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VOLUME II

PROTOHISTORY

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Issues in Harappan Archaeobotany: Retrospect and Prospect

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INTRODUCTION: THE HISTORICAL DEVELOPMENT OF HARAPPAN ARCHAEOBOTANY

Human use of plants is universal and therefore the study of people-plant relationships in the past is a crucial aspect of any holistic understanding of past societies. Integral to the development of complex societies and states is an agricultural surplus and some level of redistribution, and it is archaeobotany that provides the most direct evidence for the nature of agricultural production. Plant remains from archaeological sites provide insights into cultural ecology, agriculture and food habits and their study is therefore crucial to a number of issues in the study of the Harappan Civilization, its rise and demise. In particular archaeobotany is called upon to support, modify or contradict theories about the organization and intensity of cultivation, its seasonality, irrigation technology, and the impact of hypothesized environmental changes on urban society. In addition, the potential significance of newly introduced species in transforming agricultural ecology and the potential role of the Harappans in disseminating crops to other regions have also emerged as areas of interest. Most of this paper consist of a review of these issues after a short historical outline of the archaeobotany of the Indus Valley and adjacent areas, and detailed consideration of the hard evidence for various crops and food plants.

In general terms, the history of archaeobotany in South Asia can be divided into three broad stages in terms of the way in which research was carried out and the sophistication of understanding the nature of the evidence (see Fuller, in Vol. III of this series, for a more detailed history of the subject in South Asia). The first stage can be called the 'consultant-palaeobotanist' period, to distinguish it from subsequent periods in which individuals came to specialize in the study of archaeological plant remains. Archaeobotanical evidence at least on a small scale, has been a component of Indus Valley archaeology since the first excavations at Mohenjo Daro, Chanu Daro and Harappa in the 1930s and 1940s (Stapf 1931; Luthra 1936, 1941; Burts 1941; Shaw 1943). For the first several decades of research into this civilization, however, archaeobotanical evidence remained haphazard, collected by hand when chance led to the finding of charcoal rich pockets in the archaeological record. Such finds were then sent to botanists, who generally had little knowledge of the archaeology, and who provided species lists, with little interpretation. Early discussions of Harappan agriculture were based upon these few botanical assemblages and guesswork based on artistic depictions (e.g. Marshall 1931: 27; MacKay 1931: 324-5, 1938: 220-1). For example, Wheeler (1968: 84-6) in his discussion of farming simply catalogued the recovered seeds and those assumed to be present based on the interpretation of artefact form or pottery designs. Three field crop species (wheat, barley and peas) and three other food species (melons, sesame and dates) were then recorded from archaeological finds. Cotton cloth was taken to imply cotton cultivation. On the basis of artefact form, coconuts and possibly pomegranates were suggested to have been known, while bananas were inferred on the basis of ceramic decoration (Wheeler ibid.; MacKay 1938: 220). Fairservis (1961, 1967, 1982) and subsequently numerous other scholars reconstructed agricultural practices from settlement patterns and the position of sites in relation to local features of topography and soil types (e.g. Allchin and Allchin 1968: 236-7, 258-61; Flam 1976, 1986; Hoffman and Shaffer 1976; Suraj Bhan and Shaffer 1978; Possehl 1980; Jarrige and Tosi 1981; Mughal 1982; Lal 1984; Dales 1986). An early attempt to synthesise the available archaeological evidence within a broader South Asian context was prepared by Allchin (1969). The botanist Hutchinson (1976) considered the then known archaeobotanical evidence in relation to cropping season and modern crop geography, to argue that the basic agricultural systems of the various parts of South Asia were already established in prehistory.

The above approaches, and more general economic interests in archaeology, led to the second phase of archaeobotany when full-time archaeobotanical specialists emerged. Growing interest in early agriculture encouraged the increasing collection of archaeobotanical evidence, eventually through the use of systematic methods, such as flotation of macro remains (i.e. seeds and charcoal). With increases in the amount of evidence collected, a small number of more or less full-time archaeobotanists emerged in the 1970s, which can be considered the professionalization phase of archaeobotany (see for example, Kajale 1974; Vishnu-Mittre 1977; Vishnu-Mittre and Savithri 1982; Chowdhury et al. 1977). Subsequent to this, we can now be seen to be in a third phase of maturation as increasing thought is given to issues of taphonomy and quantification. Archaeobotanists are now coming to grips with the uniquely archaeological nature of their data and its potential for elucidating the past. In addition, other kinds of plant remains have been studied, including pollen from archaeological deposits (Singh et al. 1974; McKean 1983) and, more recently, phytoliths (Madella 1995, 1997, 1998).

The archaeobotanical evidence from Harappan sites and those in contemporaneous, adjacent regions has grown considerably since the first finds at Mohenjo Daro (see Table 1). It is only in the last two decades that there has been sufficient evidence from a number of sites to allow generalization and theorization about Harappan agriculture. Although the available evidence is still very sparse for such a large area, especially for sites in core areas like the river floodplains of Sindh, and much of it comes from unsystematically collected samples, it is at least possible to place our understanding of Harappan agriculture into an interregional context and to begin to assess its potential impact on broader historical patterns in South Asia. In the lengthy section that follows, the archaeobotanical record for north-western South Asia is criticall reviewed, with consideration given to the likely geographical sources of particular crops and the periods and directions of their dispersal. After this review of the evidence for crops, we turn to discussion of the issues surrounding the introduction of African crops to South Asia, and the analysis of non-crop (weed) taxa in archaeobotanical samples. Then we turn to

TABLE 1. INDUS VALLEY TRADITION SITES AND SITES FROM ADJACENT REGIONS WITH REPORTED ARCHAEOBOTANICAL EVIDENCE

Site Period	Map	Seeds, charred	Impressions	Charcoal	Other wood finds	Pollen	Phytoliths	Inferences from artefacts	References
Baluchistan									
Mehrgarh, I-VII, *c.* 6000 BC *c.* 2500 BC	17	+	+	x					Costantini 1983; Costantini and Biasini 1985; charcoal: Theibault 1988, 1989, 1992, 1995
Nousharo 2600-1900 BC	18	+	+	+					Costantini 1986; 1990a; charcoal: Theibault 1988, 1989,1992,1995
Pirak I-II	19	+	+	+					Costantini 1979; Costantini and Biasini 1985; charcoal: Theibault 1988, 1989, 1992, 1995
Sindh									
Mohenjo Daro, 2600-2000 BC	2	+						+	Stapf 1931; Luthra 1936; Vishnu-Mittre and Savithri 1982
Chanu Daro,	3	+						+	Shaw 1943; Vishnu-Mittre and Savithri 1982
Kot Diji, 3000-2000 BC				+			+		Castelletti et al. 1994; Madella 1995, 1997
Allahdino 2600-2000	20	+^{F}							Fairservis 1982
Balakot 2600-2000	21	+^{F}				+			McKean 1983; see Dales 1986
Northern/Eastern Harappan									
Harappa, 2600-2000 BC (earlier phases not reported	1	+^{F}			+		+	+	Burts 1941; Luthra 1941; Vishnu-Mittre and Savithri 1982; phytoliths: Madella 1998 and unpublished
Kalibangan, 3000-2000 BC	4	+	+			+			Vishnu-Mittre and Savithri 1975, 1982; pollen: Singh et al. 1974
Rohira 2300-1900 BC	5	+^{F}		+^{F}					Vishnu-Mittre et al. 1985; Saraswat 1986; Saraswat et al. 1990; Saraswat and Chanchala 1994
Sanghol	6	+		+					Saraswat et al. 1992; Saraswat and Chanchala 1997
Rupar 2500-1700 BC	7	+							Vishnu-Mittre and Savithri 1979a
Daulatpur 2000-1700 BC	8	+							Vishnu-Mittre and Savithri 1982; Vishnu-Mittre et al. 1985

(contd.)

Site Period	Map	Seeds, charred	Impressions	Charcoal	Other wood finds	Pollen	Phytoliths	Inferences from artefacts	References
Banawali *c.* 3000- *c.* 1600 BC	15	+							Lone et al. 1987
Mahorana 2300-1900 BC	9	+		+					Vishnu-Mittre et al. 1986b; Saraswat and Chanchala 1994, 1996
Burthana Tigrana 2500-2000 BC	10	$+^{F}$							Willcox 1992
Laduwala 2800-2300 BC	11	$+^{F}$							Willcox 1992
Mitathal 2000-1400 BC	12	$+^{F}$							Willcox 1992
Ganga-Yamuna Late Harappan/Ochre-Coloured Pottery									
Hulas 1800-1200 BC	13	$+^{F}$							Saraswat et al. 1992; Saraswat 1993
Lal Quila 1800-1200 BC	14	+							Kajale and Deotare 1993; Kajale 1995
Atranjikhera 1800-1200 BC	16	+		+					Chowdhury et al. 1977, 1983
Northern Periphery									
Rehman Dheri 3200-2000 BC	36	+							Durrani 1988: 28, 30
Tarakai Qila, 3000-2000 BC	35	$+^{F}$							K. Thomas 1983a, 1983b, 1989
Ghaleghay I-III 3000-2000 BC	32	+							Costantini 1987
Bir-Kot-Ghwandai 1700-1400 BC	33	+							Costantini 1987
Loebanhr 3 1700-1400 BC	34	+							Costantini 1987
Burzahom, I-II 2350-1000 BC	30	$+^{F}$		+					Lone et al. 1993
Semthan, I 1500-600 BC	31	$+^{F}$		+					Lone et al. 1993
Areas within trade contact to West and North									
Shortugai (Harappan enclave?)	46	$+^{F}$							Willcox 1991
Mundigak 3000-2000 BC	47	+							Porteres 1961; Costantini and Biasini 1985
Sharh-I-Sokhta 3200-2100 BC	48	+		+					Costantini and Biasini 1985

(contd.)

Site Period	Map	Seeds, charred	Impressions	Charcoal	Other wood finds	Pollen	Phytoliths	Inferences from artefacts	References
Tepe Yahya, VII-IV 4500-2200 BC	49	+							Costantini and Biasini 1985
Hili, Oman 3000-2000 BC	50	+	+						Cleuziou and Costantini 1980, 1982; Cleuziou 1989
Harappan Gujarat									
Lothal 2500-1900 BC	24	+	+	+					Ramesh Rao and Lal 1985
Rangpur IIA-III 2500-1400 BC	25	+	+	+					Ghosh and Lal 1963
Rojdi, A-C 2600-1700 BC	27	+F							Weber 1991
Oriyo Timbo 1700-1400 BC	29	+F							Reddy 1994, 1997
Babor Kot, I-III 2200-1700 BC	28	+F							Reddy 1994, 1997
Kuntasi 2600-2000 BC	23	+F							see Dhavalikar 1995
Surkotada, IC 2000-1800 BC	26	+							Vishnu-Mittre and Savithri 1982
Shikarpur 2500-2000 BC	22	+		+					Saraswat et al. 1995
Eastern Periphery									
Ahar 2500-1500 BC	37		+						Vishnu-Mittre 1969
Balathal 2500-2000 BC	38	+P							Kajale 1996
Southern Periphery of Late Harappan (Chalcolithic Maharashtra)									
Kayatha 2400-1400 BC	40								Vishnu-Mittre et al. 1985
Kaothe c. 2000 BC	41	+							Kajale 1990
Daimabad 2000-1100	42	+F		+F					Kajale 1977; Vishnu-Mittre et al. 1986a
Inamgaon 1700-900 BC	43	+F							Kajale 1988
Apegaon 1700-1200 BC	44	+F							Kajale 1979
Navdatoli 2000-1700 BC	45	+							Vishnu-Mittre 1961

NOTE: F = indicates that at least some samples were collected through flotation.

discussing more general agricultural issues, including irrigation and seasonality. Finally, some of the key issues and datasets of South Asian palaeoecology of the later Holocene are reviewed. An understanding of the issues and hypotheses relating to climatic change in South Asia is important for putting the agricultural evidence into its environmental context.

THE HARD EVIDENCE FOR CROPS

In reviewing the archaeobotanical evidence for the presence of various crops, an attempt will be made to assess the significance of their apparent presence or absence from different regions within the Harappan Civilization and between the Mature/Urban and Late/Post-Urban phases (i.e. Integration and Localization Eras in the terminology of Kenoyer 1991). In Weber's (1991, 1992) review of South Asian archaeobotanical variability, it is clear that some categories of crops are more often recovered than others. These differences are likely the results of factors of preservation and sampling. Thus cereals, especially the large seeded ones (wheat, barley, rice), have been much more widely reported than any other category of plant. Smaller cereals (millets) have also been quite widely reported. Pulses have not been reported from as many sites, but are widely enough reported that presence or absence in particular regions and periods can be reconstructed with a fair degree of certainty. Other types of crop plants, including oilseeds, fibre crops and fruit or nuts, have only been recovered occasionally. These differences doubtless reflect biases in the archaeobotanical record and recovery methods, thus limiting the conclusiveness of histories of crops other than the cereals and pulses. For these reasons the distribution maps in Figures 1 and 2 are limited to cereals and pulses, although other categories of food plant are included in the present tables (Tables 2-3).

As it is of interest to see which crops diffused as a package and which individually, the crops reviewed below will also be grouped according to those which share general geographical regions of origin, as this should facilitate an understanding of diffusion processes. Evidence for the geographical origins of plants comes largely from their living relatives, especially the distribution of wild relatives, and this evidence will not be reviewed in any detail in this paper (see Fuller, in Vol. III of this series for discussion of this evidence). However, not all crops have been equally researched in terms of genetic and geographical origins. Crops which have been most extensively studied are those which originated in South-West Asia and form the basis of traditional agriculture in the Mediterranean and Europe, and a synthesis of the evidence can be found in Zohary and Hopf (1993). Crops of tropical origin are very often documented on the basis of very little real evidence. There has, however, been an accumulation of new studies during the past two decades and a picture of the geographical origins of several African crops has emerged (see Fig. 3, and Fuller, in Vol. III of this series). Some discussion will be given of millets and pulses that are of particular importance to the agriculture of the Indian subcontinent. Crops of South and South-East Asian origin are often poorly documented as to the likely regions of their origin, although an assessment of current evidence can be informative (Fuller ibid.; Fuller et al. n.d.).

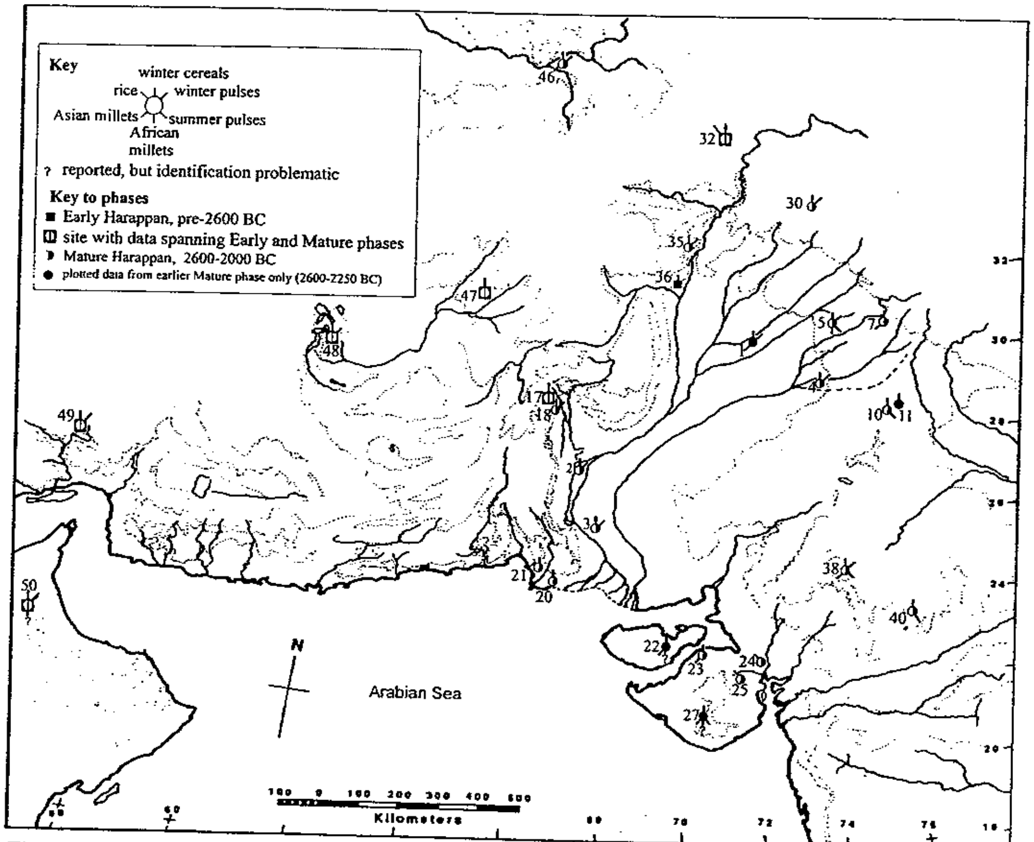

Fig. 1. Map showing distribution of archaeobotanical finds within the Harappan orbit and adjacent regions during the Mature Harappan phase and preceeding early period. Finds are summarized in terms of major crop groups defined on the basis of seasonality, and geographical origin. Site numbers, details of species reported and references can be found in Tables 1-3. Base map shows reconstructed drainage system of greater Indus Valley, including ancient Ghaggar-Hakkra river (after Kenoyer 1998).

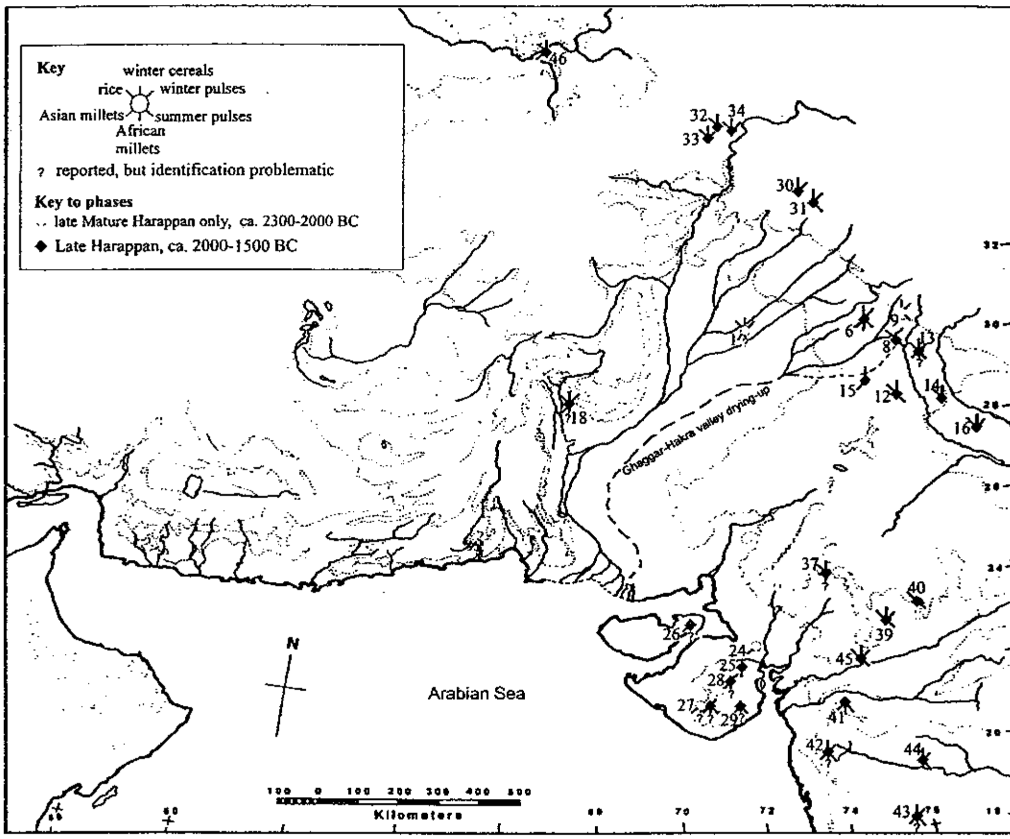

Fig. 2. Map showing distribution of archaeobotanical finds within the Harappan orbit and adjacent regions during the late Mature and late (post-Urban) phases. Finds are summarized in terms of major crop groups defined on the basis of seasonality, and geographical origin. Site numbers, details of species reported and references can be found in Tables 1-3.

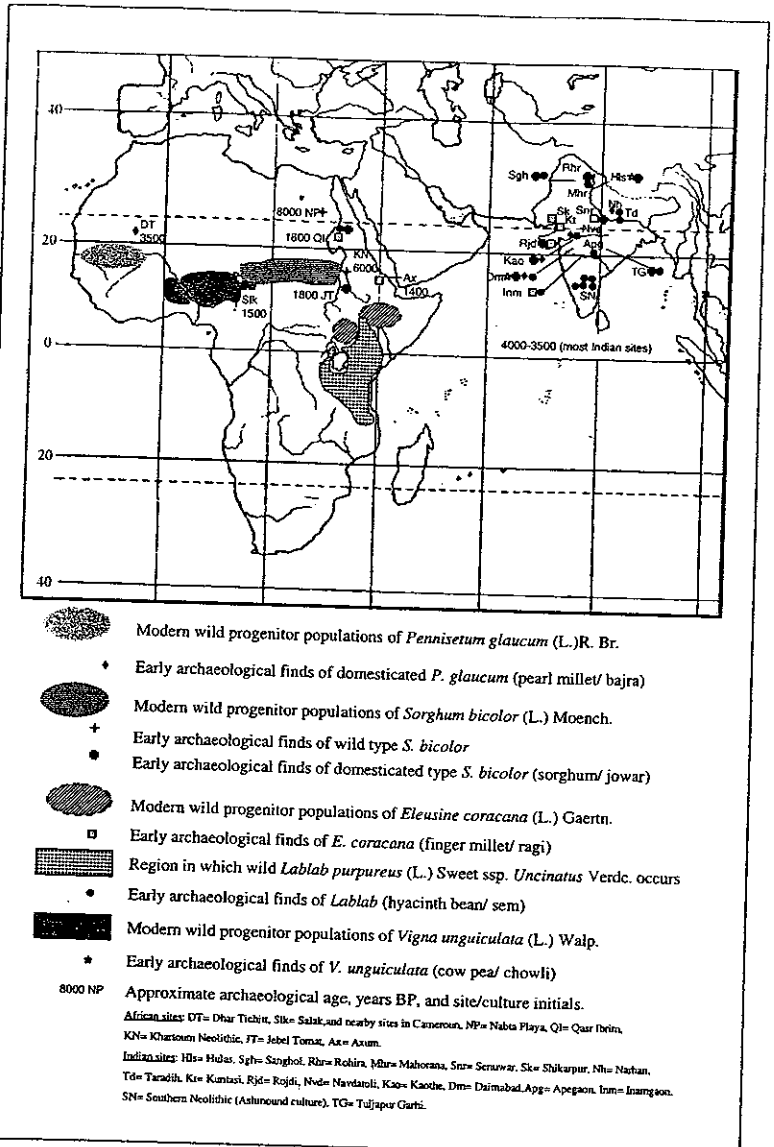

Fig. 3. Map showing the probable regions of demonstration for African millets and pulses present in protohistoric India, and early archaeobotanical finds of these species in Africa and India. World progenitor distributions based on the following sources: Tostain 1994, 1998 (*Pennisetum*), Rawal 1975; Vailencourt and Weeden; Panella et al. 1993 (*V. unguiculata*), Harlan 1992, 1995 (*Sorghum*), Verdcourt 1971 (Lablab), Harlan 1992, 1995 (Eleusine). Sources for African archaeobotanical evidence: Amblard and Pernes 1989; Wasylikowa et al. 1993; Clark and Stemler 1975; Stemler 1990; Rowley-Conwy 1991; Otto and Delneuf 1998; Sheila Boardman: personal communication 1998 (Axum); Alan Clapham, personal communication 1999 (Qasr Ibrim). Archaeobotanical evidence for all South Asian sites shown can be found in Fuller, Vol. III, in this series.

TABLE 2. CHECKLIST OF MAJOR CULTIVATED TAXA REPORTED FROM SITES OF THE HARAPPAN CIVILIZATION (INCLUDING LATE PHASES)

Region		Baluchistan					Sind			
Culture Period							Mature period			
period B.C.		4500-4000	3200-3000	2600-2000	1950-1550	2600-2000				
Site/phase		Mehrgarh II	Mehrgarh V	Mehrgarh VII-VIII	Pirak I	Nausharo	Allahdino	Balakot	Chanu Daro	Mohenjo Daro
Pulses	Map no. seasonality	17	17	17	18	19	20	21	3	2
Cajanus cajan	*kharif*									
Dolichos biflorus	*kharif*									
Dolichios lablab	*kharif*									
Vigna sp. (*radiata/mungo*)	*kharif*									
Vigna radiata	*kharif*									
Vigna mungo	*kharif*									
Vigna unguiculata	*kharif*									
Cicer arientinum	*rabi*				x					
Lathyrus sativus	*rabi*									
Lens esculenta	*rabi*									
Pisum sativum	*rabi*					x			x	x
Trigonella foenum-graecum										
Cereals										
Hordeum vulgare	*rabi*	x	x	x	x	x	x	x	x	x
Triticum sp.	*rabi*	x	x	x	x	x	x	x	x	x
Avena sativa	*rabi*		?	?	?					
Oryza sativa	*kharif*				x					
Sorghum bicolor	*kharif*				[i]					

Region		Northern and Eastern provinces								
Culture Period		Mature period								
period B.C.		2600-2300	2250-2000	2500-2000	2000-1500	2500-1700		3000-1600	2500-2000	2800-2300
Site/phase		Harappa	Harappa	Kalibagan II	Sanghol	Rupar	Rohira	Banawali	Burthana Tigrana	Laduwala
Pulses	Map no. seasonality	1	1	4	6	7	5	15	10	11
Cajanus cajan	*kharif*									
Dolichos biflorus	*kharif*			x		x		x		
Dolichios lablab	*kharif*				x					
Vigna sp. (*radiata/mungo*)	*kharif*								x	
Vigna radiata	*kharif*									
Vigna mungo	*kharif*									
Vigna unguiculata	*kharif*									
Cicer arientinum	*rabi*	x	x	x						
Lathyrus sativus	*rabi*	x	x		x					
Lens esculenta	*rabi*		x	x		x		x		
Pisum sativum	*rabi*	x	x	x	x					
Trigonella foenum-graecum										
Cereals										
Hordeum vulgare	*rabi*	x	x	x	x		x	x	x	x
Triticum sp.	*rabi*	x	x	x	x	x	x		x	
Avena sativa	*rabi*									
Oryza sativa	*kharif*		x							
Sorghum bicolor	*kharif*				x		x			

Region		Late period			Upper Ganga		
Culture Period		Late period			OCP		
period B.C.		2000-1700	?2300-1900?	2000-1400	1800-1200		
Site/phase		Daulatpur	Mahorana	Mitathal	Hulas	Lal Quila	Atranjikhera
Pulses	Map no. seasonality	8	9	12	13	14	16
Cajanus cajan	*kharif*						
Dolichos biflorus	*kharif*		x	x			
Dolichios lablab	*kharif*		x				
Vigna sp. (*radiata/mungo*)	*kharif*			x			
Vigna radiata	*kharif*				x		
Vigna mungo	*kharif*	x					
Vigna unguiculata	*kharif*				x		
Cicer arientinum	*rabi*				x		x
Lathyrus sativus	*rabi*				x		x
Lens esculenta	*rabi*			x		x	
Pisum sativum	*rabi*				x		
Trigonella foenum-graecum							
Cereals							
Hordeum vulgare	*rabi*		x	x	x	x	x
Triticum sp.	*rabi*		x	x	x	x	x
Avena sativa	*rabi*						
Oryza sativa	*kharif*	x		x	x	x	x
Sorghum bicolor	*kharif*				x		

Region		Gujarat						Late period							
Culture Period		Mature period													
period B.C.		2500-2000	2500-2000	2000-1700	2600-2200	2000-1700	2600-2200	2200-2000	2000-1700				1700-1400		
Site/phase		Shikarpur	Kuntasi	Lothal	Rangpur IIA	Rangpur III	Rojdi A	Rojdi B	Surkotada III	Babar Kot I	Babar Kot II	Rojdi C	Babar Kot III	Oriyo Timbo I	Oriyo Timbo II
Pulses	Map no. seasonality	22	23	24	25	25	27	27	26	28	28	27	28	29	
Cajanus cajan	*kharif*														
Dolichos biflorus	*kharif*										x				
Dolichios lablab	*kharif*														
Vigna sp. (*radiata/mungo*)	*kharif*														
Vigna radiata	*kharif*											x			
Vigna mungo	*kharif*						x					x		x	x
Vigna unguiculata	*kharif*														
Cicer arientinum	*rabi*														
Lathyrus sativus	*rabi*										x	x			
Lens esculenta	*rabi*										x	x	x	x	
Pisum sativum	*rabi*											x			
Trigonella foenum-graecum															
Cereals															
Hordeum vulgare	*rabi*		x				x								
Triticum sp.	*rabi*	x	x												
Avena sativa	*rabi*														
Oryza sativa	*kharif*			|	|	|									
Sorghum bicolor	*kharif*							x				x			

Eleusine coracana	*kharif*											[ ]											[ ]			[ ]	[ ]				[ ]	[ ]	[ ]			[ ]		[ ]	[ ]
Pennisetum typhoides	*kharif*																													x							x?		
Panicum sp.	*kharif*				x																												x						
Panicum milaceum	*kharif*																																						
Panicum sumatrense	*kharif*																														x	x		x	x	x	x	x	x
Setaria sp.	*kharif*												x			x						?			x	x				x	x	x		x	x	x	x	x	
Paspalum scrobiculatum	*kharif*														x																								
Oilseeds/Fibres																																							
Sesamum indicum	*kharif*										x			x																									
Gossypium sp.	*kharif/peren*	x?					x															x																	
Linum usitatissimum	*rabi*			x	x								x																				x	x	x				
Cannabis sativa	*rabi/kharif*																																						
Carthamus tinctorius	*rabi*																																						
Rincinus communis	*kharif*																						x																
Papaver sp.	*rabi*													x																									
Phoenix dactylifera	September	x				x				x	x				x																								
Vitis vinifera	summer		x	x	x	x									x						x																		
Prunus sp.	May-Oct.	x	x			x																																	
Prunus dulcis (*Amygdalus communis*)	Feb.-June																						x																
Juglans regia	Mar.-June																						x																
Citrus limon	year round													x																									
Ziziphus sp.	Arp.-Oct.	x	x	x	x	x					x	x						x	x			x				x				x	x								

Notes: Botanical authorities have been omitted from this table for reasons of space. They can be found throughout the text. For references, see Table 1.
x = presence reported (seed remains); i = present as impression only; x? = reservations expressed by original author(s);
[ ] = identification considered problematic by the present authors; ? = probably present, based on reconsideration of literature by this study.

TABLE 3. CHECKLIST OF MAJOR CULTIVATED TAXA REPORTED FROM SITES IN REGION ADJACENT TO, OR IN CONTACT WITH, THE HARAPPAN CIVILIZATION

Region		Kashmir			Swat Valley					Bannu Basin		Maharashtra												regions in contact to the North and West					
Culture Period		Neolithic			Chalcolithic							Banas			Pre-Malwa			Malwa			Jorwe								
Site/Phase		Burzahom I	Burzahom II	Semthan I	Ghaleghay I	Ghaleghay II	Ghaleghay III	Bir-Kot-Ghwandai	Loebanhr 3	Tarakai Qila	Rehman Dheri	Ahar	Balathal	Dangwada	Kayatha	Kaothe	Daimabad II	Daimabad III	Inamgaon	Apegaon	Inamgaon	Daimabad IV	Navdatoli	Shortugai I.1	Shortugai 1.2	Mundigak	Sharh-I-Sokhta	Tepe Yahya VII-IV	Hili 8
Period BC		2375-1700	1700-1000	1500-600	3000-2500	2500-2000	1900-1700	1700-1400	1700-1400	late 3rd Mill.	3000?-2500	2600-1500		2000-1500	2450-1400	c. 2000	2000-1700	1700-1500	1700-1500		1500-1200	1500-1100		2500-2000		3000-2000	3200-2100	4500-2200	c. 2900
Pulses	Map no. / seasonality	30	30	31	32	32	32	33	34	35	36	37	38	39	40	41	42	42	43	44	43	42	45	46		47	48	49	50
Cajanus cajan	*kharif*																												
Macrotyloma uniflorum	*kharif*														x	x		x	x	x	x	x	x						
Lablab purpureus	*kharif*																	x	x	x	x		x						
Vigna sp. (*radiata/mungo*)	*kharif*												x	x															
Vigna radiata	*kharif*			x																x	x		x						
Vigna mungo	*kharif*														x		x		x		x	x							
Vigna unguiculata	*kharif*																	x				x							
Cicer arientinum	*rabi*																												
Lathyrus sativus	*rabi*																x	x	x	x	x	x	x					x	
Lens esculenta	*rabi*	x	x	x				x	x	x				x			x	x	x	x	x	x	x	x	x		x	x	
Pisum sativum	*rabi*	x							x				x					x	x	x	x	x	x	x				x	
Trigonella foenum-graecum																													
Cereals																													
Hordeum vulgare	*rabi*	x	x	x			x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x
Triticum sp.	*rabi*	x	x	x		x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Avena sativa	*rabi*			x				x																			x	?	

Oryza sativa	*kharif*			x	i	i	i	x	x			x		x					x			x	x							
Sorghum bicolor	*kharif*										[ ]											x							[ ]	
Eleusine coracana	*kharif*																	[ ]	[ ]		[ ]	[ ]								
Pennisetum typhoides	*kharif*															x		x												
Panicum sp.	*kharif*													x								x								
Panicum milaceum	*kharif*												x												x			x		
Panicum sumatrense	*kharif*																													
Setaria sp.	*kharif*																		?				x							
Paspalum scrobiculatum	*kharif*																					x								
Oilseeds/Fibres																														
Sesamum indicum	*kharif*															x					x?									
Gossypium sp.	*kharif/peren.*																													
Linum usitatissimum	*rabi*								x				x?									x	x		x		x			
Cannabis sativa	*rabi/kharif*																													
Carthamus tinctorius	*rabi*																					x								
Rincinus communis	*kharif*																													
Papaver sp.	*rabi*																													
Fruits/Vegetables	season of fruiting																													
Phoenix dactylifera	September																											x	x	
Vitis vinifera	summer		x						x															x			x	x		
Prunus sp.	May-Oct. (?)	x		x																								x		
Amygdalus communis	Feb.-June		x																											
Juglans regia	Mar.-June	x	x	x																										
Citrus limon	year round																													
Ziziphus sp.	Apr.-Oct												x	x			x	x	x	x	x	x	x	x			x			x

NOTES: Botanical authorities have been omitted from this table for reasons of space. They can be found throughout the text. For references, see Table 1.
x = presence reported (seed remains); i = present as impression only; x? = reservations expressed by original author(s);
[ ]= identification considered problematic by the present authors; ?= probably present, based on reconsideration of literature by this study.

South-West Asian Cereals

Wheat and barley, seem to have formed one of the major bases of Harappan agriculture, at least within the Greater Indus Valley. Wheat and barley based agriculture spread from the Near East and reaching Baluchistan, as represented by Mehrgarh, by 6000 BC (Costantini 1983; Meadow 1996), with more recent dates possible pushing this evidence back considerably further to the eighth millennium BC (Meadow 1998). As noted in several previous syntheses (Fairservis 1971; Vishnu-Mittre and Savithri 1982; Costantini and Biasini 1985; Meadow 1989, 1996, 1998; Saraswat 1992; Franke-Vogt 1995), wheat and barley are the two most often recovered cereals on Harappan sites.

Barley/*jau* (*Hordeum vulgare L.*[1]) was once claimed to have been largely absent from prehistoric/protohistoric sites in South Asia (e.g. Vishnu-Mittre 1968c, 1970a), although it is now clear that this conclusion was a product of haphazard sampling prior to the professionalisation of archaeobotany and employment of sieving/flotation (cf. Kajale 1991; Saraswat 1992). Wheat/*gehu* (*Triticum* sp.) has been a widespread find on Harappan sites since the first excavations of Mohenjo Daro (Vishnu-Mittre and Savithri 1982; Kajale 1991; Willcox 1992; Saraswat 1992).

It is notable that wheat and barley are poorly represented on sites from Gujarat either from Harappan or Late/Post-Urban levels, the probable significance of which will be taken up below in 'Seasonality and Intensity of Agriculture' (Vishnu-Mittre and Savithri 1982; Weber 1991, 1992; Reddy 1994, 1997; Meadow 1989, 1996). For example, at Rojdi, despite intensive sampling, only 13 grains of barley were identified by comparison to thousands of millet grains (Weber 1991); at Oriyo Timbo, Babar Kot and Surkotada, wheat and barley were absent (Reddy 1994, 1997; Vishnu-Mittre and Savithri 1982). On the other hand wheat and barley are widely reported, often in considerable quantity from sites in 'inner' India from the second millennium BC, i.e. from Chalcolithic Maharashtra, Rajasthan, and the Ganga Valley (see Kajale 1988, 1991, 1996; Saraswat 1986, 1992; Vishnu-Mittre 1989). Thus the diffusion of these two crops eastwards into tropical India, which occurred during and after the Mature Harappan phase, was a selective process in which certain regions may not have participated, presumably for a combination of ecological and cultural reasons. Indeed, it can be argued that a major reason for the rapid and wide dispersal of these cereals, perhaps barley in particular, was due to cultural associations (such as prestigious or ritual value) associated with the Harappans (Fuller, in press).

Both wheat and barley include a number of different cultivated species or varieties, and it is of interest to trace these archaeologically. Barley can be sub-divided by two variables, the number of fertile (grain-producing) florets per spikelet and whether or not the grains are naked (free-threshing) or hulled (Renfrew 1973; Vishnu-Mittre and Savithri 1982; Jacomet 1987; Zohary and Hopf 1993). Two-rowed inflorescences and hulled grains are the primitive, wild characteristics of barley (Zohary 1969; Zohary and Hopf 1993). Amongst the impressions from Mehrgarh the derived naked six-row form is thought to dominate, while two-row and hulled six-row appear to be minor components (Costantini

1983). Unfortunately, it is not clear how seriously the quantification based on plant impressions should be taken, since the number of impressions depends on the size of the sherd and the number of breaks. At least the presence of these three varieties is clear. Six-rowed, naked barley is also reported from Mohenjo Daro (Luthra 1936) and Harappa (Vishnu-Mittre and Savithri 1982), while hulled barley dominates a large assemblage from Kalibangan in which naked grains were approximately 5 per cent and grains with a twisted appearance indicate the presence (preponderance?) of six-row (Vishnu-Mittre and Savithri 1982). Six-row hulled has also been identified at Banawali (Lone et al. 1987) and Hulas, a Late Harappan site of the Ganga-Yamuna Doab (Saraswat 1993). The small amount of barley from Rojdi also appears to be six-row hulled (Weber 1991). From the available evidence, it is six-row, hulled (*H. vulgare* L. subsp. *vulgare*) which appears to be most widespread in the Harappan Civilization, and it is this variety which diffused eastwards into subsequent cultures of the Ganga Valley, as indicated for example at Atranjikhera, Radhan and Narhan in the Painted Grey Ware phase, latter half of second millennium BC (Buth and Chowdhury 1971; Kajale and Lal 1989; Saraswat et al. 1994), and peninsular Indian village cultures of the second millennium BC (e.g. Kajale 1979, 1984, 1988).

The existence of a distinct, local variety of spheroid barley in Pre-Harappan Baluchistan must be assessed critically. Costantini (1983: 31) has referred to much of the barley at Mehrgarh as '*Hordeum sphaerococcum*', implying that it is a distinct morphological type similar to that recovered from early periods in Armenia, the Caucasus and southern Turkmenia (Janushevich 1978). It was later suggested that 'by the end of the Neolithic (sixth millennium BC) . . . the grain and barley underwent the peculiar local adaptations leading to a morphological convergence of the kernels of the two cereals nowadays classified as *Triticum sphaerococcum* and *Hordeum sphaerococcum*' (Costantini and Biasini 1985: 26). Neither this trend, nor the distinctiveness of '*H. sphaerococcum*' has been established by published morphometric data. Furthermore, such an approach to cereal grains is highly problematic, as noted below for archaeological '*Triticum sphaerococcum*', since charring distorts the size of grains and tends to make them more spheroid.

Unfortunately, despite reported species level identifications of wheats in the Greater Indus Valley, most of these identifications cannot be accepted. It is now well-established that the characteristics of wheat grains as unreliable for specific identification and difficulties are exacerbated in the case of charred material (van Zeist 1976; Kislev 1984; Miller 1992; Zohary and Hopf 1993; Hillman et al. 1996, Maier 1996; for further details see Fuller, in Vol. III of this series). the archaeological and agricultural literature on South Asia makes frequent reference to the presence of hexaploid wheats, especially *Triticum sphaerococcum* Perc., the Indian Shot Wheat (e.g. Vishnu-Mittre 1974a; Hutchinson 1976; Vishnu-Mittre and Savithri 1982; Costantini and Biasini 1985; Saraswat 1986, 1992, 1993; Zeven 1978; Randhawa 1980; Kulshrestha 1985; Meadow 1998). The purported former dominance of *T. sphaerococcum* Percival must be disregarded until there is adequate evidence from wheat rachis remains. From Shortugai, Afghanistan, which shows Harappan affinities in its earliest levels, hexaploid wheat (*T. aestivum* sensu lato) occurs. There is little evidence as yet for hulled wheats. A hulled wheat is present amongst the impressions from early Mehrgarh (*c.* 6000-5000 BC), although whether emmer or einkorn is unsure (Costantini 1983; subsequently both reported as present in Costantini and Biasini 1985). A hulled wheat also appears to have been present amongst the impressions from Harappan Kalibangan (cf. Vishnu-Mittre and Savithri 1975), perhaps emmer. Emmer grains have been identified nearby from Late Harappan Rohira, a site on a tributary system of the former Ghaggar-Hakkra river (Saraswat 1986), as has free threshing-wheat ('*T. sphaerococcum*'). It can tentatively be concluded that free-threshing wheats (of uncertain ploidy level) and hulled barley dominated winter cereal cultivation throughout most of the Harappan world, with the notable exception of Gujarat. Distinguishing these various wheat types is of interest for understanding their separate histories, although there may also be ecological and cultural implications in some cases. For example, *T. sphaerococcum* is generally considered highly drought resistent (Percival 1921), and emmer as a hulled wheat may be prone to less loss during storage.

South-West Asian Pulses

The argument can be made that wheat and barley were part of a crop package which included four likely legume (pulse) species: peas/*mattar* (*Pisum sativum* L., incl. *P. arvense* L.), grasspea/*khasari* (*Lathyrus sativus* L.), lentils/*masur* (*Lens culinarius* Med.), and chickpea/gram/*chana* (*Cicer arietinum* L.) (for evidence of their South-West Asian origins see Zohary and Hopf 1993). Although these species have not been reported from the early periods at Mehrgarh (Costantini 1983), this cannot be taken to indicate their actual absence, as the evidence for the cereals comes from impressions, a category of remains which one would not expect to include leguminous crops. Unfortunately because there are still few systematically studied flotation samples from the Harappan phase of the Indus Valley itself, it is nuclear the extent to which each of the South-West Asian pulse species contributed to the agriculture of the various regions. Nevertheless, the available evidence suggests that each of these species was at least present in the north-western subcontinent at this time. In addition, the Post/Late-Harappan evidence from areas to the east and south in India, suggest that all or most of these pulses were cultivated in the same areas as wheat and barley in the second millennium BC (see Fuller, in Vol. III of this series; Fuller et al., n.d.; cf. Kajale 1991; Saraswat 1992). This suggests that these crops diffused out of the Indus Valley as something of a package, although it is unclear if they entered the region as such. Peas have been reported from Nausharo (Costantini 1990); Chanu Daro/Mohenjo Daro, Harappa and Kalibangan (Vishnu-Mittre and Savithri 1982), in addition to Burthana Tigrana and Mitathal in Haryana (Willcox 1992). Lentils and chickpeas are also known from Kalibangan, while lentils and *Lathyrus* are reported from Harappa. Lentils were also found at Daimabad in Maharashtra and in the subsequent period lentils, peas and *Lathyrus* are known from several Chalcolithic Maharashtra sites, while all four pulses are known from second millennium Ganga Valley sites.

Tropical Pulses

Of particular importance in South Asian agriculture are pulses that are adapted to the savannas and are generally cropped in the summer/monsoon season, many of which are indigenous of South Asia. Unfortunately, these species have been subject to much nomenclatural confusion and revision (reviewed in Fuller et al., n.d.; for taxonomy, see Smartt 1990). Horsegram/*kulthi* (*Macrotyloma uniflorum* (Lam.) Verdocurt 1970, based on *D. uniflorus* Lam.)[2] is generally accepted as native to South Asia, its main region of cultivation, although no wild populations are known (Smartt 1985a, 1990). Horsegram has not been reported from Mature/Urban Harappan period sites, but moves into the north-western subcontinent in the early second millennium BC, with finds from Rojdi Period C in Saurashtra (Weber 1991), Rohira and Hulas in Indian Punjab (Saraswat 1986, 1993), and Haryana sites (Willcox 1992). The *Vigna* grams have also suffered from some nomenclatural confusion: green gram/*mung* (*V. radiata* (L.) R. Wilczek, syn. *Phaseolus radiatus* L., *Phaeseolus aureus* Roxb.)[3], and black gram/*urid*, *V. mungo* (L.) Hepper, syn. *Phaseolus mungo* L.)[4] are both indigenous to tropical/sub-tropical South Asia, although they derive from distinct wild progenitors and presumably have disparate geographical origins (Smartt 1985b, 1990); for further references see Fuller et al., n.d.; Fuller, in Vol. III of this series). These two species can be difficult to distinguish if the hilum is not preserved, although statistical differences exist between the ratio of plumule length to cotyledon length. One or both of these species are reported from sites around the periphery of the Harappan Civilization, in Saurashtra (Weber 1991) and Haryana (Willcox 1992), beginning in levels contemporary with the Mature period. These earliest finds may be entirely of black gram (*V. mungo*), as is the case with Rojdi A (Weber 1991) and Banawali (Lone et al. 1987). Green gram/mung (*V. radiata*) may only have become available in these areas in the second millennium BC, e.g. Rojdi C (Weber 1991), Atranjikhera (Chowdhury et al. 1977), and Hulas (Saraswat 1993). Both pulses have been reported from Balathal, Rajasthan from levels that may be late third millennium (Kajale 1996), as well as from Burthana Tigrana(?) in Haryana (Willcox 1992); species level identification uncertain). Another South Asian cultivar in the same section of this genus (section *Ceratropis*) is the golden gram/*moth* (*Vigna aconitifolia* (Jacq.) Marechal). Moth, however, is not evident in the archaeobotanical record until the latter first millennium BC, and does not concern us in an account of Harappan agriculture. Two pulses of African origin, hyacinth bean/sem (*Lablab purpureus*) and cowpea (*Vigna unguiculata* (L.) Walp, Hindi *chowli* or *lobia*), became available in regions peripheral to the Indus Valley during the Late Harappan phase (after *c.* 1900 BC), with cowpea from Hulas (Saraswat 1993) and Daimabad (Vishnu-Mittre et al. 1986a) and *Lablab* from Sanghol (Saraswat and Chanchala 1997) and Mahorana (Saraswat and Chanchala 1994) in addition to numerous peninsular Chalcolithic sites, and the Southern Neolithic (see Fuller et al., n.d., Fuller, Vol. III of this series, for full details of archaeobotany).

Millets

'Millets' during the Harappan Civilization have drawn much attention, especially those from external geographical sources, due to their potential role in a Late Harappan agricultural 'revolution'. Millets are a heterogenous group of small-seeded, edible (usually cultivated) grasses, which include species in some nine different genera (*Brachiaria, Digitaria, Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum, Setaria, Sorghum*). In some cases there is more than one species in a genus that is known ethnographically to be used as a millet. Most millets can, with some degree of certainty, be assigned to their probable geographical regions of origin, which include Africa, East Asia (probably north China) and South Asia. Within these geographical millet groups no single diffused package is discernible, so that the history of each crop must be traced individually. Unfortunately it can be difficult to distinguish native South Asian species in the genera *Setaria* and *Panicum* from sister species originating in East Asia, and discussion of useful criteria needs to be pursued by practising archaeobotanists (for discussion of some of these criteria see Fuller et al. n.d.; Fuller, in Vol. III of this series). Since reliable and generally accepted criteria for the identification of the range of millets potentially encountered in South Asian archaeobotany is not available, published reports must be assessed critically. Especially problematic are reports of finger millet/*ragi* (*Eleusine coracana* (L.) Gaertn.) unaccompanied by illustrations, since a critical review of the illustrated specimens in addition to ongoing comparative study of modern and archaeological millet specimens, indicates that *Eleusine* has been frequently misidentified, and many reports consist of mistaken interpretations of charred caryopses of *Setaria* sp. and perhaps *Echinochloa* (Fuller et al. n.d.; see section 4.2 in Fuller, in Vol. III of this series). Possible mis-identifications are indicated in Tables 2-3 and with question marks on Figures 1-2. Reports which cannot be assessed for accuracy due to lack of illustrations and clear criteria are *tentatively* accepted for the sake of discussion.

Attention has often focused on Gujarat as the most likely region for the initial adoption of African millets (Possehl 1980, 1986; Weber 1991, 1998; Meadow 1996; Kenoyer 1998: 163). It was in this region where some of the earliest finds of African millets had been reported. These millets did not appear in this region as a single package but at different times. The reported evidence puts '*Eleusine*' at Rojdi by *c.* 2500 BC, while *Sorghum bicolor* (L.) Moench. and *Pennisetum glaucum* (L.) R. Br. (syn., *P. typhoides* (Burm.) Stapf. & Hubb.) appear as much as 500 years later in the Rangpur phase (Weber 1990, 1991, 1998; Ghosh and Lal 1963; Saraswat et al. 1995). At this time, the early second millennium BC, *Sorghum* and *Pennisetum* probably occur at Kaothe south of the Tapi river (there is some possibility of contamination at this site, Kajale 1990). Other early reports in Maharashtra are not until the Jorwe period, after *c.* 1500 BC, as at Daimabad (Kajale 1977) and possibly Inamgaon (Vishnu-Mittre and Savthri 1976; reservation is warranted, however, as this report was not accompanied by illustration and this presence was not confirmed through the systematic sampling programme reported in Kajale (1988). However, there is now evidence for African crops, including *Sorghum*, the pulse *Lablab*, and possibly *Eleusine* in Indian Punjab in the later Mature Harappan era, 2300-2000 BC, at Mahorana and Rohira (Saraswat and Chanchala 1994; Saraswat 1986). This suggests that earlier evidence for these crops in more coastal regions must await discovery. Reports of *Eleusine* from the Harappan north are more problematic. It has recently been reported from Harappa (Weber 1998), although full publication is still awaited. In the early second millennium BC, *Eleusine* is reported further east at Hulas in the Ganga-Yamuna Doab (Saraswat 1993), although the illustrations are more suggestive of *Setaria* caryopses and fragments of the rugose lemma/*palea* of *Setaria*. An impression of *Sorghum* has been reported from Pirak west of the Indus Valley, after *c.* 1900 BC (Costantini 1979) and, if confirmed, suggests that indeed *Sorghum* (and possibly other millets) spread throughout the Harappan region and were taken up in appropriate localities only after the collapse of Harappan integration (this issue is addressed further, below).

In considering evidence for foxtail millets (*Setaria* spp.) and panic grasses (*Panicum* spp.) it must be recognized that there are species indigenous to China and native to the monsoon grasslands of South Asia. Although both Chinese millets (*Setaria italica* (L.) P. Beauv. and *Panicum miliaceum* L.) have been identified on Late/Post-Harappan sites in Gujarat, it is unclear how these species were definitively distinguished from indigenous congeneric species, such as the edible *S. verticillata* (L.) P. Beauv., *S. intermedia* Roem. & Schult. (syn. *S. tomentosa* (Roxb.) Kunth.) and *S. pumila* (Poir.) Roem. & Schult. (the latter also domesticated) and the little millet (*Panicum sumatrense* Roth. ex Roem. & Schult.). The work by Weber (1991) and Reddy (1994) appears to have relied on differences of size alone, although no statistical studies of modern samples nor the effects of experimental charring are reported to support these metrical criteria. *Panicum miliaceum* L. has been positively identified from Kashmir in the Indo-Greek period, i.e. late first millennium BC (Lone et al. 1993). *Setaria* probably to be identified with *S. italica* (L.) P. Beauv. also comes from roughly the same period and region (ibid.). In addition, *Setaria* sp. caryopsis, and a rugose lemma similar *S. italica* type is illustrated from Hulas (Saraswat 1993; Pl. II, 10-12), although it was misidentified as *Eleusine coracana* (L.) Gaertn. *S. italica* (L.) P. Beauv. is also reported from Banawali (Lone et al. 1987). *Panicum miliaceum* L. is present at Shortugai in Afghanistan but not in the earliest levels that are thought to be associated with a Harappan foundation. This millet remains prominent at the site throughout the second millennium BC, i.e. after those levels with Harappan affinities, while *S. italica* is absent (Willcox 1991). If reported identifications are accepted, then *Setaria italica* is present in the north-western part of the subcontinent by the mid-third millennium BC, with only a few possible grains of *Panicum miliaceum* (Kajale 1996; Reddy 1997; Weber 1998); most *Panicum* having been attributed to the little millet (*Panicum sumatrense* Roth. *ex* Roem. & Schult.), a native of India (De Wet et al. 1983a; Hiremath et al. 1990). While De Wet et al. (1983a) tended towards the possibility of multiple domestications across India, Hiremath et al. (1990) argued that a region of the eastern peninsula was likely to have been a primary centre. The report of *Panicum sumatrense* Roth. *ex* Roem. & Schult. from Harappa back to *c.* 3000 BC (Weber 1998; Meadow 1998) could be indicative of a separate domestication in the north-western subcontinent. *Panicum/Setaria* type articulated phytoliths have been recently noted in samples from Harappa (Madella, unpublished data).

Other millets do not appear to have played a significant role during the Harappan periods in the north-western subcontinent. Two millets native to peninsular grasslands, Kodo millet (*Paspalum scrobiculatum* L.), a relic crop in parts of peninsular India today (De Wet et al. 1983b), and sawa millet (*Echinochloa colona* (L.) Link) was found from Rojdi C, in the Rangpur phase (Weber 1991), although the quantities were fairly small and could indicate that the species was present as a weed, or was insignificant in the overall subsistence. Another peninsular millet, browntop millet (*Brachiaria ramosa* (L.) Stapf, still lacks an archaeobotanical record.

The available evidence raises important questions about the eras of domestication and the routes of dispersal of these species. The presence of *Lablab*, *Sorghum* and perhaps *Eleusine* during the later urban period (Late Mature Harappan) on sites not too distant from Harappa, indicates that these crops must have become available through the trade networks of the Harappan Civilization and adjacent regions. The resource maps of Kenoyer (1995, 1998: 91-4) indicate that the most likely routes are via the Indus/Ghaggar-Hakkra Valley or perhaps up the Luni river and across the Thar desert. That these species were not adopted in more of the Harappan regions cannot be attributed to their unavailability but must be sought in cultural factors such as agricultural organization. While *Panicum sumatrense* Roth. *ex* Roem. & Schult. and the native *Setaria* spp. could have been native components of the Kathiawad grasslands, utilization of which was taken up independently by local communities, it is also possible that the practice of their utilization spread from the Deccan. Hiremath et al. (1990) suggested, although on admittedly slim evidence, that *P. sumatrense* may have origin in northern Andhra. If more detailed genetic studies on wild and cultivated populations bear this out, then a diffusion of this crop westwards prior *c.* 2500 BC would have to be envisioned. *P. sumatrense* Roth. *ex* Roem. & Schult., *Setaria verticillata* (L.) P. Beauv. and possibly *S. pumila* (Poir.) Roem. & Schult., and/or *S. intermedia* Roem. & Schult., were all cultivated by the Southern Neolithic peoples (northern Karnataka) from sometime in the third millennium BC (not yet well-dated) and these crops could have dispersed from there, although the lack of village sites back to 2500 BC in Maharashtra does not favour this view. On current evidence, therefore it seems plausible that the inhabitants of Gujarat (or elsewhere in the north-western subcontinent) began to utilize and domesticate *Panicum* and *Setaria* species that were available as wild components in the native flora.

Rice

The presence or absence of rice (*Oryza sativa* L.) from Harappan agriculture has long been an issue of controversy. While there is growing evidence for the cultivation of rice during this period in various regions of the subcontinent, there is no reason as yet to believe that it was an important crop for the Harappan Civilization, although it appears to have been locally important in some areas. Reported rice impressions from Kalibangan were mis-identified (Vishnu-Mittre and Savithri 1975). Impressions are also known from contemporary sites in Gujarat (Ghosh and Lal 1963; Ramesh Rao and Lal 1985) and

Rajasthan (Vishnu-Mittre 1969), while actual grain evidence for rice comes from Haryana (Willcox 1992) and Balathal in Rajasthan (Kajale 1996). In addition, rice phytoliths have been reported from Harappa (Fujiwara et al. 1992), and ongoing phytolith studies from the site confirm this presence (Madella, unpublished data). The macrobotanical remains also indicate rice at Harappa but only in the later urban period, after *c.* 2200 BC (Weber 1997). Impression of rice are also known from Ghaleghay II, 2500-2900 BC (Costantini 1987). This evidence suggests that rice was *available* as a crop for the Integration Era cities and towns of the Harappan region but not adopted. That rice does not feature in the agriculture, as it is presently understood, of the core regions of the Indus (including the Ravi river, e.g. Harappa during the early Mature phase, 2600-2300 BC) and Ghaggar-Hakkra systems, indicates that there must have existed aspects of the agricultural traditions and organization of Harappan Civilization which prevented the adoption of rice. Systems of irrigation, tillage and seasonal labour scheduling could all have operated against the spread of rice. Or less tangible cultural food values may have been involved. As previously discussed by Allchin (1984) regions along the northern Indus Basin, such as the Gomal and Swat Valleys, appear not to have participated in the urbanization and interaction systems that characterized the Mature Harappan Civilization despite the presence of Early Harappan sites in these areas. One of the contributing factors of this could have been that the rest of the Indus system, where the Harappan Civilization was established, shared in separate developments of agricultural production (Allchin 1984).

Fibres/Oilseeds

After the cereals and pulses, the most significant category of agricultural plants was likely to have been those that yielded fibres and/or edible oils. The most significant crop in this broad category for the Harappans may have been cotton which produces both textile fibres and oil from its seeds. Although disagreements persist, there are plausible arguments for the origin of one of the old world cottons, tree cotton (*Gossypium arboreum* L.) somewhere in South Asia, although the wild progenitor populations may now be extinct (Zohary and Hopf 1992; Wendel 1995). Early evidence of cotton seeds has been reported from Merhgarh, *c.* 5000 BC (Costantini 1983). Although some concern may be warranted given the uncharred preservation of this find (cf. reservations in Costantini and Biasini 1985: 24), the date is approximately as should be expected given that cotton had reached the Arabian peninsula by *c.* 4400 BC (Betts et al. 1994), although cotton cultivation in Mesopotamia is not documented until much later in the first millennium BC. Cotton cloth was found at Mohenjo Daro (Gulati and Turner 1929; Janaway and Coningham 1995), while better evidence for cultivation, seeds, have only been reported from Hulas in the Late Harappan, 1800-1300 BC (Saraswat 1993), and Loebanr 3 in Swat (Costantini 1987). Possible cotton pollen was reported from Balakot (McKean 1983; see Dales 1986).

Somewhat better documented archaeobotanically is flax/linseed (*Linum usitatissimum* L.), which is of South-West Asian origin and was incorporated from an early date into the

Neolithic package of the fertile crescent (Zohary and Hopf 1993). Although the cereals and most of the pulses of this package are known from Urban period Harappan sites, flax has only been reported from Nausharo (Costantini 1986, 1990) and at Chalcolithic Balathal, a site outside the Harappan orbit but contemporary (Kajale 1996). There are numerous finds, however, from the Late/Post-Urban phase, i.e. early second millennium BC, such as at Rojdi, phase C (Weber 1991) and Pirak (Costantini 1979b).

Possible seeds of jute (*Corchorus capsularis* L. or *C. olitorius* L.) were recovered from Rojdi (Weber 1991: 69). Although most of the *Corchorus* seeds recovered represented modern contamination, 19 charred examples came from secure archaeological contexts. Although two of the species in this genus are cultivated today for fibre, it is generally assumed that they were domesticated as fibre crops relatively recently as 'a deliberate attempt to search for new fibres to replace hemp in cordage and sacking' (Singh 1995: 476). Nevertheless, these and related species could have been utilized for fibre from a wild state, and some species also have edible parts. As these species are herbaceous annuals, their archaeological occurrence could also be due to their presence as arable weeds in the past. Another possible fibre crop which entered South Asia during the Harappan era may have been hemp (*Cannabis sativa* L.). Hemp has been reported in the form of charcoal from Neolithic Senuwar in Bihar, 1800-1200 BC (Saraswat et al. 1995). This species is thought to originate in temperate Central Asia, Afghanisatan or parts of the Himalayas (Small and Cronquist 1976; Zohary and Hopf 1993: 126). It is thought to have been present in China by the early third millennium BC (Li 1974). Preliminary study of phytolith samples from Harappa include morphotypes that have been provisionally identified as hemp (Madella, unpublished data). As is well-known, this species provides a psychotomimetic drug as well as fibres.

Oilseed finds have also been rare. Sesame (*Sesamum indicum* L.), which may have originated in South Asia (Bedigian and Harlan 1986; Zohary and Hopf 1993) has been reported from Harappa (Vats 1941: 467; Allchin 1969) and a Mature Harappan phase site in Makran (Tengberg 1998). That sesame had been domesticated by this time is given further confirmation by its presence in the third millennium in Mesopotamia (Charles 1989), thus making the identification of sesame with 'oil-plant' in Sumerian literature plausible (cf. Postgate 1985; Zohary and Hopf 1993: 133).

There are number of other oil crops, of various origins, that have been sparsely reported. The source of castor oil (*Ricinus communis* L.), thought to have originated in Africa is reported from Hulas, 1800-1300 BC (Saraswat 1993), and must therefore be added to the list of early crops to arrive in South Asia from Africa. Some sort of mustard (*Brassica* sp., probably *B. campestris* L., brown sarson) was also probabaly cultivated for its oily seeds, with occassional finds of *Brassica* from Rojdi (Weber 1991: 66), Babar Kot and Oriyo Timbo (Reddy 1994: 253, 284), and Mohenjo Daro (Vishnu-Mittre and Savithri 1982). A single record of poppy seeds (*Papaver* sp.) comes from the Bara phase at Sanghol in Punjab (Saraswat and Chanchala 1997); these seeds are to differ from the domesticated *P. somniferum* L. As this species probably arose from the wild *P. somniferum* subsp. *setigerum* (DC) Arc. of the western Mediterranean (Zohary and Hopf 1993: 128-30), we would expect it to be fully recognizable by the time it reached India and the Hulas find should perhaps be attributed to another species in the genus. The safflower, *Carthamus tinctorius* L., probably from South-West Asia (Zohary and Hopf 1993), has been recovered only from sites of inner India in Post-Harappan periods, including Jorwe phase Daimabad (Kajale 1977) and second millennium BC Senuwar in Bihar (Saraswat et al. 1995).

Melons, Cucumbers, Squashes

Seeds of the cucurbitaceae have been reported from a number of sites. Melon (*Cucumis melo* L.) seeds were recovered in the early excavations at Harappa (Vats 1941). *C. melo* L. was probably domesticated in South-West Asia from wild types indigenous to that area. while modern Indian and East Asian forms are thought to derive from a separate domestication from tropical varieties (Zohary and Hopf 1993: 182). Which type was present in the Harappan region is unclear. *C. melo* L. was also probably present on the Peninsula from at least the Malwa period, 1700-1500 BC (Kajale 1988). At Hulas, 1800-1300 BC, seeds of the Ivy gourd/*kundru* (*Coccinia grandis* (L.) Voigt., syn. *C. cordifolia* (L.) Cogn.) were found (Saraswat 1993); this species is wild and sometimes cultivated in India. *Cucumis* spp. have also been identified from Rojdi C, 2000-1700 BC, which include the native, wild *C. prophetarum* L., and two other undetermined species (Weber 1991). *Cucumis* sp. (which could be a wild species, *C. melo* L. or *C. sativus* L., the cucumber, probably native to the Himalayan belt) is reported from Chalcolithic Balathal (Kajale 1996) and Loebanr 3, 1700-1300 BC (Costantini 1987: 158). Pollen of a cucurbit was present in the archaeological strata at Balakot (McKean 1983; Dales 1986).

Arboriculture

Fruit trees (and perennial vines) are a category of food plant that almost certainly had a separate history from the cereals and pulses and developed through a different process of arboricultural domestication (Zohary and Spiegel-Roy 1975; Zohary and Hopf 1993: 134-7). Cultivated dates (*Phoenix dactylifera* L.) are probably of South-West Asian origin and the earliest archaeological finds come from Ubaid period Mesopotamia, fifth millennium BC (Zohary and Hopf 1993). The reported stones from Mehrgarh appear to be broadly contemporary with this (Costantini 1983). Dates have presumably had a presence in the Indus Valley ever since, with reported finds coming from Harappa, Mohenjo Daro (Marshall 1931: 27; Sahni 1931: 215; MacKay 1938: 220, Vats 1940) and Nausharo (Costantini 1990a). The domesticated date, important in the north-western subcontinent must not be confused with the Indian wild species, *Phoenix silvestris* (L.) Roxb. which has been reported from a few sites in inner India (e.g. Kajale 1988). Palm phytoliths, although not identifiable to species, are a regular component of samples from Kot Diji Harappa (Madella 1995, 1997, 1998, unpublished), and are most likely to have derived from groves of date palms. Also palms (perhaps dates) were a common motif on Harappan painted pottery (MacKay 1931: 324, 1938: 220; Vats 1940: 290).

Other fruits that came to the Indus Valley from the west were grapes (*Vitis vinifera* L.) and hackberries (*Celtis caucasica* Willd., syn. *C. australis* auct. pl. non L.). Grape pips have been reported from Nausharo, Baluchistan (Costantini 1990a), Rohira, Punjab (Saraswat 1986), Mahorana (early Bara Culture/Late Harappan), *c.* 2300-2000 BC (Vishnu-Mittre et al. 1986b), as well as Post-Harappan contexts in the Swat Valley, such as Loebanr 3, *c.* 1700-1400 BC (Costantini 1987) and Burzahom in Kashmir after *c.* 1700 BC (Lone et al. 1993). In addition, the cultivation of grapes is suggested by wood charcoal from Baluchistan, Punjab, and Post-Harappan Kashmir (Thiebault 1988a, 1988b, 1989, 1992, 1995; Saraswat et al. 1990; Lone et al. 1993: 180). Hackberries/ *kharak* (*Celtis caucasica* Willd.) may have come to South Asia in the Late Harappan period where they have been recovered from sites in the northern periphery, such as Swat (Costantini 1987) and Kashmir (Lone et al. 1993). This species is thought to originate in the eastern Mediterranean (Zohary and Hopf 1993).

Arriving in South Asia also originally from the West were two nuts. One is the almond (*Amygdalus communis* L., syn. *P. amygdalus* Batsch., *Prunus dulcis* (Miller) D. Webb) an early nut of South-West Asia (Zohary and Hopf 1993; Browicz and Zohary 1996) reported from Late Harappan Hulas, after *c.*1800 BC (Saraswat 1993) and Kashmir after *c.* 1700 BC (Lone et al. 1993). Almonds are reported wild over a wide area from the Levant and Turkey to Central Asia. While some authorities have considered Central Asia as the likely home of the Almond (e.g. Kester et al. 1991), more recently Browicz and Zohary (1996) have questioned this since wild species of the same subgenus are absent form this region. Thus South-West Asia is most likely to have been the region where almonds were originally wild (Zohary and Hopf 1993: 173-7). The two early finds from India are both from the only regions where almonds have been grown in recent times, namely Kashmir and Punjab (Watt 1908). Also common walnuts (*Juglans regia* L.) arrived by this time. They have been reported from Neolithic Kashmir (Lone et al. 1993) and Late Harappan Hulas (Saraswat 1993). This species could have come into Kashmir from the north as it is known wild in pockets today from the north-eastern Turkey, north Iran through the Caucasus to Central Asia and the Tien Shah province of western China (Zohary and Hopf 1993: 177-8).

Several fruits native to South Asia may have already been present in the Indus Valley or else derive from further east. *Zizyphus mauritania* Lam. (syn. *Z. jujuba* (L.) Gaertn., nom. illeg.), a frequent archaeobotanical find was available locally, as the widespread occurrence of *Zizyphus* wood charcoal attests (Thiébault 1988a, 1988b, 1989, 1992, 1995; Castelletti et al. 1994). At some undetermined period, this species was brought into cultivation and diffused westwards to South-West Asia, Egypt and sub-Saharan Africa (Zohary and Hopf 1993). In addition the sour caper (*Capparis decidua* (Forsk.) Edgew.), present in wood charcoal assemblages (Castelloeti et al. 1984), was probably utilized from the local flora although hard evidence is still lacking. Fruits from more tropical regions to the east that may have been utilized in mango (*Mangifera indica* L.), *jamun* (*Syzygium cumini* (L.) Skeels) and *amla* (*Phyllanthus emblica* L, syn. *Emblica officinalis* Gaertn.) but hard evidence has not yet been recovered archaeobotanically. Evidence for the latter two crops comes from the Chacolithic Deccan (Vishnu-Mittre 1961; Kajale 1988), while the only evidence for mangoes comes from Iron Age wood charcoal in the middle Ganga plain at Narhan (Saraswat et al. 1994). Seeds of some sort of fig (*Ficus* sp.) were present through the cultural sequence at Rojdi and probably indicate the collection and use of wild(?) fruits (Weber 1991). A single find of a *Ficus* sp. seed from Babar Kot, although classified by Reddy (1994: 269, 285) as a weed of crop processing, could also indicate a one-off inclusion of seed from fruit consumption. The leaves of the *pipal* tree (*Ficus religiosa* L.) are amongst the most common plant motifs on Harappan painted pottery (MacKay 1938: 220; Vats 1940: 290).

The only early archaeobotanical evidence for *Citrus* fruits comes from the Late Harappan (Bara phase) site of Sanghol in Punjab where seeds of lemon (*C. limon* (L.) Burm. f.) have been reported (Saraswat and Chanchala 1997). This is of great interest as these fruits are thought to have been domesticated somewhere in the area spanning from north-eastern India to south China and South-East Asia, although there remains no firm evidence for precisely where or when (Roose et al. 1995). This evidence suggests that lemons diffused westwards, presumably along the Ganga Valley in the early second millennium BC. Further west, in South-West Asia, the citron (*C. medica* L.) occurs as early as *c.* 1200 BC, while the lemon arrives later in the first millennium AD (Zohary and Hopf 1993).

Additional fruits which entered the subcontinent during this general period were two species of *Prunus*, which being better suited to more temperate climates, appear to have been adopted only in Neolithic Kashmir (Lone et al. 1993), including peach (*P. persica* (L.) Batsch), and apricot (*P. armeniaca* L.). Both of these species are thought to be native to mountainous areas in Tibet, western China and the Tien Shah mountains of Central Asia (Zohary and Hopf 1993: 172; Watkins 1995). These species, like the lemon, only reached South-West Asia and Europe much later, at the end of the first millennium BC. An additional *Prunus* sp., but presumably not almond, has been reported from Baluchistan from as early as Mehrgarh II, 4500-4000 BC (Costantini and Biasini 1985; Costantini 1986, 1990). It may be that this represents locally wild, collected fruits. Otherwise they would indicate quite early arboriculture. More specific identification details are needed.

The above evidence suggests that these fruits species diffused from further west. Their arrival should not be seen as part of the initial Neolithic founder package, as there is no evidence that they were cultivated yet in South-West Asia at the period contemporary with early levels at Mehrgarh. In general, grapes and arboriculture may not have become important agricultural practices until *c.* 4000 BC (Zohary and Hopf 1993). Thus the adoption of fruit vine and tree crops in the Greater Indus Valley should be seen as part of a process of agricultural expansion during the Regionalization Era in which more complex forms of social organization and redistribution emerged in the Pre-Harappan cultures and long-distance trade with the west made exotic perennial corps available. The above evidence suggest that there was little diffusion of fruit crops from South Asia to the west until the period that is definitely Post-Urban/Late Harappan. This is in contrast with the adoption of fruits from the West into South Asian cultivation prior to or during the Harappan era, continuing during the Post-Urban/Late phase, and the spread of selected South Asian field crops like sesame and cotton further west also during this earlier period.

Bananas (*Musa paradisiaca* L.), have been identified on the basis of a common ceramic motif, noted first as Mohenjo Daro (Wheeler 1968: 85; MacKay 1938: 220, Pls. LXIX 15, LXX 5, 18; Marshall 1931: Pl. XCII 5, although this latter images were first suggested to be a 'millet' by MacKay 1931: 324). As domesticated bananas are seedless, they cannot be recovered through conventional archaeobotanical sampling, although it is clear that they produce distinctive phytolith forms (Tomlinson 1969; Wilson 1985). Ongoing study of phytolith samples from Kot Diji by one of us (Madella), indicates the presence of possible *Musa* phytoliths, and the necessary comparative study is underway. If confirmed this is of great interest, as domesticated bananas are thought to have originated from southern South-East Asia, in present-day Indonesia, from mutations in wild *M. acuminata* Colla. Within India, these cultivars were hybridized with *M. balbisiana* Colla, presumably native to the southern and eastern India and Sri Lanka, which provided adaptation to drier and monsoonal climate (Simmonds 1995). Evidence of wild banana seeds from an Early Holocene site in Sri Lanka (Kajale 1989) probably attest to traditions of utilization of *M. balbisiana* by cultures in southern India, within which hybridization with domesticates could have occurred at a later date. *M. balbisiana* Colla, does not have a sweet flavour and is seldom eaten as a fruit today. Sweet hybrid varieties of bananas were apparently not present in Sindh at the beginning of the twentieth century AD. Cultivation of *M. paradisiaca* L. hybrids on an intensive scale began only after partition (Rahman 1993: 186-7). The Harappan period evidence could indicate either a discontinuity in the cultivation of sweet bananas in some Post-Harappan era or else the utilization of non-sweet, starchy varieties.

THE HARAPPAN ROLE IN THE DIFFUSION OF AFRICAN CROPS: A RECONSIDERATION

A popular theme in discussions of Harappan archaeobotany is the presumed role of Harappan long-distance trading networks in introducing and disseminating crops, especially millets of African origin. Possehl (1980: 8-9, 54) suggested that millets from Africa played an important role in the subsistence of Gujarat in the Harappan and Post-Harappan periods. These millets included *bajra*/pearl millet (*Pennisetum glaucum* (L.) R. Br.), *jowar*/sorghum (*Sorghum bicolor* (L.) Moench., and ragi/finger millet (*Eleusine coracana* (L.) Gaertn.). In addition, there has been much interest in reports of *Sorghum* in the early second millennium BC of North-Western South Asia (e.g. Costantini 1979; Costantini and Biasini 1985; Jarrige 1985; Tosi 1986; Ratnagar 1994: 123; Haaland 1995; Possehl 1997, 1998). The presence of these crops on sites in this peripheral region contrasted with the dominance of winter crops in the Harappan 'core' (the Greater Indus Valley). The distinctiveness of cropping in Gujarat has been taken up by other authors and supported by a growing archaeobotanical database in which wheat and barley are under-represented while millets play an important role (e.g. Meadow 1989, 1996; Dhavalikar 1995; Weber 1991; Reddy 1994, 1997). This evidence has been compared with that from Pirak in Baluchistan from the Late/Post-Harappan period (early second millennium BC), where *Sorghum* sp. and *Panicum* sp. were reported (Costantini 1979), in order to argue that on the periphery of the Harappan Civilization a transformation in agriculture took place in the Late Harappan period in which exotic summer crops were adopted (Costantini and Biasini 1985; Jarrige 1985, 1997; Cleuziou and Tosi 1989; Meadows 1989, 1996, 1998; Franke-Vogt 1995: 32-4; Singh 1996). Possehl (1986) also put forward the hypothesis that millets of African origin (finger millet/*ragi*, pearl millet/*bajra*, and sorghum/*jowar*), which became available through Harappan long-distance trade by the end of the third millennium BC, played a critical role in the establishment of agriculture in peninsular India and allowed agricultural lifeways to develop in the savanna environments of inner India (cf. Hutchinson 1976). However, despite the continuing attraction of this narrative, it remains a 'just-so' story.

A critical re-examination of the available evidence for crops of African origin (not just the millets) in prehistoric South Asia undermines the likelihood both of the primary importance of African crops and the role of Harappan long-distance trade (see Fig. 3; for details of the evidence beyond that discussed earlier, see Fuller, in Vol. III of this series; Fuller et al. n.d.; cf. Kajale 1991). First of all, a number of the earlier reports of *Sorghum*, especially from pottery impressions, have been called into doubt (Willcox 1992; Rowley-Conwy et al. 1997; Deakin et al. 1998; Fuller et al. n.d.; Fuller, in Vol. III of this series). Nevertheless, there remain valid reports of prehistoric *Sorghum* from India which argue against Rowley-Conwy et al. (1997) hypothesis of a late domestication. In addition, finger millet has been widely identified, although critical re-examination of the published record suggests that many of these are mistaken identifications of other small millets, especially *Setaria* spp. and possibly *Echinochloa* spp. (see above and Fuller et al., n.d., Fuller, in Vol. III of this series). When the doubtful reports are removed, the distribution of most of the finds falls outside the Harappan area. Although less widely reported, pearl millet also is both external to and post-dates the Harappan Civilization. Also of critical importance but largely undiscussed in the past are two pulses of African origin, *Lablab purpureus* (L.) Verdc. and *Vigna unguiculata* (L.) Walp. (which is *not* the *V. unguiculata* reported by Weber from Rojdi, see note 1). These finds make it hard to accept a dispersal through Harappan trade. *Ricinus communis* L., the castor plant, also probably came from Africa and was present at Hulas in the early second millennium BC. The evidence as it stands does not suggest that any of the African millets were crucial to the settlement of the Indian peninsula as Possehl (1986) had suggested, but rather that they were incorporated at an early stage into pre-existing agricultural systems. Indeed finds of winter cereals (wheat, barley), as well as winter and summer pulses are as early or earlier than African millets at all well-reported sites. More importantly, as Weber (1998) suggests, the African millets appear to be adopted into a region where there is evidence for indigenous millets already present (also, Meadow 1998), and indeed emerging evidence from the southern Deccan suggests that the first cultivation in that region may have depended entirely on indigenous pulses and millets, and could have provided a pre-existing monsoonal cropping system (Fuller et al. n.d.).

The available evidence is suggestive of a gradual and piecemeal adoption of African crops in South Asia. This need not surprise us, since our current understanding of the botanical evidence for wild progenitors of African crops indicates that they were domesticated in widely separated regions of Africa (Fig. 3). None of the sites from which one species has been reported have evidence for the rest of the crops of African origin, although African crops do often co-occur in pairs. Hyacinth bean (*Lablab purpureus* (L.) Verdc.) co-occurs with one or the other of the reported millets from peninsular sites of the early second millennium BC (see Fig. 3). However, hyacinth bean also appears to have spread more widely, and has been found recently in relatively large quantities for the latter period of Southern Neolithic sites for which there is no evidence for African millets (finger millet reports appear to be largely mistaken from this region; see Fuller et al., n.d.; Fuller, in Vol. III of this series). The co-occurrence of *Sorghum* with other African crops, such as cowpea and castor at Hulas. (Saraswat 1993), and both *Lablab* and cowpea at Daimabad (Kajale 1977; Vishnu-Mittre et al. 1986a), strengthen the case for the presence of *Sorghum*. These finds therefore contradict the claims for a late first millennium BC domestication of this crop, argued from Nubian evidence by Rowley-Conwy (1991; Rowley-Conwy et al. 1997; Deakin et al. 1998).

Despite enthusiastic arguments on the part of a number of archaeologists, there remains no good archaeological evidence for trade or direct contact between prehistoric South Asia and Africa. S.R. Rao (1973) argued for contact with East Africa and Egypt on the basis of supposed baboon and mummy figurines, although these have not been accepted as Egyptian types (Chakrabarti 1990: 40). Similarly, some authors have pointed to ceramic headrests from south Indian sites as evidence for contact with Africa, where this tradition is known, spanning back to ancient Egypt (Allchin 1966; Nagaraja Rao 1970). However these latter arguments ignore the existence of a similar tradition in South-East Asia and the Pacific; and do not take into account the equally likely possibility of a local development (and subsequent abandonment) of such a tradition. Dhavalikar (1995) presents an argument that the presence of finger millet on sites in Saurashtra indicates contact with East Africa and Egypt, since *Eleusine* comes from Ethiopia—ancient Axum and/or *Punt*(?)—and Ethiopia was part of the Egyptian Empire. The latter claim is certainly not accepted by most Egyptologists, and finger millet is not known from Pharaonic Egypt (for a recent review of the relationship between Egypt and ancient Ethiopia, see Phillips 1997; Kitchen 1993; for Egyptian archaeobotany, including artistic evidence, see Germer 1985). Despite the wealth of evidence for Harappan involvement in trade with Mesopotamia and the Persian Gulf (Powell 1983; Cleuziou 1984; Mitchell 1986; Tosi 1986; Chakrabarti 1990; Potts 1993; Ratnagar 1994; Possehl 1997, 1998), there is nothing to indicate contact with Africa, or even with the Yemen side of Arabia. The archaeobotanical presence of crops of African origin, despite a number of likely misidentifications, is suggestive of at least indirect contact, but this evidence is stronger for peninsular India than sites within the Harappan orbit, although the earliest evidence to date does appear to occur in Harappan Punjab (see above). As a number of Harappan and Post-Harappan sites have now been explored in Gujarat without any clear evidence of contact, there is need for a contemporaneous site to be found and explored on the Konkan-Kerala coast where the first evidence of African-Yemeni contact should perhaps be sought.

NON-CROP SEEDS

Archaeobotanical samples often contain seeds of herbaceous species that are not those of well-established crop plants, both in India and elsewhere. Large assemblages of non-crops species were quite rare prior to the use of flotation in sampling, although one large, anomalously diverse assemblage including 25 species was recorded from Late Harappan Surkotada (Vishnu-Mittre and Savithri 1978; Vishnu-Mittre 1990). A few other samples with quantities of non-corps come from Sanghol (Saraswat and Chanchala 1997), Shikarpur (Saraswat et al. 1995), Loebanr 3 (Costantini 1987). On the other hand, most sites sampled using flotation have yielded relatively large numbers of non-crop species, e.g. Rojdi (Weber 1991), Babar Kot and Oriyo Timbo (Redy 1994), Balathal (Kajale 1996) and Burzahom (Lone et al. 1993). The traditional approach to these taxa has been to assume that these were utilized and therefore to seek ethnographically documented uses, as famine foods, condiments, medicines or the like (e.g. Weber 1991). However, ethnoarchaeological studies and a large number of archaeobotanical analyses in Europe and the Near East argue strongly that most, if not all, of the non-crop seeds recovered archaeologically because they were weeds that infested cultivated fields and were therefore harvested inadvertantly with the crop and removed during crop processing leading to their presence in significant quantities in habitation areas (e.g. Hillman 1981, 1984; Jones 1984, 1987; Reddy 1994, 1997). Subsequently, charring leads to their preservation. Thus the taxa present may not provide the type of information suggested by Weber, can on the other hand offer potentially more important insights into the ancient ecology of cultivated fields, while changes in the assemblage composition can be used to infer changes in agricultural practices (or the practices of crop-processing). Another potential source argued for South-West Asian and some South Asian weed assemblages is through dung used as fuel (Bottema 1984; Miller 1984; Reddy 1994; Charles 1998).

Some taxa may occur as either weeds or crops and their status must be assessed for each individual case. Kodo millet (*Paspalum scrobiculatum* L.), for example, is today a well known weed of cultivation, especially of rice, as are *Echinochloa colona* (L.) Link and *Coix lachryma-jobi* L. (Job's tears) (Hohn et al. 1977). Indeed all of the native millets are potential weeds. But experience has shown that most charred assemblages are dominated by likely crop plants (especially cereals), so that large quantities of potential millets in an assemblage can be assumed to represent a crop [good examples are furnished by the quantities of *Setaria*, *Panicum* and '*Eleusine*' at Rojdi, Babar Kot and Oriyo Timbo (Weber 1991; Reddy 1994, 1997)]. Large quantities of species other than cereals or pulses, are more difficult to interpret.

A controversial example is that of *Chenopodium album* L. at Rojdi, which Weber (1991) argues was harvested as a crop. *C. album* L. is widespread in Eurasia as a weed (Hanf 1983; Langer and Hill 1991: 207), and in modern times at least has been widespread in South Asia as a weed of cultivation and disturbed ground. It is nuclear whether or not *C. album* occurred wild in India in the past, although a perusal of floras does not suggest populations unassociated with human impact. Thus we can expect it to turn up on archaeological sites as a weed. Within South Asia, however, there is ample ethnographic evidence for this species being harvested and indeed cultivated in widely separated regions both as fodder and for human consumption, including both leaves and seeds (Watt 1908: 293; Weber 1991: 67-8, 121-2; Reddy 1994: 201). Weber's attribution of crop status to *C. album* at Rojdi during phase B rests on the ubiquity (32 per cent of secure provenances) and large quantities (57 per cent of seed from secure provenances) recovered from Phase B, in particular stratum 9: 'In light of the large volume of *C. album* seeds and their density, it is difficult to imagine how their presence could be due to anything other than intentional collection' (Weber 1991: 121). However, most of this quantity is accounted for by a single sample that contained 476 *C. album* seeds (Trench 46L, stratum 9). Reservation is warranted as *C. album* is a prolific seed producer, with individual plants averaging 3,000 seeds and having as many as 20,000 seeds (Hanf 1983: 202). In many other samples *C. album* occurs as one or a few seeds, not significantly different than the *Chenopodium* sp. quantities reported by Reddy (1994) from Babar Kot and Oriyo Timbo. Weber further argued that because the seeds of this species could be harvested and processed much like the small millets (see also Reddy 1994: 201), which were also present at Rojdi, this species may have been categorized together with the millets (Weber 1991: 122, 144). While *C. album* does occur in higher densities and ubiquities than most non-millet taxa, it remains less frequent than the millets overall, and notably so when the one sample with 476 seeds is removed from consideration. The overall ubiquity of *C. album* is not significantly different from *Trianthema*, a well-documented weed of millets (cf. Reddy 1994, 1997). It is certainly possible the *C. album* was used, and it is likely that it was utilized on at least a small scale, but it is difficult to accept the argument that it was utilized as a crop when this interpretation relies on its large quantity in a single sample. At present, therefore, the evidence for whether or not *Chenopodium album* was cultivated at Rojdi during any period remains inconclusive. If Weber's argument is considered plausible, then it raises the question as to why at the particular site of Rojdi during this particular period, late Mature Harappan (2200-2000 BC), *Chenopodium album* L. became important Weber (1991: 122) suggests that decreasing production of millet surpluses may have promoted use of *C. album*. That this may have been connected to decreasing security in intersite trade in foodstuff is worth considering, and it is notable that while barley was recovered in Rojdi, phase A, in small quantities, probably imported, it and other winter crops are absent from Rojdi B. Weber's (ibid.) contention that it would have been harvested in spring, rather than autumn, seems problematic, given that floristic reports indicate the normal flowering time as November after the monsoons (Cooke 1908), similar to that of millets.

If we accept that most of the taxa present in the Rojdi samples were crop weeds, entering the archaeological record through repetitive crop-processing activities, it become possible to examine changes in the composition of the Rojdi assemblages through time in terms of changes in either arable ecology or the organization of crop-processing activities. The evidence from Rojdi points to a substantial change in assemblage composition between phases B and C, i.e. *c.* 2000 BC (Weber 1991: 135-8). Rojdi C showed a greater diversity of taxa, especially a greater range of recovered food plants, such as pulses, additional millet taxa (*Sorghum*, possibly-cultivated *Echinochloa* and *Paspalum*), and possible oilseeds (*Linum* and *Brassica*). In addition, several new 'weed' taxa occurred while others were present in much larger quantities than previous levels. Most notably *Carex* was found in large quantities while it has previously been absent. *Cyperus articulatus* L./*rotundus* L. and *Fimbristylis* cf. *tenera* Roem. & Schult., although present previously, were recovered in larger quantities. As all of these taxa are sedges (cyperaceae), a family generally associated with wetlands, it suggests that a new or previously lightly-exploited type of micro-environment was being used for cultivation, areas with higher water tables, such as river or pond edges. Several of the other taxa present only in phase C. could also have come from such environments, including *Echinochloa colona* (L.) Link, *Paspalum scrobiculatum* L., and *Neptunia* sp., which could be the aquatic *N. prostrata* (Lam.) Baillon, although this genus also includes non-aquatic shrubs.

Another possible change in Rojdi C may have been in the organization of crop processing. Weeds in general were more common and more diverse than in previous periods (Weber 1991: 152). Their presence could be due to cultivation in a greater range of micro-environments or alternatively be a simple reflection of processing techniques that allowed more efficient separation of weeds from crops. In addition, as Weber (1991: 154) notes, there is a decrease in the density of wood charcoal which could suggest that other fuel sources, in particular dung, were increasingly used, and may have introduced more non-crop seeds to the site and/or to the record, since they would get charred. The relative proportions of the different millets also underwent change, with *Setaria*, including *S.* cf. *italica* (L.) P. Beauv. and *S.* cf. *pumila* (Poir.) Roem. & Schult. (reported as *Setaria glauca* nom. illeg.) becoming more common. *Setaria* was also found in a less-processed state in this level, often retaining its glumes (Weber 1991: 131). While Weber sees this increase in *Setaria* as indicating an increase in the use of this species, the fact that it is found in a different state than previously, i.e. less-processed, suggests that the change might be due to differences in handling the crop in period C. This suggests that *Setaria* was less fully processed at the time of harvest which might mean that harvesting and storage had become less centralized, at least for this particular crop, since the large labour investment needed to process an entire harvest at one time would imply some sort of community centralization. This lack of community-based labour investment could reflect actual social change or reflect a decrease in importance for this particular crop that relegated it to family-level processing, due to increasing emphasis placed on other, more productive crops, such as the newly adopted *Sorghum*.

Thinking of archaeobotanical assemblages in terms of crop-processing, it becomes possible to examine issues of the social organization of agricultural production. Hillman (1981, 1984) first suggested that producer sites, those that harvest and process grain from their own fields, and consumer sites, i.e. those that import their grain, ought to be distinguishable on the basis of the chaff components and weed types present (see also M. Jones 1985; Van der Veen 1992; Thompson 1996; Fuller, in Vol. III of this series, section 3.1). This model was adapted by Reddy (1994, 1997) for millet-based agriculture and applied in her interpretation of the archaeobotany of Oriyo Timbo and Babar Kot. Reddy observed that the weed taxa and chaff that are normally by-products from the early stages in crop processing were absent from Oriyo Timbo but present at Babar Kot, and therefore concluded that Oriyo Timbo had been consuming millets cultivated elsewhere. This assumes, however, that all stages of crop-processing will be preserved archaeologically in all cases; there are obvious problems with any assumption of 'total' preservation. It is more parsimonious to assume that those processing stages represented by archaeological assemblages are the activities carried out most frequently (repetitively) on site, in the vicinity of fires, during the life of the site: this latter approach argues from what is preserved rather than what is not. While the contrast between Oriyo and Babar Kot is significant, it may well be attributable to a different form of organization of the harvest and storage, in which at Oriyo Timbo move of the processing was done in bulk prior to storage, with only the final phases of cleaning done immediately before food preparation. While there are other reasons to believe that cultivation was not carried out at Oriyo, in particular evidence that it was inhabited seasonally in the dry season, March-June (Rissman 1986), the archaeobotany does not reflect 'consumption' so much as a greater degree (and organization?) of crop-processing done ahead of time, before the millets are taken up for day-to-day preparation on site. This could indicate a greater degree of community organization in the processing, storage and redistribution of millets during this later phase, 1700-1400 BC, at least in some areas of Gujarat where cultivation and transhumant pastoralism were well integrated.

Despite the remaining uncertainties, the evidence from the systematically reported samples from Rojdi, Babar Kot and Oriyo Timbo clearly illustrate the potential of archaeobotanical evidence for more than merely assessing crop presence. Instead, assemblages can be related to practices of cultivation and crop-handling. These practices in turn may relate to larger issues of social organization and complexity.

ISSUES OF IRRIGATION

The question of the presence of an irrigated agriculture in the Greater Indus Valley has often been an issue of controversy (see, e.g. Chakrabarti 1995: 43-6, 49-51, 87-8; Misra 1984). The Indus flows in a typical alluvial plain as a result of two main features: the insufficiency of the main channel for carrying the maximum flood discharge and the immense quantity of silt suspended in river's water (Lambrick 1986). During periods of maximum flooding, the river tops its banks and the bed is incapable of containing the muddy waters which pour out over the plains. This process leads to the formation of gentle slopes on either side of the river bed, leaving the river 'suspended' with respect to the rest of the landscape. Nevertheless, part of the flood concentrates into well-defined flood channels, which in turn often overspill their banks. The whole alluvial plain then is constructed by the ridges (*kacchas*) along the river beds and the secondary channels and valleys in between. The ridges and parts of the valleys must have been covered in the past with forest growth of varying extent and density. It is still possible to observe tracts of this forest in Sindh today. In Punjab, where the high gradient of the river is still sufficient to cause erosion during any season, the river beds are carved into the plain. These floodplain beds, known as *khadir*, may be several miles wide and the river is free to meander within them. The raised land between two *khadirs* is known as *bhangar* or *bar*.

Prehistoric agriculture in the Greater Indus plain would probably have been carried out in areas with different hydrological characteristics, and it might be envisaged that lands were arranged along a gradient of water availability. *Rabi* (winter) crops could have been grown following the *sailabi* (inundation) technique along the spillage areas (in the valleys) and the *kacchas* (river ridges). During the nineteenth century, and the first half of this century the sailabi technique was still used in Sindh (Chakrabarti 1995: 49-50; Lambrick 1986). The land is submerged by the spill of the flood and is sown in autumn (October-November) when the inundation passes, often without ploughing or manuring the fields, especially in the *kacchas*. The *rabi* crops (barley, wheat and associated pulses) can be reaped in March or April. Further watering is not necessary, but additional water might come from winter rains in early January. The whole procedure involves minimal labour, energy and use of implements. Raised land like the *bhangar* might have seen the use of the *shadoof* technique, where water is raised from a well and distributed in the field by means of small (ephemeral) earth-works. A linear representation of a man operating a *shadoof* is reported by Lambrick (1986; provenance unclear) to suggest that the Harappans were acquainted with this technique.

In the Harappan agricultural economy there is also evidence for some *kharif* (summer) crop production. Once more there is no need to infer the presence of complex architectural structures devoted to irrigation, as *kharif* cultivation was still practised, until very recently, without the need of canal irrigation systems (Misra 1984; Chakrabarti 1988: 96, 1995: 50; Lambrick 1986). The chosen piece of land, normally near the Indus or one of the old inundation canals, was surrounded with an earth embankment with an opening to admit the flood water as soon as the first spill occurred. Then the opening is blocked, trapping the water in the field, and the land is ploughed and sown. While the inundation continues, potentially damaging water is kept outside by the earth bunds and let in only when needed. The best areas for *kharif* cultivation are the ones in the vicinity of regular flood channels where the farmers can exercise greater control over the water. It should, however, be noted how risky this cultivation method might be, since there is always the possibility of water overtopping the bund an destroying the fields.

Fairservis (1967) argues, on the basis of the modern hydrology of the central Indus Valley and the distribution of Harappan sites in northern and western Sindh, that the central-western portion of the ancient Indus system (until the Mature Harappan period) is generally comparable with the modern one (for geography, see Fig. 4). Spills of the flood along the western banks of the Indus north of Sukkur are documented in Moghul times (Raverty 1979). The flood water would have moved westwards, passing south of Jacobabad and north of Larkana and might have been the main water supply for Judeirjo Daro and Jhukar (Fairservis 1967). Moving south, the water from the Indus would have been channelled again along the edge of the Khirtar Range in east Baluchistan where

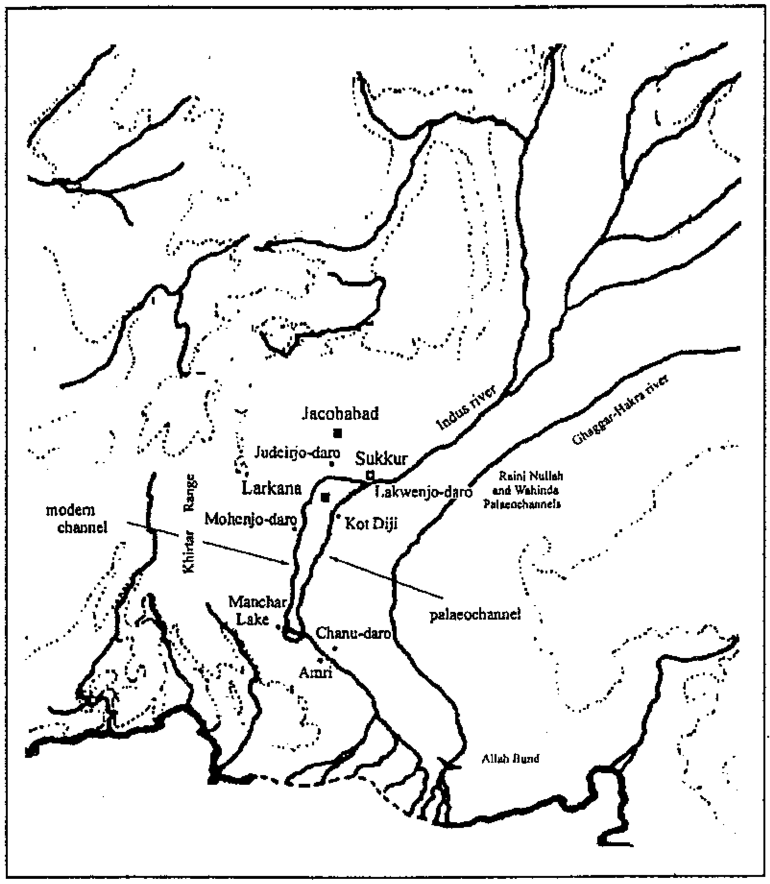

Fig. 4. Map showing modern and geographical feature mentioned in the text and selected sites of the Indus Valley tradition in central Sindh falling in the active area of the Indus river system.

water discharge from seasonal streams originating in the range could have increased the flow. The river course would eventually have opened into the shallow body of water of Manchar lake were two Harappan village sites are to be found (Fairservis 1967). Finally, the water would have rejoined the main stream of the Indus river via the Aral Channel. Mohenjo Daro, Lohumjo Daro, Kot Diji, Naru Waro Daro, Lakwenjo Daro and Amri all fall in the active area of this river system of the Indus Valley. For all these Harappan sites (and many others not mentioned here), their location suggests easy access to the flood waters of the Indus river and its related drainage system for agricultural purposes. There is no evident pattern of site distribution in respect to a possible artificial system of canal irrigation, but rather the location of the sites seems to be related to maximizing access to the Indus flood plain (see also 1967: 24-9, Fairservis 1971; Flam 1986).

This small-scale approach may have contrasted with that which has been envisioned for parts of the eastern Harappan province in the upper regions of the Ghaggar-Hakkra system. In this region, artificial canal systems have been reported through reconnaissance and test-pitting (Bisht 1982; Francfort 1992: 88-100; Chakrabarti 1995: 50-1, 87-8). However, as noted by Francfort (ibid.) much of the water for irrigation may have been provided by the natural network of meandering channels, thus obviating the need for large-scale irrigation works of the sort necessary for agricultural production in Mesopotamia.

A brief remark is needed on the peculiar structures known as *gabarbands*, which have attracted the attention of several archaeologists. *Gabarbands*, dam-like structures observed in Baluchistan and south-western Sindh (see Dales 1962: 30-9; Fairservis 1967: 10; Raikes and Dyson 1961: 265-81) and assumed by Stein (1937) to be built to store water from seasonal streams, can effectively trap water runoff, slowing water speed and allowing the silt in suspension to be deposited. These dam-like structures are often built in sequence, along the direction of drainage (Fairservis 1967, Fig. 5). This process in turn creates small patches of cultivable, rich and moist soil in an otherwise barren landscape. It can also support the formation of small bodies of standing water and marshes. Similar structures have been noted by Lambrick (1986) in southern Kohistan where *barani* (rain-fed) cultivation is practised. *Gabarbands* can sometimes be very complex structures, such as the ones observed in the valley of the Has river (Sindh Kohistan) by H. Buller (*Jhalawan Gazetteer*: 227). The valley, about 7 miles in width in its southern portion, provides a great expanse of cultivable land with rich soils reaching as deep as 30 feet. Rainfall in Sindh is highly variable and there might be years of less than average rainfall, during which time the structures are often abandoned. However, there are also years when rainfall is more abundant and it is worthwhile to cultivate on these fields, as they can yield good crops with sufficient water.

As this short description demonstrates, the Greater Indus Valley environment accounted for several different realities in terms of landform and water availability. This in turn might have required from the Harappans a certain flexibility in the exploitation of the land. However, it is worth remembering that cultivation in Sindh at the beginning of this century (and also in the Thar desert), under a dry climatic regime, was undertaken on rain

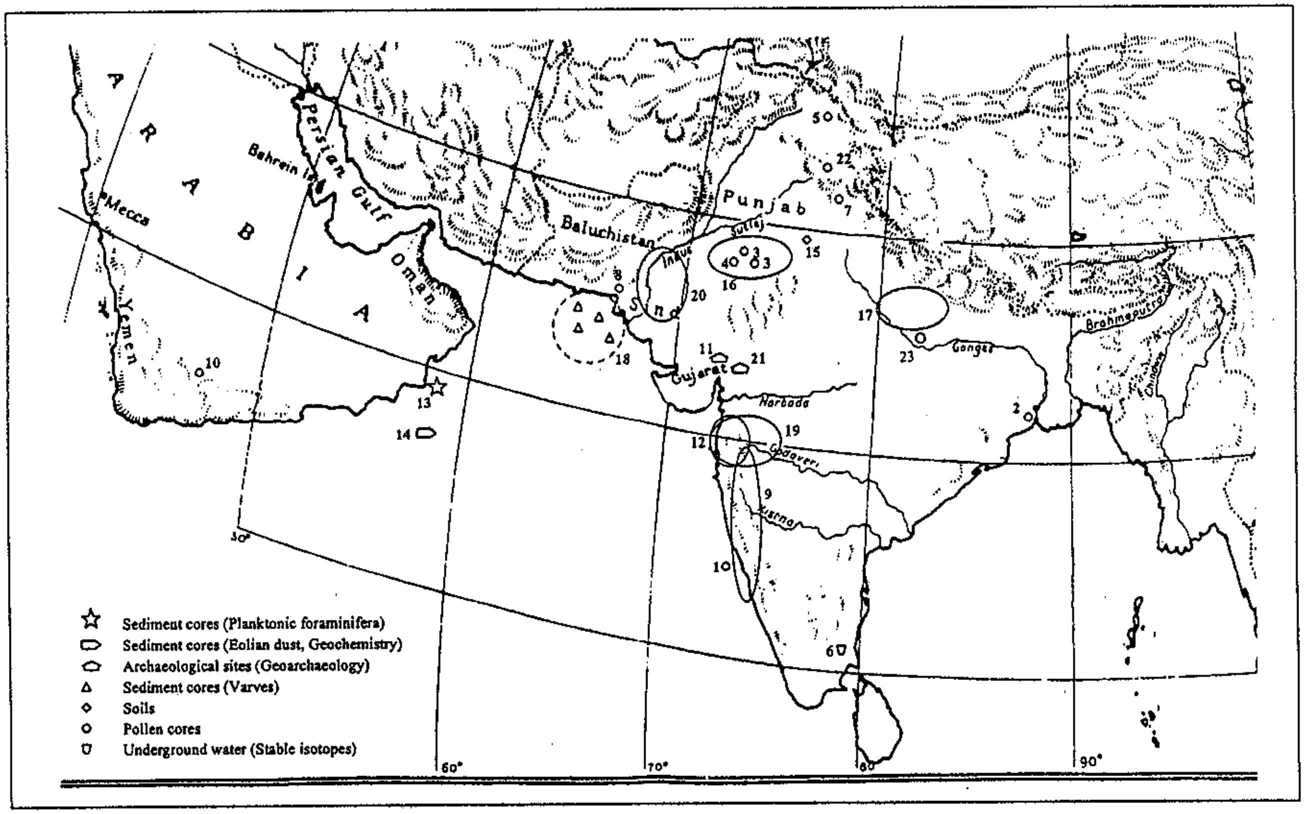

Fig. 5. Map showing the distribution of sites and regions of palaeoenvironmental studies. Site/region numbers and references are given in Table 4.

alone (Lambrick 1986). Under these circumstances and given the complete absence of archaeological evidence, it does not seem necessary to invoke, during the Harappan period, complex canal systems and centralized management for the irrigation of the land. This argues strongly against the application of Wittfogel's (1957) 'Oriental Despotism' model of the state to the ancient Indus Valley (Morrison 1994). More possibly there was a small scale association, possibly at the extended family level, to organize and manage the fields and the inundation water. As noted by Meadow (1989, 1996) and Kenoyer (1998), more important to the maintenance of Harappan urbanism than a highly organized or technologically complex irrigation system was the 'safety net' which provided inter-regional trade in foodstuffs in order to buffer local failures.

SEASONALITY AND INTENSITY OF AGRICULTURE

Beyond tracing the individual histories of particular crop plants, of particular importance for understanding an ancient civilization like the Harappan are reconstructions of the economic organization of agriculture. Although the number of intensively sampled Harappan sites are few, some important insights have come from the discussion of agricultural systems. The first systematic consideration of Harappan agricultural practices was carried out by Fairservis (1961, 1967, 1971: 304) who worked from archaeological settlement distribution patterns in the hilly and piedmont areas west of the Indus to infer factors of water, soils and topography. Fairservis hypothesized a winter (*rabi*), rainfed cultivation that utilized systems of bunds to conserve and channel water. Working from this model, Fairservis explored both the evolving subsistence system which allowed settlement on the Indus alluvium with subsequent urbanization and possible agricultural changes associated with the demise of the Harappan urbanism. In discussing the end of urbanism, Fairservis (1967, 1971: 311) attributed a role to the development of rice agriculture in regions east and south of the core Harappan region, which encouraged the dispersal of population and decentralization. While this hypothesis lacks the support of much hard evidence, as Fairservis himself admitted, it takes a form similar to explanations that have been offered by several authors more recently, usually involving millets rather than rice.

The accumulation of further data has continued to demonstrate the importance of the winter (*rabi*) crops in the Indus Valley, with summer (*kharif*) crops being represented largely by oilseed and fibre crops, such as sesame and cotton. While it can be argued by modern analogy that two cropping seasons must have been undertaken in Harappan times (e.g. Chakrabarti 1988: 96, 1995: 50), the archaeobotanical evidence suggests that Harappan subsistence agriculture was focused most intensively on one season of crops, namely the winter (*rabi*) crops. The food staples were probably the winter-sown, spring-harvested cereals and pulses of South-West Asian origin. Some summer crops (*kharif*) were present, in the form of fibres such as cotton and flax, as well as sesame (see Meadow 1989), but there is no evidence as yet for cereals or pulses of summer seasonality in the core Harappan regions (Indus or Ghaggar-Hakkra valleys). It must be remembered, however, that systematically-collected archaeobotanical samples are still lacking from this region, so that current conclusions are somewhat precarious. While *rabi* crops could have been fairly easily irrigated by winter rains, combined with harnessing run-off and river-flooding through fairly simple means (see discussion of irrigation, above), crops that flower and fruit in the late summer-autumn would have required greater efforts at water management. As their growing season coincides with the flood season of the Indus system, their cultivation in flood plain areas would have risked destruction by inundation if water was not diverted by barriers. On the other hand, soils at higher levels would have been particularly dry at this period. Such higher and drier sites would have required labour-intensive irrigation, probably from wells by *shadoof*. It is conceivable that the combination of readily available stores of winter staples and the labour needed for summer crops would have promoted concentration on smaller areas of cultivation for 'important' crops, not otherwise available, such as the fibre crops of sesame, and perhaps some fruits. Cotton and fruits were all probably grown as perennials and would have required some irrigation and attention throughout the dry season.

Kharif crops were of importance in a number of regions outside the 'core' Harappan region, especially in the later part of the Mature Harappan period ('Integration Era', after *c.* 2300 BC) and during the Post-Urban period. Gujarat, throughout the era of the Mature Harappan, focused on *kharif* cropping of small millets, and the little wheat and barley which were present may have been imports. On the other hand, in the region east of Harappan near the head waters of the ancient Ghaggar-Hakkra system and present-day Yamuna, several Harappan sites show that winter cereals and pulses were cultivated in addition to some summer crops, such as at Hulas, Rohira and Sanghol (see Table 2, and 'Hard Evidence,' above). This indicates that double-cropping was present during the Mature Harappan phase, even if this was not adopted in some of the core regions of the Indus and Ghaggar-Hakkra valleys. It is notable that this eastern region falls definitely within the area watered by monsoon rains which would have made such *kharif* cropping readily possible. The presence of two cropping seasons could have offered an extensive approach to agriculture as an alternative to the more intensive agriculture that might be postulated for the core Harappan regions. Double cropping allowed productivity to be spread across time, and in order to maintain soil fertility it may also have been spread across space, or else cereals could have been alternated with nitrogen-fixing pulses.

Another summer crop, present in the eastern province and at Harappa after 2200 BC was rice. Details about the nature of rice cultivation are still lacking, however. Rice can be cultivated as an irrigated crop, a labour intensive form of cultivation, or as a 'dry' crop, in which it is watered only be the monsoon, as in usually the case with millets (Grigg 1974). For wet-rice cultivation, fields need to be flooded, either by bunding or channeling water, and the seed planted in soils of a muddy condition, usually ploughed. Understanding which approach to rice cultivation was utilized is of interest both for tracing the history of this farming technique and for assessing the agricultural complexity of the eastern Harappan regions. The systematic collection and analysis of weed assemblages and phytolith samples should be able to indicate whether the rice crop was significantly associated with wetland species or showed a range of weeds similar to those of millets, as would be expected in the case of dry-cropping. If rice was dry-cropped, then this provides one possible explanation of why rice cultivation may have been slow to spread westward, since the summer rains are likely to have been inadequate in most of Pakistan for growing summer crops. The adoption of rice in the west may have had to wait until more labour-intensive, irrigated system of cultivation was developed. The presence of rice at Pirak in the second millennium BC, together with evidence for *Panicum* millet and possibly *Sorghum* (Costantini 1979; Jarrige 1985), should probably be seen not merely as the adoption of new crops and a new cropping season, but also new systems of cultivation. In this regard, it is interesting that rice turns up so early in Swat (Costantini 1987): could irrigated, wet-field systems have already been in operation there in the third millennium BC?

In general, while there has been a great awareness of the seasonality of different crops, there has been less discussion of issues of intensity. These are clearly issues of importance for understanding the organization of Harappan agricultural production and the stability of the agricultural base of the civilization. Intensive agriculture, although normally more productive, might also have been more prone to catastrophic failure in bad years. On the other hand, extensive systems which included double-cropping are likely to have had more inherent buffering from the vagaries of climatic variability. It is perhaps in regions with the latter kinds of agriculture systems, such as the Eastern Harappan province and probably Gujarat, where greater long-term stability might be expected, and indeed it is these areas where much of Late Harappan continuity has been identified (Allchin and Allchin 1982, 1997; Chakrabarti 1995; Kenoyer 1991, 1995, 1998; Possehl 1997). The issue of agricultural stability, raises the question of climatic stability and climatic change, to which we turn next.

THE CHANGING ENVIRONMENT AND CHANGING SOCIETY

The area spanned by the Harappan Civilization was vast and encompassed several ecological areas, with rainfalls varying from less than 50 to *c.* 600 mm per year. However, on the whole, the entire area can be considered as arid or semi-arid, with a few semi-humid sectors (e.g. the gallery forest along some of the rivers) (Agrawal and Sood 1982; Allchin and Allchin 1997: 21-5; B. Allchin 1998). This geographical region is nowadays dominated by two main climatic systems, the winter cyclone from the west and the summer monsoon from the east. There has been considerable debate about the degree and extent of climatic changes that occurred in this large area before and during the Harappan Civilization, and also the degree of influence of such hypothetical climate changes in driving the transformation of Harappan society during the second millennium BC.

Early theories about climatic change were based on the evidence of settlement distribution. Stein (1937) inferred wetter conditions on the basis of the presence of settlements and *gabarbands* in Baluchistan (see 'Issues of Irrigation' above). But there is no need to postulate a higher precipitation rate to justify the construction of *gabarbands*.

as the production of silt deposits would be worthwhile even for sporadic cultivation at long intervals because of the very poor, thin soils present in the area. Also, the process of building these structures does not always involve high energy expenditure (Madella, personal observation during a survey in the wadis of the Rohri Hills—Thar desert, Sindh). Piggott (1950) and Wheeler (1959) postulated a more luxuriant environment on the basis of the fauna depicted on the Harappan seals and pottery, considered to be typical of a jungle environment (rhinoceros, elephants, tigers, etc.). The Indus and many other important rivers are nowadays still flanked for good tracts of their banks by dense gallery forest which creates a more humid microclimate. The survival of this type of forest is not influenced by the general climate but only by the conditions set by the presence of a river, and such forests represent an ideal environment for all the species depicted in the Harappan pictography. The gallery forest and associated riverside swamps could probably have supported these animals with little or no change in climate; the absence of these species today is probably to be attributed to human impact, including agricultural development and hunting. The Moorish traveller Ibn Batuta described an encounter with two rhinoceros, in an environment similar to the modern one, during his travel in Sindh in 1333 AD (Dafremery and Sanguinetti 1855: 100). It is also important to stress, as already noted by Fairservis (1967), that most of the 'Harappan' animals represent species adapted to survive in a range of environments and they are today to be found also in open forest and grasslands. Furthermore, Harappan pictography on artefacts such as seals might represent 'special' animals rather than those that were part of the everyday repertoire (one might note Ashoka's wide use of the lion in regions where such animals were unlikely to have lived; or even the use of the lion as a royal symbol in Britain!).

A further argument for change was based on the archaeological observation of the enormous quantities of baked bricks in Harappan cities (Marshall 1931; Piggott 1950). It was suggested that the production of burned bricks would have required quantities of wood that could only be accommodated in an environment of more forest cover. However, Raikes and Dyson (1961) calculated that only 400 acres of gallery forest would be needed for each rebuilding of Mohenjo Daro. Modern production of bricks in Sindh is still largely based on the same technology utilized by the Harappans (Madella, forthcoming) and the wood is supplied by the three main trees today growing in areas of water availability within this arid zone: *Acacia arabica* Willd. (babul), *Tamarix* sp. (lai) and *Prosopis cineraria* (L.) Druce (kandi, khejri). Other wood is also available in well-watered sectors (e.g. along the river banks) in the form of *Populus euphratica* Olivier (bahan), *Dalbergia sisso* Roxb. (tali, sheesham), *Salvadora persica* L., *S. oleoides* Decaisne, *Ficus* sp, and *Tamarix* sp. In general, these seem to be the same species of tree/shrub that dominate charcoal assemblages thus far analysed from the Greater Indus Valley (Saraswat et al. 1990; Castelletti et al. 1994; Saraswat 1994; Thiebault 1988b, 1989, 1992, 1995; Saraswat and Chanchala Srivastava 1997). Alongside wood, dung and the crop processing by-products from wheat, barley, rice and cotton are sometimes used in brick production. There is then no need to postulate a higher wood availability to produce the quantity of bricks involved in the construction of the Harappan settlements.

From the 1960s, scientific palaeoenvironmental and geological studies in Sindh suggesting possible climatic or environmental changes appeared to support the archaeological evidence. In this perspective, the Indus river emerged as one of the dynamic factors that intervened in processes of cultural change during the Late Harappan period. In 1965 Raikes published his famous article, 'The Mohenjo-daro floods', in which he suggested that an uplift or a series of uplifts of the Indus Valley in the areas of Sehwan were responsible for the creation of a permeable natural dam which retained the solid fraction transported by the water. These sediments slowly engulfed several settlements of the area in mud (see also Raikes 1964, 1967a, 1967b, 1968, 1979). This hypothesis was sustained also by Dales (1965a, 1965b, 1966a, 1966b; also Dales and Raikes 1968; Raikes and Dales 1977, 1986). The evidence adduced to support this theory is quite inadequate and prompted several critiques (Lambrick 1967; Possehl 1967; Agrawal 1971, 1982; Wasson 1984, 1987). It is argued that if the barrier was permeable it would have been unlikely to endure the force of the hundred thousand cubic feet per second of the Indus floods for more than a few years (Lambrick 1967; Wasson 1984, 1987). A similar geomorphological occurrence, known as the Allah Bund, took place in northern Kachchh in 1819 (Fig. 4). A structure of soil was created by an earthquake and obstructed the Nara (one of the eastern canals from the Sukkur barrage and possibly the southern portion of the bed of the former Ghaggar-Hakkra river). This bund was destroyed only after 7 years by what was probably the first flood of spill water (Lambrick 1967). Lambrick suggests instead a major change in the course of the Indus river upstream from Mohenjo Daro. This might have shifted the bed of the river about 30 miles eastward, depriving the town of nearby inundation and thus encouraging the dispersal of population from the city.

Tectonic uplift and changes in the course of river beds also had a major impact on another area of the Harappan Civilization. Archaeological research in Cholistan, along the dry channels of the Ghaggar-Hakkra river (often identified with the lost Sarasvati and Drishadvati rivers) has led to the discovery of a large number of sites (Stein 1942, 1943; Gosh 1952, 1953; Field 1959; Suraj Bhan 1971-2, 1972, 1973, 1975; Bisht 1976, 1977; Lal 1954-5; U.V. Singh 1977; Joshi 1978a, 1978b; Dikshit 1979, 1981; Flam 1976, 1981, 1986; Dalal 1980; Mughal 1982, 1997; Misra 1984). Both in Cholistan and along the Ghaggar-Hakkra there is a relatively high frequency of settlements during the Mature Harappan which suggests a well-watered river and inland delta (in a area around Derawar). In comparison, there are fewer sites during the Early Harappan, which might reflect a decreased amount of water in the drainage system during this earlier period (see also Mughal 1997 and Possehl 1997b for an extensive review). By the time of the Painted Grey Ware (PGW) the river must have been dry, because several sites of this period are found in the fixed river beds. Lack of water in the Gagghar-Hakkra fluvial system seems to be related to possible tectonic and geomorphological processes (Agrawal and Sood 1982; Agrawal 1992: 237-42) rather than climatic changes. Although most authors have seen the drying up as a rather sudden, Late Harappan event, micromorphological work by Courty and colleagues (Courty 1986; Courty and Federof 1985; Courty et al. 1989: 269-83) calls this view into question. The study of sediments from the paleochannels suggests instead a much longer, more drawn out process of drying-up, although it is clear that during the Mature Harappan period these channels were subject to regular flooding, presumably during the monsoon/Indus flood season. The presence of river with variable water flow can be seen as according with the name given to the Gagghar-Hakkra in the *Rigveda*, '*Saraswati*' which means 'Chain of Pools' (Possehl 1999). The description of the Sarasvati in the *Rigveda* as a mighty and powerful river can be seen in the light of the seasonal floods which might have transformed an intermittent flow of water (indeed, a chain of pools) into a full flowing river. Contrary of what Possehl (1999) argues and in the light of the works of Courty and colleagues, the description of the river in the *Rigveda* and the literal meaning of the name can be reconciled and seen as two (seasonal) expressions of the same river. By the time of the Painted Grey Ware, these channels were being infilled by windblown sand. Movements of sand in the Cholistan and Thar deserts could be, indeed, responsible for the absence of physical evidence of the river between the Derawar Fort inland delta and the two palaeochannels east of Sukkur, the Raini Nala and the Wahinda (cf. Possehl 1999).

The relation between the drying up the Ghaggar-Hakkra course and the consequential depopulation of the area, and the general decline of the Harappan Civilization is not clear. Misra (1984) and Chakrabarti (1995: 274) suggest that the disappearance of the Ghaggar-Hakkra introduced a weakness that affected the entire Harappan distribution area and resulted in de-urbanization. However, the causative link between the river system and the Harappan settlements remains unexplored (Fuller and Boivin, in Vol. of IV this series). A possible explanation is that the valley of the Ghaggar-Hakkra represented the grain basket of the Harappan Civilization, with the surplus production of wheat and barley redistributed in the settlements of Sindh and Punjab. This would explain why changes in the Ghaggar-Hakkra system would have had such a destabilizing effect on Harappan society.

Nevertheless data representative of possible changes in the climate have been documented in north-western India over the past 11,000 years (Table 4; Fig. 5). Widely influential and controversial was the analysis of pollen and sediments from four lakes in Rajasthan (G. Singh 1971; G. Singh et al. 1974; Vishnu-Mittre 1976, 1978; Meher-Homji 1980, 1994a, 1994b; Bryson and Swain 1981; Swain et al. 1983; Wasson 1995). Additional relevant evidence comes from the study of oxygen isotope ratios and pollen assemblages from the Arabian Sea (Van Campo 1986; Caratini et al. 1994), the assessment of Quaternary geomorphology in Rajasthan (Allchin et al. 1978) and Maharashtra (Kajale et al. 1976; Kale and Rajaguru 1987), and the climatic modelling of monsoon intensity and area of influence in the past (Kutzbach 1987; Prell and Kutzbach 1987; Wasson 1995; Meher-Homji 1994a, 1996a; Naidu 1996; Sirocko 1996). Certain disagreement remains between different authors, but in general terms it is possible to highlight that the period between 11,000 BP and 10,000 BP represented a peak in seasonality with stronger monsoons from the west and considerably higher rainfall. This situation persisted, although slowly decreasing, until *c.* 3500 BP.[5] The summer monsoon today does not reach the highlands of Baluchistan, but it has been suggested that it may have been of some importance in the

TABLE 4. SOURCE OF PALAEOECOLOGICAL EVIDENCE FOR THE LATER HOLOCENE OF INDIA AND ADJACENT REGIONS, GROUPED INTO BROAD REGIONS, INDICATING THE TYPE OF EVIDENCE THE NATURE OF THE INFERRED CHANGE, AND GIVING REFERENCES (Numbered sites are plotted in Fig. 4).

Site or Region (numbers refer to Fig. 4)	Map no.	Discipline	Climatic Evidence for Change around 2nd millennium BC	Reference
North-western Subcontinent				
North-west India/Pakistan		Climatology	Monsoon	Ramaswamy 1968
Western Rajasthan (India): salt lakes Didwana and Lukranasar	3	Pollen analysis; also micro-charcoal count	Changes in pollen assemblage and grass/tree ration (also micro-charcoals) Vegetation changes linked to winter and summer rainfall quantities	Singh 1971; Singh et al. 1974; Bryson and Swain 1981; Swain et al. 1983; Wasson 1995 critiques: Vishnu-Mittre 1976; Meher-Homji 1980
Rajasthan and Sindh (India-Pakistan)	16	Geoarchaeology		Allchin et al. 1972
Indus Valley (Pakistan)	20	Geology	Tectonic	Snelgrove 1979
Western Rajasthan (India)	16	Geology	Calcrete/Dunes (not adequately dated)	Agrawal 1992
Indus Valley (India)	20	Geology	Tectonic	Raikes 1984a, 1984b
Haryana-Rajasthan (Ghaggar River Valley, India)	15	Pedology/Soil micromorphology	change in sedimentation, decreasing alluviation, increasing wind-blown sand, indicates drying-up of Ghaggar-Hakkra	Courty 1986; Courty and Federoff 1985; Courty et al. 1989: 269-283
Balakot (Pakistan)	8	Pollen analysis	No change	McKean 1993; synopsis in Dales 1986
Western Rajasthan (India): salt lakes	4	Pollen analysis and Sedimentology		Deotare and Kajale 1996; Kajale and Deotare 1997; Deotare et al. 1998
Thar Desert (India)	16	Stable isotopes		Andrews et al. 1998
Western India				
Langhnaj (Gujarat, India)	21	Archaeology/ Geomorphology	Re-activated sand dunes	Sankalia 1965
Maharashtra (India)	19	Geoarchaeology	Alluvial fills	Kajale et al. 1976
North-west Deccan (India)	12	Geomorphology	Landforms	Kale and Rajaguru 1987

(contd.)

Site or Region (numbers refer to Fig. 4)	Map no.	Discipline	Climatic Evidence for Change around 2nd millennium BC	Reference
Kanewal (Gujarat, India)	11	Archaeology/ Geomorphology	Re-activated sand dunes	Rajaguru and Mishra 1997
Himalayas				
Kashmir Himalaya (India)	5	Pollen analysis	Changes in pollen assemblage	Gupta 1975
Siwalik (India)	22	Pollen analysis		Awashi 1992
Western Himalaya (India)	7	Pollen analysis	Changes in pollen assemblage	Sharma 1992
Kashmir		synthesis of various data sets		Agrawal 1992; 1995
Ganga plain				
Meander lake, Sarai-Nahar-Rai Uttar Pradesh	23	Pollen analysis	Changes in pollen assemblage	Gupta 1976
Bengal Basin (India)	2	Pollen analysis		Gupta 1981
Calcutta peat (India)	2	Pollen analysis	Changes in pollen assemblage	Barui and Chanda 1992
West Bengal (India)	2	Pollen analysis		Arghya et al. 1996
North-central India	17	Pedology		Srivastava and Parkash 1998
Southern India				
Karwar (West South India)	1	Pollen analysis	Changes in pollen assemblage and grass/tree ration	Caratini et al. 1991; 1994 critique: Meher-Homji 1994b, 1996a, 1996b
Western Ghats (India)	9	Ecology, synthesis	Vegetation history	Subash Chandran 1997
South India: Tamil Nadu	6	Ground water isotopes		Sukhija et al. 1998
Arabian Sea and Arabia				
Arabian Sea	14	Climatology	Eolian dust and geochemistry	Sirocko 1996
Arabian Sea	13	Climatology	Monsoon upwelling	Naidu 1996
Southern Arabia (Yemen)	10	Pollen analysis and Palaeohydrology		Lezine et al. 1998
North-eastern Arabian Sea	18	Sedimentology	Precipitation and river runoff	Von Rad et al. 1999

TABLE 5. ARGUMENTS IN FAVOUR OF CLIMATIC CHANGES AND COUNTER ARGUMENTS TO SUPPORT ANTHROPIC INTERFERENCE IN THE LANDSCAPE OF SOUTHERN WEST INDIA (Western Ghats, Karnataka) (modified after Meher-Homji 1994b)

	Interpretation of the pollen assemblages in favour of climatic change around 3500 bp (uncalibrated). (Caratini et al. 1991 and 1994)	Interpretation of the pollen assemblages in favour of anthropic interference on the environment (Meher-Homji 1994a, 1994b and other authors)
Point 1	Decline of pollen from evergreen and deciduous forest taxa and parallel increase of savanna suggesting a more dry climate with less overall rainfall.	Savanna vegetation at low and moderate altitude in the Western Ghats could be the result of repeated fires (Pascal 1984). If change in vegetation cover should be related to a drier climate, then the species of the thorn forest not the savanna would replace the evergreen and deciduous forests (Meher-Homji 1994b).
Point 2	Reduction of mangrove pollen in the pollen rains suggesting the contraction of humid areas.	Mangrove can grow in semi-arid to humid conditions and are not good climatic indicators (Meher-Homji 1994b). According to Gadgil and Subash Chandran (1988) shrinkage of mangrove vegetation may be due to the introduction of paddy cultivation in the estuaries.
Point 3	Flow of water of terrestrial origin from rivers diminishes as indicated by to an increase of ^{13}C stable isotope in the sedimentary organic matter.	Bruijnzeel (1986) argues that deforestation and burning of grasses would result in increased water discharge. Large scale deforestation may affect the local, convectional rainfall without causing any change in the monsoon pattern (Meher-Homji 1991).
Point 4	Notably lower rate of sedimentation (7cm/100 years) in recent period as compared with rate prior 3500 bp (18cm/100 years) could indicate a decrease in rainfall.	Soil erosion on slopes should be higher under savanna vegetation cover than under forests (Meher-Homji 1994b).

past (Snead 1968). The interpretation of seasonal laminated sediments (varves) deposited in the oxygen minimum zone (OMZ) off the Makran and Karachi coasts indicates a decrease in sedimentation which von Rad et al. (1999) suggest could indicate a decrease in precipitation in southern Pakistan after 4000-3500 year BP (*c*. 2000-1750 cal BC). They attempt to correlate this with hypothetical aridification in the Near East. The chronometrical control on sedimentation rate does not appear to be sound, however, with only four radiocarbon dates available for the entire sedimentary sequence (Von Rad et al. 1999, Fig. 6), and thus the chronology of the crucial changes is based on assumptions of sedimentation rates. Furthermore, Von Rad et al. (1999) do not take into account the potential impact on sedimentation rate of the capture of the Ghaggar-Hakkra water by the Ganga system, postulated for about this time (e.g. Agrawal and Sood 1982; Misra 1984; Courty and Federof 1985; see above). Thus the absolute chronology of the changes in this varve sequence is not clear, and their linkage to climatic changes rather than tectonic processes is insecure.

The monsoon is the very pulse of the Indian subcontinent, and affects the Indus Valley even if to a lesser degree than the eastern and peninsular areas. The south-west monsoon of the summer months is the origin of most of the rain for the semiarid and arid regions of the Thar desert. Naidu (1996), on the basis of distinctive planktonic foraminiferas from Arabian Sea core especially the indicator species *Globigerina bulloides*, calculated the upwelling due to the south-western monsoon in the Arabian Sea over the past 19,000 years. Upwelling indices reveal the lowest values during the Holocene occurred between *c.* 3500 BP (*c.* 1500 BC) and 1200 BP (*c.* 800 AD) suggesting a decrease in the monsoon activity over the Indian subcontinent during this period, followed by some increase. Ramaswamy (1968), however, had argued for an opposite situation on the basis of the data supplied by Lamb et al. (1966) and an accurate study of modern daily charts for the northern hemisphere, that between 2000 BC and 500 BC the south-west monsoon must have extended into Pakistan far more frequently than today because low pressure troughs would have been present in the west. This would have induced monsoon activity and also caused any monsoon from the Bay of Bengal to move further and to curve to the north, north-east. Ramaswamy might be disregarded, however, on the ground of poor dating evidence. Indeed, the pollen data of G. Singh et al. (1974) from Lunkaransar lake (Bryson and Swan 1981; Swain et al. 1983) were interpreted as representative of higher monsoon activity and winter rains during Early and Mature Harappan period. This was followed by the much debated hypothetical climatic change towards dryness, postulated by G. Singh et al. (1974) and Bryson and Swan (1981) around 3700 BP (2129, 2982, 2043 cal. BC intercepts), leading to the mobilization of sand dunes. Although it is clear that sand dunes have formed and moved in the past across parts of Rajasthan where they are today stabilized by vegetation (Allchin et al. 1971, 1978; Allchin and Allchin 1982: 19-22), the dating of these dune-movement episodes (and the implied aridity) is still unfixed—a parallel case exists for the sand dunes of the central Sudan (Warren 1970). Modern chronometric techniques need to be applied to the problem.

The most detailed studies on pollen from the Greater Indus Valley are those of G. Singh and his colleagues already referred to above (G. Singh 1971; G. Singh et al. 1972, 1974; discussed by Bryson and Swain 1981; Swain et al. 1983). Recently, Kajale and Deotare (1997) have undertaken new work in this region. The sediments of three salt lakes or playas (Lunkaransar, Didwana and Sambar) in north-western Rajasthan were analysed by G. Singh et al. (1974). However, several saline playas are found west of the Aravalli range. The origin of these depressions is heterogeneous, some being the result of old channels of a disorganized drainage system (i.e. Pachpadra and Thob) while others are due to structural depressions (i.e. Didwana and Kuchman) (Kajale and Deotare 1997). The basal deposits of the studied lakes consisted mainly of aeolian sand overlaid by lake sediments with variable preservation of pollen grains. Pollen assemblages are interpreted by Singh (1971) as showing a dryer phase around 18,000 BP, followed from around 16,000 BP by a more seasonal climate and higher summer precipitation. The assemblage is rich in the pollen of grasses, sedges, *Chenopodiaceae/Amaranthaceae* and *Artemisia*, and it is interpreted as reflecting the development of a grass-steppe vegetation following a period of extreme aridity. Between 5000 BP (3900-3700 cal BC) and 3800 BP (2400-2100 cal. BC), the pollen of trees and shrubs became more frequent, reflecting a possible moist phase. Starting sometime before 3500 BP (1900-1700 cal BC), wetter phase was interrupted by a drier period. Pollen of trees and shrubs disappear from the sediments and the lakes became gradually drier until *c.* 1500 BP (400-640 AD) when the lakes had dried up completely and conditions similar to the present day set in. This interpretation of the pollen data, which emphasises climatically-driven desertification processes in the north-west of the Indian subcontinent was contested by Vishnu-Mittre (1974b, 1976, 1979, 1982), whose criticism was based upon the use of certain pollen types as climatic indicators. Vishnu-Mittre (1974b, 1976, 1979, 1982) and the bio-climatologist Meher-Homji (1980, 1994a, 1994b, 1996a, 1996b) are inclined to see the onset of local aridity as the result of anthropic action rather than climatic factors.

Further work on three more playas of western Rajasthan has been carried out by Deotare and Kajale (1996; Kajale and Deotare 1997; Deotare et al. 1998). The litho-stratigraphic column at Bap-Malar playa (Jodhpur district) suggests that the final activity of the now stabilised dunes around the lake is *c.* 7000 BP and the lakes appear to have dried up by around 6000 BP (Deotare et al. 1998). This would imply relative stability of the level of precipitation since well before the Early Harappan period. The pollen analysis at Pachpadra and Thob playas (Barmer district) (Deotare and Kajale 1996; Kajale and Deotare 1997) shows fluctuating plant assemblages which might be a response to changes in *local* hydrological conditions. An episode of relatively dry (local?) conditions is suggested for the end of the Pleistocene on the basis of the presence of *Ephedra* pollen. However, for Deotare and Kajale (1997) it does not seem necessary to invoke climate to explain most intra- and inter-lake variations. Changes in vegetation and hydrology, if present at a given lake, should not be generalized into climatic changes for the whole of Rajasthan, let alone the entire Harappan region. Indeed, many other processes, like geomorphological, topographical and tectonic changes, could be responsible for local changes in hydrology and vegetation. Other pollen sequences near the core Harappan region come from the archaeological site of Balakot, north-west of Karachi near the Arabian Sea coast (McKean 1983; synopsis in Dales 1986), where sediments dated between 5500 and 3500 BP were analysed. The interpretation of pollen from anthropic sediments in terms of climatic characteristics is never totally safe. Several variables, related to human occupation, might influence the pollen rain and make the data set less sound as a source for reconstructing natural vegetation (and therefore climate). In addition, there are serious taphonomic and preservation concerns, as archaeological pollen is prone to mixing and contamination by intrusive pollen from insect-pollinated plants (Bottema 1975). Nevertheless it is worth noting the conclusion of McKean (1983) that: 'there is nothing in the Balakot pollen data, which might suggest that the climate during the protohistoric period in Las Bela was decidedly wetter than at present'.

Human interference could also have significantly influenced the structure of the vegetation at different scales. The decline of evergreen, deciduous and mangrove pollen in favour of grassland species in the off-shore Karwar core (Caratini et al. 1991; 1994) was interpreted as marking the onset of a weaker phase of the monsoon, indicating a less humid phase around 3700-3500 BP (*c.* 1430 cal BC). However, deforestation for intensified agriculture and exploitation of the land cannot be ruled out. Anthropogenic interference related to slash and burn practices and possible heavy deforestation has probably had an important role in shaping the vegetation, as already pointed out by Meher-Homji (1994a, 1994b, 1996a, 1996b) and Subash Chandran (1997). The Chalcolithic and Neolithic archaeological and archaeobotanical evidence in peninsular India for the second millennium BC suggests intensification in the form of a proliferation of villages and the adoption of double-cropping (Fuller, in Vol. III of this series; Fuller et al. n.d.). Unfortunately, most of the available palynological data for the subcontinent during the Holocene appear to have some ambiguity and observed changes could be related to both climatic variables or anthropic action (see Table 5). In the case of the middle Ganga region, the palynological evidence has been taken to suggest that the early cultivation (early second millennium BC) did not significantly affect the forest cover (Gupta 1976; Erdosy 1998).

A final remark about temporal correlation of the various sedimentological sequences from north-west South Asia and the Arabian Sea is due. Unfortunately there is weak evidence for sound correlation on the basis of calibrated radiocarbon dates, which further adds to problems arising from inter-laboratory variations (Edwards 1979). When calibration is performed and dates transformed into calendar years, climatic events recorded in the sediments and considered to be contemporaneous with socio-political and agricultural changes in the Indus Valley may effectively be separated by a time lapse of about 500 years (e.g. the 'dry' event in the Rajasthan pollen sequence of G. Singh et al. 1974 and the offshore pollen sequence of Caratini et al. 1991, 1994).

Some information about ancient climate might be gathered, with caution, from carbonized wood recovered from archaeological sites (anthracology). In the interpretation of this evidence it is especially important to consider the presence of human choice and the fact that the wood represented may not all be available in the vicinity of the site or may represent several ecological zones around the site. Preliminary studies from the sites of Mehrgarh and Nausharo (Thièbault 1988a, 1988b, 1989, 1992, 1995) show that *Tamarix* sp. (lai), *Acacia* sp. (babul?) and *Prosopis* sp. (kandi?) dominate the charcoal assemblages from the eighth till the mid-fifth millennium BP. The same taxa are dominant in the present vegetation. By the third millennium BP, a more diverse assemblage of wood seems to be exploited, with *Juniperus* sp. (juniper), *Zizyphus* sp. (jujuba), *Vitis vinifera* L. (grape) and *Populus* cf. *euphratica* (poplar, bahan) found alongside the previous taxa. In Mehrgarh there seems to be an increase in the use of tamarisk wood in the late third millennium, but this might be related to the particular context analysed, a kiln (Thièbault 1995). As observed by one of the authors (Madella) during several survey journeys in Sindh, tamarisk wood is still very much in use today as kiln fuel and sometime forms the only wood used for firing. This is possible connected to the widespread availability of the plants, along rivers and canals, and in the wastelands and saline areas. Charcoal analysis from Kot Diji (Castelletti et al. 1994), in the middle Indus Valley (Sindh), has shown that both Pre-Harappan and Harappan populations exploited a wide array of wood from several ecological areas, spanning from arid and semi-arid zones (*Calotropis* sp., *Capparis decidua* [Forsk.] Edgew, *Zizyphus nummularia* [Burm.] Arn., *Prosopis cineraria* [L.] Druce, *Acacia* sp.) to salty lands (*Tamarix* sp.) and the riverine hygrophylus forest (*Populus euphratica* Olivier). Poplar is predominant in all but one of the samples, the Pre-Harappan layer 5A, where *Capparis decidua* Forsk. (Edgew). (caper) is more abundant. However, the wood assemblage tends to be quite homogeneous over time and does not show any appreciable variability between the Pre-Harappan and Harappan cultural levels. The plants exploited in Mehrgarh, Nausharo and Kot Diji do not indicate wetter conditions in Baluchistan and the central Indus Valley during the Pre-Harappan, and the Early and Mature Harappan. Instead, they indicate the presence of xerophytic forests and pockets of mesophytic and hygrophylus vegetations. Indeed the exploitation of several ecological niches available in the territory of the settlements is likely. There may even have been substantial trade of exotic wood from the Himalayan foothills towards Punjab and Sindh. For example, a wooden coffin excavated in Harappa (Cemetery H) was made with *Ulmus* sp. (elm) and *Cedrus deodara* (Roxb. ex Lamb.) G. Don f. (deodar) wood (Chowdhury and Ghosh 1951). Charcoals from the Late Harappan site of Sanghol (Punjab) yielded a more diverse assemblage where along with *Acacia* sp. *Ziziphus* sp., and *Tamarix* cf. *articulata* were also identified *Ficus glomerata* Roxb., *Albizzia lebbeck* Benth., *Ephedra* sp. and *Jasminum* sp. (jasmine) (Saraswat and Chanchala 1997). At the Pre-Harappan and Mature Harappan site of Rohira, in Punjab, *Tectona grandis* L. (teak), *Cedrela toona* Roxb. (toon), *Manilkara hexandra* (Roxb.) Dubard (khirani), *Cedrus deodara* (Roxb. ex Lamb.) G. Don f. (deodar), *Lawsonia inermis* L. (henna) and *Nyctanthes arbor-tristis* L. (parijat) charcoals were also identified. These charcoal assemblages suggest the exploitation of the sub-Himalayan and Himalayan valleys which lay to the north and north-west of the sites.

There is also additional 'climatic' evidence in terms of Mesolithic sites observed near Thari village during a survey carried out by the Rohri Hills Archaeological Project in the westernmost part of the Thar desert (Sindh, Pakistan) (Biagi and Kazi 1995 and Madella: personal observations). All those sites are to be found on stabilized sand dunes highlighting that, at least for the western portion of the desert, climatic characteristics were more or less stable since the deposition of these artefacts (i.e. early Mid-Holocene). Site LSI produced both Mesolithic artefacts and a few Harappan potsherds (Biagi and Kazi 1995). The potsherds were heavily weathered, red or brown in colour. It is useful to recall here that Mesolithic hunter-gatherers might have coexisted for a long period with the urban Harappan Culture communities (Possehl and Kennedy 1979; Allchin 1982; Possehl and Rissman 1992; cf. Guha 1994). Additional evidence for the co-existence of Mesolithic (hunter-gatherer) communities alongside the Harappan urbanized society come from hinterland regions such as Langhnaj in north Gujarat (Sankalia 1965) and Budha Pushkar in Rajasthan (Allchin et al. 1978). Mesolithic continuity up to and possibly through the

Harappan period provides general but non-conclusive support for relative stability of the environment.

The Greater Indus Valley and the Harappan Civilization have often been discussed by archaeologists as a single geographical entity to be understood in terms of unitary changes. However, this area comprises several ecological zones, from the coast of Sindh and Gujarat to the sub-Himalayan hills via the 'valleys' of the Indus and several other rivers in Sindh and Punjab, including the former Ghaggar-Hakkra. The scanty palaeoclimatic data available are often extended to the whole area. Thus, even assuming that there may have been a more arid phase in the general climate starting in the early second millennium BC, the reaction of the various ecosystems to it might have been quite different (cf. Vishnu-Mittre 1982). Indeed such local and regional variations in response to climatic variation may be shown through a comparison of the pollen assemblages from different lakes in Rajasthan, such as Lunkaransar lake in comparison with that from Didwana lake, separated by only 150 km (see Bryson and Swain 1981). Thus while the Indian subcontinent must have been affected by global or large scale climate changes like those in the Indian Ocean monsoon system (reflected also in the palaeoclimatic record in north Africa, see Grove 1993; Sirocko 1996) and in East Asia or north Australia (see Wasson 1995), it is unclear what the rapidity or intensity of these changes were within South Asia, and how these might have affected local regions, their fauna, vegetation and human societies (see also F.R. Allchin 1982). There is a growing discomfort with simplistic environmentally determined understandings of change (Paddayya 1994). When environmental data are confronted with the archaeological evidence for change, which begins in some areas *c.* 2200 BC and continues through the second millennium BC, it is no longer possible to attribute a single collapse of the Harappan Civilization to a single episode of climatic change. The picture seems to be less unitary and interpretations should allow for more locally articulated explanations of the changes in relation to regional variables during the late third and second millennia BC.

DISCUSSION: AGRICULTURAL CONSERVATISM AND CHANGE

The agricultural basis that allowed the rise of urbanism in the Indus Valley is a familiar one, shared with the early civilizations of Mesopotamia and Egypt. As noted in numerous pervious reviews, a crop complex based on winter-sown, spring-harvested crops all watered by winter rains or run-off, with their origins much further west in the fertile crescent, became established in the valleys and piedmonts west of the Indus before the sixth millennium BC (Costantini 1983; Meadow 1989, 1996, 1998; Kenoyer 1991, 1998: 37-9; Bar-Yosef and Meadow 1995; Franke-Vogt. 1995). Subsequently, these winter crops were taken out onto the vast Indus and Ghaggar-Hakkra flood plains, where the ability to produce large surpluses presumably fueled social differentiation and craft specialization. The rise of cities was dependent upon an integrated trade network that allowed surplus in one region to furnish the towns and cities in another during times of local shortage: 'The geographic and climatic diversity of the Indus Valley was a kind of safety net, because if the crops failed in the hinterland around one city, surplus production in other regions could have been brought in to feed the general population' (Kenoyer 1998: 162). Although there is no direct evidence for the trade in foodstuffs, the abundant evidence for trade in minerals and seashells attests to the development of the kinds of trade networks necessary for agricultural integration. It is the same kind of developments, based incidentally on the same group of crops, that allowed the development of early civilizations in the Nile Valley and Mesopotamia.

There is no evidence for any major agricultural changes correlating with the rise of the Harappan Civilization, but rather a continuation of diverse local cultivation practices tied to local hydrological conditions and cultural traditions. There is, however, one possible agricultural development that could have been important. It may have been the case that the adoption of animal-drawn ploughs allowed more efficient cultivation in the river flood plains (Allchin and Allchin 1997: 169). The earliest clear evidence for ploughing in South Asia comes from preserved tillage marks sealed beneath Early Harappan levels at Kalibangan on the erstwhile Sarasvati river in northern Rajasthan (Lal 1971). These show that ploughing was established prior to urbanization in the major river basins. In addition, there is a possible schematic depiction of ploughmarks painted on a piece of pottery from Mohenjo Daro (MacKay 1938: 221, Pl. LXVIII, 25). However, it is possible that ploughing was not a widespread, common practice and that the inundated soils were not subjected to this practice. With the collection of systematic archaeobotanical samples it may become possible to corroborate this through the analysis of weed assemblages which would also allow some assessment of the importance of tillage in other regions.

At present there are important limitations to what we can irrefutably claim about Harappan agriculture. There is still a real dearth of published archaeobotanical assemblages that have been collected through systematic means such as flotation or sieving. This is especially the case for most of the core Harappan areas, including the middle-lower Ghaggar-Hakkra and Indus valleys. Although systematic archaeobotanical samples are lacking from most of the Indus Valley, evidence from Baluchistan (Mehrgarh, Nausharo and Pirak) has been taken to represent the situation in the Indus Valley (Costantini 1979, 1990; Jarrige 1985, 1997; Meadow 1989, 1996; Franke-Vogt 1995). As already stated earlier, the Greater Indus Valley is not a homogeneous area and several microclimates and ecotones are present. It might be possible that the archaeobotanical assemblages taken as general examples are, in fact, geographical variants of a more complex agricultural package, flexible and adaptable to regional climatic, geological and geographical characteristics of the territory. The flotation of samples from Harappan town and village sites in floodplain areas should be a priority for future research.

When Harappan agriculture is discussed, the great regional differences must be acknowledge (Vishnu-Mittre 1982). Several authors have recognized different regional traditions within the Harappan Civilization, and amongst the differences between these regions, aspects of cultural ecology are likely to have been significant (Possehl 1989, 1997b). Despite the still slim database, differences between some of the regions in terms of the crops they utilized is clear. While winter crops were probably the norm in core areas, in regions east of the main Indus and Ghaggar-Hakkra valleys, other crops were already being utilized, especially *kharif* crops that are well-suited to cultivation in monsoonal environments. During the Mature Harappan period summer crops, including millets and at least one of the South Asian *Vigna* pulses were present in Gujarat. Also *Macrotyloma uniflorum* (Lam.) Verdc. and *Vigna* spp. were being cultivated in Haryana (Willcox 1992). Irrigation practices also are likely to have varied between sites in different parts of the river valleys, as well as between flood basin sites and sites in the uplands. In regions where summer crops were the norm, i.e. Gujarat, irrigation may have been largely absent, with dependence on rainfall instead. As noted earlier, in the discussion of the Rojdi weed flora, the strong presence of sedges in the final period at that sites, dating to the early second millennium BC, suggests cultivation in areas with high water tables, such as wetlands or perhaps along the edges of ponds. That such ponds could have been artificial, a kind of simple tank irrigation, is worth exploring.

There is an apparent half millennium lagtime between when *kharif* cropping of annual field crops was practised in peripheral areas like Gujarat and Haryana and when it may have become important in core Harappan areas, i.e. west of Gujarat or the Ganga-Yamuna Doab region. It must be noted, however, that the only real evidence for this comes from the archaeobotanical sequence from Mehrgarh-Nausharo-Pirak (Costantini 1979, 1986, 1990; Costantini and Biasini 1985). Meadow (1989, 1996, 1998) argued for an agricultural transformation on the southern and eastern fringes of the Harappan Civilization, facilitated primarily by the African millets, with the arrival of 'Asian' millets, possible from the west, *Panicum miliaceum* L. and *Setaria italica* (L.) P. Beauv., also summer crops. This supposed *kharif* crop revolution opened up new zones to extensive agriculture as opposed to the intensive, presumably irrigated, Harappan system (Possehl 1980: 33). The first adoptions of these crops, alongwith rice, in the Harappan core area may date of after 2000 BC (Franke-Vogt 1995: 32-4). Meadow (1989, 1996, 1998) has suggested that these hypothetical Late Harappan cropping transformations are part of a broader economic revolution. This would have included new livestock species that facilitated transport and communication, namely horses, donkeys and camels. This transport revolution may have facilitated the migration of Harappan agriculturalists into areas where the new crops could be exploited, such as peninsular India. Reliable evidence for domestic horse (*Equus caballus*) in South Asia dates to *c.* 2000 BC at Pirak in Baluchistan (Meadow 1986, 1987: 907-10), although earlier evidence for domesticated horses has been reported from Surkotada (Sharma 1993). Meadow and Patel (1997) question this evidence, while other experts maintain it. Resolution of this issue must await the discovery of new osteological remains. Setting aside the problems of new animals, however, the role of African crops appears to be overstated, and the presence of the Chinese millets is not entirely clear. That there may have been a certain agricultural conservatism inherent in the bureaucratic urban system of the Harappan Civilization which resisted the adoption of new crops in core areas is worth considering. However, this concept of an agricultural 'revolution' correlating roughly with the end of Harappan urbanism needs to be carefully assessed as new data become available. As Weber's (1997) preliminary discussion of data from

Harappa indicates, the major agricultural changes there appear to occur by *c.* 2200 BC, well before the period of devolution, and he has elsewhere attempted to address the apparent disjunction between agricultural and other kinds of change (Weber 1996). Furthermore, the choice not to utilize millets in the major river valleys may have had more to do with emphasis on other kinds of crops in the summer, such as fruits and fibres, which had important non-subsistence economic roles.

Environment has evidently played an important role in shaping and, up to a certain point, promoting changes in the Harappan economic and sociocultural systems. The shift of the Ghaggar-Hakkra drainage system from west to east must have had tremendous repercussions on the agricultural productivity of one of the cardinal areas for the production of wheat and barley, and one of the most heavily populated Harappan regions. The vagaries of the bed of the Indus river could have played some role in diminishing the importance of towns left too far away from the main course (Mohenjo Daro?) or heavily inundated during the floods. Global and regional scale climatic changes would also have had some effect on the environments of the Greater Indus Valley. These effects might be reflected in some of the *adjustments* produced by the Late Harappan societies during the second millennium BC. However, the comparison of environmental data—even if scanty—and the Post-Urban archaeological assemblages found in the Greater Indus Valley give evidence that an explanation based only upon environmental determinants is simplistic and unrealistic.

The transformation that occurred during the second millennium in North-Western South Asia is one of decline in the core area but also of regional developments in the periphery, i.e. a localization era (Kenoyer 1991; Shaffer and Lichtenstein 1992). New political powers seem to develop from the Pre-Harappan cultural traits thus destroying the apparent consolidation achieved by the Harappan Culture during the integration era. New political foci appear in the north, in Afghanisatan and Central Asia, and in the east, in the Ganga-Yamuna Doab, while more localized chiefdoms emerged in the northern Deccan and possibly Gujarat. Some of the shifts might be explained by core-periphery models (Kenoyer 1991, 1995, 1998; Lamberg-Karlovsky 1989; 241-50) which were helped along by the concomitance of environmental changes, regardless of whether they were induced by global changes or human impacts. In the core area of the Harappan Civilization, power may have been too consolidated to allow for new social, political and possibly religious ideas, whereas the periphery may have offered the ideal setting for the emergence of new indigenous polities and a new urban process (Kenoyer 1998). The process of de-urbanization in the Indus Valley was certainly facilitated by hydrographic and climatic changes (even of local scale), but it is hard to see these as driving and determining the course of change. Possible important factors were the captures of several river courses, especially the Sutlej, and tributaries of the Ghaggar-Hakkra which left totally deserted of water the area that is now the Cholistan desert, as well as vagaries of the Indus in the lower valley, south of the Sukkur gorges. The new environmental conditions of the southern portion of the Indus Valley might have also forced some movement of population towards the south-east and the north-east (Misra 1984). Within this context of decentralization and population relocation, additional crops, such as millets and pulses from peninsular India or those from Africa, become more widely available, although their separate adoptions should be seen as local choices rather than some nebulous 'revolution' over a vast area. In some areas, such as in Gujarat and eastern Punjab, these monsoon watered crops may have allowed for more local subsistence independence, and such adaptation may have both decreased the need for and the maintenance of the interregional 'safety-net' presumed to have been so important for the establishment of Harappan urbanism (if such a system indeed existed).

Although the cultural legacy of the Harappan Civilization in later South Asian cultural traditions is clear (Allchin 1982; Allchin and Allchin 1997), its agricultural legacy is not. Evidence for the adoption of wheat, barley and several winter legumes (i.e. the Harappan staples) during the second millennium BC may link these crops with the first fully settled agriculturalists of the northern Deccan (Maharashtra). Peas, lentils and *Lathyrus* became important counterparts to the summer-sown grams, i.e. *Vigna* spp, *Macrotyloma uniflorum* (Lam.) Verdc. While there is some evidence for possible *Eleusine* and *Sorghum* at this time (i.e. 2000-1500 BC), the *rabi* cereals may have been more important for the establishment of sustained agriculture in the Deccan (contra Possehl 1986). This evidence supports, to an extent, the contention of Chakrabarti (1995: 164-7) that the development of agriculture in peninsular India came about through a process of interaction between 'Harappan plough-agriculturalists' (presumably immigrant) and local Mesolithic populations. However, there is a small body of evidence to indicate that agriculture had spread east of the Indus system into areas such as Rajasthan and parts of Gujarat during the pre-Urban/Early Harappan phase. The evidence from Balathal, now dating to the beginning of the third millennium, indicates reliance on the *rabi* crop complex, including wheat, barley and lentils (Shinde 1999). It is perhaps more likely that these extra-Harappan societies provided many of the crops for the development of village in Maharashtra rather than that came from the Harappans as Chakrabarti implies. Also, there is as yet no firm evidence for plough agriculture in Chalcolithic Maharashtra, with the data suggesting instead the use of hand-held implements such as digging sticks and hoes (Shinde 1987). In addition, these introductions must be considered against a background of cattle pastoralism and indigenous pulse-millet agriculture which was established in the southern Deccan (Karnataka-Andhra Pradesh), perhaps between 3000 and 2500 BC (Allchin and Allchin 1982: 122-5; Possehl and Rissman 1992; Devaraj et al. 1995; Korisettar et al., in Vol. I of this series; Fuller et al., n.d.). This southern agricultural complex appears to have provided *kharif* crops to the evolving villages further north, and it is unclear if some of the millets cultivated in Gujarat during the Mature Harappan phase might be derived from contemporary societies of the Indian Peninsula or could have been locally domesticated in Gujarat.

Although many practices from the Harappan period, such as irrigation techniques, have continued into modern times, the most significant agricultural developments for later South Asian history may have been those which took place in the Late Harappan period in areas peripheral to the urban core. The integration of summer and winter crops in Chalcolithic Maharashtra, and perhaps even more significant, the double-cropping which included rice that became the norm in the Ganga Valley, became the most widespread agricultural systems on the subcontinent in more recent times. The surpluses that could be produced, especially through a combination of rice agriculture and irrigated winter cereals, was a prerequisite for South Asia's second urbanization. It is perhaps not surprising then, that the regions identified as 'nuclear regions' for post-Harappan cultural developments in South Asia (Allchin and Allchin 1982: 249-50), correspond roughly to the regions in which these agricultural syntheses occurred. It is also these regions of agricultural synthesis, in particular the upper Ganga Valley-Yamuna region, where the agricultural system was probably more stable, and better buffered against the social and tectonic upheavals of Harappan decentralization.

Since the first excavation report of an Indus Valley site (Marshall 1931), archaeobotanical evidence and discussions of possible environmental changes have been a part of Harappan studies. The collection of evidence to address these issues in a systematic way, however, has only just begun. The gaps in the available evidence, due to unsystematic methods of collection in the past must be bept firmly in mind. Nevertheless, it is clear that the Harappan Civilization arose out of and devolved within a diverse set of environments in north-western South Asia which both constrained and enabled this civilization. These environments were not static but dynamic on several time scales, from the variations in annual floods and rainfall, to longer term trends of change due in part to larger processes of climatic change but also to the impact of human agro-pastoral activities. The understanding of these environmental processes must rely upon a judicious use of palaeoecological data that takes into account difficulties of correlation and the confounding effects of climatic and anthropogenic forces. In order to better understand these relationships, far more environmental archaeology is needed, and continual dialogue must be maintained between those scientists involved in palaeoecological work and those involved with interpreting the archaeology. In the review here, we have hoped to lay some groundwork for such a dialogue, by laying out the available sources of data and by highlighting important issues of debate.

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NOTES

1. Throughout this text botanical species names are followed by the standard abbreviation for the authority upon which the species definition is based. Although these letters may appear cumbersome to the archaeologist, we feel these are necessary in this context as several of crop taxa have been subject to taxonomic confusion in the archaeobotanical literature. The abbreviation in parentheses, if present, refers to the first author(s) to describe the species and establish the specific epithet, while the abbreviation without prentheses refers to the authors who first established the full genus-species binomial.
2. Horsegram (Hindi *kulthi*) is usually referred to in Indian floristics and agronomic literature as *Dolichos biflorus* L. However, this species of Linnaeus actually describes catjang type cowpea (Hindi *chowli, lobia*), now grouped in the polytypic species *Vigna unguiculata* (L.) Walp. Thus *D. biflrous* L. is a synonym for *V. unguiculata* (L.) Walp. This equation has, however, been wrongly used by Weber (1991: 98), Reddy (1994), and Kroll (1996, 1997, 1998), since the archaeological finds traditionally described as *D. biflrous* are *not* cowpeas! *D. biflorus* is an invalid name for the horsegram/*kulthi*, which was first properly described by Lamarck as *Dolichos uniflorum*. It has now been transferred to the genus *Macrotyloma* (Verdcourt 1970, 1971; Smartt 1985a, 1990). The recent suggestion that '*Dolichos uniflorus*' is the wild form of '*Dolichos biflorus*' and localized in the southern and eastern peninsula (Mehra 1997), requires botanical clarification.
3. *Phaseolus aureus* and *P. radiatus* are *not* domesticated and wild forms, respectively, as suggested by Lone et al. (1993), but synonyms for the domesticated crop, the wild form of which is *Phaseolus sublobatus* Roxb. As they have all been transferred to *Vigna* and the wild progenitor has been demoted to subspecies following the nomenclatural system of Harlan and De Wet (1971), the wild progenitor is now known as *Vigna radiata* subsp. *sublobata* (Smartt 1985b, 1990).
4. The equation of *Phaseolus mungo* L. with *Vigna angularis* (Weber 1991; Reddy 1994) is an incorrect synonomy, as *V. angularis* (Willd.) Ohwi & Ohashi, the adzuki bean, is a distinct domesticated species cultivated in China, Korea and Japan where its wild progenitor also occurs (Smartt 1985b, 1990; Lawn 1995).
5. Dates are hereafter calibrated to a calendar timescale with CALIB 4.0 (Stuiver and Reimer 1993; Stuiver et al. 1998), which includes the most recent corrections for marine carbon reservoir effects. Uncalibrated dates are given as small capital case BC or BP. It should be noted that when marine reservoir effects and calibrations are taken into account the various *c.* 3700-3500 BP events cited by several authors *do not* correlate, and are separated by as much as 500 years.

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