7 Synthesis

The major goal of this study is to advance our understanding of climate and landscape evolution in Central Asia during the Holocene. The regional focus is the Ugii Nuur basin located in the steppe region in central Mongolia. Understanding Holocene climate variability and its effects on landscape evolution in this area is crucial to assess the mechanisms of environmental change in the Mongolian Plateau which are largely governed by the interplay of the EA monsoon and the Westerlies. Investigating Holocene climate and landscape evolution in this area thus contributes to linking results gained in the drylands of northern China and the boreal region in southern Siberia. Moreover, the basin is part of a greater region in Central Asia that has only been sparsely investigated.

7.1 Main conclusions

This study provides an environmental chronology of the Ugii Nuur basin. It is shown that a dry climate persisted during the late Pleistocene/Holocene boundary. Ugii Nuur was desiccated and aeolian processes of sand transport caused the accumulation of extensive sand sheets. During this time, increasing insolation caused the northward expansion of the summer monsoon. The Ugii Nuur record suggests that climate in this region was not affected by the summer monsoon but by the Westerlies that were largely governed by Eurasian glacial boundary conditions.

The Early Holocene (10-8 ka) was characterized by climate amelioration. Ugii Nuur was an endorheic lake and biological productivity was increasing. Since terrestrial records point to ongoing sand dynamics during this time it remains unclear if rising lake levels were due to temperature rise and increased glacial meltwater runoff or precipitation. It is suggested that subsiding air masses in the arid zone of China caused a shift of the Westerlies north of the Mongolian Plateau.

The Mid Holocene (8-4 ka) experienced more favorable moisture conditions and higher

air temperatures. High lake levels caused an activation of the lake outlet. This time also marks the beginning of the accumulation of loess-like sediments in the basin, most probably provoked by a denser vegetation cover acting as dust trap.

From 4-2.8 ka the lake sediment proxies show a strong decline in lake level and lake productivity. The timing of this dry phase corresponds to marked phases of environmental change recorded throughout Central Asia which have so far been attributed to short-term variations in the solar radiation causing strong fluctuations in northern Hemisphere climates.

The Ugii Nuur record points to a relatively humid, stable period during the Late Holocene (2.8 ka to present). This period is characterized by ongoing loess-like deposition. Uncertainties remain on the causes of this favorable climate and concomitant mineral dust input. Since the Orkhon Valley experienced perseverative human influence during the last three millennia it is suggested that human activity was an important driver of landscape evolution in the Late Holocene.

Concerning the methods applied in this study it is shown that electrical resistivity tomography is a valuable tool to investigate the near-surface underground in this area. Strong conductivity contrasts between the unconsolidated periglacial debris covers and the consolidated bedrock facilitate an estimation of debris cover thicknesses. It is concluded that the periglacial debris layers found in the study site cover a strong bedrock topography below the relatively smooth surface topography.

The application of a principal component analysis for the reduction of the variable space of geochemical elements in lacustrine sediments is a valuable statistical tool supporting the interpretation of lacustrine records. While many studies rely on the assumption that approaches to interpretation of geochemical proxies can be transferred to other lake systems, this method can provide basin specific factors of lake evolution. Although this approach introduces a certain degree of freedom in the interpretation of geochemical lake sediment records, it accounts for the uniqueness of lake basins and their environmental conditions.

The findings of this study underpin the notion of significant environmental variability in Central Asia during the Holocene. The fact that environmental changes do not always manifest themselves similarly in different regions demonstrates the underlying complexity

behind environmental change and the difficulties to transfer findings at the local scale to regional or global mechanisms of climate change. Moreover, studies of climate and landscape evolution provide a long-term view of landscape forming processes and their feedbacks with human activity. Such insights are urgently needed to assess the past, present and future of human-environment interactions.

7.2 Future research directions

There are various research issues beyond the scope of this study that could improve our knowledge of environmental change in Central Asia and the Ugii Nuur basin in particular.

A major issue of research should be the mechanisms governing the distribution of loess-like sediments in Mongolia. Loess-like deposits are ubiquitous in the steppe region of Mongolia but their source regions and the climatic controls behind their mobilization are still unclear. In addition, silt-sized sediments exert a strong influence on the hydrological cycle (Yair and Bryan, 2000). Understanding these mechanisms is essential to assess feedback mechanisms between dust accumulation, climate change and human activities particularly on the local to regional scale.

The fluvial dynamics of the Orkhon River are an uncertainty in the interpretation of the Ugii Nuur lake sediment record. Analyzing the temporal and spatial evolution of the Orkhon and Old Orkhon River and their deposits is promising to improve our knowledge on the sediment cascade in the Ugii Nuur basin.

Research in the Orkhon Valley should especially focus on assessing records of environmental change during the Late Holocene. This phase was marked by increased influence of human activities. Yet, it is not well understood, in how far environmental conditions effected societal evolution in this region, and how human activities in turn altered the sensitive steppe ecosystems. Combining archaeological investigations with the analysis of Late Holocene archives of environmental change is promising to improve our knowledge on human-environment interactions in this region.