Weber S.A., *et al., Man and Environment* XXXV(1): 62-75 [2010].
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Ecological Continuity: An Explanation for Agricultural Diversity in the Indus Civilization and Beyond

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Abstract

The northwest portion of South Asia was characterized by great ecological and cultural diversity from the prehistoric to the historic era. Soils, climates and moisture patterns that differentiate one region from another remained relatively stable from the time of the Indus Civilization into the colonial period. Ecologically distinct regions were closely associated with specific agricultural strategies that were equally as distinct. The argument put forward in this paper is that we can better understand the agricultural diversity and hence, cultural diversity of northwest South Asia in these periods, by identifying those ecological zones that remained relatively stable over time.

Introduction

The Indus or Harappan Civilization, located in the northwest portion of South Asia, has been extensively studied and appears prominently in the literature as one of the earliest urban civilizations of the ancient world. The urban period, from 2600 to 1900 B.C., includes nearly a thousand sites dispersed in an ecologically diverse environment throughout northwestern India and Pakistan. Models of the agricultural practices of these Harappan communities are based on region-wide environmental conditions that are mainly driven by the seasonal constants of summer monsoons and winter rains. These models, while correct in distinguishing the general moisture patterns, fail to incorporate how local environments and different regional ecosystems determine diverse and distinct agricultural communities. The importance of understanding the impact of local environments on any specific agricultural community is primary in understanding agricultural strategies, responses to climatic shifts, and the development of social systems. While these issues have not gone unnoticed (Possehl 1996; Madella 2003; Miller (unpublished); Madella and Fuller 2006), mega-regional modelling is still the norm. This paper will demonstrate why we need to focus more on micro-regional models and lay out how this might be done.

Received : 11-07-2009
Revised : 03-11-2009
Accepted : 28-11-2009

The Indus Civilization and the Importance of Agriculture

The socio-political, economic and environmental conditions that prevailed during the Indus Civilization are still hotly debated (Weber 2003: xii). While there may be little consensus as to why this region developed such a civilization, how it evolved, or even why it disappeared, no-one disputes the importance of agriculture in this sequence. Agricultural production of the Indus civilization was based on a long history of food production, incorporating many different groups of people, spread over a very large area.

Geographically, the Indus civilization extends from the Himalayas in the north to the Arabian Sea to the south. This area incorporates the coastal regions from Saurasthra in India westward to the Iranian-Pakistan border. To the west, it is bordered by the Baluchistan mountain ranges and on the east by the Thar Desert and Ganga-Yamuna Doab area. Covering an area of over 1,000,000 km^2, the Indus civilization is one of the largest of its time (Fig. 1). At its height, around 2600 B.C., the civilization had communities containing houses with uniform sized bricks, granaries, large city walls, gateways, and extensive areas of craft production (Kenoyer 1998; Possehl 2002). Craft products were often standardized and distributed throughout the region. The demand for raw materials, food, and finished products meant that a significant amount of interaction was necessary and helped integrate the civilization (Weber 1999:

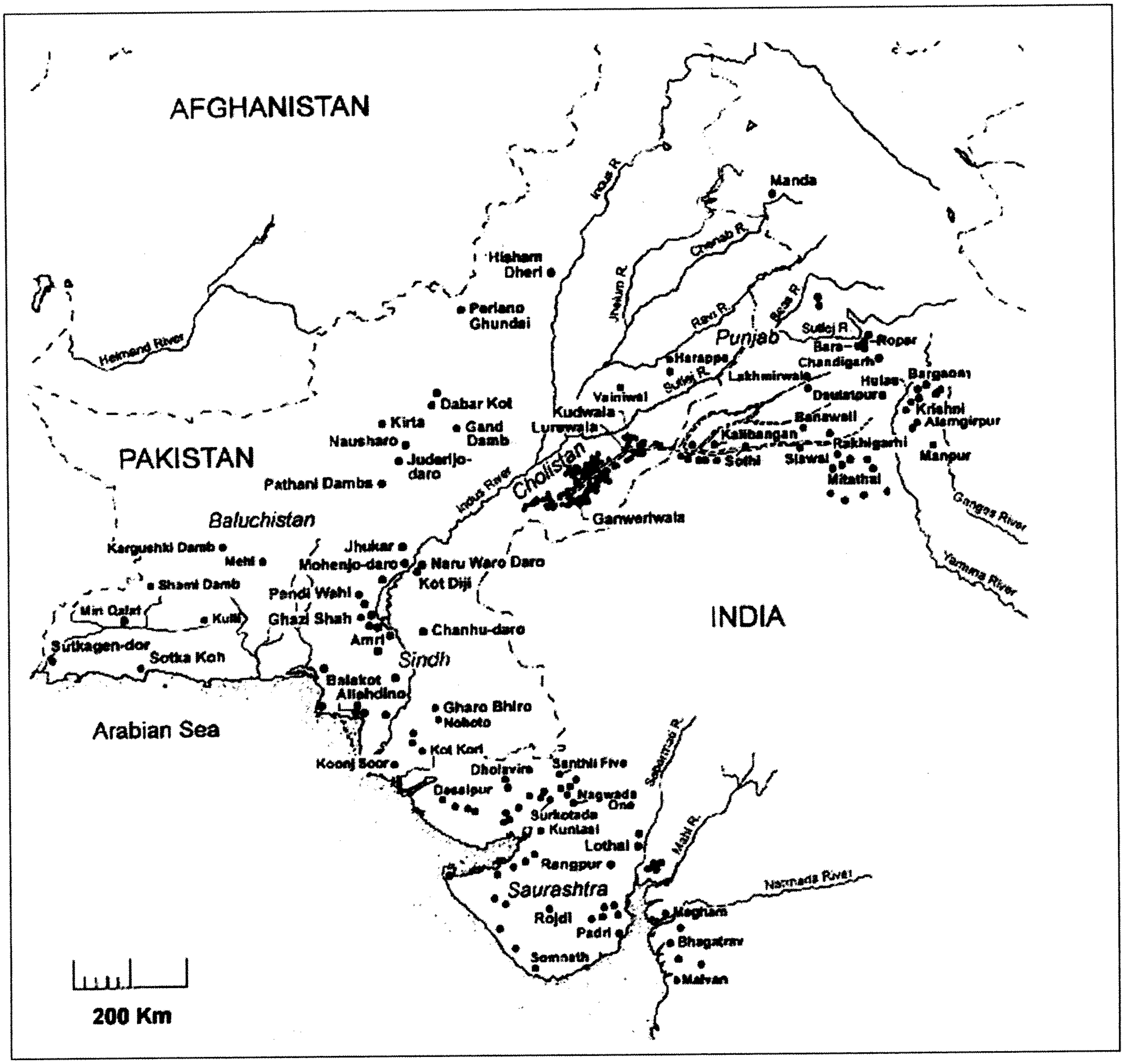

Fig. 1: Map showing Indus civilization sites

813). Common pottery, standardized weights and the widespread use of seals imply a shared ideology and the existence of an administrative system to oversee the manufacture and distribution of goods (Weber 1999; Kenoyer 1998; Possehl 2002). The cultural homogeneity that characterizes the Harappan civilization lasts for nearly 600 years or until around 1900 B.C. At this point, the cultural integration begins to break down and we see a rise in regional systems that were no longer held together by a single ideological or socio-economic system.

The subsistence system consisted of a food producing economy with domesticated plants and animals, some hunting, fishing, and wild plant gathering (Meadow 1996; Weber 1999:813). The Harappan agricultural strategy was based on two main growing seasons. The *rabi* or winter season involves crops sown in the autumn, harvested in the spring and fed with winter rains. Winter crops might include barley, wheat, oats, peas, lentils, chickpea, jujube and mustard. The second cropping season was the *kharif* or summer season which was based on plants sown in the summer and harvested in the fall, making use of the summer rains. Prehistorically, the summer sown plants included a variety of millets, dates, gram, cotton and possibly rice.

Reconstruction of Harappan agricultural practices is primarily based on a limited archaeobotanical record. Although carbonized seeds, leading to subsistence reconstruction, have been recovered from fewer than 50 Harappan sites (Fuller and Madella 2000; Weber 2003; Kajale 1991), extensive models have been developed to explain seed patterning and agricultural strategies (Meadow 1989, 1998; Jarrige 1985; Weber 1999; Fuller 2003). While the majority of these sites contained a variety of grains, implying the use of both summer and winter cropped plants, the emphasis at each site seems to have been on one season over the other. This has in turn led to modeling Harappan agriculture as either a *rabi* or a *kharif* system (Weber 1989, 1999; Meadow 1989, 1996). Harappan sites in Baluchistan, Bannu Basin, Sind, Punjab, Swat, and Kashmir are most often described as a *rabi* based agriculture system while sites in Gujarat and western India are seen as being based on a *kharif* system (Weber 1999). This pattern of dividing regions by agricultural strategy based on their primary cropping season continues through the historic record and into modern times. We will argue that focusing on either winter or summer crops is insufficiently precise, and misses distinct differences between sites that focus on the same cropping season. We can better understand the agricultural diversity, and hence cultural diversity of the Indus civilization by identifying local or micro-ecological zones that remained relatively stable over time.

Agro-ecological Zoning

There are different approaches to examining the relationship between subsistence, geography and material culture. In 1989, Gregory Possehl (1992) identified subsistence zones that coincided with stylistic zones of material culture. In this cultural ecological approach, Possehl (1992: 238) constructs a "cultural mosaic" consisting of six distinct Harappan provinces (East Punjab Harappan, Bahawalpur Harappan, Late Kot Dijian, Sindhi Harappan, Kulli Harappan, and Sorath Harappan). In contrast to Possehl's approach to connect subsistence practices with ceramics in an effort to identify Harappan cultural diversity, we believe that we must first identify local ecological zones that impact agriculture and subsistence regimes. Since crop selection, density and distribution are based on a variety of factors including the availability and amount of moisture, temperature, soils and topography, it is important to understand and identify the interactive relationship between these ecological variables and the agricultural responses for all areas of the Indus civilization. This landscape ecology approach (see: Bhan *et al.* 1997; Van West and Kohler 1996), should lead to a better understanding of the relationship between ecological variables, Harappan agricultural practices, and their impact on material culture, population demographics, and habitat loss and degradation.

The Model

The goal of the model, as seen in the flow chart (Figs. 2-3), is to demonstrate how we might identify specific Harappan Agro-ecological zones and then identify the impact these zones have on food production and ultimately Harappan culture. To identify these zones we first need to recognize the climatic and moisture based variables, the range in biodiversity and the geological and topographic variables.

Climatic constraints (Fig. 2) not only influence which crops can be grown but also Harappan agricultural productivity. Such variables as monsoon and wind patterns, rainfall, river flow and catchments, standing water resources, and temperatures, need to be considered. All but standing water resources are highly seasonal, and are differentiated by the variance between winter rains and summer monsoons. Necessary data can be found in contemporary climatic surveys and historical ethnographic data. While neither source can help us quantify the climate for the Indus civilization, it should be able to provide insight into the differences and patterns between the regions, which is the underlining goal of the model.

The second component under review is the natural biodiversity (Fig. 2). Specifically this would include the indigenous fauna and flora. This data is derived from both paleo-environmental reconstructions and also contemporary landscape ecology. Much of the latter has been the focus of conservation studies and habitat mapping. Of final consideration are the geologic variables, including soils, topography (as it relates to spatial relationships) and mean elevations. Much of this information comes from either geologic reconstructions or contemporary

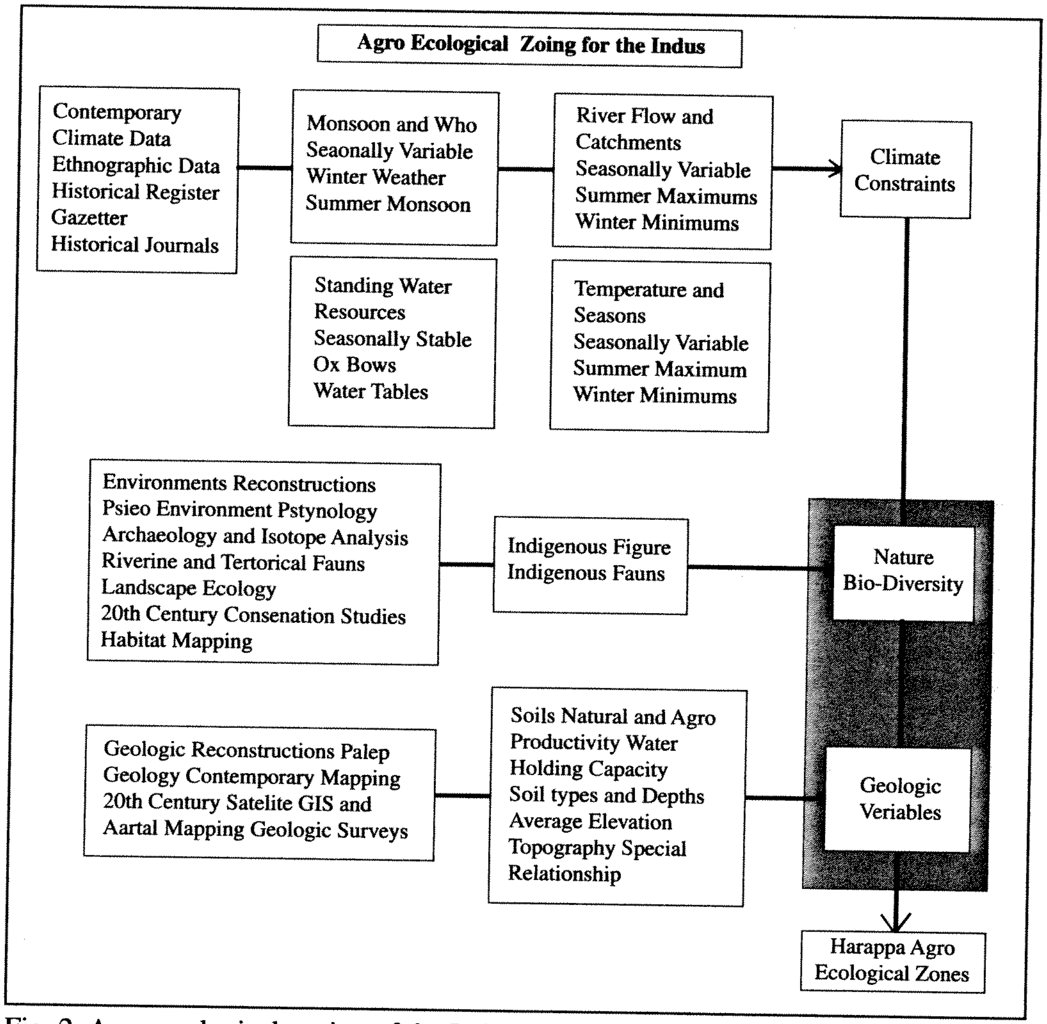

Fig. 2: Agro-ecological zoning of the Indus Civilization

satellite, GIS and aerial mapping. Once again, while this does not provide exact quantification of the local environments, it does establish patterns for differentiation and review for the region.

With these constraints in mind (Fig. 2), regional responses should be observable in the archaeological record, represented specifically in cultivation practices, animal husbandry, wild plant and animal usage, and water management (Fig. 2). These are in turn entwined with material culture, population demographics, and habitat loss and degradation. These in turn contribute to changes in the flora, fauna, soils and topography. We need to recognize that there is a continuous feedback loop between human induced changes in the landscape and agricultural practices (Figs. 2-3).

Cropping patterns should be recognizable both through the archaeological record and by ethnographic comparison. Contemporary and historical examples are summarized in government reports, ethnographies and journals. An analysis of wild plant cultivation requires paleoenvironmental reconstructions and ethnobotanical analysis such as palynology, phytoliths, and archaeobotanical studies. Research into, and evidence for water management systems for this region should identify sheet flooding, oxbow lakes, redirected waterways, and wells. Some information might be sourced through ethnographic research. Much of it, though, is inferred from careful research into tool technologies and evidence of faunal use in subsistence (for example, use of lake fish versus stream fish).

Materially these constraints should be represented in cooking and storage technologies, food selection, symbolism, and land ownership. At the same time there should be corresponding evidence within the archaeological and ecological record of varying

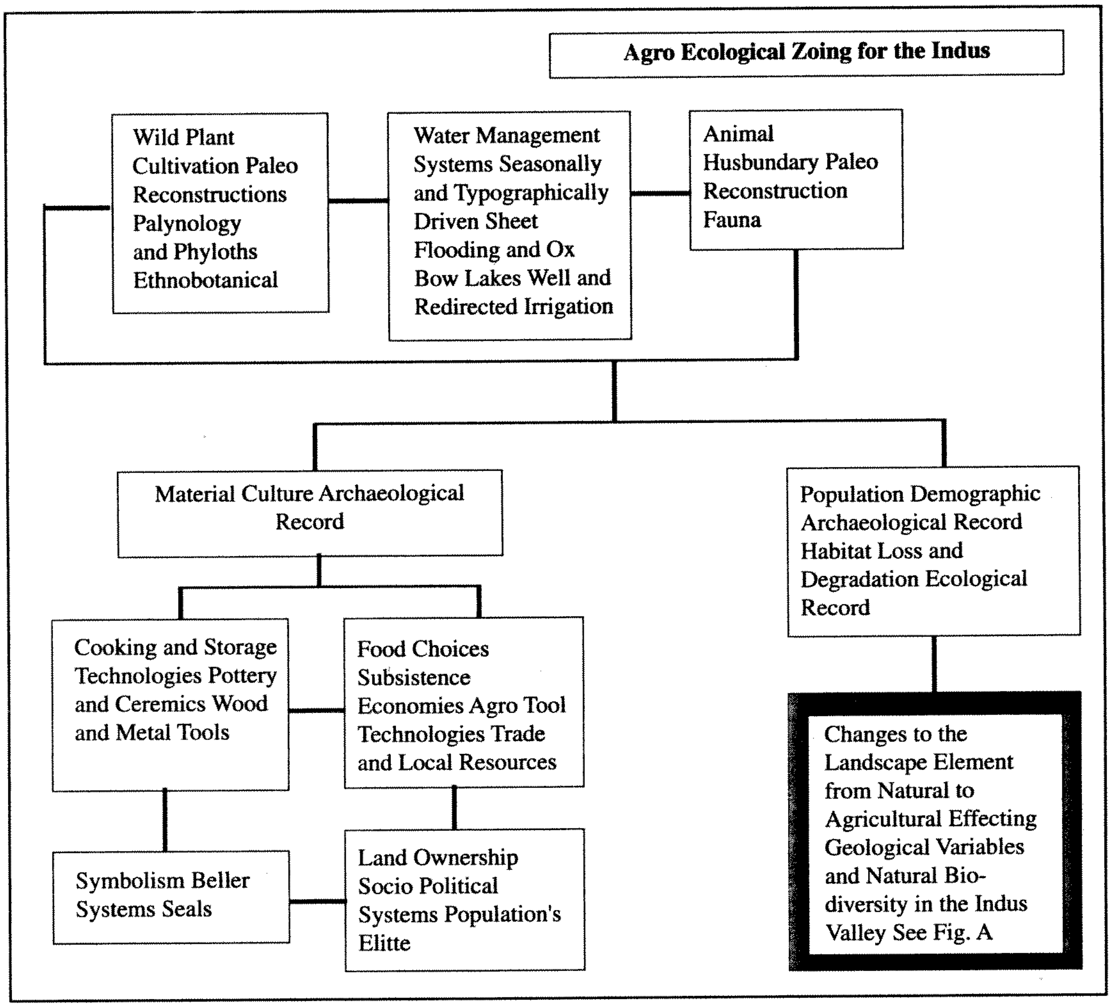

Fig. 3: Harappan Agro-ecological zones

population demographics and habitat loss and degradation. These three components should provide substantive evidence of divergence in local culture as responding to environmental constraints.

This flow chart is meant to be a tool that can facilitate analysis of regional changes as a response to ecological constraints. The assumption is that this civilization represents a mosaic of ecological niches that would be distinctively accessed by local populations. Each would respond with unique subsistence economies that provided a substantial return on investment. These variances should be recognizable in the archaeological record. Utilizing this tool should allow the researcher to recognize regional variations towards the goal of establishing agro-ecological zones that might impact local communities in distinct ways.

Continuity and Change

Ecological continuity and change in this region over the last 5000 years is difficult to document. Environmental data has been contentious and contradictory (Possehl 2003: 6; Madella 2003:238; Madella and Fuller 2006). The current understanding of the environmental conditions for the Indus Civilization is best described as enigmatic. Environmental inferences and reconstructions are most often based on palynology and sediment studies of the Thar Desert in the Western Rajasthan (Singh *et al.* 1990; Enzel *et al.* 1999; Deotare *et al.* 2004) and studies of coastal Arabian Sea and Himalayan cores (von Rad *et al.* 1999, Phadtare 2000, and Rangarajan *et al.* 2000). Most of these studies suggest that by the third millennium B.C. the climate had shifted from a 1500 year moist cycle into a dry climate pattern more similar to contemporary times. It is also suggested that by the end of the second millennium

B.C., the climate may have further desiccated (Enzel *et al.* 1999; Phadtre 1997; Singh *et al.* 1990; Staubwasser *et al.* 2003). There is growing consensus that changing moisture patterns did impact the Indus civilization and that shifts in rainfall may have been a contributing factor in the rise and decline of Harappan urbanism (Madella and Fuller 2005:16). It should be understood that shifts in the summer monsoons as well as the winter rains are results of large regional systems and not simply part of a local event. All areas of the Indus civilization were impacted by these shifts just as they are today. Local ecologies were certainly not immune to these events, and should not be studied apart from them. At the same time, in the absence of local studies, local environments have been inappropriately extrapolated from both regional studies and the analysis of material remains (Madella 2003: 238).

The basic premise of the agro-ecological zone model is that we can reconstruct the palaeoecology of the Harappan civilization and define zonal variation. Assuming climatic change both occurred, and was regionally constant, and that any local climatic changes were relative to the regional changes, the differential between Harappan sites might be viewed as a constant. That is, while it cannot be assumed that the climate of the Indus civilization represents an exact equivalent to current measures of precipitation and temperature, it might be assumed that there would be a statistical parallel to contemporary trends and seasonal variance. While prehistoric seasonal averages and variances might have fluctuated, the climatic "patterns and differentials" should not dramatically differ with regards to contemporary standards, providing a benchmark for determining site differentials. In other words, there is ecological continuity, in that the zonal ecologies of the past have been relatively stable in comparison to each other. These ecologically distinct zones, past and present, are closely associated with specific agricultural strategies that were equally distinct, identifiable and may impact cultural diversity.

Agro-ecological Zones

Where archaeologists traditionally divide the Harappan civilization into no more than six or seven regions (see: Possehl 1989: 238) and into even fewer agriculturally distinct environments (Weber 1992, 1996), the civilization could easily be subsidized into dozens of distinct agro-ecological zones. If we look at recent efforts to subdivide South Asia into ecologically distinct regions we can begin to see the possibilities of this approach. For example, the Pakistan Agricultural Resource Council (FAO 2004: 3-6) separates Pakistan into 10 Agro-ecological Zones. Each zone has a distinct soil and environmental conditions that directly influence how individuals within the local economies could and would have responded agriculturally. To simplify these zones into fewer, larger regions ignores the extensive environmental diversity of the region.

Studies of the Harappans have tended to focus on large regional trends that look for similarities and uniformity rather than differentiating important variables seen in the archaeological record. This holds true for the ecological variables as well as for subsistence regimes. Current subsistence models for the Indus civilization have been focused on a dual-cropping system that would have taken advantage of the seasonal constants of summer monsoons and/or the winter rains (Weber 1992, 1999; Meadow 1989, 1996). Through this template, agricultural research has been typically driven towards site comparison studies in an effort to identify mega-regional universals that would link them in context with an "Indus Culture Core." While this methodology has provided insight into regional similarities, it has not taken into account local environmental pressures that would have differentiated the micro-regional subsistence models. The use of local agro-ecological zones would identify unique climatic, geologic and riparian pressures that could in turn help distinguish distinct agricultural practices on a micro-level.
It is too early to attempt to subdivide the Indus Civilization into agro-ecological zones; however, to show the value of such an approach, the remaining portion of this paper will look at the available data from three of the most well known Harappan sites, and build a local agro-ecological zone for each. In so doing we can demonstrate the interpretive value of such an approach.

Comparing the Agro-ecological Zones of Harappa, Mohenjo-daro and Lothal

Of the many options for potential agro-ecological zones that may have existed within the borders of the Indus Civilization, we will limit our analysis to three specific regions that contain sites that have been subject to extensive archaeological investigations. Only through comparing the historical and contemporary water resources, soil context, and climatic patterns of the local regions around Harappa, Mohenjo-daro and Lothal, will we begin to understand their respective cropping patterns. Harappa and Mohenjo-daro are generally classified as dependent on the winter crops of wheat and barley, Lothal is seen as based more on the summer crops like millets. What becomes apparent is that all three sites are in ecologically distinct environments and subsequently had very distinct agricultural strategies. Where past studies distinguished differences in their climates (Kenoyer 1998) or in aspects of their cultural remains (Possehl 1992), this analysis focuses on their ecological setting and its potential influence on agricultural production.

At a separation of 5.15° NE-SW and 5.92° NW-SE from Harappa and Lothal respectively, Mohenjo-daro represents the geographic centre for this analysis. This spatial division would be similar to that of Chicago, Memphis and Kansas City. The distinction in these three zones is clearly revealed not by their geographic distance, but rather by the significant differential in their water resources as seen in Table 1. Specifically, at 7-8 cm (three inches) rainfall per annum, Mohenjo-daro receives nearly one-fourth the rainfall of Harappa and only one-tenth that of Lothal. The seasonality of the rainfall patterns is distinct for this region; after the collapse of the winter westerlies come the southwest monsoons during the summer months of June, July, August and September. During this regionally rainy season, the ratio of rainfall between the three zones remains nearly constant with only Lothal showing a marginal increase over time. When the summer months are compared as a percentage of annual rainfall in each zone, Mohenjo-daro shows significantly less variability with the summer months only representing 70 % of its annual rainfall against the winter months at 20%. This is due in part to the overall low amount of rainfall at Mohenjo-daro. Harappa and Lothal show a much greater seasonal deviation at 78 and 95% for the summer and 11 and 2% for the winter, respectively. Thus, while Harappa and Lothal have distinctly moister climates, they also tend to greater seasonal extremes in rainfall patterns.

Comparing contemporary trends to the historic records indicates a great deal of congruity in the variance in rainfall for the region. For example, between the years 1866 and 1883, the average annual rainfall for Sahiwal (Harappa) was 10.3 inches (Gazetteer of the Montgomery District 1884: 15); the average annual rainfall for Larkana (Mohenjo-daro) was 3.28 inches between the years 1896 and 1917 (District Gazetteer of Sindh 1916); and the annual rainfall for Ahmadabad (Lothal) from the years 1877 to 1902 was 29 inches (Imperial Gazetteer 1908: 95). While the differences between these numbers and those today are less than 8%, the variances seem relatively constant. This implies that not only are there are similar trends and variances over the last 150 years, but that there is continuity between these three areas.

While the differential in volume of rainfall for the three zones is staggering, it is important to note that rain is not their only source of water. Each is tied to a riverine network that supports seasonal irrigation to varying degrees (Table 1). For Mohenjo-daro, the Indus river represents a primary water source. Fed by five separate rivers originating in the Himalayan glaciers, as well as the monsoon rains, its catchment is 933, 563 km^2 (364,700 sq. miles). During the period of 1922 to 1961, an annual average flow of 93 million acre-feet (MAF) was recorded in the northwest at Tarbela, and nearly 154 MAF for the entire river system. Nearly 85% of this water flow occurs during the summer runoff of April 1st to September 30th.

The case of Harappa and the Ravi river is different both with regards to flow and seasonality. The site of Harappa, also built in association with a "subrecent floodplain" (Schulderein 2002: 54), has shown similar morphological changes even though the 675 km (422 mile) long Ravi river is maintained by a much smaller catchment of 40,297 km^2 (15,741 sq. miles). The volume for the river was recorded at 7 MAF between the years 1922 and 1961. Interestingly, only 66 % of the average annual flow of the Ravi occurs during the period of April 1st to September 30th as compared to 85% for the Indus. Once again these figures represent contemporary averages that have been influenced by extensive anthropomorphic changes.

The analysis of the catchment and annual volumes for Lothal's ancient tributary of the modern Bhogavo River presents a more complex challenge. Formerly much closer to the Gulf of Cambay, this paleo-estuary appears to have had its origins in the confluence of a fresh water creek flowing from the northeast and the tidal forces of the nearby bay that

Table 1: Water Resources

	Harappa (Ravi River)	Mohenjo-daro (Indus River)	Lothal (Bhogavo River)
1. Contemporary Annual Rainfall	28.2 cm	7.6 cm	77.2 cm
- Average Winter Rainfall	3 cm	1.5 cm	1.3 cm
- Average Summer Rainfall	22.1 cm	5.3 cm	73.4 cm
- Summer Rainfall, Percentage of Total	78%	70%	95%
- Winter Rainfall, Percentage of Total	11%	20%	2%
- Historical Annual Rainfall	26.2 cm (1886-83)	8.3 cm (1896-1915)	73.7 cm (1877-1902)
2. Average Annual River Flow (1922-61)	7 million acre feet	154 million acre feet	Limited
- Percentage of Flow in Summer	65%	85%	Limited
- River Catchments	15, 741 sq miles	364, 700	Limited
3. Irrigation	Summer Flooding Summer Oxbow Lakes	Summer Sheet Flooding Winter Rains	?

The contemporary climatic variables were compiled through comparing the data from World Climate.org (2005) and Weatherbase.com (2005) for the weather stations at Sahiwal, Sukkur and Ahmadabad, respectively. The Average Annual River Flow was compiled from Pakistan Water Gateway (2005). The Historical Annual Rainfall was compiled through data from their respective Gazetteer (1884; 1908; 1915).

seemed to reach beyond the settlement (Khadkikar *et al.* 2004: 898-899). These resulting dynamics created a shallow but wide water system that bracketed the saltwater marshes on which Lothal was developed (Khadkikar *et al.* 2004: 901). As a result of the turbulent monsoon season and its proximity to the nearby Gulf, it would have been under significant flooding pressures (Khadkikar *et al.* 2004: 902).

In reviewing the context of the three sites, it is important to note that the significant anthropogenic changes that occurred along all the waterways of the Indus Basin since 1890s have dramatically altered the sedimentation and flow patterns, and as such, it is difficult to compare contemporary statistics to prehistoric environments other than to document potential trends (Table 2). For example, the construction of Sukkur Barrage in 1932 and the barrage at Kotri-Hyderabad in 1961 have significantly affected the ecology of the Sindh in that they have lowered the river level (UNESCO 1998: 4), reduced alluvial deposits, tamed the meanderings and seasonal flow variations of the Indus, and raised the local water table. These factors have led to a drastic increase in soil salinity (Allchin 1976:473) and the elimination of several natural riverine flora (UNESCO 1998:4). We also need to take into account that currently of the 154 MAF, about 104.7 MAF is diverted for irrigation, 39.4 MAF flows to the sea and about 9.9 MAF is consumed by the system losses that include evaporation, seepage and spills during floods (Pakistan Water Gateway 2005).

Beyond water resources, the cropping environment for these zones would also have been significantly impacted by soil (Tables 1-2). In this case, three rivers of distinctly different "temperaments" (of which two are derived from similar origins) had direct impact on the soil at these sites. Feeding off its enormous catchments, the Indus river has annually supplied (in a fashion similar to the Nile river) large amounts of alluvial deposits to the Sindh; with 2x1011 kg per year of sediment discharge. Excavations have indicated that since the 3rd millennium B.C. between four to five meters of sediment has been deposited at Mohenjo-daro (Allchin 1976: 473). Prior to its 20 km northern shift some 4000 years ago, the dynamic "fluvial regime" of the significantly smaller Ravi river was also able to provide Harappa with the necessary, and similar, alluvial deposits (Schulderein 2004: 794). For Lothal, the extensive sedimentation appears to have been limited to that provided by a small river system that was surrounded by marshland and alluvial plains in combination with dropping sea levels. This final context is much more difficult to interpret than the former two zones as the soil deposits might not have been in the context of river flooding, but rather from seasonal monsoons (Khadkikar *et al.* 2004: 902).

Table 2: Geology and Landscape. This data was compiled through personal communications with Rita Wright and Richard Meadows (2004), Gazetteer (1884; 1908, 1915), Schuldenrein *et al.* (2005); Belcher (2003), and Khadkikar *et al.* (2004).

	Harappa (Ravi River)	Mohenjo-daro (Indus River)	Lothal (Bhogavo River)
1. **Surrounding Landscape**	Multiple River Systems Separated by Hills, Terraces and Alluvial Plains	Single River System Surrounded by Extensive Alluvial Plain and Desert	Single River System Surrounded by Alluvial Plains
* Description of River	High Bank - Narrow Bed Below Alluvial Plain - Fast Flow	Low Bank - Wide Bed Raised Above Alluvial Plain-Slower	Small Creek Leading To Tidal River of Bhogavo
* Location of City	Terrace Overlooking Plain	Raised Platform On Plain	Adjacent to Creek
2. **Irrigation**	Summer Flooding Summer Oxbow Lakes Summer & Winter Monsoons	Summer Sheet Flooding Winter Rains Hillside Dikes?	???
3. **Anthropogenic Changes** Since 1932	Damning Has: Redirected Water Flow Reduced Seasonal Variations Controlled Annual Flooding Reduced Alluvial Deposits	Damming Has: Reduced River Levels Tamed Meanderings Reduced Seasonal Variations Reduced Alluvial Deposits Increased Ground Salinit	Large Sedimentation Distance to Estuary Increased

This data was compiled through personal communications with Rita Wright and Richard Meadows (2004), Gazetter (1884; 1908, 1915), Schuldenrein *et al.* (2005); Belcher (2003), and Khadkikar *et al.* (2004).

Temperature is an integral component of agriculture production (Table 3). Harappa and Mohenjo-daro have very similar temperature patterns with only a 4% differential in mean annual temperature. The divergence for these two zones comes from Mohenjo-daro having slightly higher seasonal temperatures and less seasonal variation between summer highs and winter lows as compared to annual averages. Harappa, with a slightly more temperate climate, tends to greater seasonal extremes. Lothal on the other hand, shows a significantly higher annual mean temperature, but distinctly less seasonal variation in comparison to the other two zones. The average low winter temperature at Harappa is 128% of the mean for Lothal and Mohenjo Daro, while its average high summer is less than 95 % different.

The ecological context of Harappa, Mohenjo-daro, and Lothal are thus tied to the seasonal flow and sedimentation of three unique, but not always independent rivers (Table 2). Further, each zone represents a continuum of climatic gradients and seasonal variation. Yet similarities in the sites' settlement patterns seem to contradict their ecological differences. Mohenjo-daro was situated on a raised landform some 25 km from the Sindhu Nadi, an area in direct line of river flooding. This situation would have allowed, and possibly encouraged, the use of sheet flooding and other low level technological solutions to irrigation issues (Jansen 1989; Schulderein *et al.* 2004). In comparison, Harappa occupied the protection of a terrace overlooking an abandoned reach of the Ravi that allowed easy access to the fertile soils of the river's floodplain (Schulderein 2002: 71; Wright 2000). Lothal was located in direct contact with the Arabian Sea, and should be considered a marine environment. Today, sedimentation has eliminated the water ingress that separated much of the Kathiawar Peninsula from mainland, but in the past the site was situated on a marshland estuary that was desiccated over time. Knowledge of its irrigations systems and soil patterns are thus limited, but it can be assumed considering the environment that they would have been necessary. Thus, while the former two sites provided easy access to "fresh" alluvial deposits and short-term, standing irrigation, it is expected that the Lothal zone would have required greater efforts by the workforce to capture the summer rains for future distribution during the growing seasons.

Table 3: Temperature Variants

	Harappa (Ravi River)	Mohenjo-daro (Indus River)	Lothal (Bhogavo River)
Contemporary Mean Temperature	23.8 o	25.5 o	27.8 o
Average Temperature in Winter	15 o	17.8 o	22.8 o
Average Low Temperature in Winter	7.2 o	10 o	16.1 o
Average Temperature in Summer	32.2 o	33.3 o	30 o
Average High Temperature in Summer	37.8 o	39.4 o	33.3 o
Average Low Winter Temperature Percentage of Avg. Mean Temp.	60%	64%	74%
Average High Summer Temperature Percentage of Avg. Mean Temp.	133%	132%	112%

The contemporary climatic variables were compiled through comparing the data from WorldClimate.org (2005) and Weatherbase.com (2005) for the weather stations at Sahiwal, Sukkur and Ahmadabad, respectively.

The unique weather patterns and seasonality for Mohenjo-daro and Harappa also would seem to indicate differing water storage technologies and methods at the two sites. While both sites overlook a floodplain, the context and seasonality of the rivers and rainfall patterns does not necessarily lead to identical methods. In the case of Mohenjo-daro, the primary means of water storage and irrigation would have included: sheet flooding of the agricultural plain (Jansen 1989; Possehl 2002: 64; Schulderein *et al.* 2004), the use of *gabarbands* (stone dams) that diverted the water of small streams and torrents into the fields (Possehl 2002: 65), and potentially the brick lined wells that are typically associated with the urban settings, but which in the contemporary context in association with animal labour, are used as storage vessels for small areas of irrigation (Possehl 2002: 104 and Gupta 1985: 378). Excavations have documented 69 wells in the Lower Town of Mohenjo-daro, which supported on average 1,326 m^2 (Possehl 2002: 104).

The site of Harappa differs from Mohenjo-daro in several respects. While it receives significantly greater rainfall, it still is subject to seasonal variations and limitations, and shows signs of water storage and irrigation. These methods include those previously mentioned for Mohenjo-daro: sheet flooding, wells, and *gabarbands*. In addition, the region surrounding Harappa is known for the oxbow lakes that form following the flooding of the Ravi (Gazetteer 1884:5 and Belcher 2003:150). These lakes are excellent storage vessels for both water and fish resources up through the first segment of the dry season. The increased volume and dependability of monsoon rainfall in itself acts as a water storage mechanism for Harappa in comparison to Mohenjo-daro.

Interestingly, none of the three sites had yielded signs of significant irrigational improvements or earthworks. The archaeological record is rather limited to date and has been singular in nature. It would seem that whatever their storage or irrigation technologies or methodologies, in this area of sporadic and limited rainfall they were able to maintain enough water storage to support their agricultural systems. Thus, it is important to think of the Indus, Ravi, the Lothal's paleo-estuary less as "flowing rivers," and more for their ability to supply water sufficient water to the drainage systems for agricultural and domestic purposes.

Based on the description of these three agro-ecological zones, a number of generalizations can be made (see Table 4). First, with distinctly lower precipitation, a slightly higher mean temperature, and less deviation in its seasonal patterns, Mohenjo-daro represents a more "fragile" environment with less climatic variations that thus depends greatly on the Indus for its water needs. The agricultural strategy would have been mostly limited to the winter planted, spring harvested, crops of wheat and barley and would have been more vulnerable to the river and its flow than the other two zones. The archaeobotanical record at Mohenjo-daro is limited and it is therefore difficult to substantiate which other crops may have played a role in their agricultural system. Other crops of significant potential outside of the winter harvest might have been dates and saccharum cane.

Harappa, in comparison, shows greater extremes in seasonal climate, with larger deviations in both precipitation and temperature. A multi-seasonal cropping strategy would help mitigate the extreme seasonality of the water supply and temperatures.

Table 4 : Comparative summary of Harappan agro-ecological zones

	Harappa (Ravi River)	Mohenjo-daro (Indus River)	Ahmadabad-Lothal (Bhogavo River)
1. Contemporary Annual Rainfall	++	+	+++
- Average Winter Rainfall	++	+	+
- Average Summer Rainfall	++	+	+++
- Historical Annual Rainfall (Pre 1915)	++	+	+++
2. Contemporary Mean Temperature	++	++	++
- Average Temperature in Winter	+	++	+++
- Average Low Temperature in Winter	+	++	++
- Average Temperature in Summer	++	++	++
- Average High Temperature in Summer	+++	+++	++
3. Average Annual River Flow (1922-61)	++	+++	+
- Percentage of Flow in	++	+++	n/a
- River Catchments	++	+++	+
4. Surrounding Landscape	Multiple River Systems Separated by Hills, Terraces and Alluvial Plains	Single River System Surrounded by an Extensive Alluvial Plain and Desert	Single Small River System Surrounded by by Marshland and Alluvial Plains
- Description of River	High Bank- Narrow Bed Below Alluvial Plain - Fast Flow	Low Bank- Wide Bed Raised Above Alluvial Plain - Slower	Small Creek Leading To Tidal River of Bhogavo
- Location of City	Terrace Overlooking Plain	Raised Platform On Plain	Adjacent to Creek
5. Irrigation Flooding	Summer Flooding Flooding Summer Oxbow Lakes Summer& Winter Monsoons	Summer Sheet Winter Rains Hillside Dikes?	Potential Large Scale During Monsoon Season
6. Anthropogenic Changes Since 1932	Damming Has: Redirected Water Flow Reduced Seasonal Variations Controlled Annual Flooding Reduced Alluvial Deposits	Damming Has: Reduced River Levels Tamed Meanderings Reduced Seasonal Variations Reduced Alluvial Deposits Increased Ground Salinity	Large Sedimentation Distance to Estuary Increased Desiccation of Marshland Extensive Irrigation

+++ Abundant ++ Sufficient + Limited n/a Unknown

Our understanding of the agro-ecological zone representing Harappa is unique in that we have a very large archaeobotanical database. This data, representing nearly 150,000 carbonized plant remains (see Weber 2003), clearly supports the argument that in a rain and river fed ecology, a much more diverse, and less winter dependent agricultural base would develop. The agricultural strategy at Harappa during the urban period was heavily dependent on both winter (wheat, barley, lentil and peas) and summer (millets) crops. With a wide range of plants being cropped and the winter cereal grains being of primary of importance, the use of summer crops remained an important food supplements throughout the occupation of Harappa. In comparison, Mohenjo-daro which is consistently grouped with Harappa as a winter based system, yet the rather limited archaeobotanical data base shows little crop diversity nor the dependence on summer crops as Harappa. If further carbonized seeds were recovered from Mohenjo-daro it is unlikely that they will include anywhere near the crop range found at Harappa.

With increased summer rainfall, more temperate climates, unreliable riverine water resources, and a distinctly more marine environment, the area of Lothal offers a unique ecological comparison to the other two zones. It is likely that the use of manmade irrigation and storage mechanisms would have been in use to extend the water supply into the winter growing season. Based on the ecological setting of Lothal and the need for a stable agricultural strategy, summer crops were likely the focus. Although the limited archaeobotanical record cannot substantiate this, the large database at the contemporary site of Rojdi might be used to gain insight into Lothal agricultural practices (Weber 1991). At Rojdi, a site also located in Gujarat and in an environment that today is clearly dependent on the summer monsoon rains, both winter and summer crops were prominent in the archaeobotanical record (Weber 1991, 1999). Summer millets were the main cereals, yet barley was present and winter cultigens can be found throughout the site's occupation. Although agricultural production at Lothal was clearly different from what occurred at either Harappa or Mohenjo-daro, it did more closely resemble the large diverse cropping strategy of Harappa than the more limited, river dependent system at Mohenjo-daro.

The Implications of an Agro-ecological Zone Approach

A focus on agro-ecological zones not only forces one to identify the variables that influence as well as limit agricultural production but such an approach exposes the variability of agriculture and the range of potential subsistence strategies within the Indus Civilization. Our preliminary application of this approach, based on the analysis just presented, allows for a number of generalizations or suggestions regarding the Indus civilization (Fig. 6). For example, the subsistence strategies of Mohenjo-daro, with its dependence on the Indus River for its water needs, would have been focused on crops supplying the highest return on investment. To take full advantage of the yields would require augmented irrigation and tool technologies. The limiting potential for summer cropping, and the focus on high yield crops, could also indicate a need to supplement resources through trade. The increased availability of water and distinct seasonality of Harappa is expressed in an increased breadth of domesticates that took advantage of local climatic support and variability. Thus, the archaeobotanical database confirms a large number of taxa harvested in both the winter and summer seasons. Lothal, with its unique temperate climate and temporally limited access to water resources should have made a wider use of a water management system that may have incorporated a multi-cropping strategy.

The archaeological record should confirm both a divergence in secondary crops, summer subsistence strategies, and water storage and irrigation methods for Harappa, Mohenjo-daro, and Lothal in accordance with these patterns. Variations in the material and settlement systems may in turn be better explained once we understand the agricultural strategy at a given site. The cultural distributions identified across the Indus may therefore be a reflection of, or at least influenced by, the local ecology. Not only will this become clearer as we develop agro-ecological zones throughout the Indus civilization, but we may also see greater continuity with historic and modern times.

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Joglekar P.P., *et al.*, *Man and Environment* XXXV(1): 76-86 [2010].
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Faunal Remains from Jaidak (Pithad), a Sorath Harappan Site in Gujarat

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Abstract

This article reports the results of the analysis conducted on the faunal material unearthed during excavations at Jaidak, a Sorath Harappan site in Gujarat. A single trench (5AC3) was selected as a judgement sample (n = 3885). The analysis revealed a wide spectrum of animal species that includes domestic mammals, wild mammals, reptiles, birds and molluscs. Every bone fragment was carefully examined for any signature of bone modifications to reveal various aspects of taphonomy. It has been noticed that people were involved in skinning, evisceration, dismembering, filleting and fracturing the bones for the extraction of marrow besides using the broken fragments of longer limb bones for bone working.

Introduction

The Harappan site at Jaidak (22° 39.5' N; 70° 34.43' E), locally known as *Jaidak no timbo* is situated about 4 km south of the Pithad village of Jamnagar district, Gujarat. It is situated on the right bank of Aji River, and is surrounded by vast fertile fields (Figs. 1-2). The site was first brought to notice in 1960 during an exploratory survey by a team of archaeologists of the Rajkot Office of the Bombay State Archaeology Department (IAR 1959-60). Bagasara and Kuntasi, both in the Rajkot district, are other important Harappan sites in the region, located about 20 km north and 50 km northeast, respectively (Ajithprasad 2008).

The Department of Archaeology of the M.S. University of Baroda conducted excavations at the site for two seasons (2005-06 and 2006-07). According to excavators, the excavation revealed two distinct phases of Harappan occupation: Period IIA and Period IIB (Personal communication: Dr. Ajithprasad). Period IIA (2200/2100 to 1900 B.C.) is contemporary to the terminal stages of the Mature Harappan, while Period IIB (1900 to 1700 B.C.) revealed assemblage similar to Rojdi C, Kuntasi II and Rangpur IIC. The architectural features exposed during the excavation suggest a classic/urban plan and layout of the Harappan settlement; however, artefacts unearthed during excavation and collected from the surface do not incorporate any classical Harappan traits. The antiquities on the other hand seem to be belonging to the Sorath Harappan as defined by Possehl and Raval (1989).

Identification, Recording and Analytical Methods

The animal skeletal remains collected during the excavation are housed at Baroda. This analysis was done at Baroda during a visit in 2008 with a view to obtain a preliminary picture of animal-based economy at Jaidak. A single trench 5AC3 was selected for this faunal analysis. This trench revealed a cultural deposit of about 2.30 m, which was divided into 8 layers, all belonging to Period IIA. The assemblage related to Period IIB is in form of a surface deposit in this trench. The last two layers (7 and 8) yielded very few skeletal fragments in a very fragmented condition. These, therefore, are not included in the analysis.

Securely identifying a specimen is crucial to archaeozoological interpretations and the most secure approach to identifying species relies on comprehensive skeletal reference. Therefore, comparative reference material housed at the Archaeozoology Laboratory (Deccan College, Pune), and at the Osteology Laboratory, M.S. University Baroda were used to determine the most precise level of identity that could be attributed to a bone. A particular mention of the modern equid (wild ass, domestic ass and domestic horse) reference material available at the Baroda is necessary. In addition, to achieve fine-level identification among closely related species (cattle/buffalo/nilgai and sheep/goat/antelope), help from published literature has been taken, e.g. Joglekar *et al.* (1994), Higham (1975), Gupta *et al.* (1987, 1990), and Prummel and Frisch (1986). Furthermore, the general identification

Received : 17-11-2009
Revised : 02-01-2009
Accepted : 27-02-2010