindia.com/bangalore/report-3000-year-old-site-in-bangalore-is-history-1675707 (retrieved on 25 June 2017).
51. Srivatsa, S. S., Pre-historic sites lost to rapid urbanization. In *The Hindu*, Bengaluru, 3 May 2014; http://www.thehindu.com/news/cities/bangalore/prehistoric-sites-lost-to-rapid-urbanisation/article5973534.ece (retrieved on 25 June 2017).
52. Joshi, B., US company to move Tipu Sultan's 18th century armoury in single piece. In *Economic Times*, 29 May 2015; http://timesofindia.indiatimes.com/india/Tipus-armoury-will-roll-across-to-new-location/articleshow/47579945.cms (retrieved on 17 October 2016).
53. Rao, M., Ramamurthy, V. S. and Raj, B., Standards, spatial framework and technologies for national GIS, National Institute of Advanced Studies, Bangalore, 2015.
54. Schmid, F., Cai, C. and Frommberger, L., A new micro-mapping method for rapid VGI-ing of small geographic features. *Proc. GISci.*, 7th International Conference, 2012.
55. Sylaiou, S., Basiouka, S., Patias, P. and Stylianidis, E., The volunteered geographic information in archaeology. *ISPRS Ann.*

Photogrammetry Remote Sensing Spatial Inf. Sci., 2013, **II-5/W1**, 301–306.
56. Haklay, M., Basiouka, S., Antoniou, V. and Ather, A., How many volunteers does it take to map an area well? The validity of Linus' law to volunteered geographic information. *Cartogra. J.*, 2010, **47**(4) 315–322.
57. Stathopoulou, E. K., Georgopoulos, A., Panagiotopoulos, G. and Kaliampakos, D., Crowdsourcing lost cultural heritage. *ISPRS Ann. Photogrammetry Remote Sensing Spatial Inf. Sci.*, 2015, **II-5/W3**, 295–300.
58. Lin, A. Y., Huynh, A., Lanckriet, G. and Barrington, L., Crowdsourcing the unknown: the satellite search for Genghis Khan. *PLoS ONE*, 2014, **10**(3); doi:https://doi.org/10.1371/journal.pone.0121045.
59. Agosto, E., Ardissone, P. and Rinaudo, F., GIS and web-GIS, commercial and open source platforms: general rules for cultural heritage documentation. *Int. Arch. Photogramm. Remote Sensing Spatial Inf. Sci.*, 2007, **XXXVI-5/C53**, 625–630.
60. Myers, D., Dalgity, A., Avramides, I. and Wuthrich, D., Arches: an open source GIS for the inventory and management of immovable cultural heritage. In *Progress in Cultural Heritage Preservation* (eds Ioannides, M. *et al.*), EuroMed, Lecture Notes in Computer Science, Springer, Berlin, Heidelberg, 2012, vol. 7616.
61. He, J., Liu, J., Xu, S., Wu, C. and Zhang, J., A GIS-based cultural heritage study framework on continuous scales: a case study on 19th century military industrial heritage. *Int. Arch. Photogramm. Remote Sensing Spatial Inf. Sci.*, 2015, **XL-5/W7**; http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-5-W7/215/2015/isprsarchives-XL-5-W7-215-2015.pdf (retrieved on 5 January 2017).
62. Premi, M. K., The missing girl child. *Econ. Polit. Wkly*, 2001, **36**(21), 1875–1880.
63. Article 3, Universal Declaration on Cultural Diversity, November 2001.

ACKNOWLEDGEMENTS. In this article, we have drawn examples of various sites from the past and ongoing projects at NIAS, Bengaluru and we thank the funders of these projects: ISRO, Karnataka Knowledge Commission, SERB DST Young Scientist Scheme, Homi Bhabha Fellowships Council, and Prof. Frederick Asher (University of Minnesota, USA). We thank Ravi Korisettar (Karnatak University, Dharwad) for sharing his experiences regarding the challenges in the protection of prehistoric sites. We also thank Baldev Raj (Director, NIAS) for institutional support and encouragement and the anonymous reviewers for their valuable inputs.

doi: 10.18520/cs/v113/i10/1961-1973