A new institutional and organizational set-up in the Forest Department is required for tagging farm-grown timber using high-end technologies like DNA barcoding and microscopic anatomical authentication. Another aspect is the development of a standard certification mechanism for legal logging of trees on farmlands and custody of the harvested produce in trade. Similar to timber handling in Panama[14], establishing a timber traceability and monitoring system through the use of electronic-microchip tagging and linking to the national database will help monitor timber flow from agroforests and farm forests in the country, and ensure the legality of tree cultivation on private lands and authority of wood ownership. Generation of data-based QR codes and application software for the verification of farm-grown timber in transit holds the key to informed decision-making and sustainable production of TOFs, besides protecting the existing natural forest in the country.

The International Day of Forests 2022 envisaged forests for sustainable production and consumption by provisioning wood for people and the planet on sustainable basis. Sustainability can be achieved when all stakeholders participate in the process and each gets a justified share of profit for their role. Though farmers are cultivating sandalwood and red sander trees, the Forest Department has to extract the wood and fix the prices. This process keeps the growers in a vicious cycle of doubts. In order to avoid such bottlenecks and enhance the green cover of the country with sustainable wood production process, policy reforms and special institutional mechanisms are required for dealing with TOFs.

India has set a target of bringing 33% of its geographical area under forest cover as envisaged in the National Forest Policy, 1988. The latest forest cover assessment claims a marginal increase in the country's total forest and tree cover. However, the claim of an increase in forest cover that was celebrated by the Government, was disputed by sector experts as they highlighted discrepancies in the methodology noting that the report counted plantations on the road, as well as rubber, coffee and tea plantations and also patches of trees as forest cover[15]. Many experts highlighted the duality in the definition of a forest. The Forest Conservation Act 1980 does not include forest land diverted for non-forest purposes and roadside plantations as forests. However, the biennial assessment of forest status considers such areas as forests. This needs to be addressed by formulating a separate policy. Trees are considered as the ecosystem service station. There is a need to provide incentives to farmers who adopt agroforestry in their farmlands for providing various ecosystem services. Further, there is a need to value trees beyond timber, viz. oxygen production potential, carbon sequestration potential, nutrient cycling, etc.


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# Insights on Indus settlement in the palaeo-Saraswati basin, Bhiwani district, Haryana, India

The famous South Asian Bronze Age civilization, also known as the Indus or Harappan Civilization, that flourished between 3200 and 1400 BC, is considered one of the three greatest urban riverine civilizations in the world[1,2]. The Indus Valley Civilization (IVC) spread along the Indus river and extended from northeast Afghanistan to northwest India[2,3] (Figure 1 *a*), encompassing a vast area with an ecologically diverse environment[4,5]. About 1500 Indus sites, ranging from village farming communities to large cities with thousands of people, were known to exist in the subcontinent[2]. However, in comparison to its wider extent, the true potential of the Indus/Harappan sites is yet to be explored. There is an ongoing debate regarding the cropping pattern and how the ancient societies responded to variable environments and ecological changes during the last 5000–3500 yrs BP[4,6].

So far, information on socio-economic conditions of the Harappan Civilization due to plant- and animal-based subsistence economy is available. Extensive data regarding floral[2] and faunal diversity[7,8] are available. However, a systematic and multiproxy approach is needed in the near future to evaluate regional subsistence patterns vis-à-vis varying monsoonal changes from more sites. Various studies have correlated climatic events with cultural transformations identified by archaeological studies[9–13], but these only address the decline and ultimate abandonment of sites, underestimating the ecological diversity and cultural variation. A multiproxy approach using macrobotanical remains and isotopic studies of habitational layers at the Indus site Khirsara in Kutch district, Gujarat, India, has been employed to evaluate regional subsistence pattern vis-à-vis varying monsoonal climate[14]. Therefore, insights using the multiproxy approach appended with Accelerator Mass Spectrometry (AMS) dates will shed new light on human–environment interactions and responses to climate change.

A few sites cannot represent the whole IVC. The Indian subcontinent is diverse in its landforms, flora and fauna, vegetation pattern, rainfall, climate, soil types and cultural background. So, to properly understand the human–environment interrelationship, an understanding of the local context and environment is needed.

The present study was undertaken to understand the human–environment relationship at the Indus/Harappan site Tigrana (lat. 28°53′25.9″N and long. 76°08′08.8″E), located in Bhiwani district, Haryana, India (Figure 1 *a*–*c*). The location of this site between the Indo-Gangetic Plains and the Thar desert in Rajasthan makes it distinctive. Tigrana is considered as one of the important sites in the upper Saraswati Basin, which is located on the southern periphery of the alluvial plains. The hydrography of the area has not yet been defined. However, an old channel depression can be observed on the southern side of the archaeological site[15]. To understand the nature of the archaeological site, its chronology and the culture–climate–subsistence relationship, an excavation was conducted in 2020–21.

The ceramic assemblages and antiquities from the cultural deposits revealed Early Harappan, Mature Harappan and Late Harappan phases at the site. The ceramics

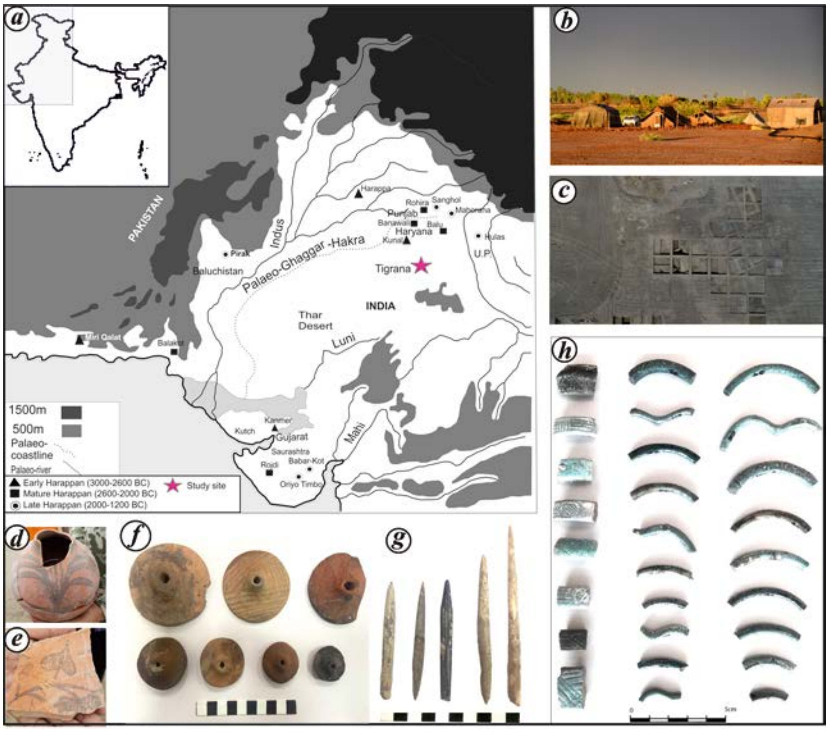


**Figure 1.** ***a***, Map showing the study site along with Indus/Harappan sites in northwest India evaluated for archaeobotanical records. ***b***, Panoramic view of Tigrana site showing the field excavation camp. ***c***, Aerial view of trench layout plan for excavation ***d***, Potsherd showing painted floral motifs, possibly paddy plant. ***e***, Potsherd showing painted floral motifs, possibly peepal (*Ficus religiosa*). ***f***, Terracotta wheels. ***g***, Bone points. ***h***, Faience bangles.

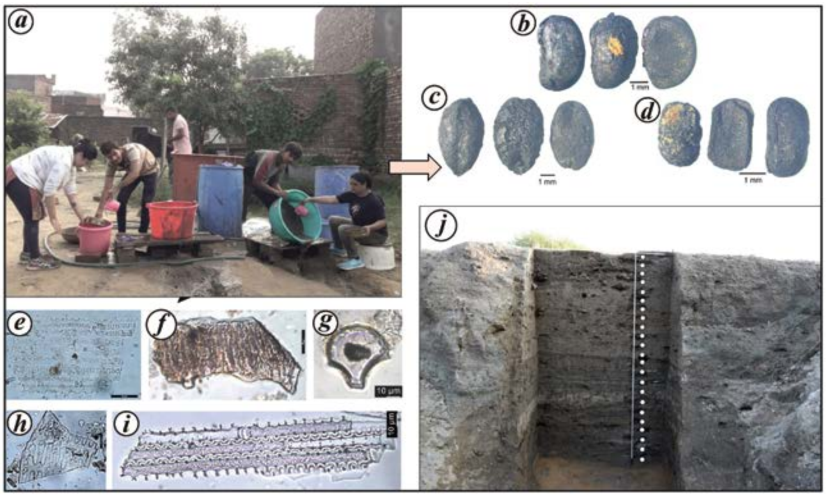


**Figure 2.** ***a***, On-site wet-floatation for recovery of macrobotanical remains. Carbonized remains of grains/seeds. ***b***, *Macrotyloma uniflorum* (horse gram). ***c***, *Hordeum vulgare* (barley). ***d***, *Vigna radiata* (black gram). ***e***, Multicell panel of grasses. ***f***, ***g***, Rice type phytoliths. ***h***, Millet type multicell panel. ***i***, Multicell panel of grasses. ***j***, Trench profile for multiproxy (phytolith, pollen and isotopic) analysis.

**Table 1.** AMS radiocarbon dating of carbonized grains at the Inter University Accelerator Centre, New Delhi (lab code: IUACD)

| Sample | Lab ID | Radiocarbon age (BP) | Cal BP ($2\sigma$ range) | Cal BC ($2\sigma$) |
|---|---|---|---|---|
| TRN/ZA1/140-170 | IUACD#21C3590 | 3790 ± 32 | 4290–4010 | 2341–2061 |
| TRN/ZA1/190-204 | IUACD#21C3591 | 3845 ± 32 | 4405–4151 | 2456–2202 |
| TRN/ZA1/235-243 | IUACD#21C3592 | 3836 ± 37 | 4405–4100 | 2456–2151 |

mostly dull red or light coloured, well-fired, wheel-thrown, fired to red or grey core and painted with black colour (Figure 1 *d* and *e*). Numerous steatite beads, terracotta bangles and copper objects were found. Miniature pots having horizontal bands on the neck were also retrieved[15].

Along with ceramics, a variety of ornaments, objects and tools were retrieved from Tigrana (Figure 1 *f* and *g*). Locally produced faience and terracotta objects were dominant. No faience fragment was found in the Early Harappan phase and the first occurrence of faience bangle was from the Mature phase (Figure 1 *h*), which showed a better representation in the Late phase. Several faience antiquities, including bangles of faience (light blue to sky blue-coloured) and terracotta, animal figurines, wheels, balls and beads of semiprecious stones (agate, carnelian, steatite) were recovered. On the basis of raw materials and slags of faience along with evidence of furnace, it can be surmised that the Tigrana site was inhibited by craftsmen and served as an important regional centre for the production of faience objects in the Late Harappan phase. The faience manufacturing during that time must have played an important role in connecting different settlements with each other[15].

To compare the information of various sites and establish a spatio-temporal human–environment interaction over a vast area requires well-dated information. At Tigrana, stratigraphical evidence showed a continuous cultural transformation from the Early to Late Harappan period. A similar cultural sequence was revealed from the Indus site Balu[16,17]. The earliest cultural materials from the adjoining sites, i.e. Mitathal-I, Farmana-I and Manheru-I showed a close affinity with Tigrana and belonged to the Sothi–Siswal phases A and B, and were dated between 3200 and 2600 BCE. There is no doubt that the earliest cultural materials of Tigrana were related to the Late Siswal phase B and can be placed around 2800 BCE[15]. So far, we have three direct dates of barley grains (AMS; Table 1), which authenticate the Mature phase. However, more dates from the lower and upper stratum will confirm the Early and Late phases along with the ceramics.

An on-site wet floatation was carried out to study past subsistence strategies (Figure 2 *a*). Preliminary studies of the floated samples revealed evidence of *rabi* and *kharif* crops such as cereals, pulses, oil-seeds and fibre-yielding crops along with weeds and wild taxa (Figure 2 *b*–*d*). This was further attested by micro-remains (phytolith) analysis (Figure 2 *e*–*i*). The integration of macro- and micro-botanical remains holds great potential to complement each other and to provide further information on crop processing[13]. At Tigrana, the presence of rice along with other cereal crops in the Mature Harappan level was significant, as it is a crop of the Gangetic Plains and its early diffusion into Indus is still being debated[18]. Tigrana is located in the eastern periphery of the Harappan extension. Information on socio-economic activities is meagre from this region, as few sites have been studied for plant-based subsistence economies.

A careful understanding of subsistence, ecology and regional climate systems is needed to interlink human–environment relationships. In order to understand the cropping pattern, vegetation and palaeoclimate of the region, on- and off-site soil samples were collected systematically during the course of excavation (Figure 2 *j*). Ongoing analyses at Birbal Sahni Institute of Palaeosciences, Lucknow, including macro-remains, phytolith and geochemical studies will help refine the existing knowledge. The expected outcome would enable us to draw firm conclusions about climate–culture–subsistence relationships during 5000–3500 yrs BP in an unexplored palaeo-Saraswati basin.


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