GEOSPATIAL ANALYSIS TO STUDY AND PRESERVE CULTURAL HERITAGE LANDSCAPES

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India's high population density coupled with the rapid development of towns, industries, and transportation networks places an immense premium on land. In this context, protecting India's rich built heritage is a huge challenge. The Archaeological Survey of India (ASI) is responsible for over 3,600 sites, including many of the 30 sites inscribed by UNESCO as World Heritage Sites and 42 that are in the Tentative List (properties intended to be nominated). Further, each State's Department of Archaeology is typically responsible for a few hundred sites. As per the provisions of the Ancient Monuments and Archaeological Sites and Remains (AMASR) Act (1952, amended in 2010), these agencies recommend which archaeological sites should be protected. The recommendation for a site is based on its authenticity and integrity. The policies proposed in this note seek to strengthen the ability of these agencies to protect the integrity of archaeological remains of our nation's past without stifling present and future development.

Background

As defined in the ASI's Draft Guidelines (2009) , the integrity of an archaeological site is "a measure of wholeness or intactness" of the site, including "all elements necessary to express its national importance from historical, artistic or archaeological points of view". Integrity is particularly relevant when a site consists of several historical structures spread over a region. While determining the integrity of a site, the ASI guidelines require assessing whether the remains are "safe enough or is already suffering from adverse effects of development and/or neglect." Thereafter, a suitable Protected Area is selected based on traditional exploration on-site and surveys of remains that are visible from the ground. Once the Protected Area is determined, the Act provides definitions of Prohibited and Regulated Areas, which respectively extend to 100 m and an additional 200 m in all directions from the Protected Area.

Issues

This article will discuss two key issues.

1. The need for leveraging a combination of historical data as well as satellite imagery and GIS technologies to identify the historical extent of the site, and thereby define/redefine more effective protection boundaries.
2. The need for establishing a National Archaeological Database (NAD) to serve two purposes:
   a. Effective monitoring of activities within the Protected, Prohibited, and Regulated Areas by multiple stakeholders (including local communities).
   b. Efficient planning for development projects while preserving archaeological remains to the extent possible.

QUESTION 1

Are there more effective ways of delineating protection boundaries to ensure site integrity?

For Nationally protected monuments, ASI's draft guidelines (2009) adopt several of the recommendations of UNESCO's World Heritage Convention (WHC). Among these is the use of satellite imagery and GIS to identify site protection boundaries. ASI presently leverages these technologies at sites where the Protected Area has previously been identified through traditional means. Specifically, the BHUVAN geoportal uses GIS to automatically extend the (digitized) Protected Area of each ASI site to 100 m (Prohibited Area) and 200m further (Regulated Area), forming two concentric annuli around the former.

However, these cost-efficient and non-invasive technologies, which complement traditional on-site surveys and exploration, have not been used to define the Protected Area at any UNESCO, ASI or State Department site in India. The WHC recognises that some countries lack economic, scientific, and technological resources to develop an effective and permanent system of protection in accordance with modern scientific methods. These challenges should not apply to India.

The Heritage Science and Society programme at NIAS has developed expertise in leveraging these technologies (together with historical/archaeological scholarship) to identify several unprotected archaeological structures that have been overlooked by on-ground studies. Often, these structures lie close to Protected Areas but have been unwittingly excluded. The recently published book *Patterns in Past Settlements: Geospatial Analysis of Imprints of Cultural Heritage on Landscapes* describes many instances of this phenomena. A case study based on our research at Nalanda is presented to demonstrate how better site integrity can be ensured by utilizing these technologies in defining the Protected Area.

QUESTION 2

Can spatial information pertaining to protection boundaries be made widely accessible?

For sites under ASI protection, an online decision support system named SMARAC has been created to efficiently process requests for clearances to develop nearby plots of land. Further, by making this spatial information publicly accessible, this valuable service enables other stakeholders (including members of the local community) to monitor the land use within the Protected, Prohibited, and Regulated Areas and report potential misuse to the authorities in a timely manner. Extending this service to sites outside ASI's protection, as well as to unprotected sites with potential or confirmed archaeological value will further strengthen the fragile integrity of built heritage, at least in their present state. To demonstrate this point, a case study of Bodhgaya (not an ASI site) is presented, where significant development has taken place, particularly since the site was inscribed as a World Heritage in 2002.

CASE STUDY 1: **Nalanda**

Nalanda has been protected by ASI from early 20th century, and it was recognized as a World Heritage site in 2016 . In preparation for such recognition, UNESCO's

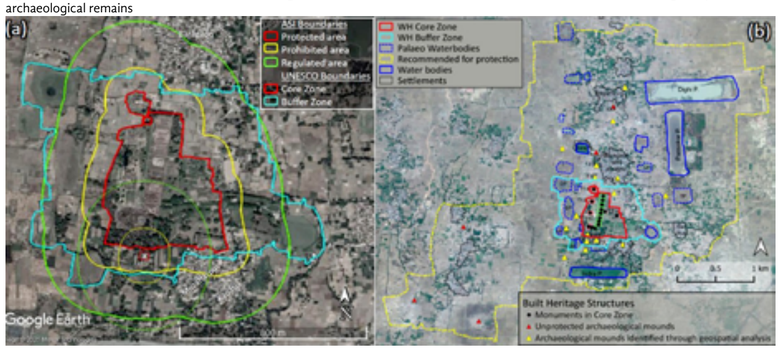

Fig. 1: (a) Protection boundaries around the heritage site of Nalanda, (b) Core and Buffer zone contextualized in the larger expanse of archaeological remains

World Heritage Convention (WHC) necessitates marking so-called Core and Buffer zones. The WHC Operational Guidelines state that boundaries are drawn to include "all those areas and attributes which are a direct tangible expression of the Outstanding Universal Value of the property", as well as "those areas which in the light of future research possibilities offer potential to contribute to and enhance such understanding".

One of the factors that makes Nalanda outstanding is that it was the largest and longest serving (5th century CE to 13th century CE) monastic-cum-scholastic establishment in the Indian Subcontinent. At its peak, it accommodated thousands of scholars, and such numbers could not have been supported within the 0.23km^2 area that ASI presently protects. Thus, in seeking World Heritage status for Nalanda, there were strong reasons to define boundaries differently to the stipulations of the AMASR Act. However, as shown in Fig. 1a, the Core Zone corresponds precisely to the area ASI had previously identified as the Protected Area for the site, and the Buffer Zone falls largely within ASI's Regulated Area. The same is true at most other sites in India that have attained World Heritage status or are in the tentative list.

Using satellite imagery (Remote Sensing) and GIS technologies, we have identified a palaeochannel that drew water to the site, as well as a cluster of past and present water bodies whose shapes, proximity and pattern of spread suggests a more realistic historical extent of the Nalanda's establishment (Fig. 2a).

As long as these regions remain unprotected, we risk losing an opportunity to enhance our understanding of intangible heritage, such as the engineering skills involved in planning the water system. For such cases, simply prioritizing such research could help us glean what we can, after which subsequent development could proceed. Unprotected structures face a far greater threat. In conjunction with historical records, we have identified archaeological remains in a much larger 9.79 km^2 area (Fig. 1b). Note that some of these remains lie just outside the Protected Area (Fig. 2b, which shows one unexplored temple mound to the south and three further mounds to the north), and some lie slightly outside the Buffer Zone (Fig. 1b). These unprotected structures face elevated risk of damage, particularly as nearby development activities are likely to intensify now that the site has acquired World Heritage status. As the next Case Study shows, this is not a hypothetical scenario.

CASE STUDY 2: **Bodhgaya**

Bodhgaya, which is the site of Buddha's enlightenment, was inscribed as World Heritage in 2002. Fig. 3 (left) shows a satellite image from late 2003 as well as the Core and Buffer-1 zones submitted to UNESCO. (The Buffer-1 zone extends 1 km in all directions from the Core zone). Within these zones, we identify several archaeological mounds, an ancient canal, and waterbodies through geospatial analysis.

It is clear from the more recent Fig. 3 (right) that by 2020, although the Core zone was well protected, several modern buildings had been constructed within the Buffer-1 zone (this is also reflected in the successive State of conservation reports of the WHC). Some of these constructions abut archaeological features and diminish their contours. At non-ASI sites such as Bodhgaya, other governmental agencies are authorized to forbid development within these zones if they are close to remains of cultural heritage. However, since these agencies have finite resources, they cannot always prevent unauthorized development. Since BHUVAN does not list any information about non-ASI sites such as Bodhgaya, it is difficult for other stakeholders (including concerned citizens) to alert authorities about potentially unauthorized development within this zone.

Fig. 2

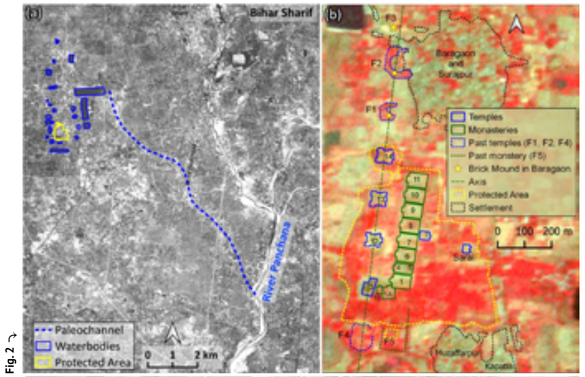

Fig. 3

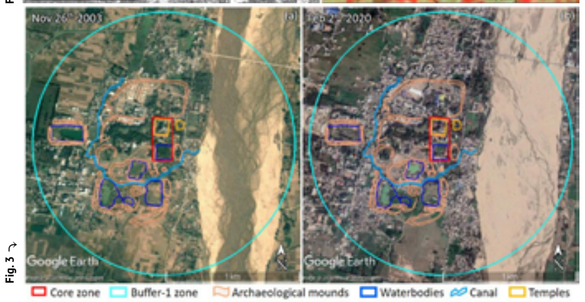

Fig. 4

Fig. 5

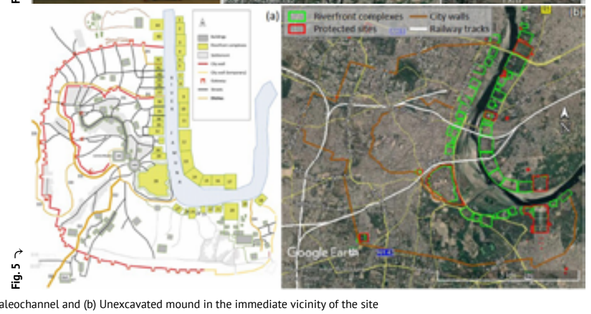

Fig. 2: (a) Nalanda's Protected Area amidst cluster of waterbodies and a paleochannel and (b) Unexcavated mound in the immediate vicinity of the site

Fig.3: The property of Bodhgaya inscribed as a World Heritage site in 2002 in the context of the archaeological landscape identifiable through geospatial analysis. Note the increased number of concrete structures from 2003 (left) to 2020 (right).

Fig. 4: Sarnath (a) Archaeological extent visible in 1861 (sketch by Alexander Cunningham);(b) archaeological landscape disintegrated by roads and railway track identifiable through geospatial analysis; (c) Dhamek stupa, the iconic monument of Sarnath

Fig. 5: Agra (a) A drawing adapted from map of Mughal Agra made by Sawai Jaisingh in 1720, showing a town with 50 riverfront complexes flanking either sides of river Yamuna with a settlement to its west enclosed by 2 tiers of city walls; (b) a Google Earth image showing the locations of key features marked in Jaisingh's map in the context of crisscrossing roads and railway lines.

Fig. 3 clearly indicates that protection boundaries are a double-edged sword. Once they are set, they protect the structures within while simultaneously heightening the threat to structures outside. This risk is heightened at World Heritage sites, as redevelopment projects aim to cater to the growing number of visitors. Hence, site protection boundaries must be selected with utmost care.

Proposed Policies:

1. The historical extent of a cultural heritage site based on geospatial analysis should be considered when determining its Protected Area

A careful study of the landscape in the vicinity of a site using satellite imagery can lead to two important types of discoveries that may improve our overall understanding of the site: the discovery of further instances or attributes of built heritage, and the discovery of artefacts such as former water bodies, canals, and mounds associated with past human activity at the site. This geospatial analysis must be integrated with historical spatial records such as old maps, records, paintings, and field surveys to estimate the site's historical extent. The distribution of confirmed and probable authentic remains within this extent should be considered, in addition to traditional on-site exploration and surveys, to determine the Protected Area for the site.

The onus for identifying the historical extent must rest with the academic research community for two main reasons. First, there is often insufficient evidence to precisely determine a site's historical extent. Hence, any proposed historical extent must be evaluated based on a peer review of objective facts. This includes evaluating fresh evidence, such as data obtained using new technologies. Second, there is no uniform or formulaic approach to geospatial analysis of all cultural heritage sites, because the process of analysis is sensitive to variations between sites. Hence, a peer review of the techniques applied is necessary before the analysis can be relied upon.

2. Adequate funds must be provided to conduct geospatial analysis at all sites

When compared to traditional on-site exploration and surveys, geospatial analysis is extremely efficient, both in terms of time and cost. Unfortunately, there is presently a lack of capacity to conduct such an analysis for all sites in a short period of time. Hence, the following steps should be taken:

a. Prioritise rapidly developing areas. As we have seen, many archaeological remains are inadequately protected. In areas where rapid development is underway or imminent, it is necessary to perform geospatial analysis on priority. This includes all sites inscribed as World Heritage sites where, as noted earlier, sustained developments due to high tourist footfall can be expected.

b. Training. Institutions with the necessary expertise should be provided support to run training programmes for ASI, State Departments of Archaeology, and other partner institutions so that geospatial analysis of sites can be rapidly scaled.

Multiple sources should be tapped for funding for these activities, including Government, Industry CSR funds, philanthropy, as well as regional and international organizations who may have interests in protecting specific sites, or sites in specific regions. Finally, continued research funding for applications of science and technology to study cultural heritage landscapes is crucial to sustain research in new techniques and in leveraging new technologies.

3. A national-level geospatial database of all cultural heritage landscapes must be created and mandatorily consulted prior to authorizing any development

The negative impact of developmental activities on India's cultural heritage is not a recent phenomenon. For instance, several 19th century public works projects caused significant damage to cultural landscapes at Sarnath and Agra (see Fig. 4 and 5). If there is lack of awareness about the extent or value of archaeological heritage present in a region, even authorized developmental activities can cause significant damage. Therefore, it is imperative to create and maintain a geospatial database that identifies archaeological landscapes. Further, this authoritative resource must be made available publicly and referenced while authorizing all development. 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 absence of such a database can lead to significant economic losses, as illustrated in Srirangapatna. One of Tipu Sultan's armouries was located very close to the railway tracks. When the track-doubling project was proposed, a database that listed this historic structure would have alerted planners to the problem. At this early stage, the public could have been informed of the need to either demolish this historic structure, or to consider alternatives with a range of associated costs. Unfortunately, the project was sanctioned and later stalled by the awareness of the structure. The government then proposed relocating the armoury (Fig.6) at significant additional expense, when it was too late to consider less expensive or less disruptive alternatives.

Unlike a database such as BHUVAN, this resource must include not just confirmed and protected sites, but also potential remains of cultural heritage identified through geospatial analysis. This database should be regularly updated based on new research findings.

Finally, the database must be publicly accessible so that agencies involved in cultural heritage protection, as well as concerned citizens, can assist with monitoring changes to land use in the vicinity of sites,

Fig. 6: Armoury of Tipu Sultan at Srirangapatna located near the railway station (photo taken post relocation). A series of Google Earth images showing it locations before and after relocation.

and to alert authorities in charge of their protection in case anything suspicious is observed. Efforts to sensitise communities to their local cultural heritage can begin even at the school level, in line with the recommendations of the National Education Policy 2020 (4.29, p.16).

Concluding remarks

We are fortunate that so much of our built heritage has survived, and some of these surviving remnants have not yet been discovered. While it may not be feasible to protect everything of historical significance, finding as much of what has survived is far less costly. Our interest therefore is to find and record as much of our cultural heritage as quickly as we can, so that we can make carefully considered decisions on what we must preserve. If we must forego something, it should only be due to a lack of resources, or competing demands in the public interest – but never because we were unaware that it had survived. □

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PROGRAMS

Summer School for Women in Mathematics and Statistics
14—21 June 2021 ✦ *Organisers* — Siva Athreya and Anita Naolekar

Online School and Discussion Meeting on Trapped Atoms, Molecules and Ions
10-22 May 2021 ✦ *Organisers* — Bimalendu Deb, Sourav Dutta and Saikat Ghosh

Non-Hermitian Physics
22-26 March 2021 ✦ *Organisers* — Manas Kulkarni and Bhabani Prasad Mandal

Probabilistic Methods in Negative Curvature
1-12 March 2021 ✦ *Organisers* — Riddhipratim Basu, Anish Ghosh and Mahan M.J.

OUTREACH

Kaapi With Kuriosity has been temporarily renamed Kuriosity During Quarantine. All talks are held online.

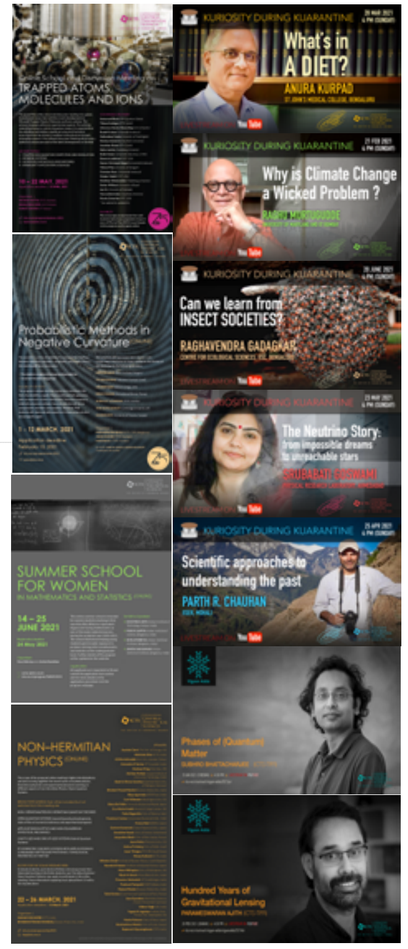
KURIOSITY DURING QUARANTINE

Can We Learn From Insect Societies?
20 June 2021 ✦ *Speaker:* Raghavendra Gadagkar *(Indian Institute of Science, Bangalore)*

The Neutrino Story: From Impossible Dreams to Unreachable Stars
23 May 2021 ✦ *Speaker* — Srubabati Goswami *(Physical Research Laboratory, Ahmedabad)*

Scientific approaches to understanding the past
25 April 2021 ✦ *Speaker* — Parth R. Chauhan *(Indian Institute of Science Education and Research, Mohali)*

What's in a Diet?
28 March 2021 ✦ *Speaker* — Anura Kurpad *(St John's Medical College, Bengaluru)*



Why is Climate Change a Wicked Problem?
21 February 2021 ✦ *Speaker:* Raghu Murtugudde *(University of Maryland and IIT Bombay)*

VIGYAN ADDA

Phases of (Quantum) Matter
15 June 2021 ✦ *Speaker* — Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*

Hundred Years of Gravitational Lensing
28 February 2021 ✦ *Speaker* — Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*