Water Supply, Labor Requirements, and Land Ownership in Indus Floodplain Agricultural Systems

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The development of ancient floodplain civilizations like the Indus is often associated with the need for managers to direct irrigation systems, leading to the rise of an elite class through their control of the water supply necessary for surplus agricultural production. Such ideas are most strongly associated with Karl Wittfogel's (1976 [1957]) classic statement of the role of hydraulic agriculture in the rise of oriental despotism. As several of the chapters in this volume note, the recognition of the efficient creation and management of small-scale irrigation systems without hierarchically ranked managers resulted in general repudiation of Wittfogel's hypothesis. Nonetheless, many texts continue to cite irrigation agriculture as one of the factors in the development of state-level political units in the Indus Valley during the third millennium BCE, in spite of the lack of any evidence for large-scale irrigation systems. A recent exception is Vernon Scarborough's (2003:145–146) conclusion that water management was unlikely to have been a method of promoting state power and elite control.[1] In this chapter I will go even farther, and argue that Indus Valley Tradition systems for the management of agriculture may in some ways have restricted the hierarchical power of state-level political units, particularly with regard to control of wealth from elite land ownership, yet encouraged the existence of state-level corporate mechanisms for arbitrating disputes about land ownership.

This is not to say that agricultural technology and management were not important to the Harappan Phase state. On the contrary, a stable agricultural supply would have been essential. And that is the point of this volume, which addresses topics that arise from two well-known but heavily modified or rejected theories: Wittfogel's original statement about the role of hydraulic agriculture in state formation and Ester Boserup's original strong linking of population increase with agricultural intensification. Both of these authors addressed the more general idea that forms the basis for this volume, that agricultural intensification in some form is related to the rise of states. It is the exact way in which agricultural intensification is related to state power that is the source of debate, and which varies so much from case to case, even in similar environments.

For example, for ancient Indus Valley farmers the supply of water would have been the limiting factor in agricultural production, as in any classic Wittfogelian state. Their choice of methods for increasing water supply would have been affected primarily by the type of land available. For some water-supply systems the available labor was also important, particularly for the most labor-intensive water-supply system discussed here, that of well and lift irrigation. But for the most part, rather than seeing the need for large-scale irrigation, I conclude that a multiplicity of water-supply systems were likely employed by Indus farmers, with particular choices about intensification and/or extensification reflecting the type of crops in use, the type of land obtainable, the labor availability, and the demand for increased production.

Whether or how political leaders were actively involved in agricultural management is another question, however. As with later periods and other regions, leaders may have benefited from and even encouraged agricultural intensification, but focused their energies on extracting agricultural surplus as tribute or taxes in exchange for religious or military protection, rather than trying to control agricultural production directly via land ownership or infrastructure development. Therefore, I am not merely interested in management of water supply, but have more broadly examined the connections between agricultural production and the Indus state in terms of wealth production.

Food production is usually seen as one of the two major sources of wealth in ancient economic systems, the other being manufactured goods. Wealth from craft production and trade has seen considerable attention for the Indus Valley Tradition, especially for the urban integration period of the Harappan Phase, c. 2600–1900 BCE (chronology after Shaffer 1992). In contrast, the accumulation of wealth and prestige from food production, and particularly from land ownership, has not yet been a focus of models of Indus Valley Tradition social and political organization, even though much recent research has been devoted to the investigation of Harappan Phase food production systems more generally. Although an early debate on the nature of the Harappan Phase political system included a discussion of cattle herds as a source of wealth and political power (Fairservis 1986; well summarized in Possehl 1998), agriculturally based wealth and prestige has generally been taken as a given (Leshnik 1973 is a crucial exception). The lack of appropriate data has been a major reason for this state of affairs, especially the lack of textual information, although the great advances in South Asian plant analysis over the past decade are starting to inspire more complex interpretations. Nevertheless, it is useful to explicitly examine the implications of the different water supply and land ownership systems possible for this region because they have very different implications for sources of wealth and power, and thus contribute substantially to broader interests in the sources of Indus political power and social structure (Kenoyer 1998; Possehl 1998 for recent summaries).

In the spirit of Timothy Earle's (2000) call for optimism, creativity, and critical methods in the archaeological investigation of land ownership, I present here several possible models of the ways water supply, labor requirements, and land ownership might have affected Harappan Phase economic, social, and political systems. There are a limited number of possible agricultural systems for this region, as is true of most areas. This is particularly true with respect to potential water-supply systems, and given the semiarid nature of this region, water supply has been a key part of all agricultural systems. From the perspective of water-supply requirements, there are four basic agricultural water-supply systems possible for the Indus Valley floodplains during the Harappan Phase: (1) riverine inundation, (2) rain-fed, (3) small-scale canal irrigation to extend the inundation, and (4) well or lift irrigation. Given our very incomplete data for any kind of Harappan Phase agricultural water-management system, my strategy here will be to construct a range of possible agricultural models for the regions of the Punjab (northern floodplains) and Sindh (southern floodplains) (Figure 5.1) during the Harappan Phase and analyze their socio-economic implications.[2]

The various water-supply systems have a crucial effect on land ownership, especially as the rivers shift often and make previously valuable land worthless. Therefore, for the cities and large-scale cultural system of the Indus civilization to have been sustained, agricultural systems must have been organized to allow some degree of long-term stability of the agricultural base. To evaluate strategies ensuring stability, I indicate how each of the four water-supply systems possible in the Indus floodplains during the time of the Harappan Phase would affect and be affected by labor requirements and land ownership, and assess the varying levels of risk of crop failure. Throughout, I provide any available archaeological evidence for these hypothetical models. I conclude with the case of agricultural change toward the end of the Harappan Phase and offer a discussion of how land ownership practices might have affected Harappan Phase socio-political systems. To provide the necessary background for assessing likely agricultural choices, I first briefly outline the two main cropping regimes and the agricultural processing stages employed in the Indus Valley floodplains in the Punjab and Sindh.

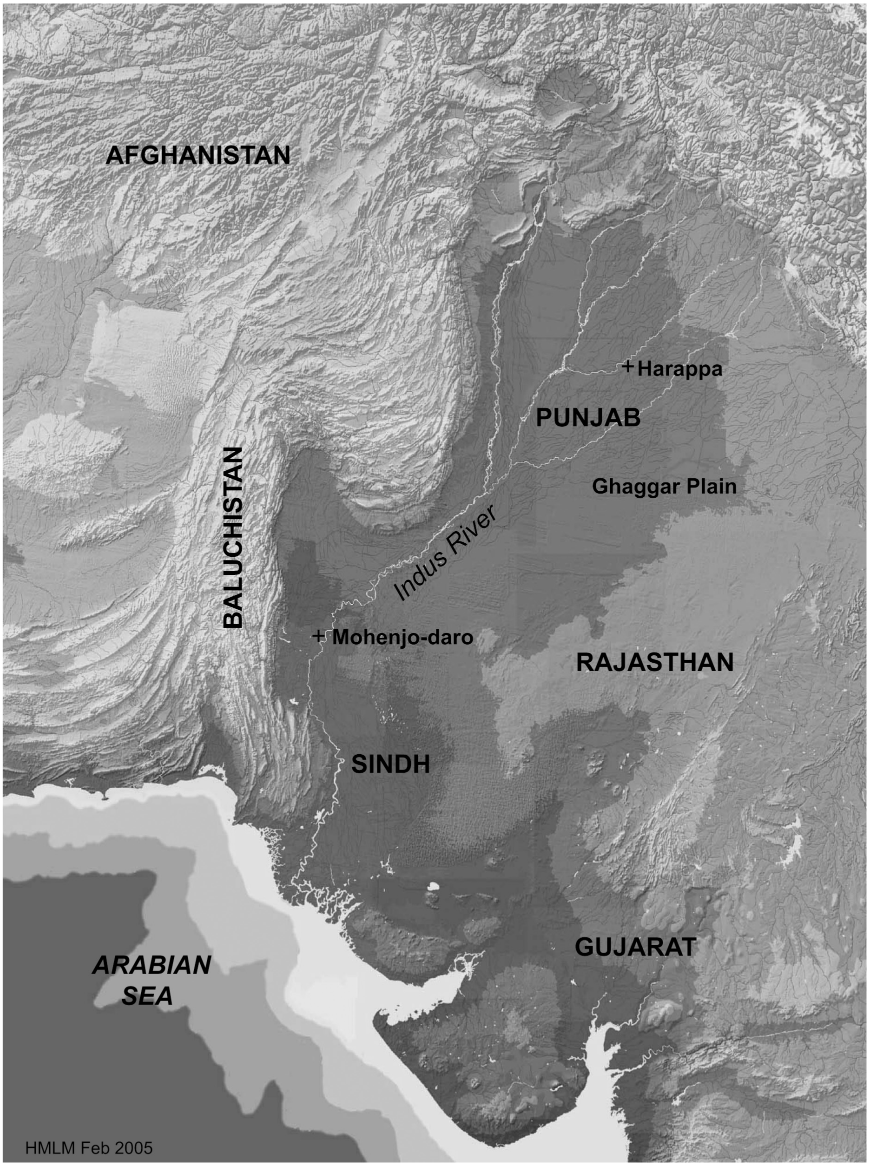

Figure 5.1. The Indus Valley floodplains and surrounding regions, with the modern river system. Base map courtesy of Randall Law.

CROPPING REGIMES AND AGRICULTURAL PROCESSING STAGES IN THE INDUS FLOODPLAINS

My reconstructions of Indus floodplain cropping regimes and agricultural processing stages, like others in the literature, are based on the few archaeological finds to date, on generalized modern and historic agricultural accounts, and on casual ethnographic reports. There has been little ethnoarchaeological research on crop management and processing for the Indus floodplains as yet, in contrast to Seetha Reddy's (1994, 1997, 2003) work from very different environments in Gujarat. Detailed overviews of these cropping systems and the archaeological finds to date as they pertain to the Harappan Phase situation are given in Richard Meadow (1996) and Dorian Fuller and Marco Madella (2000), updated by Steven Weber (2003) and Madella (2003). Ifran Habib (1999) is also a particularly useful source, providing a painstakingly researched account of agricultural systems in the Indus and Gangetic valleys during the Mughal period (1556–1707 CE).

Cropping Regimes and Types of Crops

The two main cropping regimes for the Indus floodplains are divided by season of planting: the *rabi* (winter-planted) crops and the *kharif* (summer-planted) crops. The third cropping regime, perennials, includes cotton as well as tree crops and vegetable gardens (Figure 5.2). At the moment, researchers are concluding that past environmental conditions were roughly the same as the present, as is discussed in the section on rain-fed agriculture below. These cropping regimes make use of rainfall and especially river water, both of which are affected by the two rainfall systems that serve the Indus Valley: the winter cyclonic system of Western Asia, which reaches as far east as the Indus Valley, and the South Asian summer monsoon system, which reaches as far west as the Indus Valley then moves back across the northern mountains (Himalayas), increasing the summer water flow of the Indus River system.

As the Indus River system falls exactly at the meeting point of the two rainfall systems, it is the point at which both systems are weakest and most irregular. Today the average annual rainfall for the Indus Valley is less than 25 cm, making it the most arid portion of the South Asian subcontinent (Oxford University Press 1955). The northern Punjab is slightly wetter, with 25–50 cm mean annual precipitation, and is exactly bisected by the two weather systems so that the winter rains are the stronger system to the west, and the summer rains are stronger to the east (Figure 5.1). Given the lower temperatures, the most reliable rain-fed agriculture is in the winter in the northern Punjab, especially to the northwest. For the entire Indus Valley region, however, river water is far more important and reliable for agricultural water supply than rainfall.

***Rabi* (Winter-planted) crops**
- Plant in Oct-Dec
- Harvest in March-May
- Water: winter rains,
  receding inundation

examples:
wheat, barley, peas, lentils

***Kharif* (Summer-planted) crops**
- Plant in April-August
- Harvest in Sept-Dec
- Water: summer monsoon,
  active inundation

examples:
millets, rice, various pulses

Perennials: year-round use of land; example: cotton, harvested with *kharif* crops

Figure 5.2. Cropping regimes in the Indus Valley floodplains.

The riverine inundations are thus paramount in the agricultural regime, with flood peaks in the late summer, allowing planting of winter crops in the early fall on the newly deposited wet silts.

Lawrence Leshnik (1973:Table 6.2) gives the cycle of the rivers and cropping regimes for the Punjab during the nineteenth and twentieth centuries:

Low water mid-January to mid-April:	*rabi* crops harvested mid-March to mid-May
Rising water mid-April to mid-August:	*rabi* crops harvested mid-March to mid-May
	kharif crops planted mid-April to August or later
High water mid-August to mid-September	
Subsidence mid-September to mid-January:	*rabi* crops planted October to mid-December
	kharif crops harvested mid-September to December

This cycle might be a few weeks different for Sindh, with the delay in the inundation downstream as well as the greater heat and lesser rainfall.

These cropping regimes are still used today, although they are often heavily modified by the modern water-supply system and the introduction of new crops. The crops discussed here are those known to have been used during the Harappan Phase, and this list is almost completely dependent on work done at the ancient city of Harappa itself, the only Indus floodplain site where large quantities of plant remains have been systematically recovered. My comments here about water supply refer to the system of management prior to the large-scale building of massive riverine irrigation canals by the British in the early 1900s and prior to the modern tube-well irrigation systems; primarily small local ditch or canal systems supplied by well, oxbow, or riverine water.

Rabi crops are planted in November or December and are harvested in April or May. They primarily depend on the wet soils of the receding summer riverine inundations and on the winter rain system in the north, although some crops are also watered by various artificial water-supply systems. The ancient crops typical of the rabi system from Harappa and other sites are the winter wheats (*Triticum* spp.), the barleys (*Hordeum vulgare* spp.), common peas (*Pisum sativum*), chickpeas/gram (*Cicer arietinum*), grass peas (*Lathryus sativus*), lentils (*Lens culinaris/esculenta*), linseed/flax (*Linum usitatissimum*), and probably mustard (*Brassica* sp.). Almost all of these are also the main crops in Western Asia.

Some of these species may have been indigenously domesticated here as well as in Western Asia, such as the barleys. Some species must have been domesticated in Western Asia and traded or brought east, such as the einkorn or emmer wheats (present at the site of Mehrgarh, albeit sparsely documented). Bread wheat (*T. aestivum*) could have been indigenously domesticated here as well, although only if tetraploid wheats had been brought from the west (Zohary and Hopf 1988). Certainly some species were modified in this eastern region to form new varieties or morphological types, such as the various sphaeorococcoid barleys and wheats. (As a side note, Percival 1921 is completely unreliable for his classification of these varieties, as he relied on a few specimens sent to him from India, out of the great range that existed.) The full tale of distant versus indigenous domestication and modification must await further work on the earliest periods of the Indus Tradition, as we currently only have early plant remains from the Baluchi site of Mehrgarh, which has some domesticates even in the earliest levels (Costantini 1984; Costantini and Costantini Biasini 1985; Meadow 1996). However, we do not have to wait to determine that from the beginning the people of the Indus Tradition were active experimenters and selectors of new varieties of plants and animals. This should not surprise us, given the records of the early British agricultural specialists in this region, who recorded dozens of varieties of wheats in the Indus Valley and especially Baluchistan, varieties selected for characteristics from relative drought resistance to cooking properties (Howard and Howard 1909a, 1909b; Howard et al. 1910). (See also Thomas 2003 for modern and ancient risk- and food-related strategies of farming in the Bannu region to the northwest of the Indus floodplains.)

Kharif crops are typically planted in May or June and harvested in October or November. They may make use of low-level river inundation from snowmelt in the early summer planting period, or monsoon rainfall in the northeast of the Indus Valley. Standing kharif crops might also be watered by river inundation in July to September, with floods from the northwestern edge of the summer monsoon, although this runs the risk of drowning the crops around harvest time. However, more often they depend on artificial water-supply systems of various types during the growing period, although it should not be assumed that these water-supply methods were necessarily complex or labor-intensive, as described below. Crops typical of this system from the site of Harappa and elsewhere in the plains include some of the millets (*Panicum* spp., perhaps *Setaria*, but not *Sorghum* or *Eleucine*), rice (*Oryza sativa*, based on both charred grains and phytoliths from glumes), various gram beans (*Vigna* sp., *Medicago* sp.), sesame (*Sesamum indicum*), and fruits such as melon (*Cucumis* sp.). No information is yet available as to whether this may have been wet or dry cultivated rice.

As Weber (1998, 1999, 2001, 2003) has elaborated in several articles, at Harappa most of these crops are present in the Harappan Phase, but their ubiquity increases at the end of this period and in the following Punjab Phase ("Late Harappan" period). The inhabitants of Harappa during the late third and early second millennia BC appear to have extended their agricultural regime to increasingly employ two cropping regimes, which may have been done by multi-cropping on a single plot and/or seasonal use of different lands, as appropriate for water supply and environmental conditions. However, the rabi (winter-planted) crops are clearly the most important staple crops at Harappa throughout the Harappan Phase. Note that double-cropping has not been suggested for the beginnings of the Indus civilization but rather for its end.

Perennials form a third class of crops. The potentially most important case is that of cotton (*Gossypium* sp.), as it may well have been a major crop during the Harappan Phase. There is some question as to the type of Old World cotton used by the Harappan Phase people, as both species of Old World cotton are known in both perennial and annual forms today, although all are ready for harvesting in the late autumn with the kharif crops (Watson 1983; Meadow 1996). It seems likely, however, that the annual forms of Old World cotton were only developed in the past two thousand years, so varieties grown by the Harappan Phase people were perennial plants (Watson 1983:31–41 and footnotes). Because cotton is a perennial, land would have to be dedicated to its growth year-round and could not be multi-cropped with winter crops, such as barley and wheat. Cotton cloth (in the form of metal pseudomorphs) is known from Harappan sites, but little is known about its prevalence as a fabric or as a crop. It may have been a major trade item for the Harappan Phase people, or it may not have been widely grown till a later date; we simply do not know, although the former seems more likely. The dye plant indigo, so important in this part of the world historically, is still completely unknown for the Harappan

Phase but might have been another crop grown perennially to allow multiple cuttings, as was done in this region historically (Habib 1999:47).

Other perennials are tree, shrub, and vine crops. Particularly well-attested in the archaeobotanical record is the fruit of the jujube shrub (*Ziziphus mauritania/jujuba*), found in both domesticated and wild forms and harvested with the rabi crops in the spring. Finds of dates *(Phoenix dactilifera*) at several Indus sites indicate that they were traded in from elsewhere or cultivated, as they do not grow naturally in the floodplain itself. Cultivation seems more likely than trade alone, particularly in the south, especially given recent *Phoenix* phytolith finds from the Sindhi site of Kot Diji (Madella 2003). Finds of domesticated grape seeds (*Vitis vinifera*) are also reported in low quantities from several Indus sites, including Harappa, although more research is needed to help determine its importance as a crop. Madella (2003) also reports finds of phytoliths from the banana family from Harappan Phase deposits at Kot Diji but indicates that these cannot yet be identified to species, whether wild species of various types or the domestic varieties of banana and plantain. Andrew Watson (1983:51) notes that Greek accounts of Alexander's march through the Indus Valley reported bananas being cultivated in 325 BCE, but this is the earliest firm report for the region as yet. Other possible shrub and tree crops have yet to be positively identified; mango in particular will be an interesting case, as the earliest reports in Sindh presently come from Arab writers (Watson 1983). Certainly in the historic and modern period, small orchards were a habitual part of the agricultural regime in the Indus floodplains.

Finally, many vegetable crops likely were grown together or in rotation in garden plots requiring a "perennial" dedication of land use. Unfortunately, vegetables and greens are always elusive in archaeobotanical research because of a variety of problems affecting preservation of identifiable remains. Although we have no evidence for the nature or the very existence of Harappan Phase mixed gardens for growing vegetables and small-scale crops, such gardens were very important in the Punjab region historically, with farmers growing multiple crops per year for exchange with local towns and cities, sometimes even in mono-cropped fields (Habib 1999:52 and elsewhere). Unlike many early cities, the Harappan Phase cities appear much too densely packed to have allowed much garden space within the city walls. While city families may have had garden space just beyond the city walls, exchange for garden foods may have been necessary for some city families. During the Harappan Phase, such crops likely included peas and beans, melons, greens, other vegetables, and even small patches of grains, particularly special varieties for special purposes. Northwestern South Asia is the suspected origin location for eggplant (*Solanum melongena*) and spinach (*Spinacia oleracea*), to name just two of the many vegetables and greens grown here historically (Habib 1999; Watson 1983).

The *Brassica* spp. reported as mustard (above, as a rabi crop for seeds) could also have been grown as a green in other seasons. Semi-wild (weedy) and wild plants were also collected for food and other uses, including jujube (*Ziziphus*) and no doubt many greens and herbs, as well as grasses for mats and basketry (Madella 2003; Miller 1991).

AGRICULTURAL PROCESSING STAGES AND LABOR REQUIREMENTS

All of the agricultural systems discussed here required various stages of processing, including plowing and other soil preparation stages, planting, possibly weeding, supply of water, and harvesting and other crop processing techniques. Each of these stages is briefly described, any available archaeological evidence given, and the potential labor requirements assessed.

Soil preparation for this region in the recent past consisted of both large-scale field preparation techniques, including plowing, and smaller-scale "garden" preparation methods, such as the use of digging sticks and hoes. We know that fields were plowed in at least some parts of the Indus civilization, based on the find of a plowed field at the edge of the site of Kalibangan (Lal 1979; Thapar 1973). The evidence for clay models of plows, as well as yokes, numerous types of carts, and other agricultural and traction artifacts, is well summarized by Laura Miller (2003). She is also documenting the use of zebu cattle for traction, either for carts or for plows, through analysis of faunal remains from the site of Harappa (Miller 2003). Nothing is directly known about the existence of other methods of field preparation, such as the use of digging sticks or hoes, as no digging implements of either stone or metal have been identified, although such large fragments of metal would certainly have been recycled. It is also most likely that wood would have been used to make digging implements, plows, and rakes, as in ethnographic examples from the region. Other stages of soil preparation, such as the breaking up of clods and possible fertilization techniques, are also unknown. In the recent past, however, inundation lands along the river banks were often planted with no prior preparation of the ground (Leshnik 1973), so that water-supply systems employing inundation would have had little labor associated with soil-preparation stages, allowing farmers to plant a larger area.

After the ground was prepared, *planting* was probably done by hand using broadcast sowing of seed, barring future evidence for seed drills. Although we do not have evidence either way for Indus agricultural fences restricting access by animals, modern gardens and orchards in the Punjab are often enclosed with a mud-lump wall, but fields are left open (personal observation). Whether or not Indus Valley fields and gardens were regularly *weeded* is a question for which future analyses of plant remains may provide crucial evidence. Present-day agriculturalists frequently weed their crops by hand and use the weeds as fodder for their few farm animals, including cattle and water buffalo used for dairy and traction (K. Thomas, personal observation in the Northwest Frontier Provinces; author's personal observation in the Punjab). Some of these crop weeds, the *Medicago* species, are collected, sold in market, and eaten as greens in the northwest today (Thomas 2003:418). Weeding practices of this sort, for fodder or greens collection, should be visible in archaeobotanical assemblages if practiced in the past; for example, such a suggestion was made for plant remains from the third millennium site of Tarakai Qila, northwest of the Indus floodplains (Miller 1988). Archaeobotanical studies of other sites for information on ancient weeding practices would contribute a great deal to our reconstructions of past labor requirements, as such intensive weeding requires significant additional labor input throughout the growing season. Given that this fodder can be especially suited for animals kept for milking, intensive weeding could also provide supporting evidence for a well-developed mixed-farming economy, in combination with other types of bioarchaeological data.

Water supply is the agricultural processing stage central to this chapter and will be described below. Work has been done elsewhere on the identification of water supply through irrigation via the weed seeds found in ethnoarchaeological assemblages (Charles et al. 1997, 2003; Jones et al. 1997), and it is possible that such an approach might be useful for the Indus Valley. However, it will be important to do ethnoarchaeological work in the region to see what the local weed assemblages would look like for irrigated and unirrigated fields, and the possibility of intensive hand weeding, as discussed above, complicates such an approach.

Finally, evidence for *harvesting methods* for the Harappan Phase in the Indus Valley itself also awaits future ethnoarchaeological studies (see Reddy 1994, 1997, 2003 for such studies for Harappan Phase Gujarat). No root crops are known to have been used by the Harappan Phase people, so that harvesting would have been by hand-picking or cutting with a knife or sickle. Chert blades are plentiful, but those with "sickle polish" are not so prevalent, surprisingly (Hoffman and Cleland 1977:17), and there are no sickle handles. Harvesting knives of metal may have been widely used, since the lack of metal blades of all sorts recovered from Indus sites is probably due to poor preservation conditions and a high level of recycling of metal (Kenoyer and Miller 1999). This question remains open until more work is done on both lithic and metal assemblages. No evidence exists for later stages such as winnowing and separating of grain and some pulse crops. Ethnoarchaeological and archaeobotanical work done elsewhere in Eurasia has been extremely helpful in the identification of crop processing stages, including harvesting techniques, so that this method may be of use in the Indus Valley region (Hillman 1984; Jones 1984, 1987; Miller 1991; Reddy 1994, 1997, 2003; Fuller and Madella 2000). But once again, if intensive weeding was a part of the Harappa Phase agricultural regime, as suggested above, the use of weed seeds as diagnostics for water supply and harvesting methods will be seriously compromised, and Indus specialists will need to find alternative methods of investigating these processing stages.

This brief background gives some idea of the complex agricultural systems and labor scheduling decisions faced by Indus Valley Tradition farmers. The choices they made about water-supply systems had to harmonize with these decisions, as well as other economic and social situations and goals.

POSSIBLE WATER SUPPLY SYSTEMS AND AGRICULTURAL REGIMES

There are four types of water-supply systems possible in the Punjab and Sindh, in the regions surrounding the Indus River and its tributaries (Figure 5.3). Particularly useful sources for water-supply systems employed in the Indus floodplains are Habib's (1999) detailed historical research for the Mughal period, and the portions in Walter Fairservis (1967), Lawrence Leshnik (1973), and H. T. Lambrick (1964) that summarize British and other accounts from the late nineteenth and early twentieth centuries. (The archaeological data employed by Fairservis, Leshnik, and Lambrick are out of date and largely incorrect, but their historical agricultural data are still valid.)

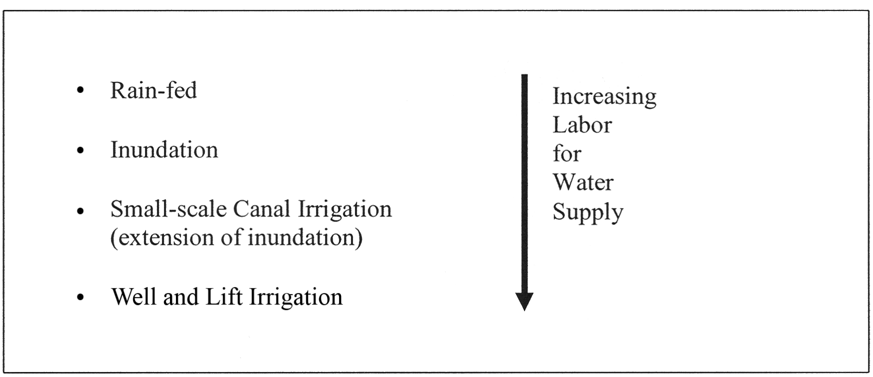

Figure 5.3. Possible water-supply systems in the Indus Valley floodplains.

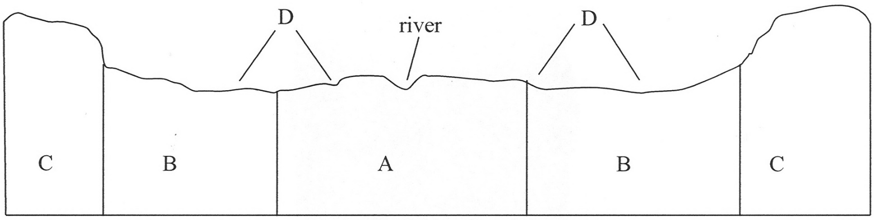

Figure 5.4. Land-use zones of the Indus Valley floodplains (after Leshnik 1973; vertical scale greatly exaggerated). A. Cultivated areas, parallel and close to the river (heavily inundated). B. Cultivated areas farther from rivers (inundated, extensions of inundation made via natural and artificial channels, and use of wells). C. Uplands (for grazing and rain-fed crops). D. Depressions, oxbow lakes, and marshes (oxbows most common in Punjab, marshes most common in Sindh).

These four water-supply types are primarily distinguished on the basis of the *land type* where they are in use (Figure 5.4). However, these water-supply types also have varying labor requirements. For all of the Indus agricultural systems, labor was needed for plowing and other soil-preparation stages, for planting, for weeding, for supply of water, and for harvesting, as discussed above. In general, the labor requirements other than water supply would be the same for all of these systems, with the exception of decreased need for soil preparation in inundation areas. The primary difference in labor relates to water supply; there is a roughly increasing hierarchy in labor requirements for their water-supply aspects between these four types, as shown in Figure 5.3.

However, these agricultural systems should not be seen as exclusive alternatives. It is likely that most or all of these types of water supply were practiced during the Indus period. The particular choice of type(s) would have depended on local environmental conditions, climatic conditions (including annual variations), labor availability, and land availability. The Harappan Phase people in the Indus floodplains almost certainly used multiple agricultural systems in varying proportions rather than one type versus another, depending on socio-economic goals and micro-environmental conditions.

Inundation

The Indus tributary rivers of the Punjab and especially the Indus River in Sindh are very aggrading, with the river perched above the floodplain around it, so that it easily overspills its banks with any increase in water supply. Such floods can cover the land for several kilometers, or even result in shifting the river to a completely new bed (Fairservis 1967; Flam 1981, 1986; Habib 1999:31–33; Lambrick 1964; Leshnik 1973). This phenomenon was the norm for the river systems of the Indus Valley during the third millennium BCE as well. Seasonal inundation was probably the single most important source of dependable water for crops in the Harappan Phase of the Indus Valley Tradition, particularly in the areas of lower rainfall to the south in Sindh. Winter crops would have been planted in areas inundated by the annual summer floods after the water had receded, leaving behind newly deposited sediments (Figure 5.4, zone A and portions of B). The soaked sediments contained extra water and nutrients for the young plants. Only a little winter rain would then be necessary to produce many types of crops. This was the primary agricultural system used for most of the region until the early 1900s, prior to the British-built large-scale canals and the deep tube wells of the last half-century.

Variability and risk. The annual summer inundation of the Indus River system is primarily dependent on snowmelt from the Hindu Kush and Himalayan mountains (which is dependent on winter precipitation), and secondarily on the summer monsoons. If the past climate was similar to the present, the inundation system was likely about the same during the Harappan Phase. Being dependent on rain and snow, the extent and to some degree the timing of the inundation is variable within the annual cycle.

More important, the frequent river avulsion (movement of the river to a new bed) common in these aggrading rivers made previously valuable inundation land into much less valuable land useful only for risky rain-fed agriculture. This would have had a major impact on stability of agricultural produce, unless farmers were able to quickly make use of the new inundation lands near the new bed of the river.

Labor requirements. Inundation farming required the least labor input of these four agricultural systems. As with rain-fed farming, there were no labor costs associated with water supply in this system. In addition, labor costs associated with soil preparation might also have been avoided, with direct planting of seed in the newly deposited riverine sediment.

Likely importance. River inundation would have been the primary method of agricultural production for winter crops, as long as enough land was available. This method could only have been cautiously used for summer crops, which ran the risk of being washed away by the summer inundation. Therefore, the proposed additional focus on summer crops at the end of the Harappan Phase most likely involved extension onto non-inundation land, employing other water-supply systems.

Land ownership implications. The prime areas for agriculture would be those inundated by riverine flooding in the summer and available for planting of winter crops. The use of inundation land would supply both fresh silt (highly fertile land) and moisture for the germination period. There would thus be competition for this prime land. However, frequent river shifting in the Indus Valley region would complicate ownership of it. It may have been advantageous to hold land in common, by kin group or clan for example. A very large region could have been owned by the group, allowing common planting and harvesting of land plots within this region as the river shifted within it. Any other systems of land ownership would have required some sort of structure for the reassignment of land after the river shifted, to maintain economic and social stability. All of these systems would have required an authority with the accepted power to reapportion land within the group on a regular basis, and also an authority to settle disputes between groups about the reapportioning of the larger tracts of land. These two authorities might be the same, or they might be different authorities; for example, group leaders might do the reapportioning within groups, while a larger corporate or single authority might settle disputes between groups.

Rain-Fed

Rain-fed agriculture could theoretically be practiced on any type of land within the Indus Valley floodplains. In this section I will discuss rain-fed agriculture as practiced on non-inundated (Figure 5.4, zone C and portions of B) land. However, in this semiarid landscape with often irregular rains, the land inundated by the summer floods was by far the most regularly used for "rain-fed" agriculture during the recent past. Thus, although rain-fed and inundation water-supply systems are treated separately here, as they potentially relate to different categories of land, they were preferentially used in conjunction in most historically known cases, except for drought-resistant crops.

In many ways the Harappan Phase use of rain-fed agriculture is the most difficult to reconstruct, as relatively minor changes in the climatic system might have a large effect on the amount, timing, and duration of the two rain systems affecting the Indus Valley: the Indian summer monsoon from the east and the winter Mediterranean or cyclonic rains from the west. The Indus is the border between the two systems, and thus the extreme range of both, so it is sensitive to any climatic change. Unfortunately, our knowledge of the climatic regime for this region during the Harappa Phase is sketchy and controversial, in large part because of the lack of suitable locations for pollen cores. The data and conclusions to date are well summarized in Fuller and Madella (2000), with additional notes in Fuller (2003; especially see footnotes) and Marie-Agnes Courty (1995). Courty's (1995) use of micromorphological as well as geomorphological research has provided much-needed new environmental evidence for this region, and has led her to conclude that conditions were not wetter during the Harappan Phase, as seems to be the general consensus given the current data.

Variability and risk. If we assume that the Harappan Phase climate was not so different from that of today, we can assume that this was a semiarid to arid region where rainfall could be quite variable from year to year. Such conditions would make strictly rain-fed agriculture risky, especially to the south in Sindh where rainfall would be low in the best of years. Furthermore, the existence of two different rainfall regimes has to be taken into account, as the relative strength of these two regimes is reversed between the eastern and western parts of the Indus Valley. At least at present, rainfall is usually greater in the winter to the west and in the summer to the east, but the decreased temperatures and transpiration rates of the winter period can make this season of greater importance for rain-fed agriculture, even in the eastern Punjab.

Labor requirements. The primary labor costs for rain-fed agricultural regimes are plowing and other ground-preparation methods, planting, perhaps weeding, and harvesting. Water supply involved no labor cost at all.

Likely importance. Strictly rain-fed agriculture would most likely have been used for rabi (winter-planted) crops, but likely only in the north for more water-demanding crops. It was perhaps most substantially used for perennial crops, with additional watering in poor rainfall years (see Well and Lift Irrigation below), since perennial crops could not be planted in the inundation floodplain. Strictly rain-fed agriculture in non-inundation areas could possibly have been used with risk for kharif (summer-planted) crops, particularly drought-resistant crops.

Land ownership implications. The prime areas for rain-fed agriculture, those inundated by riverine flooding in the summer and available for planting of winter crops, are discussed in the inundation section above. Land not inundated by the river could also be used for rain-fed agriculture, especially for drought-tolerant crops, and there would be considerably less competition for this land. It is possible that the increase in drought-tolerant crops like millets at the end of the Harappan Phase was encouraged by the desire to make use of this additional land. At least for the region around Harappa, populations became more concentrated at the urban center at the end of the Harappan Phase, abandoning other settlements (Wright 2000), so that land in the immediate vicinity would have become a matter of competition, either for group or individual ownership.

Small-Scale Canal Irrigation from Rivers (Extension of Inundation)

The Harappan Phase people certainly had great technical knowledge of water movement in the form of well-engineered water-disposal systems within their cities (Jansen 1993). This movement of water and sewage within the city is extremely impressive as a coherent, complex system that must have required extensive planning, technical ability in construction, and dedication to maintenance to keep the entire system flowing.

Such technical knowledge and managerial ability could have easily been applied to small-scale irrigation canals, which would have been on a similar scale of size and complexity of drainage. Given these abilities, the archaeological data we have, and the advantages of extended water supply, such small-scale irrigation canals were no doubt regularly employed by Harappan Phase farmers to extend the reach of the annual inundation or perhaps the regular riverine water flow. Such canals, described in eighteenth-century British accounts for this region (Lambrick 1964; Fairservis 1967; Leshnik 1973; Habib 1999: 33), simply breached the ridges along the sides of the active river channels, allowing annual summer inundation to overflow into canals, which were often natural channels that had been widened or straightened. These canals used gravity flow to extend the reach of the annual inundation, allowing lands beyond the reach of the natural inundation floodplain to be watered (Figure 5.4, zone B).

However, large regional-scale canals are considerably less likely. Construction and especially maintenance of such large canals would have been difficult because of the aggrading, shifting nature of these rivers, and their benefits might have been ephemeral. Not only would periodic investments of large quantities of labor be needed to clean out and realign large canals, but within a decade or less the river at the head of a canal might well shift its course some distance away. Certainly there is no evidence from the distribution of Harappan Phase settlements that large-scale or long irrigation canals were employed. Even four thousand years later, during the great Mughal Empire of the seventeenth and eighteenth centuries CE, the major irrigation canals in this region were constructed by simply digging out and extending old abandoned river channels, with a few notable exceptions of very large-scale works (Habib 1999:33–39).

The most thorough investigations of possible Harappan Phase irrigation canals have been done by Courty and Francfort in the eastern Punjab region in the Ghaggar plain, around the relict beds of the seasonal Ghaggar-Hakra or Sarasvati hydrological system (Figure 5.1). As noted above, Courty (1995) has done considerable work on the ancient environment of this region, but she has also focused on the possible evidence for irrigation by Harappan Phase farmers. The only irrigation canal found so far dated to 2000 BP, two thousand years after the Harappan Phase (2600–1900 BCE). However, soil crusts found in farmed, buried soils of the Harappan Phase period are "typical of irrigated soils regularly flooded by water with a high suspended load" (Courty 1995:120). This could represent the inundation of ancient fields by the small-scale canal extension of seasonal inundations in natural channels, but as Courty says, more field data are needed to support such a conclusion. In an earlier paper, Francfort (1992) refers to (undated) 1 m deep by 300–500 m wide "canals" that he describes as "the courses of ancient natural waterways which were used and perhaps, in some places, rerouted by man." The lack of a similar description by Courty suggests that her subsequent work either dated these features to a later period, or attributed them to shrewd use of areas naturally irrigated in rainy years by natural extension channels.

It is also noteworthy that Courty concludes that the Ghaggar-Hakra was never a perennially flowing river during any part of the Harappan Phase, but only seasonal meandering channels primarily based on monsoon rainfall, with occasional years of stronger flooding. This finding contradicts earlier conclusions based on the tracing of old riverbeds and associated archaeological sites, assuming that the river flowed perennially in the past because sites were located there. Clearly there is a substantial need for sophisticated geoarchaeological work of the sort Courty carried out to resolve this critical issue.

Variability and risk. Temporal variability in the water supply from small-scale canals extending the seasonal inundation into additional lands would match the variability and risk of inundation agriculture. Years with low water levels would be more risky, when inundation floods might not reach to the end of the extended system. The only other risk would be that of unusually strong floods bursting through canal walls and flooding areas planted with summer (kharif) or perennial crops.

Labor requirements. Labor associated with short canals to extend inundation areas would be of two types: initial construction and periodic maintenance. Initial construction could range greatly in labor costs, from canals that were simply short breaches in river ridges, to those constructed by digging out and straightening natural overspill channels, to canals dug for some distance without benefit of previous natural channels. For the first two types of canals, periodic maintenance might well require as much labor as the original construction, given the very high silt load of the Indus hydrological system and the tendency for floods to wear away canal walls.

These construction and periodic maintenance labor costs would be all that was required for small-scale canals used to extend the seasonal inundation. We do have evidence for sluices in the Indus city water systems (Jansen 1993; Kenoyer 1998), so if gravity flow was possible for a given field irrigation canal, the Harappan Phase people certainly had the technical skill to create a fairly sophisticated gravity-flow system, if desired. More likely, however, would have been the simple opening or blocking of access to a given canal by opening a gap or filling it with sediments, as desired. Other types of small-scale canals, those used for water supply beyond the inundation season, required more labor as gravity flow alone would not be sufficient to transport the water to the canals. These types of canals are discussed in the next section, Well and Lift Irrigation.

Likely importance. Although we have very little if any solid evidence for small-scale irrigation canals, I think they must have been widely used in the floodplains during the Harappan Phase, particularly toward the end of the period. Short canals would have been invaluable for opening up new areas for agriculture. They might also have been extremely important in evening out agricultural risk, allowing additional sources of water to otherwise rain-fed crops during periods of poor rainfall, although at the expense of some labor. Leshnik (1973:74) notes that because of the nature of the land, canals used to extend the inundation were especially prevalent in Sindh, where rainfall is also the lowest.

Information about whether late Harappan Phase rice was wet-cultivated or dry-cultivated will be particularly interesting in relation to the use of small-scale canal irrigation combined with summer inundation for rice and other kharif (summer-planted) crops. During the summer, when the rivers were full or flooding, a canal could be extended to a field just beyond the inundation, or fields within the inundation area could be surrounded by low walls and water allowed in as desired. Water supply would be plentiful, and the only risk would be of too much water breaking in on the field (Lambrick 1964; Fuller and Madella 2000:349).

Land ownership implications. This type of water-supply system has some of the same implications for land ownership as inundation. Given the movement of rivers, holding land in common might be the most desirable option for long-term security. This would also create a labor force of sufficient size to create and maintain the small-scale canal systems envisioned under a kinship-based managerial system.

Well and Lift Irrigation

Unlike the case in peninsular India (Morrison 2000, this volume), there was little use made of artificial tanks for water storage in the Indus Valley floodplains during any time period, perhaps because natural water storage bodies in the form of oxbow lakes and depressions were available (Figure 5.4, zone D). Instead, the floodplains of the Indus River systems were famous during historic and early modern times for the very widespread use of wells for agricultural water supply, especially in the Punjab (Habib 1999:28–30; Leshnik 1973), and particularly in lands adjacent to the active floodplain (Figure 5.4, zones B and A).

The same lift-irrigation techniques used in well irrigation could have been used to obtain water from other sources, including oxbow lakes and inundation-filled depressions, as well as the active river channels themselves (when not in flood). Such techniques involved the use of lifting devices to raise the water and then pour it into small-scale field canals, canals identical in construction to those described in the previous section. Alternatively, water could have been lifted into a small holding device or directly into containers, which would then be carried to individual plants. This last is such a labor-intensive method that it could only have been used for a small number of plants, perhaps household trees or small orchards.

We know that the Harappan Phase people were capable of building deep wells because we find wells lined with specially made wedge-shaped baked bricks within the sites, especially Mohenjo-daro (Jansen 1993). We know they were capable of building and maintaining fairly sophisticated gravity-flow drains, as discussed in the previous section. But what about lifting devices? Historic accounts mention three types of lifting devices for this region: the "chain-of-pots" or "Persian wheel"; a rope-and-pulley system with a container; and *shaduf*-type devices (Habib 1999:28–30; Lambrick 1964; Leshnik 1973; Watson 1983:105, 191).

Lambrick references a Harappan Phrase representation of a figure operating a *shaduf*-type lifting device but provides no provenance for this representation, as Fuller and Madella (2003:349) point out. While we have no other evidence as yet for shaduf-type lifting devices (a container on a weighted pole supported by a pivot) during the Harappan Phrase, such a device is certainly a likely possibility. There is no direct evidence for a rope-and-pulley system with a container either, but wells of the period at Mohenjo-daro show characteristic rope marks in the bricks at the top of the well, indicating the use of ropes to draw up water. Historically, these were often pulled by animals. However, the more usual animal-run lifting device, the chain-of-pots or so-called Persian wheel (most likely developed in India), is almost certainly a much later development, although the period when these water-lifting devices are first developed is uncertain (Watson 1983:105, 191 footnote 15; Habib 1999: 28 footnote 23). Thus, water-lifting devices available to the Harappan Phase peoples had relatively high labor requirements, as compared to historic populations in this region, and may have required primarily human rather than animal labor.

Variability and risk. Risks were very low for these methods; droughts would have to be very severe to dry up these sources of water. The danger of summer flooding of fields might be an issue for kharif or perennial crops planted near the river. The chief risk for this water-supply system would be insufficient labor to raise the water to the irrigation canals.

Labor requirements. This water-supply system is by far the most labor intensive of the systems presented here, no matter what variation of the system was employed. First, labor would have to be invested to create and maintain irrigation canals, as with the system described previously. Second, lifting the water into the canals would have required either seasonal or year-round labor, on a more or less frequent basis, depending on the type of land being irrigated and the season of the year. Crops planted beyond inundation areas would have to be watered periodically whenever rainfall was insufficient. Even within the inundation-extended areas, crops might need to be watered during the winter if the rains failed, or during the early summer or late fall if the inundation was low in a given year.

Likely importance. This water-supply system is likely to have been very important for perennial crops and those requiring year-round care in smaller plots, such as orchards, house gardens, and extensive vegetable plots, providing a large part of the daily food and also exchange foods. This system would also have been necessary for double-cropping on the same plot of land, except in years of high rainfall. A major question, when using the historic analogy of widespread use of well irrigation, is whether the great savings in energy provided by the chain-of-pots/Persian wheel greatly increased reliance on lift irrigation, so that the Harappan Phase people are unlikely to have used well irrigation in such abundance, given the higher labor costs. I think a substantial use of well irrigation is still likely for the Harappan Phase, since the other two lifting techniques could certainly have been used, although human labor demands probably greatly limited the extent of land utilizing this system. Therefore, it is less likely that well and lift irrigation would have been widely used for extensive field crops, as is recorded in historic and early modern accounts for the Punjab.

Land ownership implications. With sufficient labor, the use of well and lift irrigation could theoretically extend the available agricultural land to any part of the floodplain, although in actuality the higher water levels closer to the rivers would make distant areas less attractive. However, labor requirements might result in smaller parcels of land being farmed with this system, given the much higher daily and seasonal labor costs for water supply. The crops grown were likely to be those of high value or types needing year-round water. Taking all of these factors into consideration, lands watered by well and lift irrigation are the most likely to have been owned by individuals or close family groups.

SUMMARY POINTS: WATER-SUPPLY SYSTEMS AND AGRICULTURAL REGIMES

There is obviously a gradient of labor inputs from rain-fed and inundation agriculture (which require no labor for water supply), to canal irrigation extending the inundation, to well and lift irrigation (Figure 5.3). For the last two, periodic labor crews would be needed to build and maintain the canals, but this would be easily handled by a small group of people employing kin-group or village-level managerial organization (Leshnik 1973), as we see for most parts of the world. The major question from a labor perspective is how water was supplied to small-scale irrigation canals. The differing labor requirements of extending the annual inundation versus lifting water by the bucketful from a well or lake are immense. There are major distinctions in labor as well as season of use between these two types of irrigation that need to be made clear when referring to "canal irrigation" as a source of water. The easiest archaeological method to differentiate between these two types is by looking for the heads of the canals—are they from the inundation floodplain channels, or from lakes or even wells? Determining this is not as simple as it sounds for the Indus Valley floodplains because of the great alterations to the floodplains since the Harappan Phase. Literally meters of alluvium have been deposited across the old land surface, from a few meters in the Punjab to as much as 12 m in Sindh.

Based on recent and historic analogies, I expect that Harappan Phase agricultural systems in the Punjab depended on all four of the water-supply types described here: inundation, rain-fed, canal irrigation to extend inundation, and well and lift irrigation. Rainfall is higher here and more predictable than Sindh, and the lower temperatures reduce transpiration of moisture from the soil. The regions of the Punjab flooded by inundation and capable of extended inundation by canal irrigation are less extensive than in Sindh but still impressive. Finally, the consistent references throughout the last half-millennium to high amounts of well irrigation for the Punjab indicate that we must seriously explore this method of water supply, especially for intensive agriculture, even though it is by far the most labor intensive. For Sindh there was probably a much greater dependence on natural inundation and canals extending the inundation, given the natural landscape. Habib (1999:32–33, footnote 49) cites two authorities, Lambrick and Hamilton, to the effect that the vast majority of crops in Sindh prior to the nineteenth century were rabi crops produced using inundation agriculture, and Leshnik (1973) supports this. However, even in Sindh, well irrigation likely played an important role for selected crops.

The employment of each of these water-supply systems has different implications for labor requirements, as well as for land ownership systems—such as the amount of land one family could farm, the long-term profitability of a particular portion of land, or the way labor for improvements was provided (Fuller 2001:412; Morrison and Sinopoli 1992; Pollock 1999; Earle 2000; Stanish, this volume). But the multiplicity of systems available to Harappan Phase farmers was in itself a force for stability for the overall agricultural system. Farmers could employ a variety of systems in a given year, depending on the land type and labor available to them. This diversity allowed for security against the loss of one particular plot from either drought or flood or from the unexpected shifting of the rivers.

ECONOMIC, SOCIAL, AND POLITICAL IMPLICATIONS OF AGRICULTURAL SYSTEM MODELS

There are two more topics to which this modeling exercise can contribute. One is an ongoing debate about the nature of agricultural change at the end of the Harappan Phase, in relation to labor and land use. The other is the unexplored topic of land ownership systems during the Harappan Phase, as a basis for group or individual wealth and power. Both of these topics provide examples of the connections between agricultural production and evolving social or political systems.

Agricultural Change at the End of the Harappan Phase

Working at the urban site of Harappa, Weber (2001, 2003) has written about the increased ubiquity of kharif crops at the end of the Harappan Phase and the beginning of the following Punjab Phase ("Late Harappan" period), although rabi crops are still in the majority for both periods. In other words, the inhabitants of Harappa during the late third and early second millennia BC appear to have increasingly used two cropping regimes. While it would be helpful to have other sites in the Indus Valley floodplain for comparison, continued work on the Harappa material appears to be verifying this change. As specialists working in the region have indicated, the issue at present is whether this change consisted of an intensification or extensification of the agricultural system in the region (Weber 2001; Fuller 2001; Fuller and Madella 2000:353–355). For purposes of assessing water supply and labor requirements, however, we require more than a simple dichotomy of intensive versus extensive, as I will show. Instead, more detailed analyses of the combination of particular agricultural systems employed and added need to be made in order to assess the likely effects on economic, social, and political systems.

Fuller (2001:412) notes and Weber (2001:414) agrees that the term *intensification* should be reserved for the original Boserupian sense of "strategies used to increase yields from a given unit of land." (See Morrison [2000] for more extensive discussion of the term *intensification*). I also use *intensification* in this sense, which in this case would refer to multi-cropping on a single plot, primarily alternating rabi and kharif crops, but also possibly a continuous cycle of fast-growing vegetable crops on one plot. I use *extensification* to refer to the addition of new lands to an agricultural system. This includes the use of different lands during different seasons, which Fuller (2001) seems to include as part of his category of "diversification."

Intensification and extensification can both come about through the addition of new crops, new technologies, increasing input of labor, and, for this region, increasing water supply. The addition of new crops is a fact, although their relative importance is still somewhat debated. Technological innovations could potentially have had an impact on these agricultural systems. For the Harappan Phase case discussed here, however, long-term technical *experience* (where to plant each crop type, where to drill for wells, where to locate and how to shape field canals for maximum efficiency) was probably more important than new technical *inventions* (plows, digging implements, sluice gates, channel construction for gradient flow). Most of the relevant technical inventions were simple and were already known to the Harappan Phase people, and the new cropping regimes seem to have been gradually adopted, allowing time to develop experience. Except for the possibility of fertilization, still undetermined, increasing input of labor to increase yields for this region would relate directly to increasing the water supply. So how does the water-supply system relate to this discussion?

Extensification. Planting distant natural inundation areas that might or might not receive water in a given year could have been used as a somewhat risky extensification strategy, as documented ethnographically for Gujarat to the southeast (Reddy 1994, 1997). Such a strategy would involve minimal labor input, with the primary gamble being the potential loss of seed. Reddy's work on food versus fodder production shows that the use intended for each crop would be important in the effort put into their production. Rain-fed agriculture is likely to have been similarly used as a risky extensification strategy, with Harappan and Punjab Phase farmers regularly planting distant fields with drought-resistant crops in the hope that some, if not all, would produce a small crop, as is attested ethnographically to the northwest of the Indus Valley (Thomas 2003). Requiring more labor but less risk, small-scale canal irrigation extending the inundation would have been the primary system of extensification used during the Harappan Phase, in my opinion. It would have expanded the land that could be used for cultivation by extending the inundation area farther away from the river, particularly for the planting of rabi crops in wet soils (Figure 5.4, zone B). Extensification could also be accomplished by using well and lift irrigation beyond the active inundation floodplain, but the high labor requirements make this water-supply system a better candidate for intensive agriculture, unless land was at such a premium that even the distant uplands were needed for production. Given the relatively low percentage of available land under cultivation in this region during the much later Mughal period (Habib 1999), when populations were considerably higher, it is extremely unlikely that the Harappan Phase farmers were pushed to such a measure.

Intensification. Regular inundation areas are unlikely to have been used for intensification, as standing kharif crops would be flooded by the inundation. The same is probably true of areas irrigated through canal extension of the flood, as fields carefully protected from inundation waters, to keep from drowning young kharif, perennial, or vegetable crops, would not receive the inundation sediments and soaking needed to grow the most successful rabi crops. Nor would rain-fed agriculture alone have allowed reliable intensification in the form of multi-cropping in any region of the Indus. Depending on two separate and rather unpredictable rain regimes would not be a reliable agricultural strategy, although it might have been successful on occasion in the Punjab, especially for drought-resistant crops. However, winter rabi crops watered by rain or distant canal extensions could have been grown on the same ground as well- or lift-irrigated kharif crops. Canals far enough beyond the inundation to carry only slower-moving water, and not silt, could be controlled during the summer high waters to prevent flooding the kharif or perennial crops. The addition of well- or lift-irrigation systems to rain-fed or distant canal-extension lands is thus by far the most likely candidate for intensification systems in the Indus floodplains.

As in most classic intensification systems, the main limiting factor to intensification becomes labor supply. For rain-fed lands farmers would need summer labor to lift water from wells or other sources of water such as oxbows or marshes. For areas where canal extensions of the inundation provided reliable water (but not sediments) for the winter (rabi) crop, labor requirements would be especially intense: building and maintaining canals for the winter crop, making sure the summer crops were protected from flooding, and lifting water from the canals or other sources for the summer (kharif) crop. With labor, however, the previously less-desirable non-inundation lands (Figure 5.4, zone B farther from the river and lower areas of zone C) become the areas of richest continuous production. Some care must be taken by farmers to fallow or wash these lands periodically, though, as these non-inundated lands are also the most vulnerable to salinization with long-term use, especially in periods of low rainfall when the salts are not washed down below the surface.

Overall, my first three systems—inundation, rain-fed, and canal-extension water supply—offer the best agricultural systems for extensification projects and growing large amounts of staple crops. The fourth system, well and lift irrigation, is the most likely water-supply system for creating dependable intensification through multi-cropping on a single plot of land. This system is particularly suitable for small-scale farming, including vegetable gardens and orchards, for personal consumption as well as exchange. It could also have been used on a larger-scale level if enough animal or human labor was available to supply sufficient water by operating the lifting devices. This combination of water-supply and land-use systems is well suited to the sort of mixed farming system reconstructed for the Indus Valley Tradition, with cattle available for traction and possibly fertilizer (Miller 2003; Meadow 1996).

Thus, I stress again that the Harappan Phase people in the Indus basin had several options for water supply, using multiple agricultural systems in varying proportions rather than one type versus another. Therefore, we are ultimately interested in examining the relative proportions of the agricultural systems employed, and in *how the relative dependence on particular systems may* *have changed over time*, in relation to both extensification and intensification. Such proportional rather than absolute changes in the agricultural regime with regard to water supply are similar to Weber's (1999, 2001, 2003) discussions of changes to the crops used toward the end of the Harappan Phase at the city of Harappa, changes involving addition of crops and increased use of certain cropping regimes rather than replacement. A summary of proportional use of water-supply systems during the Harappan Phase is not possible with current data, but it needs to be a component of future research.

There are some existing examples of what we might expect to find. Courty's (1995) research in the Ghaggar plain (eastern Punjab region) indicates that the Harappan Phase farmers were favoring micro-depressions where rainfall was retained, as well as lowlands where seasonal inundation dropped fresh silt as well as water. She speculates, based on soil evidence, that canals extending the seasonal inundation waters may have been constructed. This one example shows Harappan Phase farmers using two, possibly three, of my four water-supply systems in one relatively small region. There is no other archaeological data of a similar nature, but Leshnik's account of early modern agricultural systems in Sindh might be a good analogy to the Harappan Phase case, and certainly Leshnik uses it as one. Leshnik (1973:80) notes that agricultural practices were both extensive and intensive, with extensive use made of large amounts of land covered by inundation for rabi crops, but intensive use of areas around wells. In the lands around wells kharif crops were grown closest to the wells, to reduce the distance of water transport, and the best rabi crops grown on this same land, but additional rabi crops grown at a farther distance, in an "infield/outfield system" (Leshnik 1973:80).

It is noteworthy that double-cropping has not been suggested for the beginnings of the Indus civilization as an aspect of state development but rather for its end. Weber discusses this apparent contradiction of increasing agricultural complexity at a time of political and urban dissolution; as usual, the Indus seems to be different from other early states. Not the origin but the end of the Indus state may be the period when we begin to have major changes in agricultural management, changes that may or may not be linked to the dissolution of the Indus cultural and political entity. It will be particularly important to discover if the double-cropping systems involved extensification or intensification. For example, if extensification was the primary strategy, the agricultural changes may be related to such diverse factors as increasing population density requiring use of additional lands; increasing rainfall allowing use of rain-fed agricultural lands; or decreasing river shifting allowing increased canal building. If intensification was the primary strategy, increased use of well and lift irrigation would require more labor, either human or animal.[3] However, farmers would then be less tied to inundation as a reliable basis for agriculture, and there might be less need to manage the redistribution of large tracts of land when rivers shifted if farmers are now more densely packed around the city. All of these scenarios have very different implications for the dissolution of the Indus political structure, as is clear when examining issues of land ownership more closely.

Agricultural Demand and Land Ownership

Leshnik (1973:80) notes that the limitations on the area cultivated during the Harappan Phase was likely to depend on the availability of water, the availability of labor (animal and human), and the size of the cooperating social unit. All of these factors affect the long-term stability and productivity of the agricultural systems used and, ultimately, the wealth and power that can be derived from them. Within these limitations, expansion of the system would have been related to demand for agricultural products.

To date, the main discussion of the role of agricultural production in the social and political organization of the Harappan Phase relates to its place in a safety net of food-exchange systems, proposed as one of the reasons for the Harappan Phase cultural and economic integration (Kenoyer 1998). Beyond acting as a cross-regional hedge for bad years (which implies a truly large-scale trade system in staple foods), such widespread exchange in foods, if it occurred, would encourage the production of crops of all kinds for exchange, for local demand as well as distant. Alternatively or additionally, rising populations of non-producers during the urbanizing Harappan Phase would require additional food production for exchange purposes. Whatever the impetus, farmers prior to and during the Harappan Phase would have had incentives to increase their crop production, whether intensively or extensively. Especially for areas near towns and cities, we would expect to see increasing competition for prime land, increasing investment into new lands, and/or increasing use of methods to produce more from the range of land available. At the same time, the high value placed on inundated land would have exacerbated disputes about land ownership that were sure to arise whenever the rivers shifted.

Given this scenario, two strategies may have been pursued, depending on the crops involved, the land and labor available, and, as Leshnik put it, the cooperating social unit. First, the best solution to river shifts was likely common ownership of huge amounts of inundated and canal-extended inundated land within a kin group (Miller 1991:122). Such an ownership system would still require a structure for rapid reallocation of fields to farmers within the group if the river moved, preventing loss of production while land squabbles were solved. This structure could easily be kin-based, with elders allotting land to families and settling disputes; an external managerial elite would not be required. However, there would likely be a need for a structure beyond the kin level to settle disputes between kin groups, once population became more densely packed around growing towns and eventually cities. These might be institutionally based structures, with representatives (whether temple priests, elected members, or a high-ranking hereditary elite) settling land disputes between the kin groups. Given the much higher rate of river movement for the Indus hydrological system than for other early states, rapid reallocation of inundation land would have been a priority for the long-term stability of the agricultural system. A form of allocation based on general consensus within a corporate group organization, rather than imposition by an elite, is much more likely given the ability of Indus farmers to move elsewhere in the vast alluvial plains if too much pressure was applied. Such a more or less consensual structure and communal land ownership could be an essential social aspect of the peculiar invisibility of Harappan Phase elite. Any power based on land allotment would depend on at least appearing to appeal to consensus within communal ownership, rather than imposing one's will, so that excessive display of power or wealth would be counterproductive. In line with Jonathan Kenoyer's (1998) suggestion for the continued role of kin groups during the urban Harappan Phase, Indus kin groups with power bases set firmly in the control of land ownership may have functioned as leveling structures, cross-cutting other non-kin-based hierarchies.

The second strategy for dealing with increased demand relates to increased improvements to and labor investment in non-inundation land, in order to increase production for exchange. This includes extending the inundation to new areas by building canals, although these new areas would be even more vulnerable to river shifts than natural inundation land and subject to the same needs for reallocation of land. It also includes building canals, wells, and lifting devices to allow the use of well and lift irrigation in a variety of land types. On a small scale this could be done by individual farm families, allowing the accumulation of family wealth through increased production. Such increased production could be by either intensive or extensive methods, adding new crops grown in other seasons or allowing production of perennial crops; the possibilities are extensive. But such improvements could also be sponsored by corporate groups of different kinds in exchange for a proportion of the returns, as Kathleen Morrison and Carla Sinopoli (1992) document for much later periods in South India. In either case, agricultural production could become a source of wealth which could be reinvested in more land, more labor, or other venues. It may be that this second strategy became more important at the end of the Harappan Phase, with increasing population densities and decreasing land availability around the cities, at least in the area around Harappa (Wright 2000). If the basis for agricultural complexity in the form of double-cropping was being managed at the family or kin-group level, it is not surprising to see this complexity remain or even increase at a time when more centrally controlled systems (such as record keeping and long-distance exchange) were tied to political dissolution.

CONCLUSION

My picture of Harappan Phase agriculture is very different from Wittfogelian hypotheses about the origins of the state stemming from the need for state-level institutions to manage and supply labor for large-scale irrigation projects designed to provide needed agricultural surpluses. In contrast, I propose that there was no need for the major extension of agriculture into new areas via large-scale irrigation projects, as smaller-scale methods of water supply were adequate to supply the needs of the early Indus state. What is more, the aggrading, shifting nature of the Indus River and its Punjab tributaries do not favor large-scale irrigation projects, particularly in the southern regions of Sindh.

I also have suggested that the majority of agricultural land may have been commonly owned and redistributed by extended kin groups, rather than by individuals or institutions. Only relatively small plots of intensively watered land, requiring high labor input, were likely to have been owned by individuals or small family groups. Such a land ownership system could help explain the unusually "flat" (truncated) hierarchy characteristic of the Indus civilization, as one major focus of wealth and power would continue to be controlled by kin-based mechanisms. In contrast, shifts from communal land ownership to some individual ownership have been postulated for Mesopotamia during the Akkadian period, a time of regional state formation (Pollock 1999:121–122). As noted, Indus kin groups with power bases set firmly in the control of land ownership may have functioned as leveling structures, cross-cutting other non-kin-based hierarchies within the social and political system. Such a strong kin-based power base within a state-level society would function to limit one of the key elements of a state—hierarchies based on power over non-kin. The political leaders of the Indus state(s) may instead have based their power on religious authority, control of trade or manufacturing, or other methods of legitimation. The lack of state involvement in the management of agricultural systems also explains why agricultural systems remained complex, or even increased in complexity, at the end of the Harappan Phase when other complex economic, social, and political structures were dissolving.

This is an entirely hypothetical reconstruction of power bases—but other conclusions about Indus power bases are currently grounded in equivalently hypothetical data. This combination of cross-cutting groups controlling different aspects of the political economy does help to explain some of the puzzling features of the Indus evidence for social status that have resulted in debates about its status as a state—the lack of differences in burial goods, the lack of representations of rulers, the meager evidence for extreme socio-economic hierarchies (Possehl 1998). Some later South Asian states have similarly invisible rulers, with regard to burial goods and representations, even though they wielded considerable power, but such power was seldom absolute and seldom extended to all aspects of the economy. Overall, the modeling of potential water-supply systems for the Indus Valley floodplains during the Harappan Phase is a surprisingly productive exercise, given the relatively small amount of archaeological data available. Whether correct or incorrect, these suggestions about Harappan Phase agriculture and its potential impact on social and political systems provide, I hope, a point of reference for future debates about the nature of Harappan Phase agriculture and the Harappans themselves.

Acknowledgments

Many thanks to Chip Stanish for kindly including me in this seminar, allowing me to dredge up memories of topics I have missed discussing for the past pyrotechnologically focused decade. I am eternally grateful to the 1987 core faculty of the M.Sc. in Bioarchaeology (Archaeobotany) at the Institute of Archaeology in London: David Harris, Gordon Hillman, and Ken Thomas. They cannot be blamed for my errors after all these years, but they must shoulder the responsibility for teaching me to think about plant use as procurement and production systems that were integral parts of economic and social systems. My gratitude goes to Seetha Reddy, Richard Meadow, and Bill Belcher for many past discussions about Harappan agricultural systems and to Steven Weber for his recent dedicated work on the topic. Finally, I much appreciate Dorian Fuller's steady supply of reprints of his extremely reliable, well-researched articles, even if they are peninsular-o-centric instead of (properly!) Indus-Valley-o-centric.

NOTES

1. Scarborough is hampered in drawing further conclusions by the need to explain the "rapid rise" of the Indus state postulated by Possehl (1990) in earlier writings. In fact, excavations at Harappa between 1996 and 2000 have well-illustrated the gradual evolution of the society at that site from village to city (Kenoyer and Meadow 2000, and additional publications in press). These data are especially important because Harappa is the only urban Indus site for which the transition has been investigated by modern excavations of all the periods in question and for which extensive radiocarbon dating has been done. The radiocarbon dating program is key to this discussion, as the argument for an unusually rapid development of urbanized Harappan Phase society has been based in part on the great homogeneity of materials throughout different levels of

the early (undated) excavations at Mohenjo-daro during the 1920s and 1930s (Jansen 1989). With the addition of radiocarbon dates, this homogeneity is now seen as evidence for gradual indigenous evolution of the Indus Valley Tradition and perhaps social mechanisms encouraging continued use of "traditional" cultural symbols. However, the dates from Harappa do not necessarily negate Jansen's (1989) suggestions for a rapid building of Mohenjo-daro at the beginning of the urban Harappan Phase period rather than following the normal gradual growth from town to city. It is entirely possible that the two cities followed different life histories, with Harappa operating as a normal diversified city and Mohenjo-daro functioning more as a capital city or preeminent ceremonial site for the civilization. However, it may be extremely difficult to ever assess the life history of Mohenjo-daro given that the early levels there are at least 8 to 12 meters below the surface, under the current water table. In any case, these new data solve Scarborough's (2003:143) difficulties with having to postulate a rapid change in agricultural systems to explain the presumed "precipitous growth around 2500 BC" of the Harappan civilization.

2. In this chapter I focus on the agricultural side of the Harappan Phase food-production system for the Indus Valley floodplains. Studies of other aspects of the Indus Valley provisioning systems include research into domesticated animal management (Meadow 1996; Meadow and Patel 2003; Miller 2003), fishing (Belcher 1998, 2003), and procurement of other wild plants and animals for food and other purposes (Madella 2003; Miller 1991; Weber and Belcher 2003a). Research has also been done on the rather different agricultural and pastoral systems from adjacent regions associated with the Indus Valley Tradition, especially Baluchistan to the west (Meadow 1996; Lambrick 1964; Fairservis 1967; Costantini 1984; Costantini and Costantini Biasini 1985; Thomas 2003; Tengberg and Thiébault 2003), and Gujarat and beyond to the southeast (Bhan 1992; Fuller 2003; Fuller and Madella 2000; Reddy 1997, 2003; Weber 1996). Weber and Belcher (2003b), which updates and summarizes previous and recent research, is a particularly valuable source for Indus Valley Tradition plant use, animal use, and environmental data.

3. The exception to an increase in labor requirements would be if this is the period when the "chain-of-pots" is first invented, allowing both intensification and extensification on a previously unknown scale. A case might be made for the sudden and widespread appearance of a new pottery type at the end of the Harappan Phase, the "Pointed Base Goblet" (PBG), as the containers used in a "chain-of-pots" lifting device. They are currently hypothesized to represent "disposable" drinking cups created at a time when at least the city of Harappa was expanding rapidly. The scoring marks on the sides of these ubiquitous and hastily made vessels would provide attachment points for string tying the pots to the wooden wheel; however, the restricted mouths might not be ideal for the purpose. Experimental work coupled with use-wear analysis and distributional analyses of finds of these vessels would be interesting. At present there is no evidence for chain-of-pots lifting devices till thousands of years later.

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