Chapter 9
Dry and Humid Periods Reconstructed from Tree Rings in the Former Territory of Sogdiana (Central Asia) and Their Socio-economic Consequences over the Last Millennium

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Abstract One of the richest societies along the Silk Road developed in Sogdiana, located in present-day Tajikistan, Uzbekistan, and Kyrgyzstan. This urban civilisation reached its greatest prosperity during the golden age of the Silk Road (sixth to ninth century CE). Rapid political and economic changes, accelerated by climatic variations, were observed during last millennium in this region. The newly developed tree-ring-based reconstruction of precipitation for the past millennium revealed a series of dry and wet stages. During the Medieval Climate Anomaly (MCA), two dry periods occurred (900–1000 and 1200–1250), interrupted by a phase of wetter conditions. Distinct dry periods occurred around 1510–1650, 1750–1850, and 1920–1970, respectively. The juniper tree-ring record of moisture changes revealed that major dry and pluvial episodes were consistent with those indicated by hydroclimatic proxy data from adjacent areas. These climate fluctuations have had long- and short term consequences for human history in the territory of former Sogdiana.

Keywords Arid Central Asia · Silk road · Precipitation reconstruction
Dendroclimatology · Social growth and decline

9.1 Introduction

Recently, there has been growing interest in the relationship between climate change and its socio-economic consequences throughout human history. Abrupt climate

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changes not only affect the dynamics of natural systems like glacial and geomorphological processes (Solomina et al. 2016) or the distribution of vegetation zones (Klemm et al. 2016), but may also have long-lasting consequences for societies by causing a rapid transformation of the prevailing hydrological regime (Boroffka et al. 2006; Sorrel et al. 2007). Possible impacts of climate on human life, migration, agricultural production, and the growth and decline of societies have been extensively studied in recent years (Hodell et al. 1995; deMenocal 2001; Weiss and Bradley 2001; Sidle et al. 2004; Buckley et al. 2010; Büntgen et al. 2011; Giosan et al. 2013; Latorre et al. 2016).

The consequences of climate fluctuations are particularly evident in arid and semiarid areas, where ecosystem responses are very rapid. In the long history of the Silk Road, rich ancient societies developed in arid Central Asia under the influence of favourable conditions in the natural environment, where access to water and fertile soil were the most important factors (Owczarek et al. 2018). One of the richest societies along the Silk Road developed in Sogdiana, located in present-day Tajikistan, Uzbekistan, and Kyrgyzstan. This urban civilisation reached its greatest prosperity during the golden age of the Silk Road (sixth to ninth century CE) (Schafer 1963; Litvinsky et al. 1996; de La Vaissière 2002; Marshak 2003; Owczarek et al. 2018). Archaeological excavations indicate that this territory, crossed by several main branches of the Silk Road, was a melting pot where Sogdian merchants met others from a wide range of areas, from China to Byzantium (Marshak 2003). Sogdiana, one of the most advanced areas and the leader of all Transoxania, collapsed in eighth to ninth century (Grenet and de la Vaissière 2002; Marshak 2003). However, Sogdiana's civilizational, economic and social achievements have been visible for many centuries after its decline.

Despite its great significance, this territory, located between the Pamir Mountains and the large mid-latitude desert systems, is relatively little known in terms of climate and socio-economic changes (Opała-Owczarek et al. 2018; Owczarek et al. 2018), in contrast to research showing links between climate and the rise and fall of empires such as the Mongolian (Pederson et al. 2014; Putnam et al. 2016) and Chinese (Fan 2015; Wei et al. 2015; Yin et al. 2016; Li et al. 2017). Recently, Yadava et al. (2016) reconstructed drought periods and historic social upheavals and invasions of India.

The purpose of this paper is to analyse dry and wet periods over the last millennium in the former territory of ancient Sogdiana on the basis of tree-ring data, with a particular focus on the relationship between changes in precipitation and economic growth and decline.

9.2 Description of the Study Area

9.2.1 Regional Settings

Ancient Sogdiana was located in the upper part of the Aral Sea basin between two large Central Asian rivers, the Amu Darya (Oxus) in the south and the Syr Darya

Fig. 9.1 Location of the ancient Sogdiana on the background of political (ca. sixth century AD) and key physiographic units in Central Asia (modified after Abazov 2008)

(Jaxartes) in the north. It stretched from the Pamir Mountains in the east to the Kyzylkum and Karakum deserts in the west (Abazov 2008) (Fig. 9.1). The axis of this territory is marked by the longitudinal Zeravshan River Valley, along which the most important towns of Sogdiana, namely Panjikent, Samarkand, and Bukhara, were situated (Owczarek et al. 2018) (Fig. 9.1). Today this area forms parts of Tajikistan, eastern Uzbekistan, and south-western Kyrgyzstan. The area is characterised by extremely diverse relief. The eastern part includes the partly glaciated Pamir Mountains, where the average height of the main ridges reaches ca 6000 m a.s.l. (max. Ismail Somoni Peak, 7495 m a.s.l.). The Pamir-Alay Mountains, which form the transition zone between the Pamir and Tien-Shan Mountains, cover the central and north-eastern part of the former territory of Sogdiana. They consist of three longitudinal mountain ridges: Gissar, Zeravshan, and Turkestan, which reach a maximum height of 5600 m a.s.l. (Rahmonov et al. 2017a, b). These mountainous regions are characterised by a high level of seismicity, connected with their location in the vicinity of the Pamir Frontal Thrust system (Schurr et al. 2014; Owczarek et al. 2017). The western and south-western parts of the former Sogdiana territory include lowlands within the Central Asian mid-latitude desert system (Kyzylkum, Karakum) and tectonically conditioned mid-mountain basins (Afghan-Tajik Depression) (Fig. 9.1).

The tree-ring sampling sites are located in the central part of the Zeravshan Ridge in the Pamir-Alay Mountains (Fig. 9.1). This area is drained by the Urech-Kshtut river system, which constitutes the left tributary of the Zeravshan River. The samples were taken from two sites located in the Urech Valley at elevations between 2200–2900 m a.s.l (Fig. 9.2a). The upper part of the valley includes a high-mountain glacier basin; surrounded from the south by Chimtarga Peak (5489 m a.s.l) (Fig. 9.2b). Below the basin, the Urech River flows through a deep U-shaped valley with alternating wide

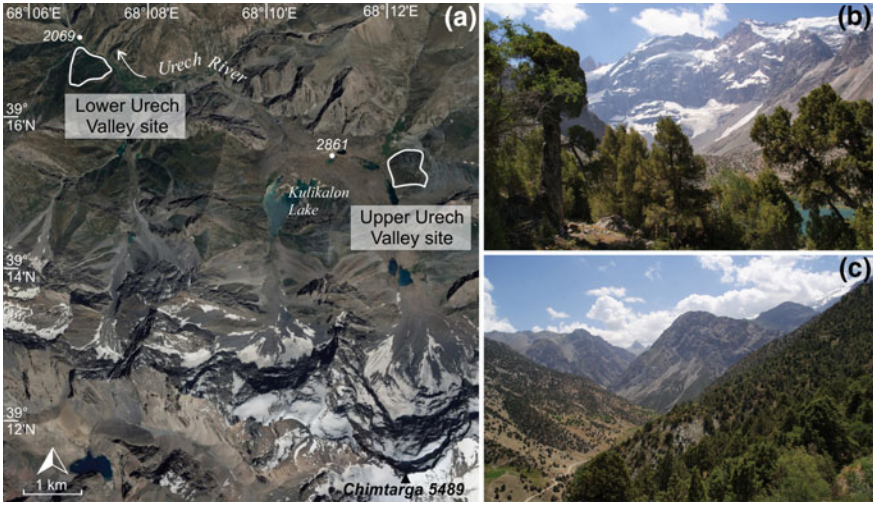

Fig. 9.2 **a** Location of the tree-ring sampling sites within the highest part of the Zeravshan Range in the Pamir-Alay Mountains (on the basis of 2018 DigitalGlobe, 16 June 2017, Google Earth), **b** general view of the Upper Urech Valley site, on the background Chimtarga Peak (5489 m a.s.l.); **c** general view of the Lower Urech Valley site

and narrow zones (Fig. 9.2c). The most important plant community here is composed of *Juniperus semiglobosa* and *Juniperus seravschanica*, which form an open forest up to an elevation of 3400 m a.s.l. (Rahmonov et al. 2017a, b).

9.2.2 Climate of the Study Area

The landlocked location of the study area and its great distance from oceanic sources of moisture makes its climate extremely continental, with hot, dry summers and cold winters. Climate conditions are characterised by extreme local contrasts dependent on altitude and landforms. Air temperatures tend to depend strongly on altitude. The mean annual temperature drops from 13.5 °C at 726 m a.s.l. in Samarkand to 10.5 °C at 1680–1700 m a.s.l. at the mouth of the Urech River, then to 0 °C at 3200 m a.s.l. near the upper line of juniper forests, and finally to −1.8° C at the Anzob Pass (3373 m a.s.l.) (Fig. 9.3). At the highest peak, Chimtarga, the mean annual temperature is estimated at about −15 °C (Rahmonov et al. 2017b).

Mean annual precipitation for the discussed area ranges from 400 to 500 mm on peaks and slopes at altitudes about 3000–3400 m a.s.l. (434 mm at Anzob Pass) to 250–350 mm in the Pamir-Alay foreland (353 mm at Samarkand). Most precipitation occurs in spring (about 60 mm per month in March, April, and May), while the summer months (JJA) receive either minimal quantities or none at all (Fig. 9.3).

Air temperatures in most areas of Tajikistan and Uzbekistan are increasing (0.3–0.5 °C in the period 1940–2000, with the warmest decades in the 1930s, 1980s and 1990s); however, changes in atmospheric precipitation are uneven due to the

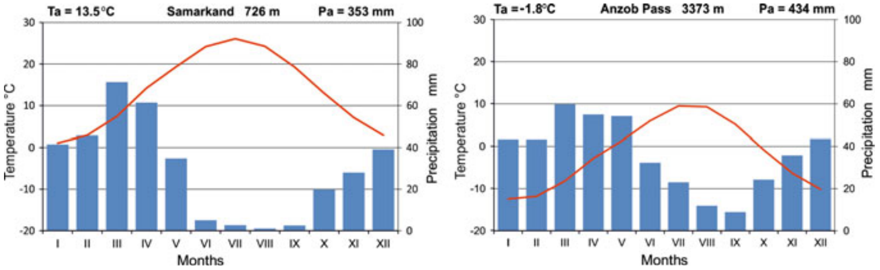

Fig. 9.3 Monthly mean temperature and mean precipitation for Samarkand and Anzob Pass meteorological stations during the period 1936–2003 on the basis of data from CATPD (Williams and Konovalov 2008)

geographic and climatic diversity of the territory (Makhmadaliev et al. 2008; Chub and Ososkova 2009; Kayumov 2010). In Uzbekistan, observed changes in the hydrological cycle include a decrease in precipitation in the west and an increase in the east of the country as well as around irrigated lands along main river valleys due to increased evaporation (Lioubimtseva and Henebry 2009; Chub and Ososkova 2009). The eastern part of the studied area, covering the territory of Tajikistan, experiences more humid conditions. In general, periods of humid weather alternate with periods of dry weather. According to available instrumental climate data the driest decade for all altitudinal zones was from 1941 to 1950. A trend towards increasing amounts of precipitation is especially visible in the second half of the twentieth century. After 1990, the rainiest period was in 1998–99; the following years 2000–01 were the driest, with drought predominating nearly throughout the territory.

9.3 Materials and Methods

9.3.1 Tree Ring Sampling and Development of Chronologies

In 2014 and 2015, we collected 110 cores using increment borers (5.15 mm in diameter). To minimise non-climatic effects on tree growth, only uninjured, healthy trees were sampled. Tree cores from junipers were collected from two sampling plots (Fig. 9.2a). The Upper Urech Valley site (UUV) is situated in a high mountain basin, partly filled by one of the Kulikalon Lakes, at an altitude of 2800–2900 m a.s.l. (Fig. 9.2b). The second site, the Lower Urech Valley site (LUV), is located at an elevation of 2200–2300 m a.s.l. on a valley slope (Fig. 9.2c).

According to standard dendrochronological techniques (Speer 2010), the sampled tree-ring cores were dried naturally and sanded to a high polish using progressively finer grades of sandpaper until the cellular structures of the rings were visible under a binocular. Ring widths were measured to the nearest 0.001 mm using the WinDENDRO system (WinDENDRO 2006). Next, we used the COFECHA program (Holmes 1983) to check our dating by comparing ring-width measurements between all series from the two sites. Before calibrating the tree-ring data with climate data, the biological age trend inherent in the raw data series had to be removed. We used the ARSTAN program (Cook 1985) to detrend individual series with a negative exponential curve to preserve climate-related variations at both high and low frequencies. The chronology was calculated as the residuals between the raw measurements and fitted trend curves, resulting in a dimensionless index series. The detrended single series were then combined into a standard chronology, using a biweight robust mean to minimise the influence of biases in tree-ring indices (Cook and Kairiukstis 1990). The reliability of the tree-ring records was evaluated using the so-called expressed population signal (EPS) (Wigley et al. 1984). To assess replication through time at every site, we used the commonly acceptable cut-off value of 0.85 (85% of common chronology signal retained) and an adequate sample size (series $\geq$3).

9.3.2 Climatological Data and Dendroclimatic Methods

The longest series of meteorological data for the studied region is available from the Samarkand meteorological station in Uzbekistan (station code 38696, 67.00° E, 39.70° N, 726 m a.s.l.). Meteorological station data were obtained from Central Asia Temperature and Precipitation Data (CATPD), 1879–2003 (Williams and Konovalov 2008). Monthly temperature means and precipitation sums for the period 1936–2015 were used in our calculations. These were also compared to monthly $0.5° \times 0.5°$ gridded climate variables obtained from the Climatic Research Unit (CRU TS 3.21, Mitchell and Jones 2005). For calculation, we used data averaged for the mountainous region 39–40° N and 68–69° E, the mountain foreland region 37–38° N and 67–68° E, and the average of the grids 38–41° N and 67–70° E, which equally represent the climates of the mountainous part and low elevations of the study area. A comparison between the precipitation levels noted in various meteorological records available for the region is shown in Fig. 9.4.

The relationship between juniper ring width variations and climate was determined by calculating a response function and conducting a correlation analysis between the site-level chronologies, mean monthly temperature, and total monthly precipitation over the so-called ‘dendroclimatological year’. As the growth of a tree can be affected by the climatic conditions of the current as well as those of the previous growing season, climate response analysis was performed from monthly data from the previous July to the current September. For calculations we used the DendroClim2002 program (Biondi and Waikul 2004), which provides estimates of bootstrapped confidence intervals for evaluating the significance of correlation coefficients. Following the successful verification and calibration procedure, the climate reconstruction was performed using the transfer function described by Cook and Kairiukstis (1990).

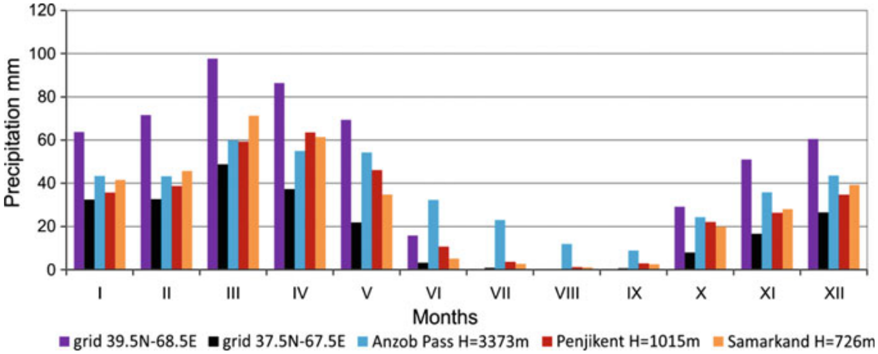

Fig. 9.4 A comparison between the precipitation levels noted in various meteorological records available for the central part of former Sogdiana territory (present-day north-western Tajikistan, eastern Uzbekistan) on the basis of CATPD dataset (Williams and Konovalov 2008) and Climate Research Unit (CRU) TS 2.1 gridded dataset (Mitchell and Jones 2005)

9.4 Results and Discussion

9.4.1 *Characteristics of Tree-Ring Chronology and Its Response to Climate*

The constructed local site chronologies showed a significant inter-site correlation of 0.49, which indicates a common climatic signal. The chronology from the lower site (LUV) covers the last 220 years (1795–2014, with EPS > 0.85 from AD 1877); the time span of the chronology from the upper site (UUV) was much longer, covering the last 1215 years (801–2015, with EPS > 0.85 from AD 1092). Difference between the length of these two chronologies is connected with timber harvesting in the vicinity of settlements, that lasts already for many centuries.

Climate response analysis showed that local chronologies are positively correlated with monthly precipitation, while the influence of temperature is minor or insignificant. In general, both chronologies are positively correlated with the monthly precipitation from the previous July to the current September recorded at the meteorological station in Samarkand. The highest significant correlations were found between tree-ring widths from the lower location and spring precipitation (March–May, $r = 0.60$; April–May, $r = 0.58$). As shown in Fig. 9.5, the correlation coefficient values for the upper location, though slightly lower, indicate a similar growth response to climatic variability. Significant correlations were found with mean monthly precipitation in spring months (April–May) and precipitation in the dendroclimatological year (pJune–September). The correlations between the gridded precipitation data were consistent to some extent with the correlations observed with weather station data (Fig. 9.5).

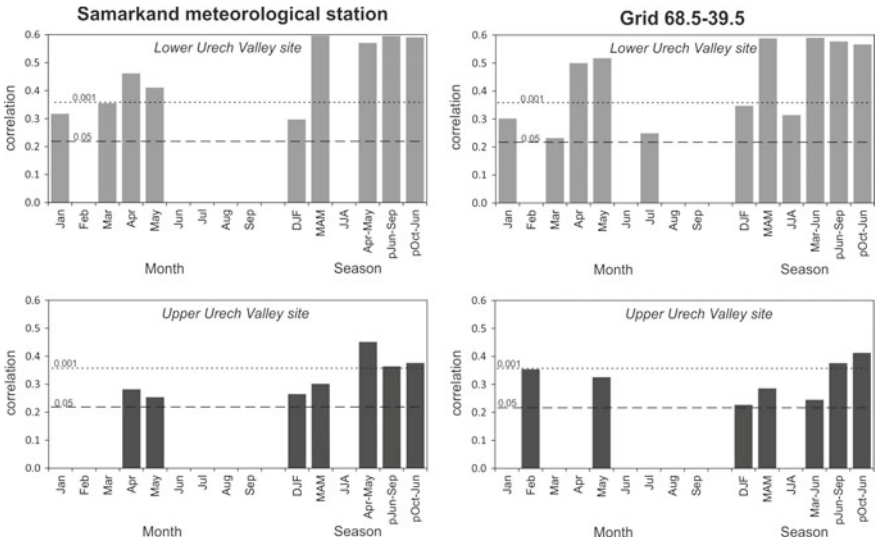

Fig. 9.5 Correlation between juniper tree-ring width chronologies from lower and upper Urech Valley study sites and precipitation data from Samarkand (726 m) and gridded dataset (68.5–39.5)

In earlier studies it was also noted that pluvial conditions during the winter months are very important for the growth of trees from southern slopes near timberline locations in the Pamir-Alay (Opała et al. 2017; Opała-Owczarek and Niedźwiedź 2018). Moreover, Seim et al. (2016) stated that junipers growing on the southern slopes in Uzbek part of the Pamir-Alay and Tien-Shan are mainly dependent on spring and annual precipitation. Differences in seasonal response are connected with local conditions (altitude, topography, location within the mountain massif). Moisture supply in the early growing season (from liquid precipitation or snowmelt) is the most important climate variable affecting the growth of junipers. As summer precipitation in the studied region is scarce, drought stress is expected to be one of the main growth limiting factors for these trees.

The significant climate-growth correlations enabled us to reconstruct April–May precipitation anomalies from the tree-ring-width chronology of junipers. The high-elevation chronology was used to calculate the reconstruction, as it allows to cover the longer time span. The moving correlation analysis indicated that the climate-growth relationship is stable only in the second part of the instrumental data period (Fig. 9.6a). Such result is usually associated with the low quality of the instrumental data in the early period of observations, but it may be not a single factor. Other possible causes are e.g. dust storms in arid Central Asia, which were especially frequent during the 1950–60s, when vast areas of natural desert pastures were dramatically transformed by agriculture and human pressure. This led to increase in the frequency of dust storms outbreaks (Indoitu et al. 2012). Therefore, we used shortened period 1966–2014 for calibration with proxy data (Fig. 9.6b).

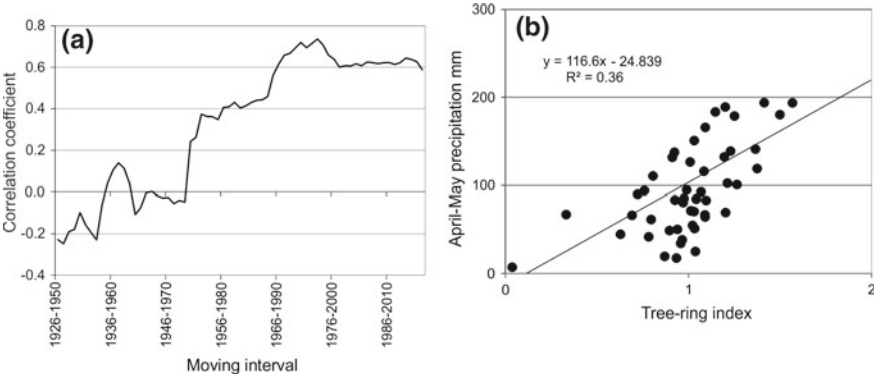

Fig. 9.6 **a** Moving correlation function between April–May precipitation and the tree-ring width index from the upper site chronology considering an interval lengths of 25 years; **b** the relation between these variables over the period 1966–2014

The regression model accounts for 36% of the variance in the instrumental spring precipitation (April–May totals) over the calibration period from 1966–2014. The results of ca 30–40% of explained variance in the dendroclimatic reconstruction is widely acceptable (e.g. Chen et al. 2015; Gou et al. 2015; Shah et al. 2018). We are aware that the dendroclimatic method of climate reconstruction is associated with a certain degree of uncertainty. However, standard methodology have been used to assess whether the model has the ability to reconstruct the climate. The cross calibration-verification tests for two split periods revealed that the model passes the standard tests of reconstruction reliability (a positive reduction of error (RE) and coefficient of efficiency (CE)). Because our calibration-verification sub-periods are relatively short (1966–1990, 1990–2014), additional verification of spring precipitation reconstruction model was made using a grid dataset (Table 9.1). Finally, a linear regression model was developed to reconstruct April–May precipitation variations back to 800 CE. The reconstruction of spring precipitation variability over the last 1200 years presented in Fig. 9.7 revealed variations on an inter-annual to decadal and centennial scale.

9.4.2 *Moisture Changes in the Last Millennium*

The reconstructed climate history of the former territory of Sogdiana for the past millennium revealed a series of dry and wet stages. Referring to the time frame of the Medieval Climate Anomaly (900–1300 CE) and the Little Ice Age (1570–1900 CE) described by Lamb (1965) and Matthews and Briffa (2005) some regional differences can be observed. In the studied western Pamir-Alay region during the Medieval Climate Anomaly (MCA) two dry periods occurred, with a shift to wetter conditions

Table 9.1 Calibration and verification statistics for split (1966–1990, 1990–2014) and entire period (1990–2014) for the spring precipitation reconstruction model based on tree rings

Type of data	Samarkand station data				Samarkand station data	Grid data[a]
Time period	Calibration (1990–2014)	Verification (1966–1990)	Calibration (1966–1990)	Verification (1990–2014)	Calibration (1966–2014)	Verification (1966–2014)
r	0.65	0.62	0.62	0.64	0.60	0.56
R^2	0.41	0.38	0.38	0.41	0.36	0.32
RE		0.41		0.42		0.21
CE		0.38		0.40		0.18
ST+/−		19/6		21/4		34/14

Explanations: r—correlation coefficient; R2—explained variance; RE reduction of error; CE coefficient of efficiency; ST sign test

[a] For independent verification data for grid (38–41° N and 67–70° E) was used

between them. The Little Ice Age (LIA) in this area was characterised by wetter conditions interrupted by a dry period with conditions closer to the average (Fig. 9.7).

According to new Pamir-Alay tree-ring data, dry periods prevailed in the following time spans: 900–1000, 1200–1250, 1510–1650, 1750–1850, and 1920–1970 (Fig. 9.7b). The first long period of arid climate conditions present in the tree-ring-based precipitation reconstruction started as early as 900 and lasted to ca 1000 CE. This drought is consistent with data from the Guliya ice cap (Thompson et al. 1995; Yao et al. 1996) and Badain Jaran Desert (Ma and Edmunds 2006), and is also in line with the modelled changes in rainfall anomalies of the ECHAM5 simulation of the arid Central Asia domain (Fallah et al. 2016). At the turn of the tenth and eleventh centuries, a shift to wetter conditions occurred. This period of two hundred years is characterised by a high level of variability with a clear predominance of above-average precipitation. Increased rainfall in Central Asia in this period is evidenced by low-resolution records, such as speleothem carbon isotope data, ostracod assemblages from lake sediments, and pollen concentration data (Chen et al. 2010).

At the beginning of the thirteenth century, a rapid transition to dry conditions is observed. This period lasted only fifty years, but probably constituted the most severe drought in the entire analysed period. Low precipitation before ca 1250 was confirmed by many other natural proxies from arid Central Asia, e.g. Uluu Too Cave (Wolff et al. 2017). After a period of considerable higher precipitation from 1300 to 1400, a homogeneous period of nearly 200 years, with values close to the long-term average, prevailed during the fifteenth century, becoming progressively drier during the sixteenth century. The occurrence of low levels of precipitation and very dry conditions during this time is confirmed by historical reports from Afghanistan (Beveridge 1921, after Yadava et al. 2016). A rapid transition between dry and wet climate conditions took place around 1650. The two most significant pluvial periods in the Pamir-Alay tree-ring reconstruction, around the eleventh and twelfth and from the mid-seventeenth to mid-eighteenth centuries, are in accord with data on Pamir-Alay glacier fluctuations (Solomina et al. 2016). The evidence for a glacier advance

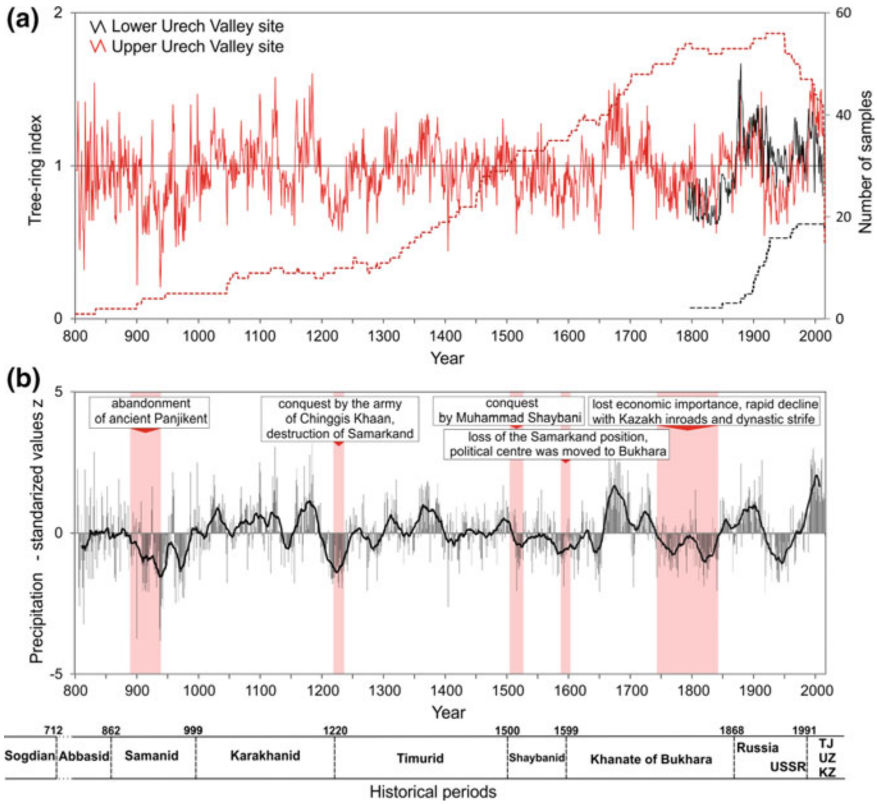

Fig. 9.7 **a** Tree-ring width chronology of *Juniperus seravshanica* from the lower Urech Valley (1795–2014) and *Juniperus semiglobosa* from the upper Urech Valley (801–2015). The solid and dashed lines represent the tree-ring index and sample depth, respectively. **b** Tree-ring-based reconstruction of precipitation variability during the past 1200 years with important historical periods for the former territory of Sogdiana. The vertical red bands denote dry periods, which correlate with rapid political and economic changes

shortly after 985 ± 115 CE was found via radiocarbon dating of shallow soil horizon below a fresh till at the Abramova Glacier (Zech et al. 2000). The youngest advance took place at the end of the seventeenth century (ca 1690 CE) as dated by a ^{14}C age determined from a trunk of *Juniperus turkestanica* broken by an advance of the Raigorodskogo Glacier (Narama 2002). In the light of glaciological evidence, these two advances were of similar magnitude, although the former was slightly larger.

The Pamir-Alay tree-ring reconstruction shows that LIA precipitation maximum (1650–1740) was followed by a long dry period, 1750–1840 (Fig. 9.7b). The first dry sub-period, 1756–1768, known as the Strange Parallel Drought, is well documented in different parts of Asia. Of the four well-documented historical droughts indicated in the Monsoon Asia Drought Atlas (MADA, Cook et al. 2010), it was the only mega-drought to occur in the studied area. At the end of the LIA, a pronounced wet period took place around 1850–1910, followed by advances of the Raigorodskogo Glacier dated to 1908–1934 (Narama 2002).

The twentieth century was characterised by two opposing precipitation regimes. A pronounced drought was observed between ca 1920 and 1970. A significant change in precipitation variability is evident during the second half of the twentieth century. The recent wetting trend in Central Asia was captured by many moisture-sensitive tree-ring series, e.g. from north-western India (Yadav et al. 2017), northern Pakistan (Treydte et al. 2006) and Kyrgyzstan (Chen et al. 2015; Zhang et al. 2015), as opposed to the case of Mongolia or of Nepal, where contemporary drought is evident (Pederson et al. 2014; Panthi et al. 2017).

9.4.3 Socio-economic Changes During the Past Millennium

The oasis of Samarkand in the Middle Zeravshan Valley was the most important political and economic centre at the turn of the first and second millennium of the common era. Samarkand was the capital of ancient Sogdiana, which collapsed in the eighth century; nevertheless, it maintained its importance in the following centuries. During this time, the area was in the possession of various tribes and dynasties (Fig. 9.7). Political changes, both negative and positive, in the former territory of the kingdom of Sogdiana, as reflected in the history of Samarkand, were often associated with climate changes, i.e. the occurrence of alternate dry and humid periods (Owczarek et al. 2018).

Following the Arab conquest at the beginning of the eighth century, most of the former Sogdiana area fell into the orbit of Islamic influence (Grenet and de la Vaissière 2002; Marshak 2003; Ghafurov 2011). The period ca 800–900 was characterised by relatively warmer and wetter climate conditions. This is confirmed not only by tree-ring data but also by other proxy data from the Aral Sea basin and the surrounding areas (Sorrel et al. 2006, 2007; Boomer et al. 2009). During this time Samarkand and its surroundings became part of the Samanid Empire. This period of prosperity was experienced not only in this area but along the entire Silk Road as well. Public buildings and mosques were enlarged and the water supply ensured by means of ancient aqueducts, conduits, and irrigation canals (Ivanitskij and Inevatkina 1999; Malatesta et al. 2012). Samarkand's oases, with their famous peach gardens, experienced a golden age at the end of the Tang Dynasty (Schafer 1963). Despite the tenth-century drought, the economy of Samarkand remained unaffected. This cannot be said of the nearby town of Panjikent, one of the most important cities in ancient Sogdiana and along the Silk Road (Fig. 9.8) (Belenitskij et al. 1973). Although the Arab conquest in 722 did not cause its definitive collapse, Panjikent gradually lost its significance in comparison to Samarkand and Bukhara (Marshak 2003). A period of drought in the tenth century was one of the influences leading to the abandonment of ancient Panjikent and the town's displacement to the lower terrace of the Zeravshan River, where water was more accessible (Fig. 9.8) (Owczarek et al. 2018). The arid conditions during this time have also been clearly documented by

Fig. 9.8 **a** General view of the ruins of ancient Panjikent, partly destroyed during Arab conquest in AD 722 and completely abandoned in the 9th/10th century, **b** archaeological excavation within the area of ancient Panjikent (photographs were taken in July 2015 by the authors)

means of pollen analysis of sediments from the northern shore of the Aral Sea (Sorrel et al. 2007) and other palaeoclimatic records from arid Central Asia (Yang et al. 2009). In the eleventh and twelfth centuries, in stable moisture climate conditions, the former Sogdiana area became part of the Karakhanid Khanate. This period was marked by continued development for Samarkand as a new administrative centre. Several buildings were erected, including a new palace in the citadel, a madrasa, and caravansaries (Davidovich 1998). The Bibi-Khanym Mosque was enlarged and, to a great extent, rebuilt (Grenet and Rapin 1993; Paul 1993).

The tree-ring data from the first half of the thirteenth century documented strong arid conditions (Fig. 9.7). This dry period was also marked by the increasing salinity of the Aral Sea (Sorrel et al. 2006), a high level of carbonate content in lake sediments (Chen et al. 2006), and falls in the levels of lakes in arid Central Asia (Boroffka et al. 2006; Narama et al. 2010), and diminishing ice accumulation in Central Asian glaciers (Yang et al. 2009). This period was marked by drastic political and economic changes in the area of former Sogdiana. In 1220, Samarkand was seized by the army of Chinggis Khaan and destroyed (Grenet and Rapin 1993). The huge losses sustained by the working population and the decreasing availability of water in connection with the dry climate conditions were the main factors contributing to the decline of Samarkand, as maintenance of the water supply required more skills and labour than were available (de Hartog 2006). The increasing humidity in the fourteenth century coincided with the rebuilding of Samarkand and re-establishment of its significance. In 1371, Timur established the city as his capital and renewed the irrigation system in the Zeravshan River valley, which was used extensively for agriculture (Manz 1989). Traces of a high water level and flooding in this period, indicating a moister climate, were found in sediment from canals carrying water from the Zeravshan River to the oases of Samarkand (Malatesta et al. 2012). The next arid interval, recorded ca 1500–1600, was marked again by violent political changes in the former Sogdiana (Fig. 9.7).

In 1500, Timurid Samarkand was conquered by Muhammad Shaybani (Grenet 2002; Mukminova and Mukhtarov 2003). The gradual decline in the importance of the Silk Road in the sixteenth century coincided with the prevailing arid conditions and the loss of Samarkand position. The political centre of the former territory of Sogdiana moved to Bukhara, which became the capital of the Khanate (Mukminova and Mukhtarov 2003). Sixteenth-century aridification was confirmed by an increase in salinity and changes of lake levels of the Aral Sea (Sorrel et al. 2006; Boomer et al. 2009; Boroffka et al. 2006). The rapid increase in humidity in the second part of the seventeenth century was marked by flood sediments in the irrigation canals in the Samarkand oasis (Malatesta et al. 2012). During the period 1750–1850, a return to arid conditions was documented. The former territory of Sogdiana lost its economic importance along with the collapse of trade on the Silk Road. A rapid decline occurred in the second part of the eighteenth century, with the inroads made by the Kazakhs and dynastic strife (Fig. 9.7). The Samarkand oasis was depopulated and the madrasas were converted by nomads into winter stables (Grenet 2002). The wet period in the second part of the nineteenth century coincided with Russian expansion. In 1868, Samarkand was conquered by the Russians and the remainder of the area of the former Sogdiana became an informal Russian protectorate (Fourniau and Poujolvc 2005). The last aridification interval occurred in the middle of the twentieth century. This was a period of rapid socio-economic changes in the Soviet republics of Central Asia. Arid conditions exerted a negative influence on increased human activity and unsustainable farming.

9.5 Conclusions

Our dendroclimatic reconstruction of changes in spring precipitation, which covers important climatic periods of the last millennium, including the drier Medieval Climate Anomaly, the wetter Little Ice Age, and modern times, revealed a series of dry and wet stages. Despite our tree-ring data were collected from relatively limited area, the newly developed proxy record of moisture changes revealed that major dry and wet episodes over the past millennium were consistent with those indicated by other hydroclimatic proxy data (such as speleothems, pollen data, glacier retreats or ice accumulation, lake sediments or changes in lake levels) from adjacent areas.

In general, during dry periods, negative socio-economic changes were observed. Our palaeoclimatic data show drought during the tenth century, influencing the abandonment of ancient Panjikent. The next dramatic decrease in precipitation took place in the first half of the thirteenth century. This period was marked by drastic political and economic changes in the former territory of Sogdiana, as Samarkand was destroyed by the army of Chinggis Khaan and additionally suffered from decreasing water availability, leading to a decline in its importance. Severe drought conditions also occurred in the sixteenth century, contributing to a deterioration in living conditions which coincided with the decline of the importance of the Silk Road and, finally, the loss of Samarkand position. On the other hand, wetter climatic conditions led to improvements in living conditions, followed by expansion and development, as was particularly evident in the eleventh, twelfth, fourteenth, and seventeenth centuries. A socio-economic perspective of wet conditions in the historic past reveals the great vulnerability of societies in arid Central Asia to climate change. However, one should keep in mind that climate may trigger problems in a society, but does not necessarily automatically lead to collapse of cultures.

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