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THE ARCHAEOLOGY OF DRYLANDS

Living at the margin

Edited by

Graeme Barker and David Gilbertson

ROUTLEDGE · Taylor & Francis Group ·

London and New York 2000

ensure the future sustainability of Turkmenistan's (and indeed Central Asia's) water distribution and irrigation network. The Central Asian Republics have inherited a Soviet-built system and must learn to work with the system and resources that are available. While we cannot revert to the past, Central Asia's water managers would do well to look to the past for some of the answers to their current and future problems.

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Table 6.2 continued

Historical period and date (cal BC/AD*)*	*Settlement*	*Irrigation systems*	*Crops*
Timurid 14th–15th centuries	New city built 1409 at Abdullah Khan Kala but decline continues.	Central dam rebuilt in Timurid period; destroyed in war of 1727.	
Safavid 1502–1736			
Turkmen 18th–19th centuries	Dispersed settlement with semi-independent landlords.	Irrigation system functioning but small-scale cultivation.	
Russian conquest 1890 Soviet Union 1919–1991 Republic of Turkmenistan 1991–present	Establishment of modern settlement at Mary; planned villages and communal farms throughout oasis.	Introduction of large-scale irrigation systems for cotton; Karakum canal completed 1967.	American cotton species

we would hesitate to identify simple cause and effect, it would appear that increased population was linked, through a complex sequence of interactions, with the expansion of irrigated agriculture and increased centralization of authority. The increase in population not only required an increase in the amount of land irrigated but also provided the workforce necessary for this expansion to take place. Irrigation flourished during periods of political stability, often when a single polity ruled over the area, and declined in periods of invasion or unstable internal political conditions.

The decline of Merv can clearly be traced to the Mongol destruction of AD 1221–2. The Mongols took advantage of the fact that Merv, like most other settlements throughout Central Asia, was reliant on a single water source. In their rapid conquest of the region, the Mongols frequently forced communities to capitulate by disrupting water supplies and damaging irrigation structures, and all they needed to do at Merv was to destroy the main dam that controlled water in the oasis. Whilst the city was in part rebuilt, the irrigation systems were never fully reconstructed until the region once again came under the influence of another empire – that of the Soviets.

Significantly, the widespread environmental degradation that plagues Soviet-built irrigation systems in the region does not appear to have been a major problem in the past, suggesting that sustainable irrigation in Turkmenistan is not only feasible but has been the norm. Traditional irrigation systems were generally localized and often dependent on a single water supply that was not only limited but also liable to fluctuate considerably from year to year. Water management required considerable skill, hence the *mirab bashi*, responsible for highly important and often contentious decisions on water allocation and distribution, was one of the most senior officials in central government – indeed, the success of many political officials often hinged on their skill at managing local water resources. Yet whilst water was managed centrally, all water users were responsible for the upkeep of the system, with those gaining more being expected to contribute more. The fact that individuals could benefit as a result of their efforts gave all users a vested interest in ensuring that the irrigation network was maintained and that water was used efficiently. The Soviet system effectively broke this link, with the system managed centrally but from afar. Together with the collectivization of land, the imposition of central planning meant that benefits were no longer linked to duty; water users had no say in how the system was managed, nor were they responsible for its maintenance. The establishment of myriad agencies to oversee different parts of the network resulted in unnecessary bureaucracy and waste. In sum, traditional irrigation and water distribution systems tended to be small, highly productive, well managed, extremely efficient and sustainable over the long term. In contrast, Soviet-built systems are huge, inefficient, inflexible, poorly managed and, for the most part, unsustainable.

The decline in the water distribution and irrigation network since the break-up of the Soviet Union is thus unsurprising. What remains to be seen, however, is how this decline will be managed, and what can be done to

Table 6.1 Simplified chronological chart of prehistoric settlement in Turkmenistan

Archaeological period and date (cal BC/AD)	*Settlement*	*Irrigation systems*	*Crops*
Neolithic 6300–4800 BC	Small farming villages on piedmont of Kopet Dagh. Key site: Jeitun.	Crops cultivated in areas of high water-table; possibly also simple diversion of streams.	Main crop einkorn; also emmer, hulled and naked barley
Eneolithic (Chalcolithic) 4800–3000 BC	Larger, complex settlements, to 15 ha with shrines and fortifications in Middle Eneolithic (4000–3500 BC); spread of settlements to Geoksyur oasis in Middle Eneolithic but abandonment of oasis by E.B.A. Key sites: Altyn-depe, Anau, Geoksyur, Namazga (phases I–III).	Simple irrigation assumed for piedmont and early occupation of Geoksyur; large irrigation canals identified in Geoksyur oasis in late Eneolithic (Namazga phase III).	Hulled barley, free-threshing wheat
Early Bronze Age (E.B.A.) 3000–2500 BC	Sites to 25 ha, restricted to piedmont zone. Key sites: Altyn-depe, Namazga (IV).	Irrigation assumed for large settlements in piedmont but no direct evidence.	Hulled barley, free-threshing wheat, grape
Middle Bronze Age (M.B.A.) 2500–1900 BC	Sites to 50 ha; monumental architecture. Abandonment of piedmont sites at end of M.B.A. Major fortified settlements appear in Merv oasis in terminal period (2200–1900 BC). Key sites: Altyn-depe, Namazga (V), Gonur depe	Smaller-scale irrigation at northern fringe of Merv oasis.	Main crop: hulled barley; also free-threshing wheat, lentil, pea, chickpea, grape
Late Bronze Age (L.B.A.) 1900–1500 BC	More dispersed, smaller sites (to 2 ha) in piedmont. Period of Bactrian-Margiana Archaeological Complex; abundant large sites in Merv oasis. Key sites: Namazga (VI), Gonur depe.	Sophisticated canal irrigation in Merv oasis, using water from main channels of rivers.	
Early Iron Age 1500–550 BC	Abundant settlements (to 15 ha) in piedmont and oases. Key sites: Tahirbaj, Yaz-depe (Merv oasis).	Introduction of *qanat* (kiariz) irrigation to piedmont. In Merv oasis settlement continues to shift to south.	Broomcorn millet

Table 6.2 Simplified chronological chart of settlement in the Merv oasis in the historic period

Historical period and date (cal BC/AD)	*Settlement*	*Irrigation systems*	*Crops*
Achaemenid 550–330 BC	Founding of Achaemenid city at Erk Kala *c.*500 BC; dispersed settlement centred on large buildings throughout the oasis and continuing to Seljuk period.		
Seleucid (Hellenistic) 330–140 BC	Construction of the city of Antiochia (Gyaur Kala), incorporating Erk Kala as citadel.	Marked reduction in rural settlement.	
Parthian 140 BC–AD 220	New settlements in north of the oasis; fortifications on perimeter such as Gobekli.	Expansion of cultivated area; possible construction of central Murghab dam and extensive canal network.	Main crops: cotton, hulled barley, free-threshing wheat; also lentil, grape, almond
Sasanian AD 220–651	Peak of settlement in the Merv oasis; much continuity with Parthian period. Possible construction of Wall of Antiochus (usually dated to the Hellenistic period), which marks northern limit of most post-bronze age settlement.	Cultivated area stable.	Main crops: cotton, hulled barley, free-threshing wheat; also lentil, pea, melon, grape, almond, peach, broomcorn millet
Umayyad Abbasid 8th–9th centuries Samanid Seljuk and Post Seljuk 11th–13th centuries Mongol conquest 1221	Continuity in settlement after Arab conquest of AD 651. Merv is capital of Seljuk empire in 11th and 12th centuries. Sultan Kala established 9th century; fortified 12th century. Devastating conquest of city by Mongols, but archaeological evidence suggests some post-conquest occupation.	Continuity in area cultivated until Mongol conquest results in destruction of dam system. Abundant textual evidence for function of irrigation system in 10th–13th centuries.	

by elected senior officials and maintained by over 12,000 workers, paid by the water users, who were also expected to take part in major construction schemes and in the annual maintenance programme.

EXPANDING THE IRRIGATION SYSTEM: THE TSARIST AND SOVIET PERIODS

When Central Asia finally came under Tsarist control in the late 1880s, the new administration attempted to introduce reforms in the irrigation sector. These failed, however, and the authorities declared that irrigation would be run 'by custom'. Notwithstanding this, a number of subtle changes was made: most important, irrigation officials became part of the Tsarist civil service and as such were no longer controlled by water users. This act severed the link between water users and providers, so effectively undermining the traditional system of water management. State salaries for officials were low and there was no longer any incentive to control the system. The situation was exacerbated by the imposition of irrigation officials unaccustomed to the traditional method of management, resulting in increased problems within the system, which became subject to corruption and abuse by the wealthy and more powerful water users.

More significant than Tsarist interventions in water management, however, were the changes in agricultural policies. The authorities in Moscow, keen to end their reliance on America for cotton (particularly following the American Civil War when supplies almost ceased), recognized that Central Asia had the potential to become a major cotton growing region; in fact, the main factor behind initiatives to increase the amount of land irrigated was cotton production (Lipovsky, 1995). The subtle, but nonetheless important, changes in water management, coupled with increased demand and use of water, appear to have caused widespread land degradation. In the Merv oasis, for example, the irrigation network was expanded by some 33,000 ha (Zaharchenko, 1990), but poor management of the system caused local water tables to rise, resulting in salinization and widespread surface ponding that not only degraded the soils but also led to outbreaks of malaria (Pierce, 1960).

The Bolshevik Revolution and the subsequent emergence of the Soviet Union heralded a period of radical change in the way water was managed in Central Asia. In 1923 the Soviet administration decreed that water management was to be taken 'out of the hands of traditional elders and councils with whom it resided' (Black *et al.*, 1991) and, like land, was to become a common resource for the benefit of all. Various government bodies were established to be responsible for the development of a regional water management strategy that would allow centrally-determined production targets to be met. With cotton production the priority for Moscow, huge sums of money were invested in the region in the development of massive, highly integrated systems of water distribution and irrigation (Micklin, 1991). Land was irrigated no longer by a single local source, as in the past, but by water often piped over considerable distances: the Kara Kum Canal, for example, considered to be one of the engineering feats of the Soviet era, now transfers in excess of 12.9 km^3 of water from the Amu Darya along its 1,400 km length every year, irrigating an area of *c.*1 million ha (Hannan and O'Hara, 1998).

There has been much criticism of the management and maintenance of Soviet irrigation systems and the inefficiency of water use (e.g. Micklin, 1991). Losses occurred throughout the system, with problems of seepage and evaporation from the many thousands of kilometres of unlined irrigation canals creating huge problems with waterlogging and soil salinization. Within a few years of the Kara Kum Canal being constructed, for instance, the water table in the Merv region had risen over 20 m (Kornilov and Timoshinka, 1975) and vast tracts of land had become salinized (O'Hara, 1997). Water use at the field level also rose, as field size increased to accommodate increasingly bigger agricultural machinery, not only increasing the amount of time that it took to water fields, but also causing the traditional practice of night-time watering to be replaced by daily, and often continuous twenty-four-hour, irrigation. Yet despite an emphasis on the need to modernize the agricultural sector, furrow irrigation continued to dominate, with large and poorly levelled fields creating huge problems for irrigators. Moreover, unlike in the past, access to water was not a problem, with diversion schemes bringing what to many seemed an infinite supply of free water; people who had long viewed water as a scarce commodity forgot its worth and wasted it.

Further exacerbating the situation was the fact that government agencies rather than individual water users were responsible for, amongst other things, maintaining the irrigation infrastructure, dredging canals and ensuring that the drainage system was clean. At the farm level, maintenance became the responsibility of a few collective workers. In all cases, the bulk of the work was done using heavy equipment. Consequently, water users had little if anything to do with the management or maintenance of the water distribution and irrigation system. Despite Soviet successes in expanding the irrigation network and increasing agricultural output, the systems they built were (and still are) inflexible and highly inefficient. By the 1980s, agricultural land in Turkmenistan was being abandoned at a rate of over 50,000 ha per annum (Zaharchenko, 1994): clear testimony to the fact that this huge irrigation system is not sustainable.

CONCLUSION

In Tables 6.1 and 6.2 we summarize the major trends in settlement and agriculture in southern Turkmenistan. It is evident that there is a strong correlation between the degree of urbanization and population size (themselves correlates of centralized political control) and the sophistication of irrigation technology. The range of crops likewise increases through time. Although the occupation of the Merv oasis: the initial colonization by dispersed but numerous bronze age settlements *c.*2200 BC; urban development in the Achaemenid period *c.*600 BC; and the gradual abandonment of intensive settlement in most of the oasis in the centuries after the Mongol invasions of AD 1221–2.

The large-scale sampling of contexts carried out at the city of Merv by the International Merv Project (Boardman, 1997; Nesbitt, 1994) has provided some the best archaeobotanical evidence for the Sasanian period. It indicates that, during the Late Sasanian period (the fifth to seventh centuries AD), cereals consisted, as before, of abundant hulled barley and free-threshing wheat and rarer broomcorn millet, lentils (chickpea seems to disappear after the Bronze Age), very abundant cotton seed, and a wide range of fruits and vegetables including cucumber/melon, grape, almond, peach and nuts. Two changes are apparent in comparison with the Bronze Age: first, an increase in crop diversity, particularly in the fruits; and second, and more importantly, the addition of cotton, which is a source of both textile and oil and, like millet, a crop that expands the growing season through the summer, after the wheat and barley harvest. Overall, the range of crops seems similar to that mentioned in Islamic times: in the tenth century Merv's famously soft cotton textiles were exported as far as Africa and Spain, and there are thirteenth-century references to Merv's fine grapes and other fruits (Serjeant, 1972).

Of the range of crops grown in the Sasanian period, barley and cotton are relatively tolerant of soil salinity (though not, of course, of heavily salinized soils), bread wheat is moderately tolerant, melon and grape are moderately sensitive, and almond and peach are sensitive (Maas, 1987). That crops sensitive to salinity are present throughout the late Sasanian sequence from Merv, and that the full suite of crops is present in broadly similar quantities throughout the sequence, strongly suggest that irrigation agriculture was sustained through this period without occurrence of catastrophic salinization. This is consistent with evidence for unbroken intensive settlement in the oasis from the Parthian to Seljuk periods. Although salinization has often been viewed as an inherent and imminent threat in ancient irrigation systems in the Near East, particularly in Mesopotamia (Jacobsen and Adams, 1958), there is increasing evidence that soil management practices that avert salinization (and which are ethnographically documented in Mesopotamia) were applied effectively in the past (Powell, 1985).

The success of Merv and other settlements in the region depended to a large extent on how water resources were managed. There were two major technological innovations during the urban period. In the foothill zone the *qanat* was introduced in the first millennium BC. Like the *foggaras* of the Sahara (Chapter 9), this system allows groundwater to be tapped by underground tunnels cut into the foothills, and is most widely used in the highland area of Iran. Qanats are difficult to date directly, but associations with sites suggest that they became widespread in the highlands of Iran and neighbouring areas at this time. In the Merv oasis, there is indirect evidence from survey work of large, state-sponsored, irrigation works in the Parthian and Sasanian periods (Bader *et al.*, 1993/94, 1996; Gubaev *et al.*, 1998), like the contemporary transformations occurring further south in Susiana (Wenke, 1975–76) and Mesopotamia (Adams, 1981). Major changes in irrigation technology in the Merv oasis are, therefore, later (if the dating is correct) than the first urbanization at Erk Kala and Gyaur Kala but coincide with the increase in the population of the oasis in the Parthian and Sasanian periods.

In contrast with the bronze age canals, these later irrigation systems are difficult to investigate because they have been largely destroyed by twentieth-century agriculture, but the medieval irrigation system of the tenth–twelfth centuries – during which time the oasis flourished – may give a good parallel. The Arab historians and geographers such as Muqaddasi, Al-Biruni and Yakut provide valuable accounts of water distribution and irrigation systems (see Bartold, 1914, 1928 and Le Strange, 1905 for translations and discussions of their works). It is evident from these that the administration of scarce water resources was central to the way in which the social and political hierarchy of settlements operated: water was viewed as a 'gift from God' that could not be owned or controlled by an individual. The city of Merv had access to only one source of water – the Murgab river, which rises in the Afghan mountains and drains northward into the Kara Kum Desert. The river's annual discharge is about 1.2 km^3, which is approximately 5 per cent of the total amount of water available for use in Turkmenistan at present (O'Hara, 1997).

The oasis was renowned for its productivity, not only producing enough food to feed its large population but exporting produce to adjacent areas (Herrmann and Petersen, 1997). The region's agricultural success was in part due to the land and water management strategies of the time. Land, for example, was divided into small plots that were intensively cultivated, receiving water on a regular basis. The amount of land cultivated in any given year depended on water availability. Muqaddasi, writing in the tenth century AD, described how a depth gauge situated at the Razik Dam to the south of the city was used to determine whether there would be a surplus or deficit of water that year. If the level reached the 60th point, water would be plentiful that year and the order would be given to increase the amount of land cultivated, whereas in years of low water availability the area was reduced and only the best lands were cultivated. The dam was extremely important and was, in effect, the only water storage facility for the city. Its maintenance was assured by 400 divers employed around the clock, each diver having to deliver a specified amount of wood and mud to the dam each day (Bartold, 1914). Yakut, who resided in the city at its zenith in the early thirteenth century, provides further details. He described how water gauges were installed at the head of every canal throughout the city. The whole system was headed by the *mirab bashi* (chief water master), and hourly reports on the water level in the main canal were passed to his office, so that he could decide which off-takes were to be opened or closed. The system was managed

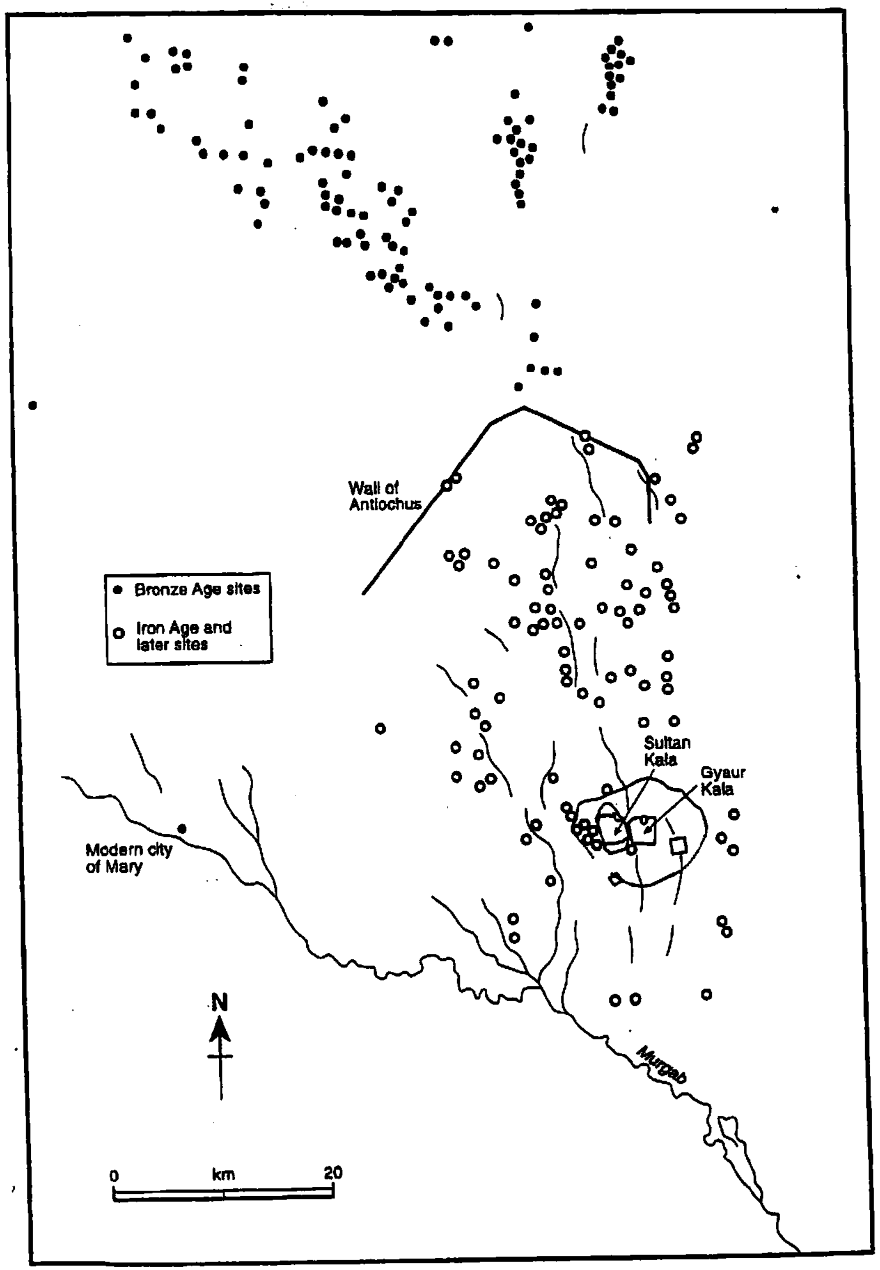

Figure 6.2 Bronze and iron age settlement in the Merv oasis (adapted from Hiebert, 1994)

bronze age settlements throughout the Near East. Late bronze age samples from Tahirbaj Tepe in the Merv oasis were also dominated by hulled barley but add broomcorn millet (*Panicum miliaceum*) to the repertoire of crops (Nesbitt, 1994).

Iron age settlements in the Kopet Dagh foothills are widely distributed and often continue on the same sites as bronze age settlements, but are smaller and marked by less material complexity (Kohl, 1984). In the Merv oasis, iron age sites are concentrated in four 'micro-oases'. The northernmost two, Takhirbai and Togolok, contain bronze age settlements, while the southernmost two, Yaz depe and Aravali, represent new occupation, thus forming part of the pattern of southward movement of settlements that continues until the Achaemenid period (Bader *et al.*, 1996; see below). This shift in settlements is most plausibly explained by increased extraction of water upstream by settlements using more sophisticated canal systems, collecting water near the head of the delta. However, early sites in the upper part of the oasis may have been masked by alluvial deposition, accounting in part for this pattern.

ACHAEMENID TO MEDIEVAL: URBAN SOCIETIES

The Achaemenid period (530–330 BC) marked two important transitions for the Merv oasis: it was the first of several periods when Merv came under the control of an empire based to the south; and for the first time a series of urban centres emerged in the oasis. From this time onwards, Merv was also militarily important as a frontier city at the northeastern part of firstly the Achaemenid and later the Seleucid (330–140 BC), Parthian (140 BC–AD 220) and Sasanian (AD 220–651) empires. Surveys of the magnificent ruins of Merv's urban centre show a steady increase in its size. The earliest city, Erk Kala, had walls enclosing an area of 20 ha. It later became the citadel of the adjoining Seleucid city of Gyaur Kala (400 ha) (Fig. 6.2), which continued to be occupied for a period of over a millennium, even after the construction of the nearby city of Sultan Kala in the eighth century AD. Survey work in rural areas in the north of the oasis confirms this basic pattern of expansion, with increasing residential areas from Achaemenid to Seljuk times (Bader *et al*, 1993/94; Gubaev *et al.*, 1998). At its greatest extent, the oasis covered *c.*700 km^2. The area cultivated appears to have fluctuated, with a decrease in rural settlement in the Hellenistic period, and a marked increase in cultivation and, probably, the first construction of a large central dam and canal network in the Parthian period.

Although written sources state that Merv was destroyed by Mongol invasions in AD 1221–2, there is archaeological evidence for a substantial post-Seljuk occupation, and in the early fifteenth century a new, much smaller, city was built by the Timurids. Notwithstanding this, the oasis declined in importance, and the Timurid city was abandoned by the nineteenth century. Overall, therefore, changes in settlement pattern suggest three key phases in conditions similar to today developed somewhat later than previously thought (just as wetter environments characterized the early Holocene in the Levant: Chapter 4). Further support for this hypothesis is provided by a recent analysis of plant remains from the site, suggesting that cultivation may have been possible without irrigation (M. Charles, *pers. comm.*). Despite this uncertainty, though, it is evident that there is a long history of agriculture in this region and that by the fifth millennium BC agricultural settlements were spread along the piedmont from Kyzal Arvat in the west to Tejen in the east.

ENEOLITHIC TO IRON AGE: PIEDMONT SETTLEMENT AND EXPANSION TO THE OASES

The establishment of agricultural communities such as Jeitun in the Neolithic was followed by several millennia of continuing settlement, largely in the piedmont of the Kopet Dagh, during the Eneolithic or Chalcolithic (*c.*4800–3000 BC), Early Bronze Age (*c.*3000–2500 BC) and Middle Bronze Age (*c.*2500–1900 BC). Sites grew significantly in size – eneolithic settlements such as Altyn Depe, Anau and Namazga cover up to 25 ha – and there were two key changes in settlement pattern: the expansion into the Geoksyur oasis in the Eneolithic and the emergence of state-level urbanism in the piedmont zone in the terminal Early Bronze Age.

The Geoksyur oasis (Fig. 6.1) is situated on the Tejen River delta and, unlike other oases in the region, is contiguous with the foothills of the Kopet Dagh. Nine prehistoric sites comprising large, widely scattered, mudbrick houses, have been found in the oasis, dating from the earliest Eneolithic (Kohl, 1984), but the oasis appears to have been abandoned by the end of the Eneolithic. Earlier eneolithic settlements are at the end of branches of the river delta, suggesting that a modified form of floodwater irrigation was practised. Later in the Eneolithic, well-developed artificial irrigation systems are documented for the first time in Turkmenistan (Namazga III period, *c.*3500–3000 BC). Aerial photographs and excavations have shown that land around the site of Geoksur I was irrigated by three parallel canals, each up to 3 km long and 5 m wide, possibly irrigating an area of about 50 ha by means of small *aryks* (irrigation canals) branching off and leading to fields (Lisitsina, 1969). The water flow into secondary canals was controlled by inlet structures where they joined the main canals (Lisitsina, 1981).

In the piedmont proper, the last part of the Early Bronze Age witnessed a transformation of settlements with the appearance of specialized production areas, fortification walls around settlements, increased status differentiation in burials, and evidence of much interaction between settlements throughout the Kopet Dag region, all consistent with a state-level society (Hiebert, 1994). These trends continued into the Middle Bronze Age, and by its terminal phase (2200–1900 BC) the foothills contained a number of very large sites such as Namazga (50 ha) and Altyn Depe (25 ha). This period of expansion

came to an end in the Late Bronze Age. The settlements at Anau and Namazga, for example, were considerably smaller, now covering only a few hectares. Relatively little is known about agriculture in the piedmont zone in the Eneolithic and Bronze Age. Irrigation canals have not been located in the piedmont, but this may reflect deposition and erosion in this geomorphologically-active zone. The presence of bread wheat and six-row hulled barley in lenolithic samples from Anau dated to *c.*4500–3000 BC has been cited as possible evidence for irrigation (Miller, 1999), but both cereals were grown in many regions of the Old World without irrigation (Maier, 1996).

Paralleling the decline of settlement on the northern piedmont was the spread of irrigation to the lower reaches of the Murgab river at the end of the Middle Bronze Age, although this occurred while some sites such as Altyn Depe were still very large. A number of factors has been cited for this shift in agricultural settlement. Masson (1957), for example, suggested that a rise in population stretched resources to the extent that people were forced to migrate, whilst some authors have highlighted the potential impacts of climate change. Lewis (1966) argued that there is no evidence of a major shift in climate during this period, but, as mentioned above, evidence is emerging for a shift to drier conditions *c.*5,000–4,500 years ago, coinciding with the rise of agriculture in the Murgab oasis. It is possible, therefore, that conditions became sufficiently dry to precipitate change.

The bronze age settlements of the Merv oasis covered an area of 100 km north–south by 50 km east–west, which is almost five times larger than the later medieval and classical oasis to the south. Hiebert's recent re-analysis of the ceramic chronology and survey data suggests that the colonization of the oasis was rapid (Hiebert, 1994). The sites cluster in 'micro-oases', forming linear patterns that presumably followed old river branches (Fig. 6.2). Settlements are characterized by large fortified building complexes with intervening fields, which, as Hiebert points out, typify Central Asian oasis architecture of the time. Initially, settlements were located on the northern margins of the oasis, with the system expanding southwards some 400 years later (Hiebert's Gonur Period 3). Initial settlement was at the northern fringe of the oasis because large-scale canals were not used. Instead, fields were irrigated by ditches carrying water from the smaller streams into which the Murgab river split near the edge of the delta. As Bader *et al.* (1996) comments, settlers from the Kopet Dagh would already have been familiar with the technology of using streams of the piedmont.

Archaeobotanical analysis indicates that, over time, greater numbers of plants and animals were domesticated. By the Bronze Age, the variety of crops grown had increased significantly compared with in the Neolithic: samples from the middle bronze age site of Gonur Depe in the Merv oasis, for instance, are dominated by hulled and naked barley, with free-threshing wheat, lentils, peas, chickpeas and grape also present (Miller, 1993; Moore *et al.*, 1994). These finds are consistent with those from the neighbouring Geoksyur oasis (Lisitsina, 1969; Lisitsina and Prishchepenko, 1976), and are typical of conditions similar to today developed somewhat later than previously thought (just as wetter environments characterized the early Holocene in the Levant: Chapter 4). Further support for this hypothesis is provided by a recent analysis of plant remains from the site, suggesting that cultivation may have been possible without irrigation (M. Charles, *pers. comm.*). Despite this uncertainty, though, it is evident that there is a long history of agriculture in this region and that by the fifth millennium BC agricultural settlements were spread along the piedmont from Kyzal Arvat in the west to Tejen in the east.

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The hydrological network is weakly developed and all major sources of water rise outside the country's borders (Fig. 6.1). The headwaters of the Amu Darya, the largest river in Central Asia, are in the Pamirs, and the river flows through a number of countries before discharging into the Aral Sea. It displays two periods of peak discharge, one during the spring, associated with snow melt, the other later in the summer when ice melt increases its flow. The other main rivers all rise in the mountains to the south, the Atrek flowing into the Caspian Sea and the Murgab and Tejen draining into the Kara Kum Desert. Although small when compared with the Amu Darya, they are an important source of water and have long been used by people occupying the region. Fed by winter rains and snowmelt, they have only one period of peak discharge during the spring. In addition to these rivers, there is a number of smaller intermittent rivers and springs, most of which cease to flow during the summer. Today, as in the past, human settlement in Turkmenistan is concentrated in two zones: the piedmont at the foot of the steep slopes of the Kopet Dagh mountains, and the desert oases.

THE NEOLITHIC: EARLY FARMING IN THE PIEDMONT

The beginning of agriculture in Turkmenistan is best documented by the important excavations at Jeitun (Djeitun) located some 25 km north of Ashgabat in the piedmont between the Kopet Dagh mountains and the Kara Kum Desert. First discovered in the early 1950s, Jeitun has been the subject of a number of detailed excavations that have produced one of the best-known archaeological sequences in Central Asia. Today, fourteen such Jeitun culture sites have been identified across southwestern Turkmenistan.

Jeitun comprises some thirty excavated small, rectangular, mudbrick houses located on the distal reach of the Kara Su (Black Water), a small ephemeral stream that rises in the Kopet Dagh and discharges into the Kara Kum Desert. The settlement covers less than 0.7 ha, and estimates of the cultivated land surrounding it in the neolithic period are between 15 and 33 ha. First excavated by Masson in the 1950s and 1960s, the site was dated to *c*.6000 BC on the basis of ceramic assemblages (Masson and Sarianidi, 1972). This date was later confirmed by a series of eleven radiocarbon dates from the British–Russian–Turkmen excavations of 1989–94, which indicates that the site was occupied between *c*.6300 and 5600 cal BC (Harris *et al.*, 1993, 1996).

Recovery of animal bones and charred plant remains from these new excavations has allowed a reassessment of the site's subsistence base. The results confirm earlier evidence for a primarily agricultural system of subsistence based on cereals and domestic sheep and goat, augmented by hunting, primarily of gazelle. The cereals are dominated by einkorn wheat (*Triticum monococcum*), with small amounts of emmer (*T. dicoccum*) and naked and hulled forms of barley (*Hordeum sativum*). Other artefacts from the site point to the importance of cereal cultivation for the inhabitants of Jeitun, with sickle blades accounting for 37 per cent of all tools found in Masson's early investigation of the site (Masson and Sarianidi, 1972). In addition to cereal cultivation, the inhabitants of Jeitun herded goats and sheep; faunal analysis shows that, although raised primarily for meat, these animals could also have been an important source of milk, wool, hair and skins. The dominance of domesticated plants and animals from the very bottom of the Jeitun sequence, together with the absence of wild progenitors of wheat and sheep in Central Asia, supports the view that agriculture and its attendant domesticated species did not evolve independently in the region, but rather reached it from the Fertile Crescent of southwest Asia, via the Zagros mountains of Iran (Harris and Gosden, 1996).

Jeitun is often cited as one of the oldest known sites of irrigation in the world (Dukhovny, 1995; Harris *et al.*, 1993; Lisitsina, 1984). There is, however, some difference in opinion as to how crops were irrigated at this time. Lisitsina (1981), for example, assumed that cultivation at Jeitun was entirely dependent on run-off from the Kopet Dag, with Lewis (1966) suggesting that Jeitun's location on the distal reaches of the Kara Su was due to the fact that neolithic farmers were better able to control and manipulate flows in this part of the river system. However, Kohl (1981) argued that Jeitun was in fact located on the distal reaches of the Tejen Delta, which at this time discharged further into the Kara Kum Desert than today. The presence of many seeds of the weeds club-rush (*Scirpus maritimus*) and goat-face grass (*Aegilops tauschii*), in association with the charred cereal remains, led Harris *et al.* (1993) to conclude that cereals were being grown in areas with high water table and high salinity ('takyrs'), rather than on stream sides irrigated by less saline floodwaters. Takyrs are highly impermeable, almost flat, clay surfaces that retain water and are of considerable importance to communities living in the desert today. All these different scenarios would largely draw on naturally irrigated land, with only relatively small-scale channels or embanking required. No definite evidence of such features has been discovered, though this may in part reflect subsequent processes of deposition or erosion.

The belief that early agriculturists at Jeitun irrigated their fields, however, is based largely on the assumption that the climate during the Neolithic was similar to today. There is some evidence to suggest that this assumption may be unfounded, for the base of the dunes overlying fluvial deposits at Jeitun has yielded an OSL date of *c*.4,500–5,000 years BP, so it is possible that arid consequences would be enormous and could ultimately undermine regional security. The question of sustainable irrigation is therefore urgent. Given that Central Asia not only has a long history of irrigated agriculture but has witnessed the rise and fall of a number of major empires over the last few thousand years, it may well be that lessons can be learned from the past. An assessment of former irrigation and water management practices may highlight whether sustainable irrigation is a feasible option, and if so how it might be achieved.

Here we review the history of settlement, agriculture and irrigation over some 8,000 years in southern Turkmenistan (Fig. 6.1). A large body of archaeological evidence is available for this region, much of it resulting from the establishment of the South Turkmenistan Multi-Disciplinary Archaeological Expedition (YuTAKE) in 1946. Many of its publications were not widely distributed, even within the former Soviet Union, but we have been able to draw on a wide range of useful syntheses published in western journals. A more recent phase of fieldwork involving a number of international research teams has resulted in a series of renewed excavations at several important sites including Jeitun, Anau, Gonur Depe and Merv. Although many of these projects are ongoing, important papers pertaining to the area have emerged (Harris *et al.*, 1993, 1996; Herrmann, 1997; Herrmann *et al.*, 1998, Hiebert, 1994), providing valuable information on changes in environment and society over this period. Historical sources are more problematic. Although literate civilizations have existed in the region since the Achaemenid period, there is no systematic body of texts comparable to the clay tablets of Mesopotamia. For the medieval period, we are largely dependent on short descriptions in accounts by Arab or Chinese travellers or Arab historians. Some Sasanian records have survived through their use by the Arab historians. Prior to this, we are again dependent on brief travellers' accounts and histories compiled far away to the west, in classical Greece and Rome. Our understanding of the political dynamics underlying the increasingly well-documented settlement archaeology is therefore currently less sophisticated than in the Near East proper.

ENVIRONMENT

Turkmenistan covers an area of 480,000 km^2, 90 per cent of which is covered by the virtually uninhabited Kara Kum Desert (Babaev, 1996). Most of Turkmenistan comprises lowlands, with mountains being confined to the southern and western parts of the country. It lies within the temperate desert zone (Babaev, 1994) and has a marked continental climate (Orlovsky, 1994). Precipitation mainly falls as snow or rain in winter, with almost none in the agriculturally-active summer months of June through to September. Average annual precipitation varies from 90 mm in Dashouz to nearly 400 mm in the southwest highlands of the Kopet Dagh, but in much of the country it

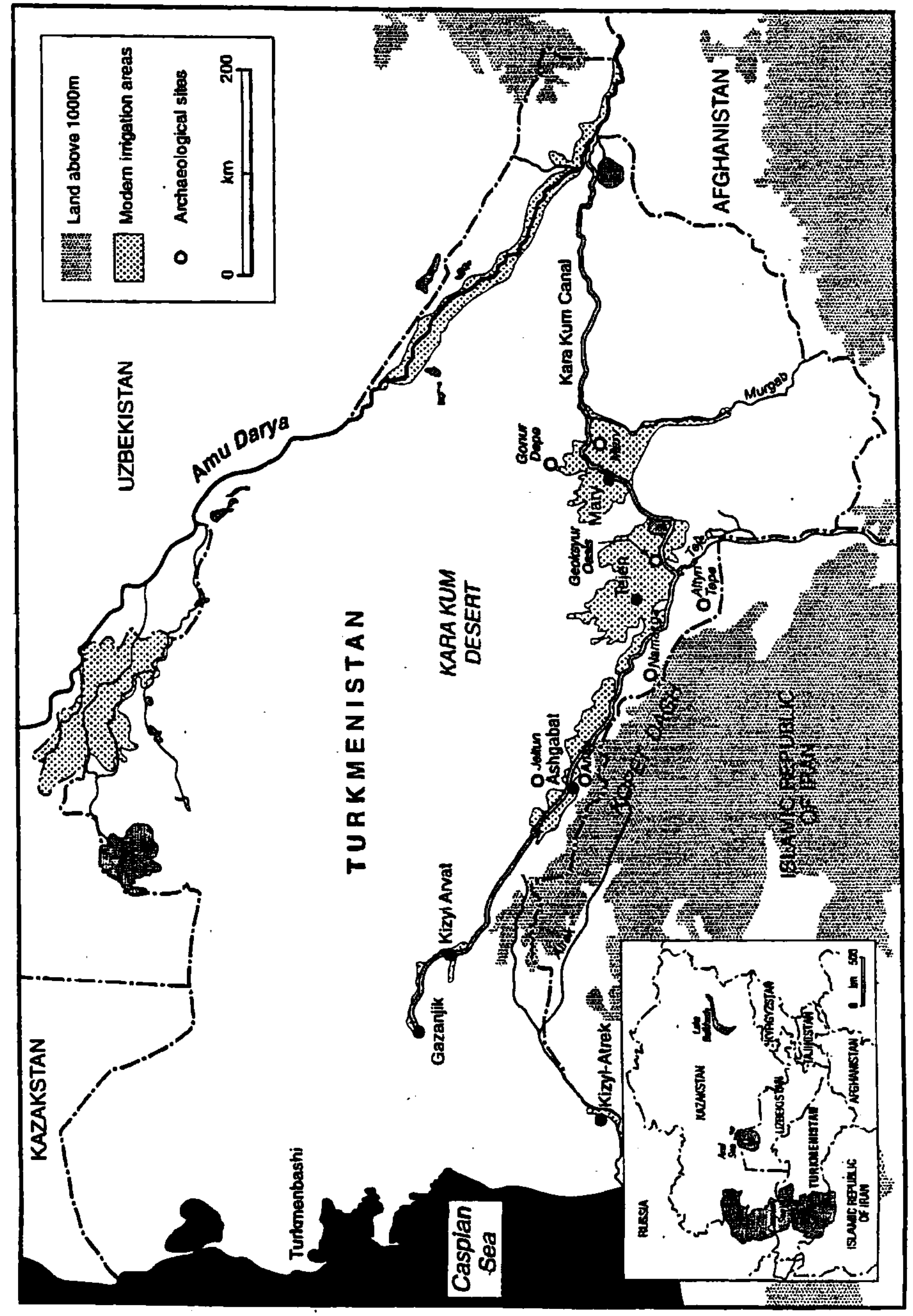

Figure 6.1 Turkmenistan, showing locations mentioned in Chapter 6

Tate, G. (1992) *Les Campagnes de la Syrie du Nord di IIe au VIIe Siècle: Un Exemple d'Expansion Demographique et Économique à la Fin de l'Antiquité*. Paris, P. Geuthner, Bibliothèque Archéologique et Historique 133.
Tate, G. (1997) The Syrian countryside during the Roman era. In S.E. Alcock (ed.) *The Early Roman Empire in the East*: 55–70. Oxford, Oxbow Books.
Villeneuve, F. (1986) Ad-Diyatheh: village et castellum romains et byzantins a l'est du Jebel Druze (Syrie). In P.W.M. Freeman and D.L. Kennedy (eds) *Defence of the Roman and Byzantine East. Volume II*: 697–715. Oxford, British Archaeological Reports, International Series 297.

6 *Irrigation agriculture in Central Asia: a long-term perspective from Turkmenistan*

MARK NESBITT AND SARAH O'HARA

INTRODUCTION

Agriculture in the newly independent republics of the former Soviet Central Asia is almost entirely dependent on irrigation. Consequently, access to water is essential and it has long played an important role in the social, environmental, economic and political situation of the region. Today, as in the past, agriculture represents the single most important economic activity throughout the region, and currently over 40 per cent of the population is employed in the commercial agricultural sector, with the vast majority of Central Asians either partially or wholly dependent on subsistence agriculture. The agricultural sector throughout Central Asia, however, is under threat because of the rapid deterioration in the water distribution and irrigation since the collapse of the Soviet Union (O'Hara, in press).

Central Asia boasts a long history of irrigated agriculture, but the exploitation of the region's water resources and the expansion of the irrigation network peaked during the latter part of the Soviet era. During this period huge water diversion and irrigation projects were constructed to satisfy Moscow's continual demands for cotton. In order to maximize agricultural output, water was taken from areas of surplus to those of deficit, often involving transfers over considerable distances and in some case from other republics. Today, however, this huge, highly integrated, network serves five independent states, each following its own agenda for reform. The implications for the region's water resources are immense and it is becoming increasingly difficult to reach a consensus on how the water distribution and irrigation system should be managed and maintained (Bedford, 1996; O'Hara, in press). Further complicating the matter is the fact that Central Asia's irrigation zones are plagued by secondary salinization and high water tables (O'Hara, 1997; Smith, 1992), and it is evident that these large-scale Soviet-built systems are environmentally unsustainable. The situation is not likely to improve and indeed could be exacerbated by changing land and agricultural policies, coupled with an increased demand for water as population rises. Should the system fail, the