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Agricultural Methods in the Indus Civilization: Goals and Farming Results

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Climate change is frequently associated with the collapse of complex societies, particularly in relation to agricultural resilience or the lack thereof. This article explores how agricultural strategies were influenced by varying demands as farmers adapted during the Late Harappan phase (1900-1700 BC) of the Indus civilization. By modelling different agricultural approaches, including monocropping versus multi- cropping, low-yield versus high-yield crops, and supply-driven versus flexible production systems, the authors examine the economic, environmental, and social factors that shaped farmers' decisions. The analysis also highlights regional variations in these strategies and their role in the broader de-urbanization process during the Late Harappan period. This archaeobotanical perspective offers valuable insights into the evolving relationship between urban societies and their agricultural foundations over time.

Keywords: South Asia, Indus civilization, climate change, archaeobotany, urban collapse, agriculture, de-urbanization

Introduction

The ability of cities and civilizations to generate and maintain reliable food sources is essential for their endurance. In both the Old and New Worlds, scholars have explored how historical food systems adapted to shifting climatic and societal contexts, with an emphasis on the importance of diversity as a cornerstone of sustainability (Demarest 2004; Marston & Miller 2014; Middleton 2017). Halstead and O'Shea (1989) underscore the role of food surpluses and distribution networks as critical components for mitigating risk. Choices surrounding agricultural diversity, specialization, productivity, and the integration of agricultural practices are believed to have shaped how urban centres managed their resources and coped with social and environmental challenges. Despite this, specific decision-making dynamics related to yield, surplus production, trade, and risk management during short-term crises and their extensive, long-term impacts-have often received insufficient attention.

Figure 1: A map depicting the Indus civilization, highlighting the locations of the key sites

Spanning present-day Pakistan and parts of north-western India, the Indus civilization (2600-1700 BC) ranks among the prominent Old World Bronze Age cultures (Figure 1, Table 1). This extensive South Asian region is shaped by two distinct rainfall systems, two major rivers, and diverse ecological environments that range from arid to semi-tropical climates. Such geographical diversity has complicated efforts to understand historical agricultural supply and demand. Farming practices within the Indus civilization evidently varied across different areas (Pokharia & Srivastava 2013; Petrie *et al.*, 2016; Petrie & Bates 2017; Bates 2019), yet the role of agriculture during the civilization's decline remains contested (Vishnu-Mittre & Savithri 1993; Madella & Fuller 2006; Pokharia *et al.* 2014; Petrie 2017; Petrie *et al.*, 2017). During the Late Harappan period (c. 1900-1700 BC)-marked by de-urbanization and aligned with the aridification event-key questions arise concerning sustainability. Specifically, researchers are exploring how the elements of the broader Indus tradition adapted to shifts in climate and society, as well as how food supplies were sustained on supra-regional, regional, and local scales.

The Indus civilization presents a valuable case for examining the difficulties encountered by an urban society amid a period marked by intertwining climate, environmental, and social pressures-an era that Petrie *et al.* (2017: 19) describe as "unpredictable unpredictability," a challenge surpassing human coping capacity. Rather than viewing the Indus as a uniform system or one focused solely on urban food provisioning, as suggested in Halstead & O'Shea's (1989) model, this analysis investigates how various elements within the Indus agricultural systems interacted with dynamic conditions. The study specifically assesses how concepts such as diversity and specialization, polyculture and monoculture, low- and high-yield practices, and adaptable versus supply-driven production contribute to understanding diverse risk mitigation strategies and potential failures. This approach involves a comparative analysis of archaeobotanical data from three primary areas: Harappa, Gujarat, and the northeastern region of the Indus civilization.

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

Era	Time Period	Description
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	

Indus agricultural modelling

The Late Harappan period saw significant social transformations, with prominent structures like the Great Bath at Mohenjo Daro falling into disuse (Possehl 1997; Wright 2010; Petrie 2019), a decline in specialist crafts, and a reduction in sophisticated production techniques (Vidale & Miller 2000). Some major sites, including Mohenjo Daro, experienced abandonment following phases of decline and population decrease (Possehl 1997; Wright 2010), while Harappa continued to be occupied, though with fewer inhabitants (Petrie 2017). There was also a shift toward smaller village settlements as populations moved away from larger urban centres. Traditionally, this period has been associated with an agricultural "revolution." Richard Meadow (1989), for instance, emphasized agricultural change as key to the Late Harappan phase, attributing it to the roles of various crops in the Indus system, as detailed in Table 2.

Table 2. Seasonal Crops by Type (Data adapted from Weber 2003, Petrie & Bates 2017, Bates 2019)

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

Meadow (1989) also connected shifts in cereal production with the climatic event, a sudden, intense arid phase starting around 2150 BC and lasting for several centuries (Staubwasser *et al.* 2003; Prasad *et al.* 2014). This climate event has been central to theories linking climate change with the decline of the Indus and other Bronze Age civilizations (Weiss *et al.* 1993; An *et al.* 2005; Staubwasser & Weiss 2006; Lawrence *et al.* 2021). Meadow (1989) argued that, amid the Late Harappan phase's increased aridity, kharif (summer monsoon) crops-such as rice, sorghum, and millets-gained prominence. This shift may have destabilized the socio-economic structure, potentially contributing to broader societal decline (Weber 2003; Madella & Fuller 2006). However, the causal link between agricultural and socio-economic change during the event is complex (Petrie 2017). Acknowledging the ecological and agricultural diversity within Indus archaeology (Vishnu-Mittre & Savithri 1993; Madella & Fuller 2006; Pokharia *et al.* 2014; Petrie 2017; Petrie *et al.* 2017) invites a re-evaluation of these "economic shift" models, particularly through the lens of human agency. This article, therefore, centers on the economic-agentive perspective of Indus agricultural diversity, examining food supply strategies and decisions with respect to farmer agency, resilience, and sustainability.

Intensification, Specialization, Diversity, and Yields

Intensification-an increase in crop yield per unit of land-can take many forms, including specialization and diversification (Brookfield 1984; Morrison 1994: 143-44). However, specialization and diversification are processes, not the same as diversity and specialty (Morrison 1994). Diversity and specialty can result from varying intensification strategies but are not predetermined outcomes. Specialization and diversification represent changes in farming strategies to increase yield, while diversity and specialty refer to differences within the agricultural system.

Harris (1972) contrasted the short-term high yields of cereals with the long-term stability of vegeculture, summarizing it in equations: vegeculture/mixed taxa versus cereal/grain dominance, diversity versus monoculture, and low versus high yields. Flexibility versus supply-driven production (stability versus instability) is another key equation. A diverse system is adaptable, compensating for changes like crop failure, but such systems may not provide the same food abundance as specialized systems. Specialized cropping strategies, though, yield high quantities of a single crop but lack flexibility and risk aversion.

Thus, farmers and society face critical decisions regarding diversity versus specialty, polyculture versus monoculture, low versus high yields, and flexibility versus supply-driven production. These choices impact producers and consumers and are heightened during climate change, when adaptation to new environmental conditions coincides with greater economic demand.

Agriculture and Urbanization in Harappa

Weber *et al.* (2010) argue that large-grained cereals, particularly rabi wheat and barley (Triticum sp. and Hordeum sp.), were essential in the rise of urban centres in the Indus. These high-yielding crops supported larger populations, facilitating urbanization. While Weber *et al.*'s (2010) analytical approach has been critiqued (e.g., Hayden 2001; Petrie 2013), their study highlights the role of these grains in supplying Indus cities during the Harappan phase. This mono-crop system likely arose from the climatic and social shifts of the Late Harappan phase.

Harappa offers the best archaeobotanical data for an Indus city, with 80% of the 250,000 seeds analyzed being cereals (Weber 1999, 2003; Weber *et al.* 2010). The majority of these are rabi cereals, especially wheat and barley. Weber (1999) proposed a tiered model of Indus cropping, with cereals as Tier I staple crops. However, only 20% of the data from Harappa has been fully analyzed, though standard data (e.g., ubiquity, density, proportions) have contributed to model building (Weber 2003). Crop choices at Harappa fluctuated over time. Barley dominated the Early Harappan phase, wheat predominated in the main Harappan phase, and barley returned in the Late Harappan (Weber 2003).

Mohenjo Daro, another urban site, also shows dominance of wheat and barley (Luthra 1941; Shaw 1943). However, its early excavations, lacking systematic flotation, may have missed smaller crops like millets. The data from Harappa and Mohenjo Daro suggest that rabi monocultures of large-grained cereals were likely driven by urban demand for food. This system probably began in the Early Harappan phase and continued through the Harappan phase. During the Late Harappan phase, as pressures from environmental and economic upheavals grew, there was a limited shift toward millets to add flexibility in food supply (Weber 2003; Petrie & Bates 2017).

Agricultural Adaptation in Gujarat's Arid Region

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 rely on summary tables (see Weber 2003), numerous sites in Gujarat provide both raw data and their quantified analysis. Gujarat is a hyper-arid region, where most rainfall occurs between June and September during the Indian summer monsoon, influencing agricultural and pastoral activities. Prolonged drought is a recurrent phenomenon, especially in the driest areas of north Gujarat and Kachchh (Ajithprasad & Sonawane 2011), impacting the resilience of agricultural strategies.

Archaeobotanical data from the site of Rojdi reveal multi-cropping strategies, including intercropping or duo-culture, with evidence for change over time (Weber 1991, 1999; Petrie & Bates 2017). This flexible millet-based system 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 recorded at Surkotada (Vishnu-Mittre 1990) and Babar Kot (Reddy 2003).

However, these patterns are not the only strategies observed. At the sites of Khirsara and Kanmer (Pokharia *et al.* 2011, 2017), a non-millet-based system prevailed for much of the time. At Khirsara, the Early Harappan cropping strategy was 90% barley, a monoculture similar to that at Harappa in Punjab. This was ill-suited to local environmental conditions, suggesting that regional or pan-regional economic demands for large rabi cereals during the urbanizing 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% of the assemblage. Kharif crops were also introduced, and a duo-crop of rice was added. By the Late Harappan phase, the assemblage was mainly kharif crops, including 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 similar dramatic change over time is also seen at Kanmer (Pokharia *et al.* 2011). The contrast between Khirsara and Kanmer on 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, possibly due to urbanizing economic demands, to more diverse polyculture and multi-season cropping, reflecting a shift toward local ecological conditions in later periods.

Village Life in the North-East: An Exploration

The agricultural systems in the north-eastern part of the Indus region display varied cropping strategies, including sequential cropping, monocropping, duo- and polycultures, and row or strip intercropping (Petrie & Bates 2017). There is no clear chronological shift tied to urbanisation or environmental stress. For example, at Masudpur VII, sequential cropping was practiced through all three Indus phases. In the Early Harappan phase, small amounts of wheat and barley monocropping were used among the rabi crops, with intercropped millets and pulses. The Harappan phase introduced mustard and pulses intercropped with rabi crops and monocropped sawa millet (Echinochloa sp.), along with pulses in strip or row intercropping among kharif crops. By the Late Harappan phase, monocrops of rice and mixed intercropped millets were added, further diversifying agricultural strategies.

This use of multiple cropping strategies suggests a flexible, resilient approach to agriculture, adjusting to both summer and winter rains and varying environmental conditions. The system emphasized diversification, with a balance between intensification and adaptation to local ecological contexts.

However, several questions remain. For instance, did Rakhigarhi, one of the cities abandoned during the Late Harappan phase (Nath 1999), rely on monocropped cereals like Harappa? If so, did this affect its resilience compared to surrounding villages, such as Masupdur I and Masupdur VII, that maintained diversified cropping systems (Bates *et al.*

2017)? These villages seemed to adapt more successfully to societal and environmental changes. Rakhigarhi's possible reliance on non-diverse food supplies could have contributed to its vulnerability, whereas the surrounding villages' agricultural flexibility may have made them more resilient.

Outcomes

The 4.2kya event created an "unpredictably unpredictable" set of conditions (Petrie *et al.* 2017: 19), but the impact of the weakening summer monsoon would not have been uniform across the Indus region. Climatic effects likely varied due to the region's complexity (Petrie 2017). Resilience or lack thereof was influenced not only by environmental factors but also by diverse agricultural strategies and, importantly, people's responses to change. Not everyone experienced this "unpredictable unpredictability" in the same way.

As Weber *et al.* (2010) argue, the concept of "cereal cities" and the monocropping of wheat and barley played a crucial role in sustaining large urban populations. Stable surplus production (Wheeler 1950; Kenoyer 2000; Weber *et al.* 2010; Wright 2010), while vital for urban support, became unsustainable during periods of climate and social upheaval. Over-reliance on large-grain rabi crops, driven by population size and the need to feed cities (yield demands), may have contributed to an inflexible system at urban centers like Harappa. Although millet use may have increased in the Late Harappan phase in response to ecological changes (Weber 2003), it was too little too late. The immediate need for high yields to feed the urban population overshadowed the long-term benefits of crop diversity and adaptability. Consequently, incorporating small amounts of non-wheat and barley crops into Harappa's food strategies may have created a feedback loop, with demand-pressure for high yields contributing to the city's decline when wheat and barley supply chains were disrupted by the 4.2kya event (Madella & Fuller 2006).

In contrast, more seasonally tailored millet duo-cultures and mixed cropping systems, such as those at Rojdi, allowed people to adapt to arid conditions and offered fallback options if one millet crop failed. Sites like Kanmer and Khirsara further demonstrate resilience through a shift from high-yield, possibly imported crops to locally grown, sustainable varieties, thereby mitigating risk. This challenges the notion of a monolithic agricultural system in Gujarat, often considered a "peripheral" zone of the Indus civilization (Madella & Fuller 2006; Pokharia *et al.* 2017). Archaeobotanical evidence from Gujarat indicates that during the urban Harappan phase, this region employed flexible agricultural strategies. This flexibility endured through the Late Harappan period, with people adjusting their cropping systems to meet changing needs. Economic demands, environmental shifts, and evolving trade networks may have fostered a dynamic agricultural approach, where farmers adapted to rapidly changing demands.

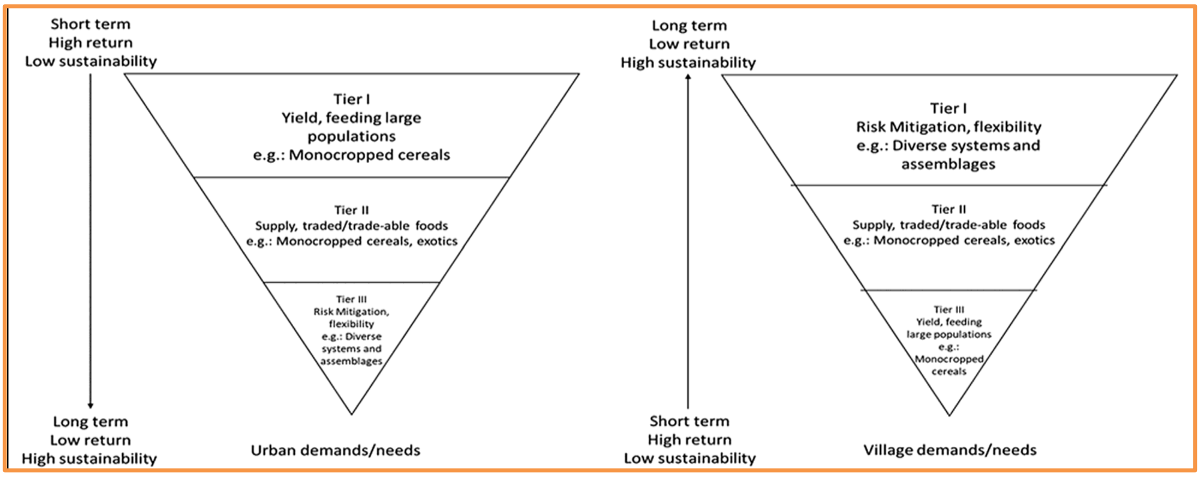

Figure 2: A conceptual model illustrating the varying demands placed on the Indus cropping systems. The decisions regarding these demands-whether economic or ecological-shaped both the immediate outcomes (e.g., crop yields) and the long-term sustainability of these agricultural systems (figure created by the authors).

In the north-east, the early adoption of multicropping systems fostered resilience in village economies. This flexibility at the local level mirrors the adaptive strategies seen in Gujarat. However, these hypotheses need to account for the varying scales of excavation data: extensive open-area excavations in Gujarat versus sondages in the north-east, and the incomplete publication of Harappa's dataset. Overall, the Indus archaeobotanical record provides valuable insights into the agricultural decisions made by Indus farmers, including choices between monoculture and diversity, low versus high yield, and flexibility versus supply-driven production (following Harris 1972; Brookfield 1984; Morrison 1994). These choices, balancing demand, population size, and access to land, crops, and labor, likely played a significant role in regional patterns of stability and instability during the Late Harappan phase.

Conclusions

As McIntosh *et al.* (2000) argue, people react not to nature itself, but to their perception of nature, and this perception acts as a filter to their reaction. The 4.2kya event and social changes during the Late Harappan phase likely created a situation where both the population and the environment were under stress, possibly putting pressure on food production and supply chains (Petrie 2017). However, this was not uniform across the Indus. Agricultural decisions were influenced by a variety of needs-economic, social, and environmental-and as these demands changed, farmers' choices resulted in diverse outcomes, creating varying levels of resilience.

Old World Bronze Age archaeology and engages with broader discussions on sustainability and risk mitigation (Marston 2015; Paloviita & Järvelä 2016; Green *et al.* 2020). Rather than focusing on overarching patterns of change or large-scale events, we propose that a more nuanced and complex situation unfolded within the Indus civilisation. Similar to the changes at Gordion in Phrygia (present-day Turkey), where a second-millennium BC shift towards agro-pastoralism occurred (Marston & Miller 2014), or Roman-period demands for irrigated wheat (Gürsan-Salzmann 2005), the archaeobotanical evidence from the Indus suggests a moment of stress within a diverse social, environmental, climatic, and geographical context. This diversity, along with the variable reactions and perceptions to these elements, led to further diversity in the strategies people employed to exploit the landscape and respond to the challenges of the Late Harappan phase. This South Asian case study, with its unique combination of environment and human responses, offers a critical archaeobotanical perspective on the successes and failures of early urban civilisations.

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