TWO

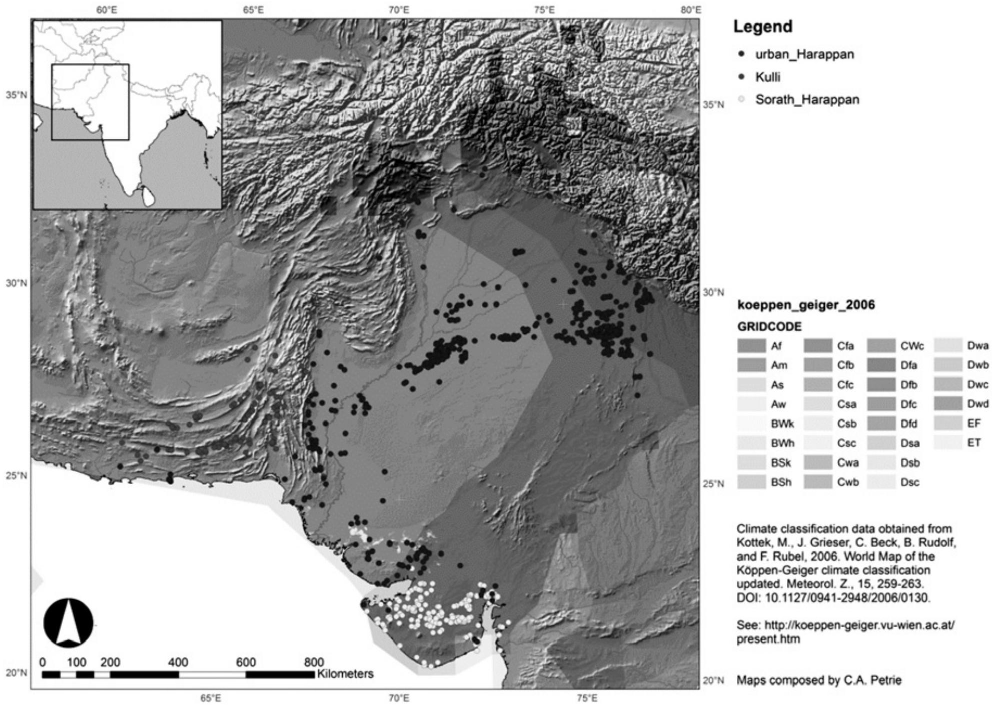
THE PALEOENVIRONMENTAL CONTEXT

INTRODUCTION

The Indus Civilization spanned large parts of modern Pakistan and India (Agrawal 2007; Chakrabarti 1999; Fairservis 1967, 1971; Kenoyer 1998; Lal 1997; Marshall 1931; Possehl 2002; Sankalia 1962; Wheeler 1968; Wright 2010). The result of this extensive geographic spread is a considerable variation in climate, hydrology and ecology in the area in which Indus settlements are found (e.g. Agrawal and Sood 1993; Joshi et al. 1984; Possehl 1982, 1992; also Chakrabarti 1999: 153–60).

Today the region is characterized by a series of distinct zones ranging from arid hot desert, to arid hot steppe, to warm temperate regions with dry winters and hot summers (see Kottek et al. 2006 for Köppen–Geiger Climate Classifications) (Figure 2). Water is available from different sources and at different times of the year. Within this is the overlap between the winter and summer rainfall systems. Within the zones for both the summer and winter rainfall is a steep rainfall gradient. Winter rain (December–February) is followed by a drier summer (March–April) and the Indian Summer Monsoon (ISM) (June–September). Water is also supplied from Himalayan snowmelt, rivers, lakes, overbank flooding and groundwater sources (e.g. wells), depending on the region (Petrie et al. 2018).

While this modern description of the environmental setting has been put to good use in exploring the agricultural strategies of Indus farmers (see e.g. Petrie and Bates 2017; Weber et al. 2010b), there is a lack of systematic and localized paleoclimatic data (Madella and Fuller 2006; Petrie et al. 2018; Weber et al. 2010b). This is critical because climate and environmental niches varied throughout the Holocene, and



2 Climate zones within the Indus and the distribution of sites laid over this. Reproduced from Petrie et al. (2017: figure 2). Created by C. A. Petrie with the VoR found in Petrie et al. (2017). Permission to use the adapted version kindly given by C. A. Petrie

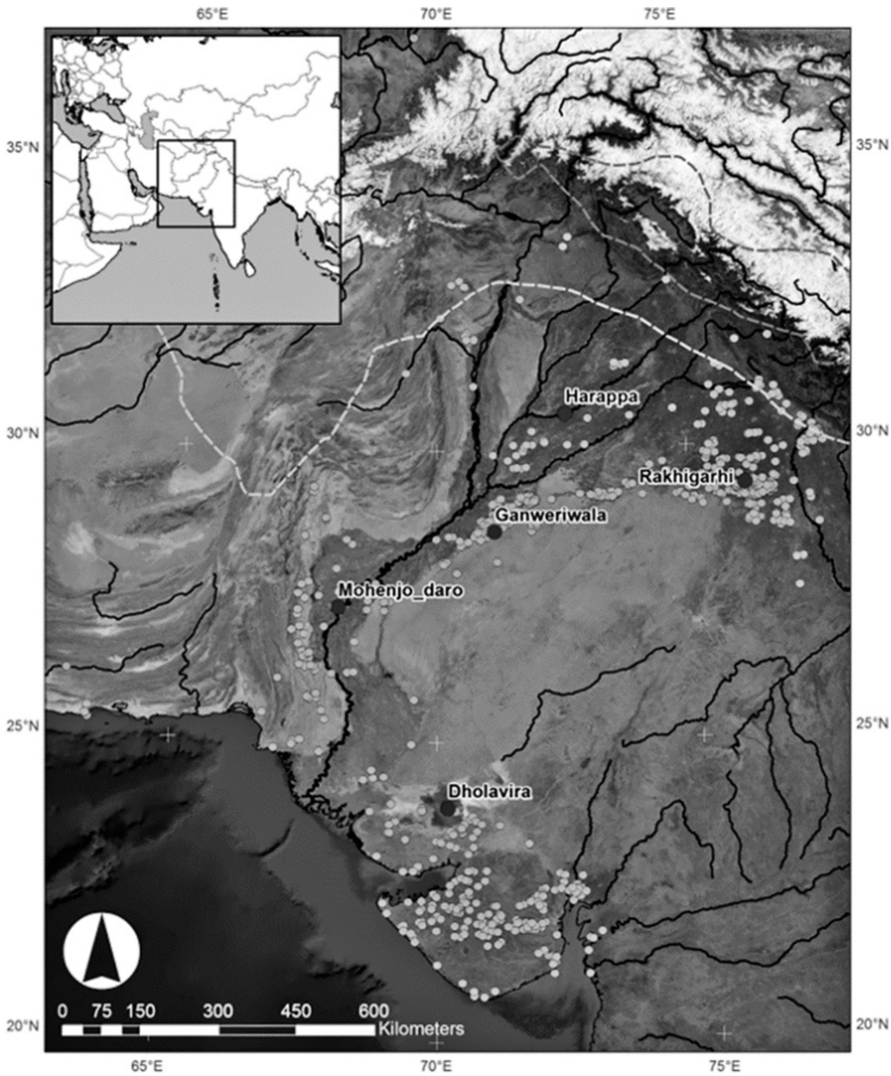
the role of paleoclimatic and paleoenvironmental change during the period of the Indus Civilization has been the driver of many debates.

Attempts to reconstruct the climate and environment during the Indus period have been carried out since its rediscovery. For example, Marshall (1931), Piggott (1950) and Wheeler (1968) all suggested that the careful control of water through intricate drainage systems at Indus cities implied a wetter environment, and that the presence of tigers on stamp seals supported theories of a wetter climate. Such discussions were called into question (see summaries in Possehl 2002 and Wright 2010: 32) because of the variable nature of the evidence provided, which could be used to argue for either drier or wetter conditions. Despite this, climate and environment reconstruction have remained an important issue for scholarship to this day.

It is important to lay out two critical factors in the Indus environment – rainfall and rivers. These two systems provide the life-water of the Indus region, and have been invoked in discussions of the civilization's agricultural strategies and in the debates surrounding climate change and the subsequent processes and their impact on agriculture and thus societal change/decline. Understanding how they operate today in order to create a baseline for modelling change is an important step that must be taken.

RAINFALL

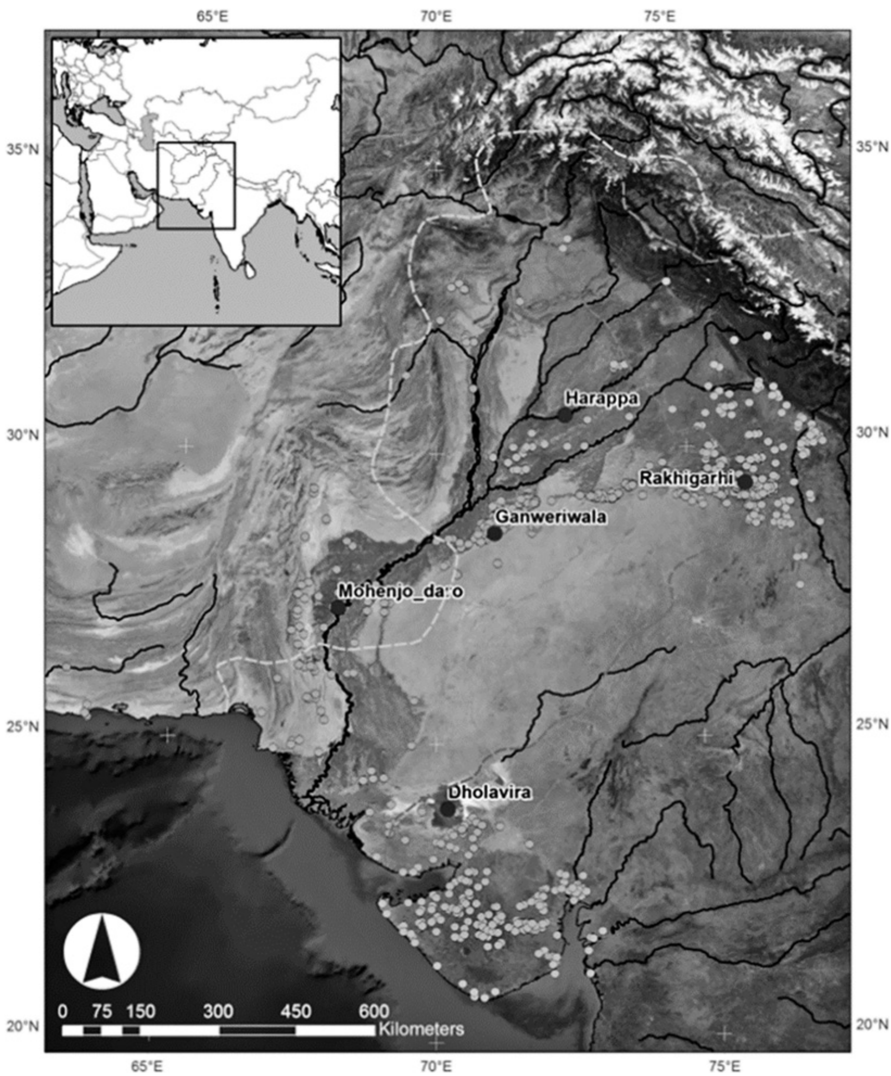
Two systems affect the Indus: the ISM and the westerly storm front originating in the Mediterranean termed the 'winter westerlies' (Aggarwal et al. 2004; Gupta and Deshpande 2003). These two systems were vital for the agricultural strategies exploited by Indus farmers. They affect the seasonal round and the crops that can be grown in the region because of the variability and diversity in water they provide spatially and temporally (Figure 3). The drivers of the ISM and the winter westerlies are of course very different, and thus their impacts and



3 Averaged distribution and isohyets of winter rainfall (p.16) and the ISM (p.17) across the Indus region. Reproduced from Petrie et al. (2017: figures 3 and 4). The VoR can be found in Petrie et al. (2017). Permission to use the adapted version kindly given by C. A. Petrie

patterns, spatially and temporally, are different. The ISM provides rain generally in the months of June through September, and the winter westerlies in January and February, but this varies because of numerous factors.

The ISM operates across a wide band of the mid-low latitudes (Cai et al. 2012), but we will focus on its impact in the South Asian subcontinent. The ISM is intimately connected with the Intertropical Convergence Zone (ITCZ). This global low-pressure belt tracks the zone of maximum solar insolation (Sinha et al. 2011; Webster et al. 1998). The ISM is driven by the differential response of the



3 (cont.)

land and sea to summer insolation, and as the ITCZ moves north between June and September, a monsoonal trough (a low-pressure belt) is created over the subcontinent. This draws moist winds from the Indian Ocean across the land and creates monsoon rainfall from two branches of the ISM – the Arabian Sea and the Bay of Bengal (Gupta and Deshpande 2003; Hassan et al. 2015; Kumar et al. 2010).

There is not a fixed or predictable occurrence of the ITCZ movement, and temporal variability is a recognized feature of the ISM (Krishnamurthy and Kinter 2003; Sinha et al. 2011). This variability is scalar. At the intra-seasonal scale, the monsoon season can be 'active' or 'break' on a cycle of thirty to fifty days (Rajeevan et al. 2010; Sinha et al. 2011). The monsoon also varies at an inter-annual to inter-decadal scale in relation to tropical sea surface temperatures, snow cover and solar activity (Berkelhammer et al. 2010; Cai et al. 2012; Cook et al. 2010; Konecky et al. 2014; Sinha et al. 2011). At the largest scale, the ISM can vary across centuries and even millennia (Breitenbach 2009; Cai et al. 2012; Tiwari et al. 2015; Zorzi et al. 2015).

The winter westerlies provide only a small proportion of rainfall to the Indus region. The westerlies are formed of bands of westerly circulation at 30–60° latitude in both hemispheres (Farhan et al. 2015), and they are strongest in winter due to polar pressure gradients. In northern South Asia, the ISM trough exacerbates this pattern by displacing the westerlies (Hassan et al. 2015) until winter, when the ITCZ moves south. However, precipitation is generally low because of the large distances air masses have already travelled over land (Treydte et al. 2014). Any moisture they are carrying therefore falls mainly in the north and east of the Indus region as the westerlies meet the Himalayas (Gupta and Deshpande 2003). As a result of these interactions, temporally, the westerlies vary in a pattern asynchronous with the ISM (Bryson and Swain 1981; Chen et al. 2008; Kotlia et al. 2015; Staubwasser et al. 2003).

In addition to temporal shifts, the ISM and winter westerlies in the subcontinent are spatially differentiated across the region. East–west and north–south rainfall gradients reflect decreasing monsoonal penetration.

RIVERS

The rivers of the Indus system are another important source of water and moisture, and have been brought into models of the rise, height and fall of the Indus. In much of the early literature (e.g. Marshall 1931; Piggott 1950; Wheeler 1950), the Indus was compared with contemporary Bronze Age civilizations and interpreted as being focused on the rivers. However, this is misleading as the number of rivers, the nature of their fluvial dynamics and whether these changed before, during or after the Indus period remain highly debated (e.g. Flam 1999; Giosan et al. 2012; Tripathi et al. 2004; Valdiya 2002;

Wright 2010), not to mention whether settlement was focused on rivers or not (e.g. see Orengo and Petrie 2017).

The most obvious river affecting the civilization is the Indus River. Recent historic events such as the 2010 flooding have shown the powerful impact of the Indus River and its ability to change course on the surrounding physical and cultural landscape. The impact of repeated flooding, both catastrophic and more regular and gentle, has even been used by some to explain the walls and 'defences' at urban centres such as Mohenjo-Daro (Dales 1964; Mackay 1938; Raikes 1964), though these interpretations are not universally accepted (Possehl 1967). At the site of Mohenjo-Daro, relict water courses can be seen, and Flam (1999) and Pendall and Amundson (1990) have tracked the shifts of both the Indus and its tributaries during the course of the Holocene. However, there is little securely dated evidence to reconstruct the Indus River basin's dynamics. Small-scale channel migrations likely occurred in both the upper and lower Indus systems. Drastic changes in the river courses have not been found (Pendall and Amundson 1990; Schuldenrein et al. 2004). This assertion is supported by new evidence showing that both the upper and lower Indus have been relatively stable since the mid-Holocene (Giosan et al. 2012). There is no evidence for a catastrophic Indus Civilization period avulsion in the north-eastern Indus region (Flam 1993, 1999). Instead there was reduction in river flow, likely linked to the climate. Staubwasser et al.'s (2003) study showed changes in planktonic δ18O isotopes in the river delta, suggesting a reduced discharge *c.*4.2 k BP, while in the upper Indus, Wright et al. (2008) suggested that discharge from the Beas, near the major centre of Harappa, reduced *c.*2000 BC, despite a millennia and a half of stability. This is a model that needs to be ground-truthed, but it is supported by Giosan et al.'s (2012) fluvial landforms study. The Indus River and changes in its flow have been linked to agricultural models, as water and soil nutrients supplied by the Indus and its overbank flooding were critical components in the agricultural strategies of the people of the Indus plains and watersheds (Petrie and Bates 2017; Weber et al. 2010b; Wright 2010).

While many settlements were located along the Indus River or its tributaries, such as Harappa and Mohenjo-Daro, the location of settlements in relation to water sources in the north-eastern Harappan zone has long been a topic of research and discussion. The north-eastern Harappan region is edged in the east by the Yamuna and bounded to the west by the Indus River. Currently no major river flows through the interfluves of Rajasthan, Haryana and the most western part of Uttar Pradesh. Instead an ephemeral feature or drainage called the Ghaggar-Hakra flows there seasonally. Just as the Indus River was critical for agriculture in the western region of the Indus, the Ghaggar-Hakra has been cited as important for agriculture in the north-eastern region (Petrie and Bates 2017; Weber et al. 2010b, 2011; Wright 2010). Today this purely monsoon-fed feature rises in the Himalayan foothills, crosses the Haryana plains and disappears in Rajasthan (Saini et al. 2009).

However, Vedic texts describe a mighty river, the Sarasvati, flowing in this region (Agrawal and Sood 1993; Oldham 1887; Possehl 2002). This has led some to hypothesize that the Ghaggar-Hakra was once a much larger perennial river. Numerous courses have been proposed for its flow. One of the most commonly proposed is the 'Nara Nadi' that joined the eastern course of the Indus (Danino 2010; Flam 1993; Giosan et al. 2012; Mughal 1997; Possehl 1999; Valdiya 2002). This hypothesis was originally based on ground observations of relict channels (Oldham 1887) and later by satellite imagery analysis of settlement distribution patters and channels (Yashpal et al. 1980) and the notion that the river must have been a major water source supporting numerous Indus sites, using later-period Vedic texts 'showing' the presence of a major river that declined at some point.

This led to theories that any decline in the Ghaggar-Hakra would have resulted in a decline in the Indus Civilization. Surveys by Ghosh (1952), Mughal (1982, 1997) and others appeared to show linear alignments of sites, suggesting settlements in the north-eastern Harappan also followed waterways. Satellite imagery (e.g. Yashpal et al. 1980) appeared to show a paleo-channel running through this region and Possehl (1997a, 1999, 2002: 239–40) argued that although no Early or Mature Harappan sites were found in the channels, settlements from the Painted Grey Ware period were, and therefore the Ghaggar-Hakra ceased to flow sometime around the Late Harappan period. The perceived shift in settlement patterns along these linear features led scholars such as Yashpal et al. (1980), Misra (1984), Agrawal and Sood (1993), Chakrabarti (1995), Allchin and Allchin (1997), Mughal (1997), Lal (2002), Danino (2010) and Gangal et al. (2010) to argue that its decline coincided with the collapse of the Indus Civilization, indeed that it was one of the main causes of Late Harappan deurbanization.

Jones (2017) summed up the arguments surrounding the importance of the Ghaggar-Hakra for Indus urban life and links between its decline and the decline of the Indus Civilization into three core premises:

1) The Ghaggar-Hakra was a perennial river carrying water until the Mature Harappan period.
2) The Ghaggar-Hakra declined in magnitude and reliability *c.*2100–2000 BC.
3) The Ghaggar-Hakra was therefore critical for Indus sustainability because, as Flam (1999: 317) puts it, the Ghaggar-Hakra was the 'lifeblood' for settlements in the north-eastern region.

However, as Jones (2017) noted, new data question these premises. Specifically these data suggest that the Ghaggar-Hakra ceased to be a perennial river before the Holocene, and thus any 'decline' occurred well before the development of the Indus Civilization. Following the use of accelerator mass spectrometry (AMS) radiocarbon dating of organic matter and optically stimulated luminescence (OSL) dating of sediments collected from drilling and trenches excavated downstream in areas of Cholistan such as at Fort Abbas and in the upper Ghaggar-Hakra interfluve, evidence is now showing that the river ceased to flow in the middle of the Holocene (e.g. Clift et al. 2012; Giosan et al. 2012). Gupta et al. (in prep) gave an even earlier date for the cessation of the Ghaggar-Hakra at *c.*14,000 BP. Tripathi et al. (2013) also suggested that while there was some mid-Holocene fluvial activity, it was monsoon-fed and ephemeral, similar to today. These differing dates and flow rates resulted from complexities in using organic material in fluvial sediments, as the methods relied on the material being of the same date as the sediments and not being mixed in from earlier events and redeposited by complex river systems, which is unlikely. Gaining a simple date for the 'end' of the Ghaggar-Hakra will be challenging, if not impossible.

The cause(s) of any decline of change in the nature of the Ghaggar-Hakra flow is therefore still up for debate as it is tied to an end date for flow, which, as shown, is hard to demonstrate. Gupta et al. (in prep.) argued that the Ghaggar-Hakra ceased to flow as a year-round river following an avulsion event that resulted in the loss of glacial meltwater from the Sutlej to this channel. Clift et al. (2012) argued that an avulsion event shifted the Yamuna east *c.*49–10 ka and that there were other avulsion events *c.*10 ka which may have resulted in changes to this system such as the capture of the Sutlej to the north. Giosan et al. (2012) suggested that the sediment in the Cholistan paleo-channel was monsoon fed in the Holocene rather than glacially fed from either the Sutlej or Yamuna as they were before the Holocene, and that as the monsoon weakened, the rivers dried and became seasonal. Petrie et al. (2017) have questioned Giosan et al.'s (2012) interpretation as misrepresenting the monsoon-induced drainage in the region, suggesting instead that monsoonal rainfall was not enough to support a perennial river at any period. Petrie et al. (2017) instead supported the data from Gupta et al. (in prep.), that no perennial river was flowing just before, during or after the Indus period. Overall, though, what we can say is that it seems there is no clear support for a major river avulsion in the Indus period, and instead any river reorganization likely predated the Indus period entirely.

To sum up the Ghaggar-Hakra debates, then: what is today a monsoon-fed, seasonal flow is likely to have been the same during the Indus period. It seems unlikely, based on current evidence, that the Ghaggar-Hakra was a 'mighty river' flowing perennially in the pre-, urban- or post-urban Indus periods, or that the drying up/avulsion of this river was a driver of social change. However, monsoonal decline, changing the summer flooding of this monsoon seasonal system, could have had an impact on the flow of the river in whatever form it came, and this could have affected the decisions farmers made in regards to their agricultural strategy/strategies. It is important, therefore, to think about how climate change has been reconstructed for this Indus period.

CLIMATE CHANGE

In keeping with the rivers debate, the current state of research for climate change events in the Indus region has developed into one that adopts a range of proxies, but these proxies are variously hampered by low resolution, ambiguities or chronological calibration concerns (Breitenbach 2009; Madella and Fuller 2006). In addition, the interaction between the more researched ISM and other systems including the winter westerlies remains unclear (Kotlia et al. 2015). As such any debate is far from resolved.

What can be summarized is that there were a series of multi-decadal or even multi-centennial 'events' imposed over a broadly wetter early Holocene phase (Achyuthan et al. 2014; Zorzi et al. 2015), followed by a long-term drying trend. These 'events' or oscillations at 8.3, 7.2, 6.3 and 4.2 ka BP still have poorly defined chronological boundaries across the span of the Indus region, and the mechanisms behind them are unresolved.

Going back to the early Holocene, strong northern hemisphere insolation led to a strong ISM (Dixit 2013; Leipe et al. 2014; Wang et al. 2005; Zorzi et al. 2015). This wetter phase was not necessarily stable, as reflected in weak monsoon oscillations at *c.*8.2, 7.2 and 6.3 ka BP (Achyuthan et al. 2014; Cai et al. 2012; Dixit et al. 2014; Gupta et al. 2003; Leipe et al. 2014; Prasad et al. 2014; Wang et al. 2005).

This wetter trend turned during the mid-Holocene towards a drier phase as the monsoon weakened after 6.5 ka BP (Breitenbach 2009; Leipe et al. 2014; Prasad et al. 2014; Sarkar et al. 2016; Tiwari et al. 2015; Wang et al. 2005). Terrestrial and marine records show a decline in the northern hemisphere summer solar insolation at a multi-millennial scale and suggest a weakening of the ISM. This was likely caused by a southward retreat of the ITCZ but also a reduction in ITCZ convective activity (Cai et al. 2012; Wang et al. 2005). As a result there would likely have been a northern penetration of the monsoon trough and the monsoon rainfall intensity would have decreased (Jones 2017).

There is debate about when the weakening of the monsoon began. A few records such as those by Sarkar et al. (2016) give an early date for the ISM weakening *c.*7.5–7 ka BP, but in most records, the shift comes later, at 6.5–6 ka BP (e.g. Breitenbach 2009; Dixit et al. 2014; Prasad et al. 2014). This later date is therefore the more commonly accepted end of the wetter period (see e.g. Dixit and Bera 2013).

Following the onset of aridity, a general trend of monsoon weakening can be seen in the later mid-Holocene, and in particular in the period relating to the

Early and Mature Harappan phases (e.g. Breitenbach 2009; Gupta et al. 2003; Nakamura et al. 2016; Sarkar et al. 2016). Details of this period are variable and complex, and in the Indus region are reliant on debated records from the playa lakes of the Thar Desert. These records have been used to argue for the development of the Indus during a period of either increased or decreased water availability.

Recent evidence helps unpack the problem and suggests a general progressive monsoon decline, even if it is not always apparent in the Thar Desert proxies (Dixit 2013; Sarkar et al. 2016). These discrepancies are likely due to the differing local hydrological responses to monsoon decline and the role of winter rainfall as well (Prasad and Enzel 2006), and the complexity of centennial oscillations in the monsoon (e.g. Breitenbach 2009).

Archaeologists have also critiqued the simplicity of linking models of climate with archaeological models of societal change (as explored more in Chapter 15), and it is with this important point in mind that we turn to the biggest debate of climate modelling – the 4.2 k event and its hypothetical impact on the end of the Indus (and beyond to other Bronze Age civilizations – An et al. 2005; Booth et al. 2005; Staubwasser and Weiss 2006; Walker et al. 2012; Weiss 2017; Weiss et al. 1993).

The 4.2 k event can broadly be described as an abrupt and severe arid phase across the northern hemisphere that begins *c*.4.2 kya or 2150 BC and lasts for anywhere between a century to several centuries (Prasad et al. 2014). This definition, however, is broad and requires nuancing.

Across the ISM domain are well dated proxies for an abrupt monsoon weakening *c*.4.2 k BP driven by long-term insolation (Achyuthan et al. 2014; Berkelhammer et al. 2012; Breitenbach 2009; Dixit et al. 2014; Giesche et al. 2019, 2023; Gupta et al. 2003; Hong et al. 2003; Nakamura et al. 2016; Staubwasser et al. 2003). However, not all records show this phase. Others are ambiguous (Gasse et al. 1996; Leipe et al. 2014), with dates for a weakened ISM several centuries outside the 4.2 k BP threshold, or suggesting that this was only part of a much longer arid phase starting well before 4.2 k BP (Prasad et al. 2014). Other scholars imply that while there was a weakening of the ISM, it was not significant in relation to the surrounding variation (Von Rad et al. 1999). This can all be contrasted with records that suggest there is no evidence for any abrupt weakening (Chauhan et al. 2015; Raj et al. 2015; Saxena et al. 2015; Tiwari et al. 2015).

There are a number of reasons a weak monsoon may not be evident in all records. A lack of sufficiently finessed chronological control including issues of calibration and age-depth modelling errors would cause gaps in the record. Alternatively, the period of interest could simply be missing from some of the records across different regions (Berkelhammer et al. 2012; Breitenbach 2009). More critically, the complexity of the underlying processes creating these proxies makes their interpretation difficult. The dynamics of the ecological and hydrological setting in which proxies are found greatly impacts the way we can interpret data. For example, if the proxy is found in a system affected by winter as well as ISM rainfall, the 4.2 k may have a less visible impact on the proxy (Sarkar et al. 2016; Staubwasser et al. 2003).

It could therefore be argued that the lack of coherent expression of the 4.2 k does not necessarily show that it did not occur. Despite some inconsistency in the paleoclimatic record, the overarching pattern is of widespread, synchronous sudden severe aridity caused by the weakening of the ISM. In the Indus Civilization region, this was also the case (Dixit et al. 2014).

On the other hand, there could have been real differences in monsoon dynamics in different areas due to the ISM front. Spatially variable trends in rainfall along the ITCZ margin as it migrated south may have occurred (Demske et al. 2009; Mishra et al. 2015). Complex shifts in circulation could also have been a cause for difference. Intensification in ENSO or changes in the Indian Ocean dipole may have led to variations in the impact of the 4.2 k (Sarkar et al. 2016; Zorzi et al. 2015). This would have led to shifts in the active/break patterns of the monsoon, changes in moisture transport and shifts in the length and timing of the monsoon (Berkelhammer et al. 2012; Sarkar et al. 2016).

As discussed, the ISM rainfall today demonstrates complexity in spatial and temporal variability (Malik et al. 2012; Tiwari et al. 2006). Over the past two millennia evidence from speleothems shows decadal to centennial oscillations in the ISM that are often anti-phase across the subcontinent. While not a direct parallel for the past (as no analogy can ever be), it can be considered likely that similar patterns of spatial complexity characterized the 4.2 k.

Our understanding of the 4.2 k is therefore limited by our proxies, our understanding of the ISM and its variability in relation to these proxies. Based on the current evidence, it seems most likely that some sort of abrupt and significant change in the ISM occurred *c.*4.2 k BP, but how this played out across the ISM domain remains unclear, and it is far more intricate than simply a reduction in monsoon intensity. Changes in seasonality, moisture transport pathways and modes of inter-annual variability were also likely part of this change (Donges et al. 2014). Given the broader context of the Holocene, the 4.2 k was not a stand-alone event; it was part of an ongoing trend of a weakening ISM.

In the Indus, how does this play out? Again, this is not fully understood. The data from Kotla Dahar in the north-eastern region of the Indus Civilization zone by Dixit et al. (2014; see also Giesche 2019, 2023) are an example of this. While a significant hydrological change is seen, the cause of this – reduction in rainfall amount or a shift towards earlier monsoon withdrawal – is unclear. In other regions such as Gujarat and Pakistan, the picture is even more fuzzy, but overall data suggest again that a significant hydrological shift occurred. On balance, then, combining the data for the Indus region and the data outside the area, the 4.2 k seems to have been significant, but exactly what this meant in terms of rainfall or how adverse conditions became remains unclear.

CAUSATION = CORRELATION? DOES CLIMATE CHANGE LEAD TO SOCIAL CHANGE?

Despite the complexities inherent in the 4.2 k, this has not prevented climate change and the 4.2 k being used to create causal models for change in human behaviour, specifically climate change models 'explaining' the rise and, more often, fall of the Indus Civilization. The debate over the impact of climate change was sparked when Singh (1971) and Singh et al. (1974) suggested that climate change had a direct impact on the development and decline of the Indus Civilization. This hypothesis, often termed the 'climate-culture hypothesis', used pollen and stratigraphy from three saline lakes in the Rajasthan desert and a freshwater lake in the Aravalli Hills to argue that conditions changed from wetter to drier and that this correlated with the rise and fall of the Indus Civilization (Singh et al. 1974).

The papers by Singh (1971) and Singh et al. (1974) led to wider systematic collection and analysis of paleoenvironmental data (see also Phadtare 2000; Von Rad et al. 1999). Other data sets contradicted their hypothesis, such as the sediment analysis of Lunkaransar playa lake by Enzel et al. (1999), which suggested the drying event(s) occurred before the urban Indus Civilization arose (*c.*2800 BC), and Deotare et al.'s (2004) analysis of the geomorphology, palynology and magnetic susceptibility of playa lakes in the Thar Desert (*c.*3000 BC). This range of results has led to a disparate picture, with paleoenvironment scholars disagreeing about whether drying occurred before or during the Indus period, and thus the impact this may have had on the rise or fall of this society (see Madella and Fuller 2006; Petrie et al. 2018; Prasad and Enzel 2006).

As a result, not only has the issue of whether climate change caused social change been debated – a point explored in more detail in Chapter 15 with regard to the role of agriculture in these models – but a far more basic question relevant to this chapter has to be asked: when did climate change occur and did it correlate to social change? Prasad and Enzel (2006) have argued that the wide range of dating techniques used in the various paleoenvironmental papers, the different date ranges, calibration methods and the different ways authors have reported the dates makes comparing the paleoenvironmental data extremely difficult. Madella and Fuller (2006) have taken this further and suggested that these same issues also exist in the archaeological record and that therefore there are problems in correlating the different archaeological data, let alone comparing them with the environmental debates. Suggesting that finely dated societal changes (centennial scale) can be compared with broadly dated (millennial scale) changes in the climate is therefore problematic (Madella and Fuller 2006). This is a crucial point for Chapter 15, to which we will return there. But here it is noted that correlating data taken from a single region with continental and even global trends stretches the data and does not take into account the local factors that influence how climate effects specific areas (Fuller and Madella 2002; Madella and Fuller 2006; Paddaya 1994; Petrie et al. 2009; Singh et al. 2010b).

A similar critique was addressed by Dixit et al. (2014, 2018) and Giesche et al. (2019, 2023). Rather than looking at data from faraway sources such as the Arabian Sea, these scholars looked to sites such as the playa lakes or speleothems within the Indus realm and/or within the ISM zone of interest to them. Their data showed reductions in the intensity of the ISM, which recovered after 200 years (*c.*3.9 ka/1900 BC) to modern-day conditions, but also regional variability in the intensity of this change. Importantly, all four papers cautioned against using data to create general trends for understanding Indus Civilization reactions to climate change. As well as noting the difficulties in correlating social change with climate change, given that the Late Harappan period is poorly understood and dated, they suggested that not every settlement would have felt the impact of climate change in the same way (Dixit et al. 2014, 2018; Giesche 2019, 2023).

A short version of this might be: not only is the ISM weakening poorly understood, but its potential impacts have been invariably oversimplified and more study is needed to understand its dynamics and how people interacted with their climate and environment during this period of sudden change. This theme is picked up again in Chapter 15 when theories on climate, agricultural and social change are explored in more depth in relation to the Late Harappan period.

To conclude on the environmental and climate setting for Indus agriculture, it is worth looking at what comes after the 4.2 k. There are limited records for the Indus region (e.g. Dixit et al. 2014; Giesche 2019, 2023; Raj et al. 2015; Staubwasser et al. 2003; Von Rad et al. 1999; Wright et al. 2008). Overall, *c.*3.9–3.2 k BP, there was some recovery in moisture across the southern and western parts of the Indus region, involving both summer and winter rainfall, though the combination and proportions of these is unclear. This recovery was not to the early-mid Holocene levels, was variable, and may have led to changing seasonality (Wright et al. 2008). Across the wider ISM system, again the recovery was moderate and the 4.2 k left its mark.

It should be noted that the Indus Civilization did not 'end' directly at the 4.2 k, the Indus decline was gradual, and it is throughout this period (between 2200 and 1500 BC) that variable forms of Indus Civilization deurbanization are seen. The impact climate *and* social change in concert would have had on Indus peoples and their farming, though, requires a subtle exploration rather than the simple causal models outlined in this chapter.

We will explore the possible impacts of climate change on Indus farmers agricultural strategies in Chapter 15 and pick up on the debates about what the 'end' of the Indus looked like, but with this broader environmental and climatic background in mind it is worth turning to look at the spread of the archaeobotanical data that has been recovered from the Indus Civilization region that we can use to look some of the questions that these two introductory chapters have brought up.