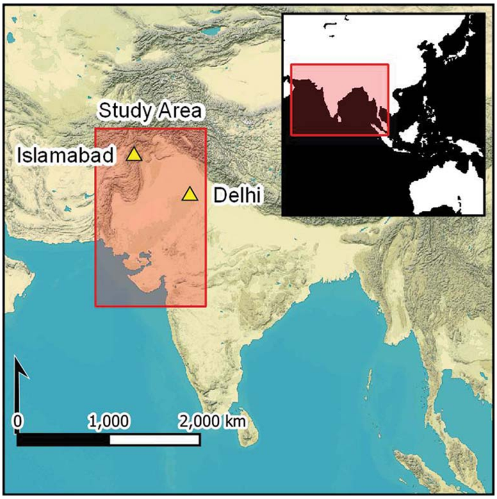
Antiquity 2023 Vol. 97 (396): 1488–1500
https://doi.org/10.15184/aqy.2023.134

Research Article

Different strategies in Indus agriculture: the goals and outcomes of farming choices

Jennifer Bates* & Jungwoo Choi

Department of Archaeology and Art History, Seoul National University, South Korea
* Author for correspondence ✉ jbates01@snu.ac.kr



Climate change is often cited in the 'collapse' of complex societies and linked to agricultural resilience or lack thereof. In this article, the authors consider how demand affected agricultural strategies as farmers navigated the transformations of the Late Harappan phase (*c.* 1900–1700 BC) of the Indus tradition. Through the modelling of monocropping/multicropping, low/high yield crops, and supply-driven versus flexible production, various economic, environmental and social demands are explored with reference to the choices of farmers and how these decisions differed regionally, and how they impacted the wider Late Harappan de-urbanisation process. The authors' archaeobotanical perspective on the Indus contributes to wider understanding of how urban societies and their agricultural bases change over time.

Keywords: South Asia, Indus civilisation, climate change, archaeobotany, cities, agriculture, collapse

Introduction

How cities and civilisations produce and sustain their food supplies is fundamental to their survival. Across both the Old and New Worlds, researchers have investigated the nature of past food supply under changing climate and social conditions, emphasising that diversity is a key aspect of sustainability (e.g. Demarest 2004; Marston & Miller 2014; Middleton 2017). As Halstead and O'Shea (1989) have noted, food surplus and the supply chain are critical in this risk mitigation. Decisions relating to diversity, specialisation, yield and the integration of agricultural systems are all thought to have influenced how urban centres were supplied and how well they weathered the challenges of social and climatic change. The nuances of decision-making around specific factors such as yield, surplus, trade and risk mitigation during short-term episodes of stress and their long-term and far-reaching implications have, however, often been overlooked.

Received: 28 October 2022; Revised: 16 February 2023; Accepted: 20 March 2023

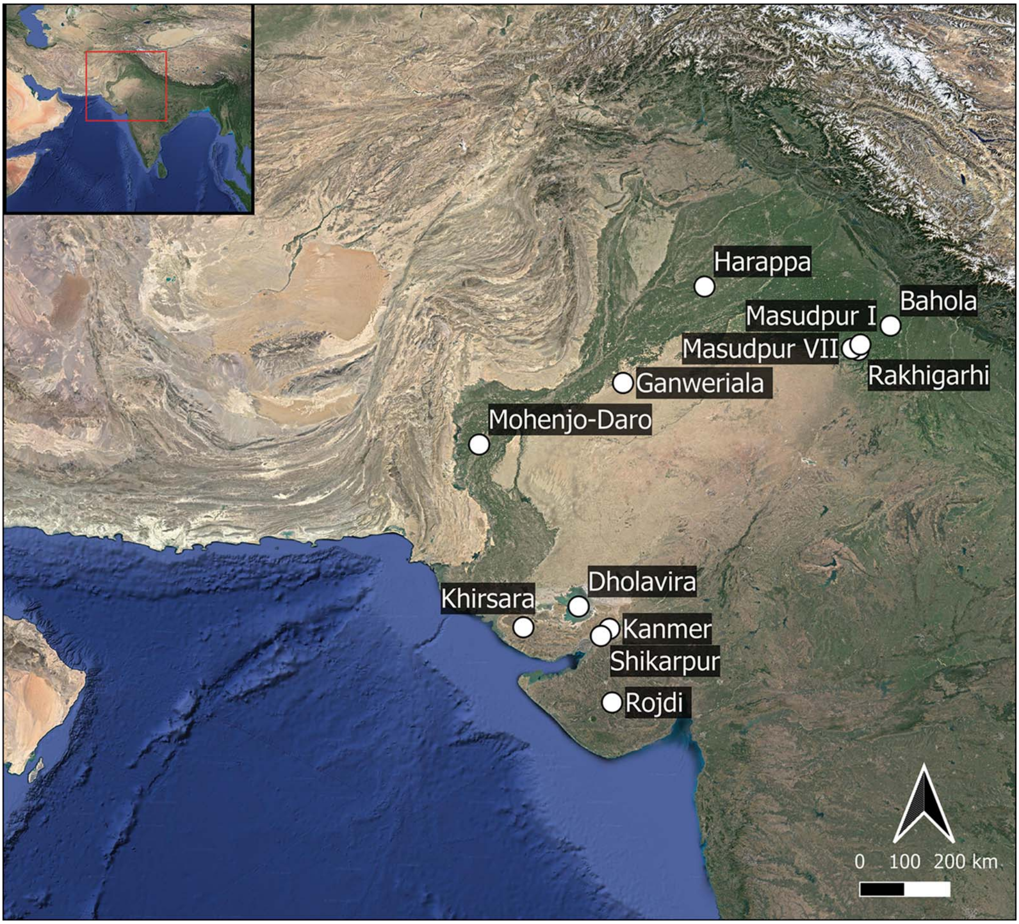


Figure 1. Map of the Indus civilisation showing the location of the main sites mentioned in the text (figure by the authors).

Extending over present-day Pakistan and parts of north-western India, the Indus civilisation (*c*. 2600–1700 BC) was one of the great Old World Bronze Age cultures (Figure 1, Table 1). This vast region of South Asia encompasses two rainfall systems, two major rivers, numerous ecological habitats and gradients ranging from arid to semi-tropical climate zones. Its geographical complexity has posed challenges for understanding the nature of past agricultural supply and demand. While farming strategies of the Indus civilisation clearly varied across the region (Pokharia & Srivastava 2013; Petrie *et al.* 2016; Petrie & Bates 2017; Bates 2019), the role played by agriculture during the decline of the Indus has been much debated (Vishnu-Mittre & Savithri 1993; Madella & Fuller 2006; Pokharia *et al.* 2014; Petrie 2017; Petrie *et al.* 2017). In the Late Harappan (*c*. 1900–1700 BC), a phase characterised by de-urbanisation and coinciding with the 4.2kya aridification event, questions centre on sustainability—that is, how the various elements of the wider Indus tradition interacted with the changing climate and societal structure and how the food supply was maintained at supra-regional, regional and local scales.

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

Table 1. Chronology of the Indus tradition (after Possehl 2002: 29; Kenoyer 2020: tab. 1).

Early food producing era (Neolithic)	***c.* 7000–5500 BC**
Regionalisation era (Chalcolithic/Bronze Age)	***c.* 5500–2600 BC**
Early Harappan phase	
Harappa: Period 1, A & B, Ravi Phase	>3700–2800 BC
Harappa: Period 2, Kot Diji Phase	2800–2600 BC
Integration era (Indus civilisation) (Bronze Age)	**2600–1900 BC**
Harappan phase	
Harappa: Period 3A, Initial	2600–2450 BC
Harappa: Period 3B, Middle	2450–2200 BC
Harappa: Period 3C, Final	2200–2000 BC
Localisation era (Bronze Age)	***c.* 1900–1300 BC**
Late Harappan phase	
Harappa: Periods 4 and 5	1900–1700 BC
Jhukar, Rangpur, Cemetery H phases	***c.* 1700–1300 BC**

The Indus provides an opportunity to study the challenges faced by an urban culture during a period in which climate, environment and social factors combined to become what Petrie *et al.* (2017: 19) have called "unpredictable unpredictability" – something beyond that which people could handle. Rather than looking at the Indus as a monolithic system, or as geared solely towards urban food supply (as implied in the modelling of Halstead & O'Shea 1989), we explore how different components of the Indus agricultural systems interacted with changing conditions. Specifically, we consider how the concepts of diversity and specialty, polyculture and monoculture, low and high yield, and flexibility versus supply-driven production can be used to look at variable risk mitigation and failure. We approach this through a comparison of archaeobotanical datasets from three key areas: Harappa, Gujarat and the north-east of the zone covered by the Indus civilisation.

Indus agricultural modelling

The Late Harappan phase witnessed a series of social changes. Larger 'monumental' features such as the Great Bath at Mohenjo Daro began to fall into disuse (Possehl 1997; Wright 2010; Petrie 2019), many specialist crafts declined, as did 'technical virtuosity' in production methods (Vidale & Miller 2000). Some large sites such as Mohenjo Daro were eventually abandoned after a period of decline and depopulation (Possehl 1997; Wright 2010), while Harappa continued to be occupied, albeit with a reduced population (Petrie 2017). Settlement reorientation is also documented, with people moving away from the larger conurbations to smaller villages. These changes are traditionally argued to have been accompanied by an agricultural 'revolution'. Richard Meadow (1989), for example, saw agricultural change as a critical component of the Late Harappan phase, based on the roles played by different crops in the Indus system. The food crops found on Indus sites are listed in Table 2.

Meadow (1989) linked changes in cereal production with the 4.2kya event. This climatic shift is broadly described as an abrupt and severe arid phase that began *c.* 2150 BC and lasted

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

Table 2. Main crops found on Indus sites, based on published data (Weber 2003; Petrie & Bates 2017; Bates 2019; for more details and more taxa, see Weber 2003).

Rabi **(winter crops)**	***Zaid*** **(summer dry crops)**	***Kharif*** **(summer monsoon crops)**
Triticum sp. (wheat)	*Citrullus* sp. (melons)	*Oryza* sp. (rice)
Hordeum sp. (barley)	*Coccinia grandis/cordifolia* (ivy gourd)	*Setaria* sp. (foxtail millets)
Pisum sp. (pea)	*Chenopodium album* (goosefoot)	*Panicum* sp. (proso/little millets)
Lens culinaris (lentil)	*Juglans regia* (walnut)	*Echinochloa* sp. (sawa millets)
Cicer arietinum (chickpea)	*Prunus dulcis* (almond)	*Brachiaria* sp. (signal grass millets)
Linum usitatissimum (flax/linseed)	*Trigonella foenum-graecum* (fenugreek)	*Eleusine* sp. (finger millets)
Ziziphus sp. (jujube)		*Sorghum bicolor* (sorghum millet)
		Pennisetum sp. (pearl/kodo millets)
		Vigna mungo (black bean)
		Vigna radiata (mung bean)
		Macrotyloma uniflorum (horsegram)
		Sesamum indicum (sesame)
		Brassica sp. (mustards)
		Gossypium sp. (cotton)
		Cannabis sp. (hemp)
		Corchorus sp. (jute)
		Phoenix sp. (date)

between one and several centuries (Staubwasser *et al.* 2003; Prasad *et al.* 2014). The 4.2kya event has formed a major part of various hypotheses linking climate change and the decline of the Indus civilisation (and other Bronze Age cultures; Weiss *et al.* 1993; An *et al.* 2005; Staubwasser & Weiss 2006; Lawrence *et al.* 2021). Meadow (1989) argued that during the Late Harappan phase, *kharif* (summer monsoon) crops, specifically rice, sorghum and millets, became more important due to the increased aridity of the 4.2kya event. This may have destabilised the socio-economic system, causing, or at least exacerbating, wider societal decline (e.g. Weber 2003; Madella & Fuller 2006). The correlation and causation of agricultural and socio-economic change and the 4.2kya event are, however, problematic (Petrie 2017). The growing recognition within Indus archaeology of the diversity inherent in ecological and agricultural systems (Vishnu-Mittre & Savithri 1993; Madella & Fuller 2006; Pokharia *et al.* 2014; Petrie 2017; Petrie *et al.* 2017) requires us to reconsider such 'economic shift' hypotheses in light of human decision-making. It is on this economic-agentive aspect that this article focuses— namely, the nature of Indus agricultural diversity in relation to food supply strategies and choices, through the lenses of farmer agency, resilience and sustainability.

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

Intensification, specialisation, diversity and yields

Intensification—that is, an increase in crop yield per unit of land—can take many forms including specialisation and diversification (Brookfield 1984; Morrison 1994: 143–44). The processes of specialisation and diversification are not the same as diversity and specialty (Morrison 1994). Diversity and specialty can be the result of varying intensification strategies but are not requisites or predetermined outcomes of intensification because specialisation and diversification are processes, increases in yield per unit of land through changing strategies, while specialty and diversity are measures of difference in the overall crop or agricultural system. Specialisation and diversification are processes; diversity and specialty are measures of difference. Here, we focus specifically on measures of difference rather than on processes of intensification.

In an article on the divergence of tropical and cereal-based agricultural origins, Harris (1972) discussed the measures of speciality and diversity, contrasting the short-term high yields of cereals with the long-term stability of vegeculture. The outcome of such modelling can be expressed in a series of equations:

- vegeculture/mixed taxa versus the dominance of cereal/grain cultivation
- (simplified to) diversity versus monoculture
- (resulting in, or with demand for) low versus high yields.

A further related equation is: flexibility versus supply-driven production or, as Harris (1972: 188) put it, stability versus instability.

A diverse system is flexible and adaptable: should some variable change, such as a crop failure, other plants or strategies can compensate. However, given the amount of land needed to support such diverse systems, the ecological requirements of diverse crops (Petrie & Bates 2017) and their longer production season (i.e. no single harvest time), such systems may not be able to supply the same abundance of food compared with more specialised systems.

Specialised cropping strategies provide large harvests of a single crop grown intensively and with much higher yields than possible in diverse agricultural systems. These specialised systems can produce such vast quantities by focusing on one aim, the so-called 'eggs in one basket' approach. On the other hand, if one or more variables of production or supply change, the entire system is at risk, with no flexibility or back-up. In a specialised system, flexibility and risk aversion are potentially sacrificed to achieve high yields.

Consequently, farmers, and wider society, must make critical decisions as to whether to embrace diversity or specialty, polyculture or monoculture, low or high yields, and flexibility or supply-driven production. Moreover, these decisions affect not only the producers but also the consumers of agricultural products, and the effects may be intensified during periods of climate change when adaptation to new environmental conditions may be combined with greater economic demand.

Harappa: feeding an urban site

Weber *et al.* (2010) have argued that large-grained cereals played a vital role in the rise of urban centres in the Indus. Large grains, mainly *rabi* wheat and barley (*Triticum* sp. and

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

Hordeum sp.), provided high yields, encouraging urbanisation by allowing larger populations to gather together. While the analytical approach taken by Weber *et al.* (2010) can be critiqued (Hayden 2001 follows a different approach; see also Petrie 2013), their study serves as a reminder that large cereal grains (i.e. wheat and barley in their article) are thought to have been the main crops supplied to the Indus cities during the Harappan phase; this monocrop supply system may have been the result of the climatic and social changes of the Late Harappan phase.

The best archaeobotanical data for an Indus city come from Harappa. Eighty per cent of the 250 000 seeds so far analysed from Harappa are cereal grains (Weber 1999, 2003; Weber *et al.* 2010). Of these, the majority are large grains, predominantly the *rabi* cereals, wheat and barley, which led Weber (1999) to build a tiered model of Indus cropping, with cereals being Tier I staple crops. The data from Harappa are, however, still only partially analysed (with just 20 per cent of the entire assemblage published to date). Although the raw data have yet to be published, the standardised data from Harappa (ubiquity, density, proportions) are nevertheless useful for model building and have been extensively discussed (e.g. Weber 2003). From this, Weber determined that the main crops at Harappa were *rabi* cereals, wheat and barley.

Crop choices at Harappa fluctuated over time. Barley was the dominant crop during the Early Harappan phase, wheat predominated in the Harappan phase, then barley took over again in the Late Harappan (Weber 2003: tab. 5.3.c). *Kharif* crops, particularly millets, also increase over time, although at no point do they represent more than seven per cent of the assemblage (Weber 2003; also Petrie & Bates 2017). Weber (2003: 181–89) has argued that an increased diversity over time was perhaps due to adaptation to changing climate, but as noted in Petrie and Bates (2017) there was little actual focus by farmers providing for Harappa on increasing yields through multicropping, and agriculture at Harappa predominantly focused on *rabi* monocultures of wheat and barley.

Mohenjo Daro is another urban site with published archaeobotanical remains, and where wheat and barley also dominate the assemblage (Luthra 1941, who also comments on its presence at Harappa; Shaw 1943). The seeds were, however, hand collected during the early twentieth-century excavations and the collection is thus not comparable to the remains retrieved by systematic flotation from other sites. Millets, for example, would have been missed given their small size. The quantified urban data available from Harappa, and probably Mohenjo Daro, therefore suggest that a monoculture of *rabi* large-grained cereals was likely to have been driven by the demand from growing cities. This is hypothesised to have begun as demand for yield to support urban growth during the Early Harappan phase and continued into the main Harappan phase when it sustained large urban populations (Weber 2003; Weber *et al.* 2010; Petrie & Bates 2017). Over time, the demand for supply versus the instability in the system created by the environmental and economic upheaval of the Late Harappan phase may have created pressure around Harappa to maintain urban food supplies. One outcome or response to this was an increased, but limited, use of millets to provide flexibility for maintaining urban food supplies under changing conditions.

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

Gujarat: surviving an arid zone

While the available data from Harappa show a predominantly *rabi*-based monoculture of wheat and barley, different cropping strategies are documented in other regions (Weber 1991, 1999; Vishnu-Mittre & Savithri 1993). Unlike the urban site of Harappa where we are reliant on summary tables (see Weber 2003), numerous sites in Gujarat provide both the raw data and their quantified analysis. Gujarat is a hyper-arid region. Most rainfall occurs between June and September, during the Indian summer monsoon, shaping agricultural and pastoral activities. Prolonged drought is a recurrent phenomenon, particularly in the driest areas of north Gujarat and Kachchh (Ajithprasad & Sonawane 2011), with implications for the resilience of agricultural strategies.

Archaeobotanical data from the site of Rojdi indicate multicropping strategies including intercropping or duo-culture, with evidence for change over time (Weber 1991, 1999; Petrie & Bates 2017). This was a flexible millet-based system that could shift between monocropping, intercropping and maslin (the practice of sowing two or more cereals together; van der Veen 1995). Similarly complex patterns of diverse millet cropping are also recorded at Surkotada (Vishnu-Mittre 1990) and Babar Kot (Reddy 2003).

These patterns are not the only strategies recorded in the region. At the sites of Khirsara and Kanmer (Pokharia *et al.* 2011, 2017) a non-millet-based system was in place for much of the time. At Khirsara, the Early Harappan cropping strategy was 90 per cent barley, a monoculture similar to that seen at Harappa in Punjab. This is ill-suited to the local environmental conditions, suggesting that regional or pan-regional economic demands for large *rabi* cereals during the urbanising period may have pushed agricultural strategies beyond well-adapted and resilient local ecological limits. This strategy diversified over time, breaking up the monoculture, so that in the Harappan phase barley formed only 49 per cent of the assemblage. *Kharif* pulses were also introduced, and a duo-crop of rice was added. By the Late Harappan phase the assemblage was mainly *kharif* crops, with pearl millet (*Pennisetum* sp.), rice (*Oryza* sp.) and sorghum (*Sorghum bicolor*). *Rabi* crops such as barley were still part of the system but played a greatly reduced role (Pokharia *et al.* 2017). A similarly dramatic change over time is also seen at Kanmer (Pokharia *et al.* 2011).

The contrast between Khirsara and Kanmer on the one hand and Rojdi on the other illustrates the flexible strategies employed in Gujarat. At Kanmer and Khirsara, there was a shift from cereal monocultures and single-season cropping which was perhaps due to economic demands in the urbanising period, to a more diverse polyculture and multi-season cropping, perhaps reflecting a shift between the economic demands of the urbanising period towards a greater emphasis on local ecological conditions in the later periods.

Trade is a further aspect to consider. Western Kachchh, and Gujarat in general, is one of the driest and least climatically predictable regions of the Indus civilisation. Trade and the exchange of agricultural goods would have been important for maintaining the Indus economy, especially in Gujarat (Bhan *et al.* 2005). The production of *rabi* crops might have been part of this elaborate trade system and it could be argued that, as trade broke down towards the end of the Harappan phase, either the availability of *rabi* crops via trade (supply) or need to produce *rabi* crops (demand) declined. To support this hypothesis, we would need crop-processing data from Khirsara to ascertain whether the site was a primary producer or consumer of *rabi* crops. A correlation between the decline in the quantity of traded goods

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

with the decrease in *rabi* crops suggests that the complexities of the Indus economic systems are related to changes in agricultural demand as well as ecological conditions (see Madella 2014; García-Granero *et al.* 2016). Khirsara managed to survive these inter-regional changes by switching to the consumption of (probably locally grown) *kharif* crops. At Rojdi, by contrast, the crop-processing data suggest that the site was both a consumer of wheat and barley traded from beyond the region but also a producer of millets for local use (Weber 1991, 1999). A similar argument has been put forward for sites such as Shikarpur in Gujarat (García-Granero *et al.* 2016). Unlike at Harappa, flexibility in attitudes towards production and consumption, created by a combination of environmental and economic choices, may therefore have formed part of the Gujarati Harappan system.

The north-east: life in villages

Villages in the north-eastern part of the Indus area reflect different patterns. The agricultural systems in this region followed a pattern of sequential cropping, using mixed monocropping, duo- and polycultures, and mix and strip/row intercropping (Petrie & Bates 2017). There is no chronological pattern to this and no indications of a shift related to (de)urbanisation or environmental stress (Petrie & Bates 2017). For example, sequential cropping is documented at Masudpur VII in all three Indus phases. There were small amounts of wheat and barley monocropping among the *rabi* crops, and intercropped millets among the *kharif* crops alongside strip/intercropped pulses attested in the Early Harappan phase. Intercropped mustard and pulses among the *rabi* crops and monocropped sawa millet (*Echinochloa* sp.) with strip/intercropped pulses among the *kharif* crops were introduced in the Harappan phase. *Kharif* monocrops of rice and mixed intercropped millets were added in the Late Harappan. This complex use of multiple strategies with continual additions to the existing systems suggests a flexible approach to agriculture, without concentrating on any single crop at any one time. It denotes shifting approaches to specialisation, diversification, specialised or diversified cropping, and intensification proper, adapting to the mix of summer and winter rains and the multiplicity of environmental conditions in the region.

Many questions remain to be answered, including what kind of food was being supplied to Rakhigarhi. Did this city rely on monocrops of wheat and barley like Harappa? What impact did this have on the city during the Late Harappan phase while the villages around Rakhigarhi remained resilient to the changes in society and climate, in part because they diversified their crops? Rakhigarhi was one of the cities that declined and was abandoned during the Late Harappan phase (Nath 1999); the data from some of the villages in the region, such as Masupdur I, Masupdur VII, Bahola and others excavated nearby, have led to questions about whether or not these villages were supplying food to Rakhigarhi during the Harappan phase (Bates *et al.* 2017). We might then ask: did Rakhigarhi rely on non-diverse food supplies such as monocropped cereals and did this play a part in the site's lesser resilience than the villages?

Implications

While the 4.2kya event created an "unpredictably unpredictable" set of conditions (Petrie *et al.* 2017: 19), the weakening of the summer monsoon would not have had the same impact

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

everywhere. In a complex environment such as the Indus we should not expect climatic effects to be the same across the entire region (Petrie 2017). Moreover, it is not only the complex environment that fosters resilience or hinders it, but also different agricultural strategies and, critically, also people's experiences and responses in the face of change; not everyone experienced this 'unpredictable unpredictability' in the same way.

As Weber *et al.* (2010) note, the idea of 'cereal cities' and the monocropping of wheat and barley could have been especially important in the rise and maintenance of large urban populations. It is hypothesised that stable surplus creation (Wheeler 1950; Kenoyer 2000; Weber *et al.* 2010; Wright 2010), while important for urban support, would have become unsustainable as a strategy during periods of climate and social change. Over-reliance on large-grained *rabi* crops, likely due to population size and the need to feed cities (yield demands), is considered here to have created an inflexible system at sites such as Harappa. While, as Weber (2003: 181) has asserted, millet use may have increased in the Late Harappan at Harappa in response to changing ecological conditions—reflecting a desire to create a more reliable and resilient food supply—it was too little too late. The need for high yields and supply in the short term (feeding the masses) outstripped the need for long-term diversity and adaptability. Consequently, only small amounts of a non-wheat and barley monoculture could be incorporated into the Harappa's food strategies, and this may have created a feedback loop of demand–yield pressures contributing to the decline of the city as wheat and barley supply chains were interrupted by the 4.2kya event (Madella & Fuller 2006).

More seasonally tailored millet duo-cultures and mixed cropping, for example at Rojdi, allowed people to be ready to deal with arid conditions and to have fall-backs should any one of the millet crops fail to produce sufficient yield. At sites such as Kanmer and Khirsara, a willingness to shift away from high-yield (possibly imported) crops to sustainable and locally grown crops also allowed for greater risk mitigation. This raises questions concerning the model of a monolithic system focused solely on extensive agricultural strategies in the so-called 'peripheral' zone of the Indus civilisation in Gujarat (Madella & Fuller 2006; Pokharia *et al.* 2017). The Gujarat assemblages suggest that in the urban Harappan phase it was a region of flexible choices with regard to supply and demand. This flexibility endured in the changing conditions of the Late Harappan phase, when people adapted their cropping strategies to suit their changing needs. The demands of the economy, the environment, ecological shifts and inter/intra-regional trade networks may have created a situation in which a single rigid agricultural system was improbable, as farmers negotiated between their own needs and demands that changed rapidly over space and time. Millet use may have been suitable at certain moments for village subsistence, while wheat growing for interaction with cities may have allowed for more engagement with different economic networks during periods of stability. In the north-east, the early adoption of varied multicropping systems, which were flexible at the local level, created a similar resilience in village economies.

These hypotheses need to be tempered by the different scales of the datasets: while extensive open-area excavations were undertaken in Gujarat, sondages were favoured in the north-east, and the publication of the dataset from Harappa remains incomplete. Overall, the Indus archaeobotanical landscape provides a wealth of data offering insights into the decisions taken by Indus farmers (Figure 2): vegeculture/mixed taxa versus a dominance of cereal/grain, diversity versus monoculture, low versus high yield, and flexibility versus supply-driven

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

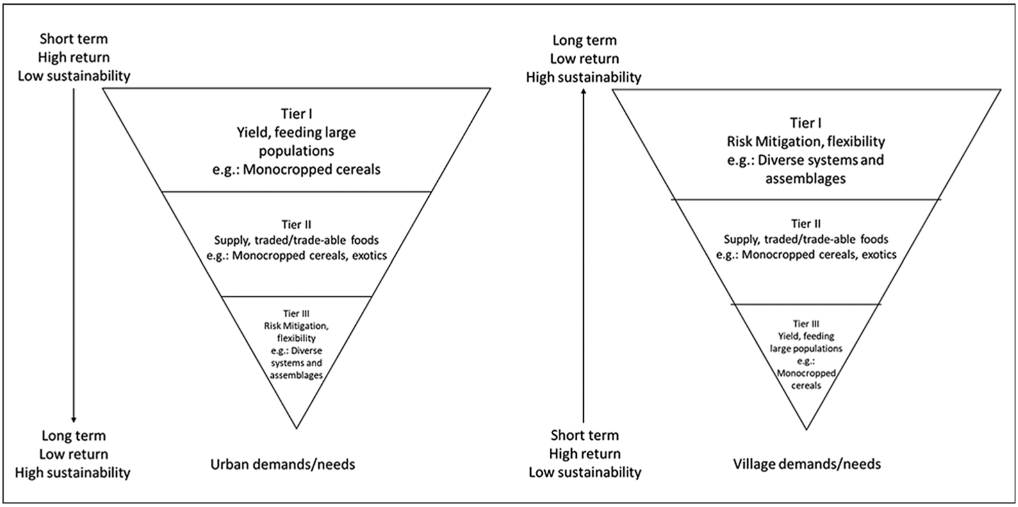


Figure 2. Schematised model of differing demands on Indus cropping systems. Differing choices relating to demand (economic and ecological) influenced both the returns (e.g. yields) and sustainability of the systems over the short and long term (figure by the authors).

production (following Harris 1972; Brookfield 1984; Morrison 1994). These choices, based on balancing demand, population size and access to land, crops and labour, may have had consequences during the Late Harappan phase, leading to regionally and even site-by-site patterns of stability versus instability as people tried to weather the different demands placed on them by the economy and the changing social and environmental circumstances.

Conclusions

As McIntosh *et al.* (2000) have argued, people react not to nature itself but to their perception of nature and such perception acts as a filter to reaction. The 4.2kya event and social changes during the Late Harappan phase is likely to have created a situation in which the population and the environment were under stress. This could have put pressures on food production and supply chains (Petrie 2017) but it was not uniform across the Indus. Agricultural decisions were guided by different needs and demands, economic, social and environmental. As these changed, the choices made by farmers in different circumstances resulted in different outcomes, creating diverse levels of resilience in changing conditions.

Our discussion echoes many that have been aired in Old World Bronze Age archaeology and touches on broader sustainability and risk-mitigation debates (Marston 2015; Paloviita & Järvelä 2016; Green *et al.* 2020). Rather than highlighting the overarching patterns of change and chronological shifts with regard to large-scale events, we suggest that something more nuanced and complex took place within the Indus civilisation. In the same way that change over the *longue durée* has been posited for places such as Gordion in Phrygia (present-day Turkey), with a second-millennium BC diversification towards agro-pastoralism (Marston & Miller 2014) and Roman-period demands for irrigated wheat (Gürsan-Salzmann 2005), the archaeobotanical evidence from the Indus points to a particular moment of stress

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press

within a diverse social, environmental, climatic and geographical context. This diversity and the variable reactions and perceptions to these elements promoted further diversity in the strategies that people employed to exploit the landscape, and in turn determined how they responded to the challenges of the Late Harappan phase. This South Asia case study, with its unique combination of environment and complex human responses, provides an important archaeobotanical perspective on the successes and failures of early urban civilisations.

Acknowledgements

This article was completed at Seoul National University, Department of Archaeology and Art History, where Jennifer Bates is assistant professor of Archaeological Science and Jungwoo Choi is a student. They are grateful for the support shown to them by the department.

References

AN, C.-B., L. TANG, L. BARTON & F.-H. CHEN. 2005. Climate change and cultural response around 4000 cal yr B.P. in the western part of Chinese Loess Plateau. *Quaternary Research* 63: 347–52. https://doi.org/10.1016/j.yqres.2005.02.004

AJITHPRASAD, P. & V.H. SONAWANE. 2011. The Harappan culture in North Gujarat: a regional paradigm, in T. Osada & H. Endo (ed.) *Linguistics, archaeology and human past*: 223–69. Kyoto: Research Institute for Humanity and Nature.

BATES, J. 2019. The published archaeobotanical data from the Indus civilisation, South Asia, c.3200–1500BC. *Journal of Open Archaeology Data* 7: 5. https://doi.org/10.5334/joad.57

BATES, J., R.N. SINGH & C.A. PETRIE. 2017. Exploring Indus crop processing: combining phytolith and macrobotanical analyses to consider the organisation of agriculture in northwest India c. 3200–1500 BC. *Vegetation History and Archaeobotany* 26: 25–41. https://doi.org/10.1007/s00334-016-0576-9

BHAN, K.K., V.H. SONAWANE, P. AJITHPRASAD & S. PRATAPCHANDRAN. 2005. A Harappan trading and craft production centre at Gola Dhoro (Bagasra). *Antiquity* 79. http://antiquity.ac.uk/Projgall/bhan/index.html

BROOKFIELD, H.C. 1984. Intensification revisited. *Pacific Viewpoint* 25: 15–44. https://doi.org/10.1111/apv.251002

DEMAREST, A.A. 2004. *Ancient Maya: the rise and fall of a rainforest civilization*. Cambridge: Cambridge University Press.

GARCÍA-GRANERO, J.J., C. LANCELOTTI, M. MADELLA & P. AJITHPRASAD. 2016. Millets and herders: the origins of plant cultivation in semiarid North Gujarat (India). *Current Anthropology* 57: 149–73. https://doi.org/10.1086/685775

GREEN, A.S. *et al.* 2020. An interdisciplinary framework for using archaeology, history and collective action to enhance India's agricultural resilience and sustainability. *Environmental Research Letters* 15: 105021. https://doi.org/10.1088/1748-9326/aba780

GÜRSAN-SALZMANN, A. 2005. Ethnographic lessons for past agro-pastoral systems in the Sakarya-Porsuk valleys, in L. Kealhofer (ed.) *The archaeology of Midas and the Phrygians: recent work at Gordion*: 172–90. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology. https://doi.org/10.9783/9781934536247.172

HALSTEAD, P. & J.M. O'SHEA. 1989. *Bad year economics: cultural responses to risk and uncertainty*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511521218

HARRIS, D.R. 1972. The origins of agriculture in the tropics: ecological analysis affords new insights into agricultural origins and suggests a fresh evaluation of the limited archaeological evidence. *American Scientist* 60: 180–93.

HAYDEN, B. 2001. Richman, poorman, beggarman, chief: the dynamics of social inequality, in G.M. Feinman & T.D. Price (ed.) *Archaeology at the millennium*: 231–72. Boston (MA): Springer. https://doi.org/10.1007/978-0-387-72611-3_7

KENOYER, J.M. 2000. Wealth and socio-economic hierarchies of the Indus Valley civilization, in

J. Richards & M. van Buren (ed.) *Order, legitimacy and wealth in early states*: 90–112. Cambridge: Cambridge University Press.

– 2020. The origin and development of the Indus script: insights from Harappa and other sites, in K. Lashari (ed.) *Studies on Indus script*: 217–36. Karachi: National Fund for Mohenjodaro.

LAWRENCE, D., A. PALMISANO & M.W. DE GRUCHY. 2021. Collapse and continuity: a multi-proxy reconstruction of settlement organization and population trajectories in the Northern Fertile Crescent during the 4.2kya Rapid Climate Change event. *PLoS ONE* 16: e0244871. https://doi.org/10.1371/journal.pone.0244871

LUTHRA, J.C. 1941. Letter quoted in excavations at Harappa, in M.S. Vats *Excavations at Harappa*: 467. New Delhi: Manohar.

MADELLA, M. 2014. Of crops and food, a social perspective on rice in the Indus civilization, in M. Madella, C. Lancelotti & M. Savard (ed.) *Ancient plants and people: contemporary trends in archaeology*: 218–36. Tucson: University of Arizona Press.

MADELLA, M. & D.Q. FULLER. 2006. Palaeoecology and the Harappan Civilization of South Asia: a reconsideration. *Quaternary Science Reviews* 25: 1283–301. https://doi.org/10.1016/j.quascirev.2005.10.012

MARSTON, J.M. 2015. Modelling resilience and sustainability in ancient agricultural systems. *Journal of Ethnobiology* 35: 585–605. https://doi.org/10.2993/etbi-35-03-585-605.1

MARSTON, J.M. & N.F. MILLER. 2014. Intensive agriculture and land use at Roman Gordion, central Turkey. *Vegetation History and Archaeobotany* 23: 761–73. https://doi.org/10.1007/s00334-014-0467-x

MCINTOSH, R.J., J.A. TAINTER & S.K. MCINTOSH. 2000. Climate, history and human action, in R.J. McIntosh, J.A. Tainter & S.K. McIntosh (ed.) *The way the wind blows*: 1–44. New York: Columbia University Press.

MEADOW, R. 1989. Continuity and change in the agriculture of the Greater Indus Valley: the palaeoethnobotanical and zooarchaeological evidence, in J.M. Kenoyer (ed.) *Old problems and new perspectives in the archaeology of South Asia*: 61–74. Madison: University of Wisconsin.

MIDDLETON, G.D. 2017. *Understanding collapse: ancient history and modern myths*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781316584941

MORRISON, K.D. 1994. Intensification of production: archaeological approaches. *Journal of Archaeological Method and Theory* 1: 111–59. https://doi.org/10.1007/BF02231414

NATH, A. 1999. Further excavations at Rakhigarhi. *Puratattva* 29: 46–9.

PALOVIITA, A. & M. JÄRVELÄ. (ed.) 2016. *Climate change adaptation and food supply chain management* (Routledge advances in climate change research). London: Routledge. https://doi.org/10.4324/9781315757728

PETRIE, C.A. 2013. South Asia, in P. Clark (ed.) *The Oxford handbook of cities in world history*: 83–104. Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199589531.013.0005

– 2017. Crisis, what crisis? Adaptation, resilience and transformation in the Indus civilization, in T.F. Cunningham & J. Driessen (ed.) *Crisis to collapse: the archaeology of social breakdown*: 43–64. Louvain: Louvain University Press.

– 2019. Diversity, variability, adaptation and 'fragility' in the Indus civilization, in N. Yoffee (ed.) *The evolution of fragility: setting the terms*: 109–33. Cambridge: McDonald Institute for Archaeological Research. https://doi.org/10.17863/CAM.40701

PETRIE, C.A. & J. BATES. 2017. 'Multi-cropping', intercropping and adaptation to variable environments in Indus South Asia. *Journal of World Prehistory* 30: 81–130. https://doi.org/10.1007/s10963-017-9101-z

PETRIE, C.A., J. BATES, T. HIGHAM & R.N. SINGH. 2016. Feeding ancient cities in South Asia: dating the adoption of rice, millet and tropical pulses in the Indus civilization. *Antiquity* 90: 1489–504. https://doi.org/10.15184/aqy.2016.210

PETRIE, C.A. *et al.* 2017. Adaptation to variable environments, resilience to climate change: investigating land, water and settlement in Indus northwest India. *Current Anthropology* 58: 1–30. https://doi.org/10.1086/690112

POKHARIA, A.K. & C. SRIVASTAVA. 2013. Current status of archaeobotanical studies in Harappan Civilization: an archaeological perspective. *Heritage: Journal of Multidisciplinary Studies in Archaeology* 1: 118–37.

POKHARIA, A.K., J.S. KHARAKWAL, R.S. RAWAT, T. OSADA, C.M. NAUTIYAL & A. SRIVASTAVA.

2011. Archaeobotany and archaeology at Kanmer, a Harappan site in Kachchh, Gujarat: evidence for adaptation in response to climatic variation. *Current Science* 100: 1833–46.

Pokharia, A.K., J.S. Kharakwal & A. Srivastava. 2014. Archaeobotanical evidence of millets in the Indian subcontinent with some observations on their role in the Indus civilization. *Journal of Archaeological Science* 42: 442–55. https://doi.org/10.1016/j.jas.2013.11.029

Pokharia, A.K., R. Agnihotri, S. Sharma, S. Bajpai, J. Nath, R.N. Kumaran & B.C. Negi. 2017. Altered cropping pattern and cultural continuation with declined prosperity following abrupt and extreme arid event at ~4,200 yrs BP: evidence from an Indus archaeological site Khirsara, Gujarat, western India. *PLoS ONE* 12: e0185684. https://doi.org/10.1371/journal.pone.0185684

Possehl, G.L. 1997. The transformation of the Indus civilization. *Journal of World Prehistory* 11: 425–72. https://doi.org/10.1007/BF02220556

– 2002. *The Indus civilization: a contemporary perspective*. Walnut Creek (CA): AltaMira.

Prasad, S. *et al*. 2014. Prolonged monsoon droughts and links to Indo-Pacific warm pool: a Holocene record from Lonar Lake, central India. *Earth and Planetary Science Letters* 391: 171–82. https://doi.org/10.1016/j.epsl.2014.01.043

Reddy, S.N. 2003. *Discerning palates of the past: an ethnoarchaeological study of crop cultivation and plant usage in India* (International Monographs in Prehistory: Ethnoarchaeological series). Brooklyn: Berghahn Books. https://doi.org/10.2307/j.ctv8bt2m9

Shaw, F.J.F. 1943. Vegetable remains, in E.J.H. Mackay (ed.) *Chanhudaro excavations*: 250–1. New Haven: Yale University Press.

Staubwasser, M. & H. Weiss. 2006. Holocene climate and cultural evolution in Late Prehistoric–Early Historic West Asia. *Quaternary Research* 66: 372–87. https://doi.org/10.1016/j.yqres.2006.09.001

Staubwasser, M., F. Sirocko, P.M. Grootes & M. Segl. 2003. Climate change at the 4.2 ka BP termination of the Indus Valley civilization and Holocene south Asian monsoon variability. *Geophysical Research Letters* 30(8). https://doi.org/10.1029/2002GL016822

van der Veen, M. 1995. The identification of maslin crops, in H. Kroll & R. Pasternak (ed.) *Res Archaeobotanicae*: 335–43. Kiel: Koeltz Scientific Books.

Vidale, M. & H.M.-L. Miller. 2000. On the development of Indus technical virtuosity and its relation to social structure, in M. Taddei & G. de Marco (ed.) *South Asian archaeology 1997*: 115–32. Naples: Instituto Italian per l'Africa e l'Oriente & Instituto Universitario Orientale.

Vishnu-Mittre, 1990. Plant remains, in J.P. Joshi (ed.) *Excavation at Surkotada*: 388–92. Delhi: Archaeological Survey of India.

Vishnu-Mittre & R. Savithri. 1993. Food economy of the Harappans, in G.L. Possehl (ed.) *Harappan civilization*: 205–21. New Delhi: Oxford and IBH.

Weber, S.A. 1991. *Plants and Harappan subsistence: an example of stability and change from Rojdi*. New Delhi: Oxford and IBH.

– 1999. Seeds of urbanism: palaeoethnobotany and the Indus civilization. *Antiquity* 73: 813–26. https://doi.org/10.1017/S0003598X00065558

– 2003. Archaeobotany at Harappa: indications for change, in S.A. Weber & W.R. Belcher (ed.) *Indus ethnobiology: new perspectives from the field*: 175–98. Lanham: Lexington Books.

Weber, S.A., A. Kashyap & D. Harriman. 2010. Does size matter? The role and significance of cereal grains in the Indus Civilization. *Archaeological and Anthropological Science* 2: 35–43. https://doi.org/10.1007/s12520-010-0025-0

Weiss, H., M.-A. Courty, W. Wetterstrom, F. Guichard, L. Senior, R. Meadow & A. Curnow. 1993. The genesis and collapse of third millennium North Mesopotamian civilization. *Science* 261: 995–1004. https://doi.org/10.1126/science.261.5124.995

Wheeler, M. 1950. *Five thousand years of Pakistan: an archaeological outline*. London: Royal India and Pakistan Society.

Wright, R.P. 2010. *The ancient Indus: urbanism, economy, and society: case studies in early societies*. New York: Cambridge University Press.

https://doi.org/10.15184/aqy.2023.134 Published online by Cambridge University Press