Extreme weather events and 10,000 years of land-use change in the Gediz River valley

Nicolas Gauthier[1], Christina Luke[2], Christopher H. Roosevelt[2]

[1]Arizona State University, [2] Boston University

ASU school of human evolution & social change — ARIZONA STATE UNIVERSITY

shesc.asu.edu

gygaia.org

Introduction

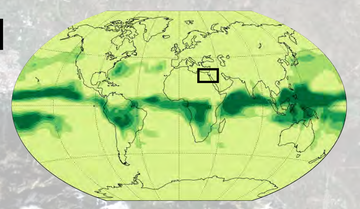
The Gediz River valley of western Turkey is one of the most agriculturally productive regions in the county. Winter storms deliver most of the valley's rain, and relatively minor variations in storm tracks can mean the difference between dry years when crops fail and wet years when floods threaten nearly 1,000 sq. km. of the valley. Until the very recent past, the valley's inhabitants managed these risks with diversified agropastoral and transhumant land-use strategies rather than intensive water-management infrastructure.

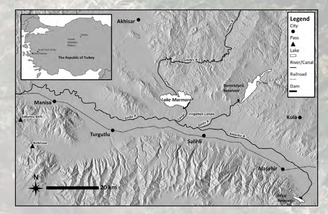
Here we reconstruct the frequency of droughts and floods in the valley over the past 10,000 years, and consider the ability of different land-use strategies to minimize the risks associated with extreme weather.

We then draw on evidence from settlement patterns, paleo-environmental records, oral histories, early traveler accounts, and municipal records to explore how broad social developments in the valley reflect changing vulnerabilities to extreme weather.

Methods

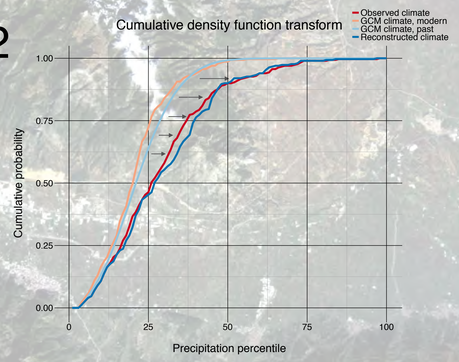
1





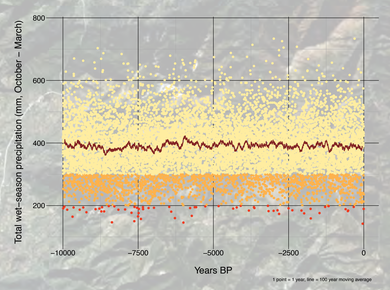
1. Get monthly rainfall data from TraCE-21k general circulation model (GCM) simulation of the past 22,000 years and monthly rainfall from weather station in the city of Salihli for 1940-1990.

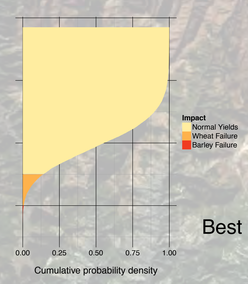
2



2. Downscale and bias correct GCM data using model output statistics (Michelangeli *et al.* 2009).
   - Transform the cumulative density function of present-day GCM data to match that of observed data.
   - Use the same transformation on GCM paleoclimate data.
3. For each century, calculate the risk of extreme events:
   - Drought risk = $\frac{\text{years when total wet-season rainfall} < 300\text{mm}}{100}$
   - Flood risk = $\frac{\text{years with at least 1 month's rainfall} > 150\text{mm}}{100}$
4. Use a payoff matrix to find the best land-use strategies given estimated risk (Gould 1963) to assess role of risk in land-use change.
5. Compare to diachronic settlement and land-use data from intensive and extensive survey and ethnographic data in the Marmara Lake basin by the Central Lydia Archaeological Survey (2005-2014) (Roosevelt 2007, 2009, 2010; Roosevelt and Luke, 2008 to present; Luke *et al.*, in press).

3





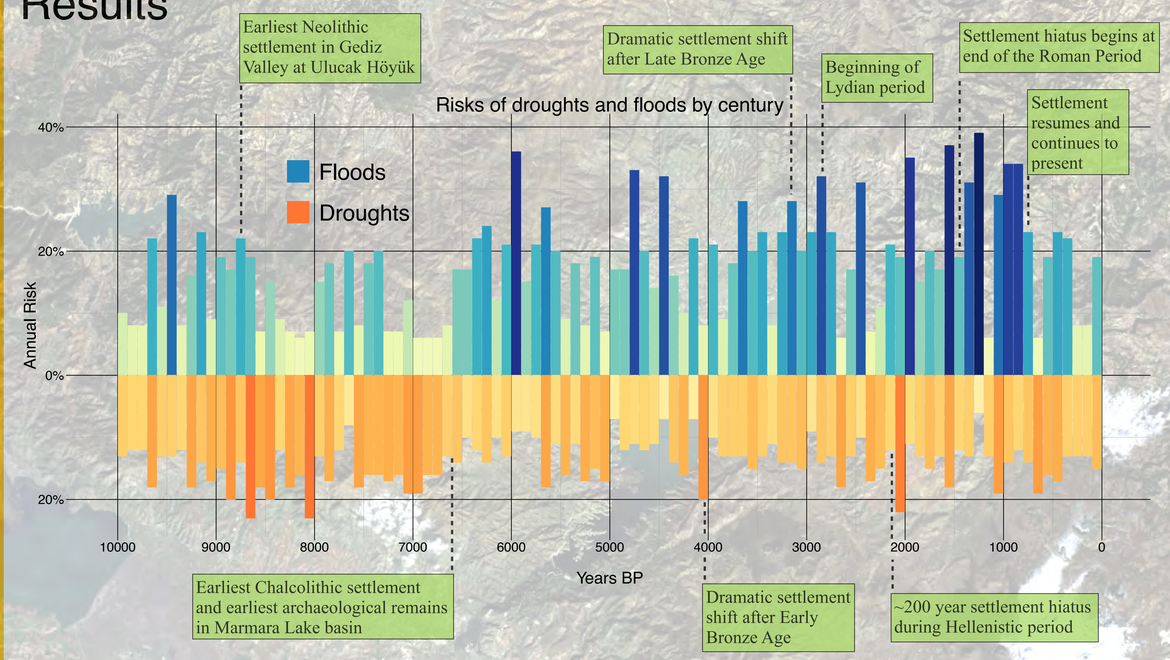
4

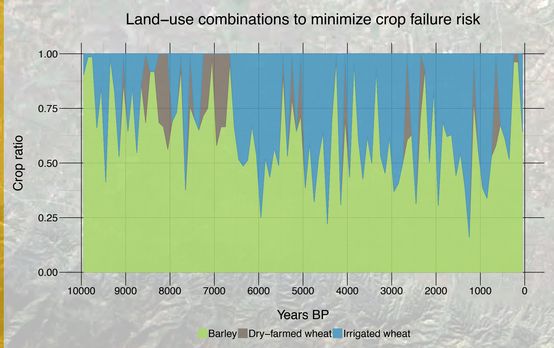
Risk:	25%	50%	25%
	Drought Year	Normal Year	Flood Year
Barley Yield	0.93	1.18	1.43
Dry Wheat Yield	0	1.6	2.09
Irrigated Wheat Yield	1.6	2.09	0

Best land-use ratio: 75% barley, 25% irrigated wheat

✶We would like to thank the Turkish Ministry of Culture & Tourism and the Manisa Museum of Archaeology and Ethnography for the opportunity to conduct this research. Please refer to handout for full references and further acknowledgments.

Results





- **Chalcolithic to Early Bronze:** High flood risk seems not to have impacted these small-scale communities. More destructive may have been the high drought risk after 6.7ka BP. A century of increased drought risk after 4.1ka BP might have contributed to the dramatic settlement changes between the Early and Middle Bronze Age.
- **Middle to Late Bronze Age:** Successive centuries of moderately-increased drought and flood risks, in association with the an expansion of economic and social networks, may have accelerated adoption of risk-management strategies. The construction of hilltop citadels around Lake Marmara highlights the degree of centralization and social-complexity in this period.
- **Lydian:** The rise of the Lydians and their expansion into a territorial empire occurred during a time of moderate drought risk and a few punctuated periods of high flood risk.
- **Roman, Medieval, and Ottoman:** Periods of settlement expansion, and presumably population growth, punctuated by near-complete settlement hiatuses. The beginnings of these hiatuses correlate well to centuries when drought and flood risks increased either in tandem or in close succession.

We find preliminary evidence that extreme-weather impacts are contingent on particular social vulnerabilities (Janssen and Anderies 2007). Societies that manage risk by diversifying land use appear to be sensitive to long-term changes in risk, while those that intensify land use are sensitive to extremes lasting only one or two centuries.

Acknowledgements

We thank Cassandra Tomkin for her work on the recent flood history of the Gediz Valley, and Michael Barton for advice on the presentation of climate reconstructions. We also thank the following sponsors and supporters of Gygaia Projects:

Sponsors	*Supporters*
Boston University	Kültür Varlıkları ve Müzeler Genel Müdürülüğü
Loeb Classical Library Foundation	Manisa Müze Müdürlüğü
Institute for Aegean Prehistory	Akhisar Müzesi
Merops Foundation	American Research Institute in Turkey (ARIT)
National Endowment for the Humanities (US)	German Academic Exchange Service
National Science Foundation (US)	Quaternary Research Group
Panasonic	The communities, colleagues, and friends of the Central Lydia Archaeological Survey and
Vecchiotti Archaeology Fund	the villages of Tekelioğlu, Hacıveliler, and Büyükbelen
Many Private Donors	

References

Araus, J. L., G. A. Slafer, and I. Romagosa. 1999. "Durum Wheat and Barley Yields in Antiquity Estimated from 13C Discrimination of Archaeological Grains: A Case Study from the Western Mediterranean Basin." *Australian Journal of Plant Physiology* 26 (4): 345–52.

Gould, P. R. 1963. "Man against His Environment: A Game Theoretic Approach." *Annals of the Association of American Geographers*, 290–97.

He, F. 2011. "Simulating Transient Climate Evolution of the Last Deglaciation with CCSM3." Madison: University of Wisconsin-Madison.

Janssen, M. A., and J. M. Anderies. 2007. "Stylized Models to Analyze Robustness of Irrigation Systems." In *The Model-Based Archaeology of Socionatural Systems*, eds. T. A. Kohler and S. E. van der Leeuw. SAR Press.

Knappen Tippetts Abbett Engineering. 1950: Gediz Havzası Amenajman Planı Hakkında Rapor: Sulama, Taşkın Önleme ve Enerji Üretimini İhtiva Etmektedir.

Luke, C., C. Roosevelt, P. Cobb and Ç. Çilingiroğlu in press "Composing Communities: Chalcolithic through Iron Age Survey Ceramics in the Marmara Lake Basin, Western Turkey," *Journal of Field Archaeology*.

Luke, C., and C.H. Roosevelt. 2009. "The Central Lydia Archaeological Survey: Documenting the Prehistoric through Iron Age Periods," in Tree-Rings, Kings, and Old World Archaeology and Environment: Papers Presented in Honor of Peter Ian Kuniholm, eds., S. W. Manning and M. J. Bruce, Oxford: Oxbow Books, 199–218.

Luke, C., and C.H. Roosevelt. in press. "Memory and Meaning in Bin Tepe, the Lydian Cemetery of the 'Thousand Mounds'," in Tumulus as Sema Space, Politics, Culture and Religion in the First Millennium BC, Excellence Cluster Topoi Series, eds., O. Henry and U. Kelp, Berlin: De Gruyter.

Michelangeli, P., M. Vrac, and H. Loukos. 2009. "Probabilistic Downscaling Approaches: Application to Wind Cumulative Distribution Functions." *Geophys. Research Letters* 36 (11).

Roosevelt, C. H. 2007. "Central Lydia Archaeological Survey: 2005 Results," Araştırma Sonuçları Toplantısı 24: 135-154.

Roosevelt, C. H. 2009. The Archaeology of Lydia, from Gyges to Alexander. Cambridge, New York: Cambridge University Press.

Roosevelt, C. H. 2010. "Lydia Before the Lydians," in Lidyalılar ve Dünyaları, edited by N. Cahill, İstanbul: Yapı Kredi Kültür Sanat Yayıncılık; T.C. Kültür ve Turizm Bakanlığı Kültür Varlıkları ve Müzeler Genel Müdürlüğü, 37-74.

Roosevelt, C. H., and C. Luke. 2008. "Central Lydia Archaeological Survey: 2006 Results," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 25(3), 305-326.

Roosevelt, C. H., and C. Luke. 2009. "Central Lydia Archaeological Survey: 2007 Results," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 26(2): 433-450.

Roosevelt, C. H., and C. Luke. 2010. "Central Lydia Archaeological Survey: 2008 Results," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 27(2-1): 1-24.

Roosevelt, C. H., and C. Luke. 2011. "Central Lydia Archaeological Survey: 2009 Results," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 28(3): 55-74.

Roosevelt, C. H., and C. Luke. 2012. "Central Lydia Archaeological Survey: 2010 Results," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 29(1): 383-400.

Roosevelt, C. H., and C. Luke. 2013. "The Central Lydia Archaeological Survey: 2011 Work at Kaymakçı and in the Marmara Lake Basin," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 30(1): 237-254.

Roosevelt, C. H., C. Luke, P. Cobb, C. O'Grady, and B. Sekedat. 2014. "The Central Lydia Archaeological Survey: 2012 Work at Kaymakçı and in the Marmara Lake Basin," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, 31 (1): 333-355.

Roosevelt, C. H., C. Luke, P. Cobb, and B. Sekedat. In press. "The Central Lydia Archaeological Survey: 2013 Work at Kaymakçı and in the Marmara Lake Basin," Araştırma Sonuçları Toplantısı, T.C. Kültür ve Turizm Bakanlığı, Volume 32.