Steven E. Falconer
School of Human Evolution and Social Change
P.O. Box 872402
Tempe, AZ 85287-2402 USA

Patricia L. Fall
School of Geographical Sciences and Urban Planning
P.O. Box 875302
Tempe, AZ 85287-5302 USA

Mariela Soto-Berelov
School of Geographical Sciences and Urban Planning
P.O. Box 875302
Tempe, AZ 85287-5302 USA

Steven E. Falconer, Patricia L. Fall and Mariela Soto-Berelov

A Comparison of Vegetation and Settlement Models for the Jordan Rift in the Third and Second Millennia BC

Introduction

The Bronze Age of the southern Levant witnessed the appearance of towns and localized polities, their dramatic collapse, and redevelopment between *ca.* 3500 and 1200 BC (TABLE 1). Many interpretations of regional settlement patterns and their implications for the development of agrarian civilization highlight historical and political links between the Levant and Egypt. While broad parallels emerge for the earlier portion of these millennia, they do not continue through the second millennium BC, which features the Middle Bronze Age highpoint of Levantine town life and the first historical documentation of Levantine polities in the Late Bronze Age. Thus, regional archaeological interpretations would profit greatly by incorporating evidence of environmental dynamics that would have affected the locations and persistence of sedentary agrarian settlements. This study links analyses of Bronze Age polity formation with new reconstructions of ancient vegetation communities to illuminate potential paleoenvironmental implications for Bronze Age settlement change in the southern Levant, especially along the Jordan Rift.

An overview of the Southern Levantine Bronze Age

The undulating trajectory of Bronze Age settlement and political change ensues from the disintegration of village-level Chalcolithic settlement systems (see Levy 1995). The subsequent Early Bronze I period (which might be combined profitably with the Chalcolithic in terms of modest settlement and political hierarchies) was characterized by relatively dispersed, occasionally fortified communities (Joffe 1993; Gophna 1995). Early Bronze II and III experienced more nucleated settlement, as signaled by the advent of numerous fortified towns atop mounded *tall* sites (Richard 1987; Joffe 1991; Gophna 1995). However, over the course of Early Bronze I-III the degree of nucleation and average settlement size actually declined (Falconer 1994;

Table 1. Archaeological chronology for the southern Levant (following Levy and Bar-Yosef 1995: figures 2 and 3; Fall, Lines and Falconer 1998: table 1).

Period	Approx. yrs. BCE	Regional Settlement and Society
Late Bronze Age	1500-1200	Urban recession
Middle Bronze IIB/C	1800-1500	Height of urbanism
Middle Bronze IIA	2000-1800	Cities reappear
Early Bronze IV	2300-2000	Urban collapse
Early Bronze III	2700-2300	Cities gradually abandoned
Early Bronze II	3000-2700	First cities
Early Bronze I	3500-3000	Village-level farming
Chalcolithic	4500-3500	Village-level farming

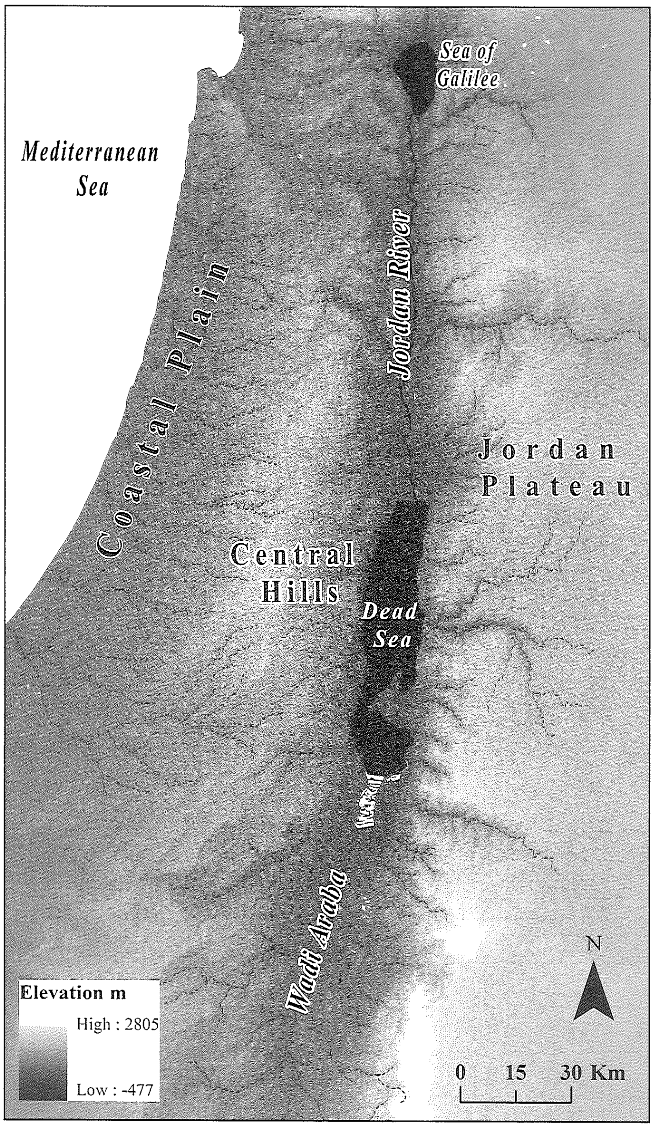
Falconer and Savage 1995). Strikingly, by the end of Early Bronze III, communities beyond a few hundred inhabitants were abandoned region-wide, and a transformed landscape became dotted with farming hamlets and seasonal herding encampments, generally in new locations. This interval, variously labeled 'Early Bronze IV', 'Intermediate EB-MB', 'Intermediate Bronze Age' etc., has engendered a lively literature that debates various iterations and critiques of a hypothesized shift from sedentary farming to non-sedentary pastoralism during this roughly three-century interruption of Levantine town life (e.g. Prag 1974, 1985; Dever 1980, 1995; Palumbo 1991). Towns then reappeared dramatically atop the *tall*s of the southern Levant during Middle Bronze IIA (alternatively known as 'Middle Bronze I'). These communities grew in size, number and scale of fortification through Middle Bronze IIB and C (alternatively Middle Bronze II and III), which are touted jointly as the zenith of pre-classical Levantine urbanism (e.g. Broshi 1979; Dever 1987; Ilan 1995). During the Late Bronze Age, the towns of the southern Levant declined in size and number, while becoming more involved in commercial interaction across the eastern Mediterranean (e.g. Gonen 1984; Leonard 1989; Bunimovitz 1995).

Archaeological interpretation of Levantine Bronze Age settlement patterns has been influenced directly and indirectly by inferred and assumed correlations with the early dynastic history of Egypt. The material assemblages denoting Early Bronze II and III in the southern Levant, especially pottery repertoires, often show relatively subtle chronological distinctions. As a consequence, these two periods often are combined in archaeological survey data and regional interpretations of settlement. Thus, in social terms, Early Bronze II / III jointly provides evidence of town life that parallels the first era of centralized political authority in Egypt during Dynasties I-V of the Old Kingdom (Kemp 1983; Ben-Tor 1991; Kantor 1992; Stager 1992). Likewise, the full abandonment of Levantine towns at the end of the Early Bronze Age and their rebirth at the beginning of the Middle Bronze Age coincided, respectively, with the disintegration of Egyptian political authority in the First Intermediate Period and its subsequent re-establishment by the Twelfth Dynasty (Ward 1971; Weinstein 1975; Dever 1980; Stager 1992). An assumed (and plausible) correlation of the beginnings of the Twelfth Dynasty and Middle Bronze IIA leads to linked interpretations of growing urbanism, as well as social and political integration, in both regions. Interestingly, however, the height of Levantine urbanism in Middle Bronze IIB / C correlates roughly with decentralized political authority in Egypt marked by the Fifteenth Dynasty of Asiatic or 'Hyksos' kings in Lower Egypt (Dever 1987). (As with Early Bronze II and III, the subtle chronological differences between material evidence for Middle Bronze II B and C [e.g. nuanced ceramic distinctions] lead to the interpretation of combined Middle Bronze IIB / C settlement patterns.) Once again, somewhat counter-intuitive patterns for the southern Levant show that the ensuing urban recession of the Levantine Late Bronze Age diverged from the unprecedented imperial power of Egypt's New Kingdom (Leonard 1989).

Thus, the evidence for regional settlement in the southern Levant suggests a generally parallel trajectory with Egypt for the Early Bronze Age and beginning of the Middle Bronze Age, but apparently divergent patterns for the later Middle Bronze Age and Late Bronze Age. These larger inter-regional inferences suggest a need to augment well-established historical links with non-historical, especially environmental, factors that will help us explain the variable and discontinuous settlement trajectories of the southern Levant more independently. To this end, we build on the results of previous analyses of Levantine settlement clustering and possible polity formation by modeling vegetation dynamics in the southern Levant. We hypothesize how these changes may have influenced the course of Bronze Age settlement patterns along the Jordan Rift.

Spatial Inference of Bronze Age Settlement Clusters and Polities

The settlement landscape of the southern Levant may be segregated into a series of major physiographic zones, including the Jordan Rift. The Rift stretches along the Wādī 'Arabah, drops to -400 m at the Dead Sea, and extends north beyond the Sea of Galilee to the Huleh Basin (FIG. 1). Spatial analysis of archaeological settlement patterns through the Bronze Age permits the statistical inference of site clusters that indicate potential spatially-defined polities on the landscape of the southern Levant (Savage and Falconer 2003; Falconer and Savage 2009). The interpretation of possible polities along the Jordan Rift particularly utilizes the settlement



1. Map of the southern Levant showing major physiographic designations.

data produced by the East Jordan Valley Survey (Ibrahim, Sauer and Yassine 1976, 1988).

Bronze Age polities (we prefer this term to 'city-states') may be reflected by clustered settlement patterns that are inferred using k-means cluster analysis (see discussions in Savage and Falconer 2003; Falconer and Savage 2009). K-means cluster analysis provides a statistical tool for inferring the most likely number and location of clusters in two-dimensional space (e.g. Kintigh and Ammerman 1982). Application of the program *KMEANS* (Kintigh 1994) has generated the most likely clustering patterns for Bronze Age settlements and possible polities across the southern Levant. These patterns have been inferred for six intervals through the Bronze Age (EB I, EB II, EB III, MB IIA, MB IIB / C and LB; see Falconer and Savage 2009). This study links Bronze Age settlement clustering (directing particular attention to the Jordan Rift) with the results of new quantitative modeling of present and past vegetation in the southern Levant (Soto-Berelov n.d.).

The program *KMEANS* generates an 'optimal' clustering solution for the southern Levant for each period through the Bronze Age. Each of these 'optimal' solutions is the least likely to simply reflect random clustering of settlements. *KMEANS* identifies the sites within each cluster, and calculates a cluster center (usually a point in space rather than a site) and the mean distance of the sites in each cluster from their cluster center (this distance is known as the 'root mean square' or 'RMS'). K-means analysis tends to generate circular clusters, for which smaller RMS circles indicate tighter, more distinct settlement clustering. Unlike previous analyses of Late Bronze Age 'city-states' (e.g. based on the Amarna Letters; see Helck 1971; Na'aman 1988, 1992; Bunimovitz 1995; Finkelstein 1997; Strange 2000), these circles do not indicate polity boundaries or territories.

The results of these k-means spatial analyses indicate numerous disarticulated settlement clusters indicative of a 'balkanized' Levantine political landscape through the Bronze Age (Savage and Falconer 2003; Falconer and Savage 2009). Amid this regional fragmentation, the number of settlements, number of clusters and mean number of sites per cluster decline through the Early Bronze Age, then rebound through the Middle and Late Bronze ages (TABLE 2). In addition to these generally opposing settlement trends, distinctly different polity configurations emerge for Early Bronze II and Middle Bronze IIB / C, the urban highpoints of their respective periods (FIGS. 2 and 3). The 17 Early Bronze Age II clusters feature highly variable RMS cluster diameters (2-19 km), suggesting a wide variety of potential polity sizes. The 24 Middle Bronze Age clusters are more consistent in area (RMS range = 5-11 km), suggesting a political landscape more tightly packed with more comparably-sized peer-polities.

Modeling Bronze Age Vegetation in the Southern Levant

As a means of incorporating environmental dynamics in the interpretation of Bronze Age settle-

Table 2. Results of k-means analyses of settlement clusters in the southern Levant and the Jordan Rift (see Falconer and Savage 2009). Numbers of sites include sites occupied during more than one period.

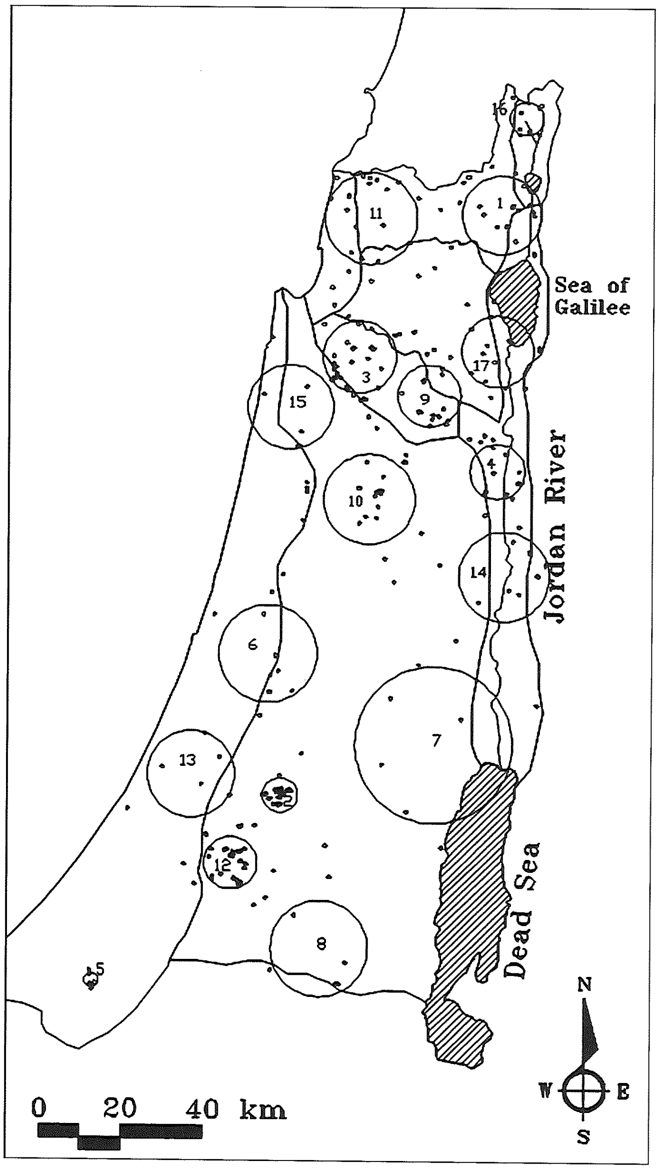
Region	Period	No. of Sites	K-means Clusters	Mean Sites/ Cluster	Mean Cluster Radius (km)
Southern Levant					
	LB	474	24	19.8	7.6
	MB IIB/C	247	24	10.3	7.5
	MB IIA	118	19	6.2	6.7
	EB III	212	17	12.5	8.4
	EB II	297	17	17.5	9.2
	EB I	374	20	18.7	8.9
	MB/LB	**839**	**67**	**12.5**	**7.3**
	EB	**883**	**54**	**16.4**	**8.9**
	Total	***1722***	***121***	***14.2***	***8.0***
Jordan Rift[a]					
	LB	103	5	20.6	6.5
	MB IIB/C	32	3	10.7	6.7
	MB IIA	16	3	5.3	5.9
	EB III	37	4	9.3	7.1
	EB II	53	4	13.3	7.7
	EB I	110	5	22.0	8.1
	MB/LB	**151**	**11**	**13.7**	**6.4**
	EB	**200**	**13**	**15.4**	**7.7**
	Total	***351***	***24***	***14.6***	***7.1***

[a]Includes Jordan Valley and Huleh Basin

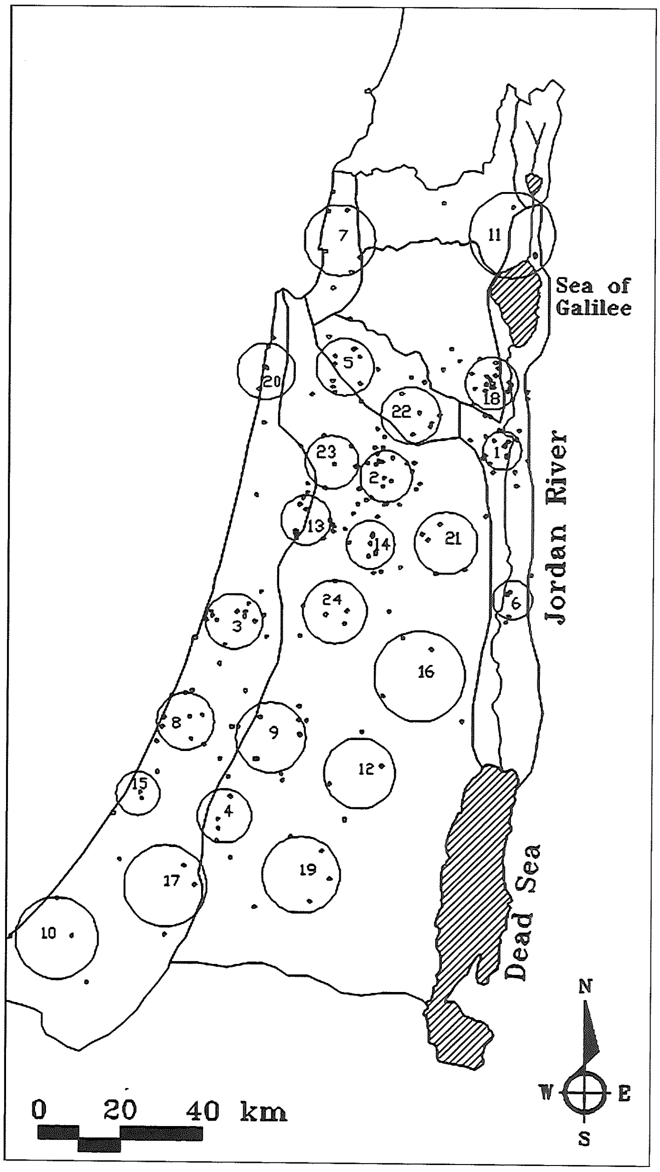
ment change, we introduce preliminary results of new research that reconstructs the present and past potential vegetation of the southern Levant. This approach is applied here to identify changes in vegetation communities and their implications for interpreting the trends in settlement clustering presented above. Our study infers potential vegetation in terms of major plant communities whose spatial distribution is predicted on the basis of climatic and topographic variables, as this distribution would be expected in the absence of human intervention.

This modeling of potential vegetation utilizes data on modern vegetation published for a series of botanical surveys conducted since the 1940s (Zohary 1944, 1973; Eig 1946; Kasapligil 1956; Zohary 1973; Qishawi *et al.* 1999; Davies and Fall 2001) that were validated and expanded by vegetation sampling conducted by Soto-Berelov and Fall in 2010. These investigations identified dozens of woody plant species (i.e. trees and shrubs) found in 1095 sample locations, each with a radius of approximately 40 m (about 0.5 ha each). These sample locations are arrayed along transects from the Mediterranean coast of Palestine to the Eastern Desert of Jordan, and along the Jordan Rift from the Wādī ʻArabah to the Sea of Galilee.

In addition to the plant species reported for each sample location, Soto and Fall determined associated geographic variables including northing and easting, elevation, geological substrate, localized



2. Settlement clusters and possible polities inferred from k-means analysis of Early Bronze II site locations in the southern Levant. Cluster circles indicate RMS radii.



3. Settlement clusters and possible polities inferred from k-means analysis of Middle Bronze IIB/C site locations in the southern Levant. Cluster circles indicate RMS radii.

aspect and distance from the Mediterranean, as well as the degree and nature of cultural disturbance. Geological substrate was determined from digitized regional geological maps (Bartov 1994; Sneh *et al.* 1998). A further suite of orographic characteristics describe the terrain between each sample location and the Mediterranean. Observed data were used to interpolate values for each of the locational and topographic variables over the southern Levant. For example, sample elevations were calculated from ASTER digital elevation models (DEM) with a spatial resolution of 90 meters.

Grids of past monthly temperature and precipitation values were created with a temporal resolution of 100 years (going back 40,000 years) and a one kilometer spatial resolution through the application of Macrophysical Climate Models (MCM; Bryson and DeWall 2007). This method extrapolates past climatic values from recent climatic information (1950-2000) by utilizing global temperature gradients that result from incoming solar radiation (i.e. Milankovitch cycles) (Bryson *et al.* 2007). These parameters are used to calibrate modern weather station data from 41 stations spread across the region, and to project these data into the past. Regional palaeoclimates and palaeoenvironments for the southern Levant also are reconstructed at multiple temporal scales based on proxy records from a variety of sources (e.g. ice cores, palynological and palaeobotanical records, lacustrine and fluvial sediments, palaeosols) (Robinson *et al.* 2006). To create continuous regional maps, paleoenvironmental values are extrapolated across the map surface through multiple regressions that link the geographic and orographic values that characterize the location of each climate station within the region (Hill, n.d.).

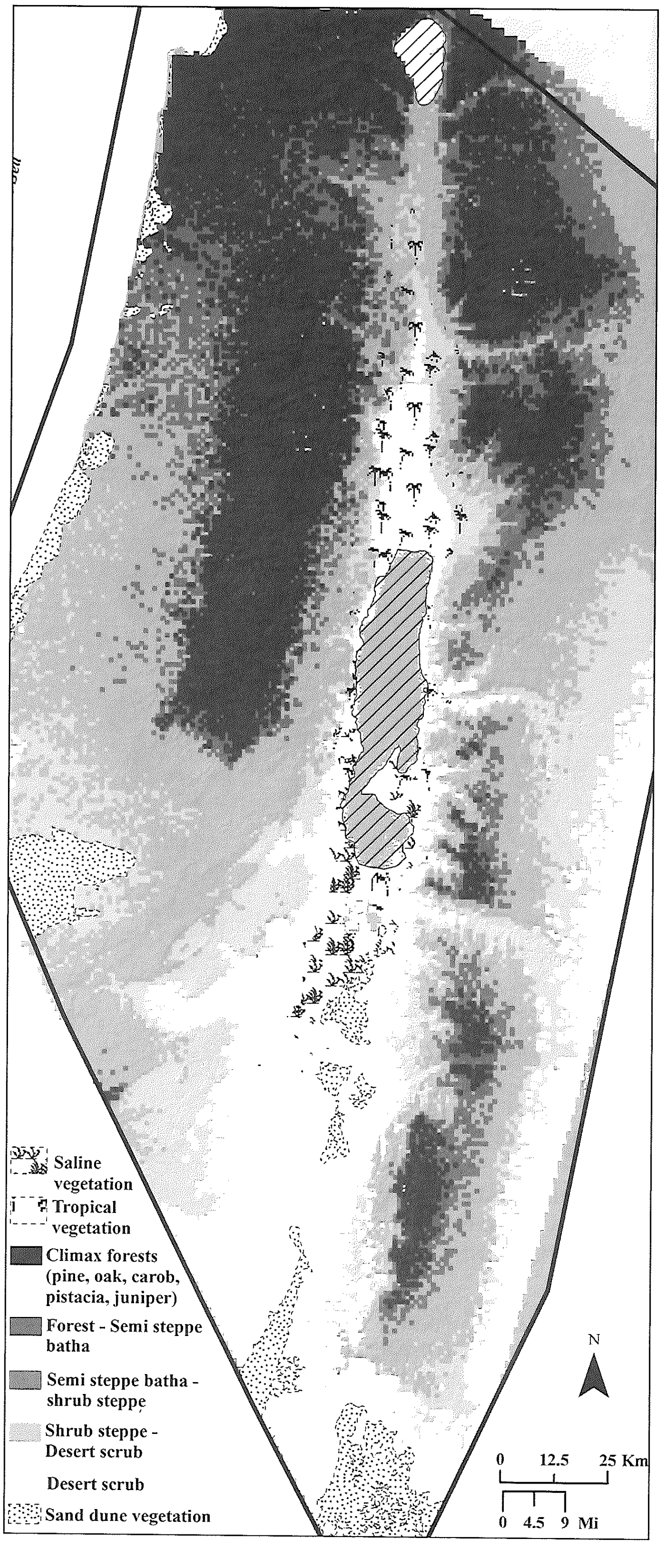
In a very simplified sense, this approach infers modern potential vegetation from the relationship between modern observed vegetation (and cultural disturbance) on the one hand, and modern geographic and climatic variables on the other. Based on this complex relationship, past climatic values guide the reconstruction of past potential vegetation using Maxent (version 3.3.1), a program for estimating most likely species distributions based on species presence data. Key indicator species and species associations are used to model and create potential vegetation maps at 500 year intervals between 10,000 BC and the present, based primarily on eight key variables: mean annual temperature, mean summer temperature, mean winter temperature, mean annual precipitation, mean summer precipitation, mean winter precipitation, elevation and geological substrate. Here we map the potential vegetation of the southern Levant based on reconstructed spatial distributions of major plant communities at 3000 BC, 1500 BC and the present.

Climax forests include the indicator taxa *Quercus calliprinos* (oak), *Pinus halepenis* (pine) and *Pistacia palaestina* (pistachio). Steppe vegetation features indicator species like *Artemisia herba alba* (sage) and *Noaea mucronata,* as well as indicator associations such as *Salsola vermiculata-Hammada scoparia* (black ḥammada). *Juniperus phoenicea* (juniper) can be found in southern Jordan associated with shrub steppe on sandstone outcrops. Desert vegetation combines a variety of desert indicators, including species found in rocky and desert savannoid areas, such as *Acacia tortilis* (Acacia), *Zygophyllum dumosum* (bushy bean caper) and *Anabasis articulate* (joined anabasys). In addition, we indicate those areas around the Dead Sea and Wādī ʻArabah with enclaves of saline vegetation *(Suaeda* spp.), sand dune species *(Haloxylon persicum* or white saxaul), and species of tropical Sudanian origin (*Calotropic procera* or giant milkweed).

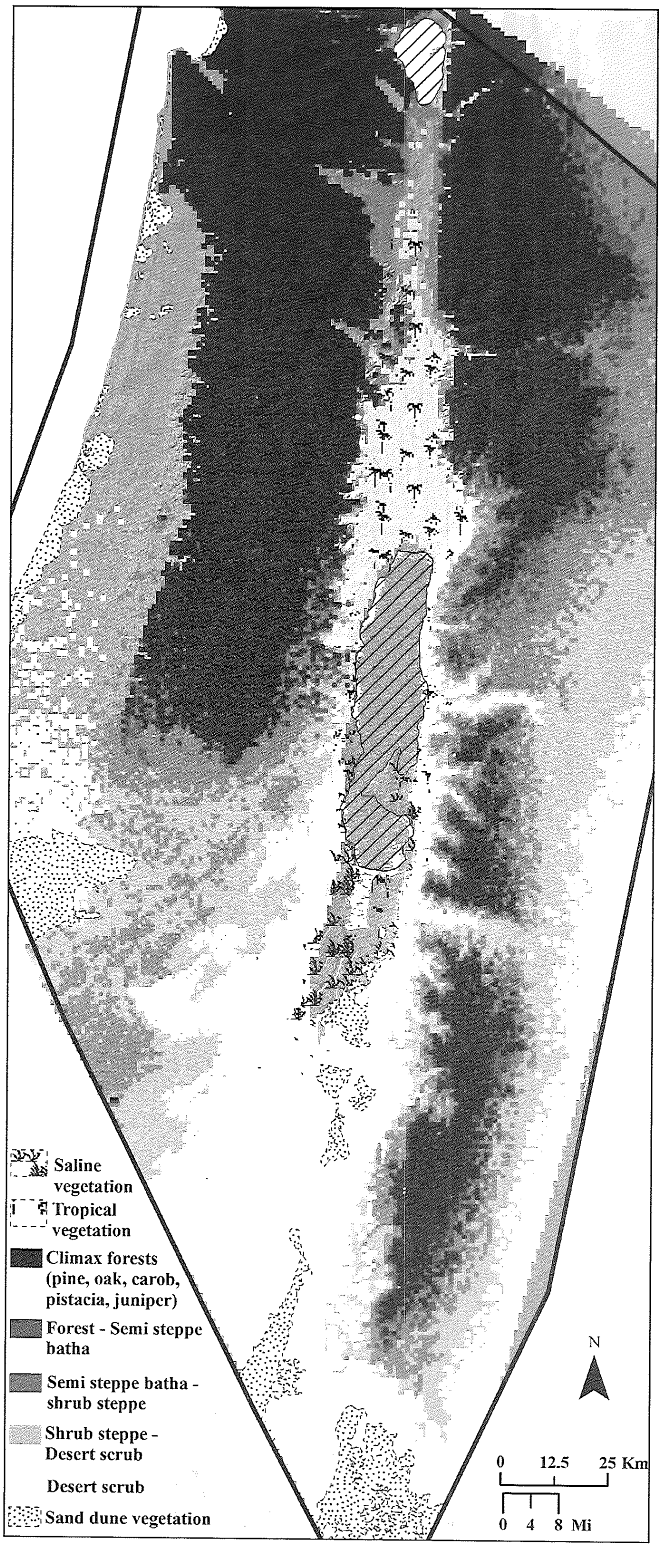
Potential Vegetation Reconstructions and their Implications for Settlement along the Jordan Rift

The analytical method summarized above produces a map of present day potential vegetation marked by substantial distributions of forest at higher elevations in the southern Levant, desert vegetation along the bottom of the Jordan Rift, with projections of steppe vegetation in the intervening regions (FIG. 4). This result features strikingly broad distributions of forest in the hills of Palestine and the higher elevation uplands north of modern Amman, substantial steppe around the northern Jordan Valley and on the Jordan Plateau and into the Eastern Desert, with desert vegetation most predominant in the southern Rift. In stark contrast, Late Pleistocene potential vegetation reveals much more limited forests, more extensive steppe along the Jordan Valley and desert vegetation concentrated to the immediate south of the Dead Sea. The potential vegetation reconstructed for 3000 BC diverges more subtly from that of the present day. Most importantly, climax forests spread over broader areas in the uplands east of the Jordan Rift and in Palestine, with somewhat reduced steppe along the Coastal Plain, in the Negev and into the Eastern Desert (FIG. 5). Potential desert vegetation was spread more widely just north of the Dead Sea at 3000 BC than it is today, while the northern Jordan Valley features mostly steppe vegetation both then and now. Moving more recently in time, the potential vegetation for 1500 BC (FIG. 6) displays reduced forests in both Palestine and Jordan. Most strikingly, however, desert vegetation extends over much greater areas of the Eastern Desert, eastern Negev and in the northern Jordan Valley nearly to the Sea of Galilee. These results suggest, not surprisingly, drastically different potential vegetation (and therefore climatic conditions) between the Late Pleistocene and the present. More nuanced, but clearly discernible changes in potential vegetation carry basic implications for Bronze Age settlement patterns along the Jordan Rift.

Bronze Age settlement along the Jordan Rift is particularly noteworthy, in contrast to other physiographic zones of the southern Levant, for persistent clusters at a series of localities, with less consistent clusters at the south and north ends of the Sea of Galilee (FIG. 7). Cluster persistence along the Jordan Rift is somewhat unexpected, since its towns are generally smaller than those on the Mediterra-

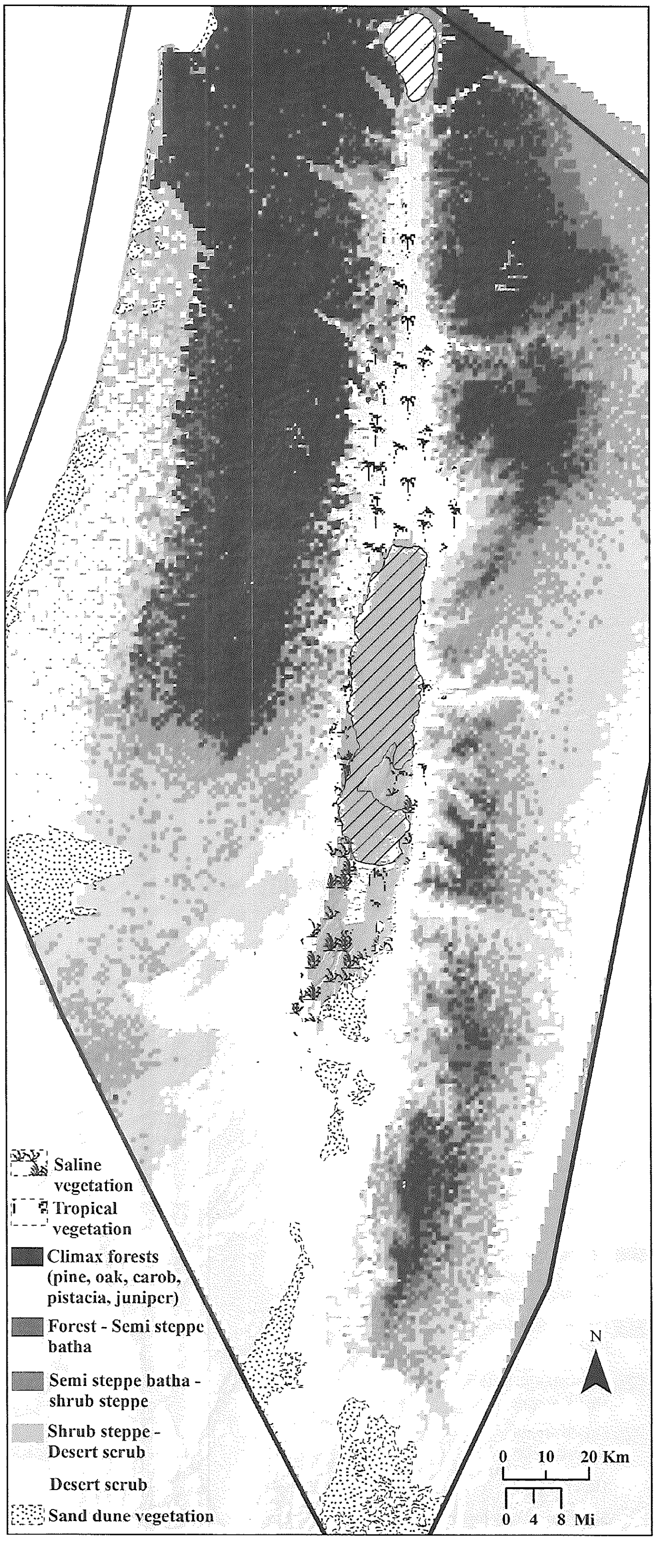


4. Map showing predicted distributions of potential vegetation across the southern Levant for the present.

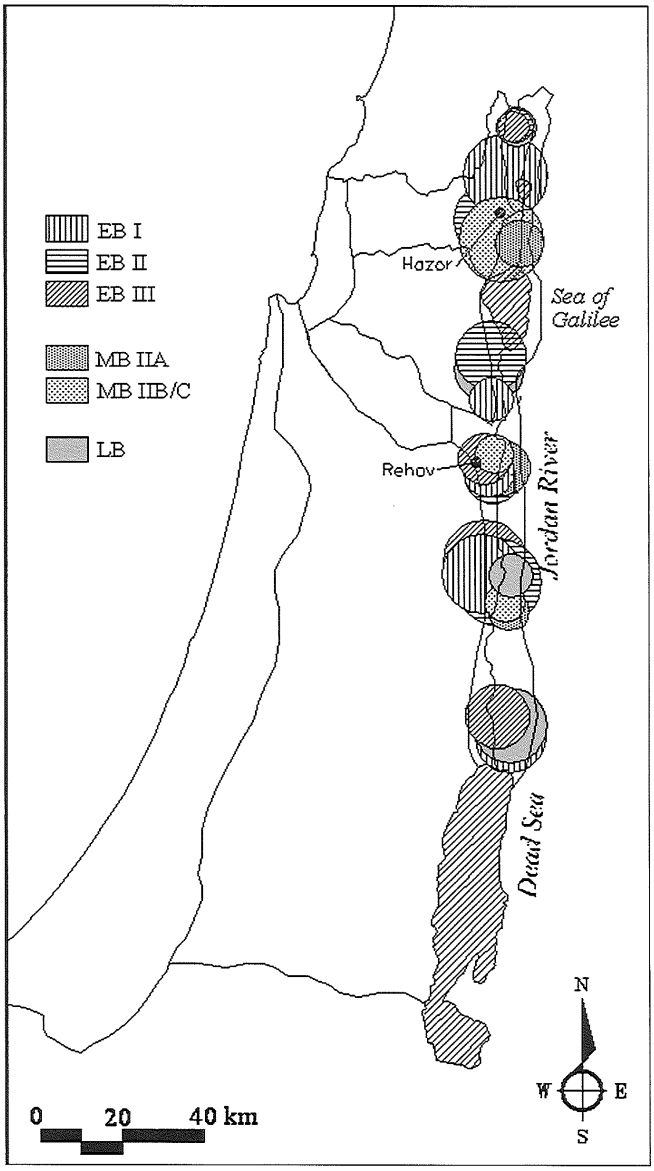


5. Map showing predicted distributions of potential vegetation across the southern Levant, *ca.* 3000 BC.

nean Coastal Plain, and might be assumed as less likely candidates for polity centers. However, the communities of the Jordan Valley, because of their greater distance from coastal trade and communication, may have formed more enduring polities with less external perturbation. The less consistent



6. Map showing predicted distributions of potential vegetation across the southern Levant, *ca.* 1500 BC.



7. Settlement clusters and possible polities inferred from k-means analysis of Bronze Age site locations along the Jordan Rift. Cluster circles indicate RMS radii.

clustering north of the Sea of Galilee around Hazor, a potential primate center reaching 80 ha in MB IIB / C and LB, is striking and unpredicted in light of its prominence in historical texts. The Amarna Letters lead to interpretation of Hazor as the capital of a Late Bronze Age "territorial kingdom" (Na'aman 1988), and the Mari archives document commercial interactions between Hazor, Mari and other cities along the upper Euphrates (Malamat 1970, 1985).

The differences between potential vegetation distributions reconstructed for 3000 and 1500 BC may reflect the climatic influences of a long-term drying trend, as has been hypothesized most notably from archaeological and sedimentological evidence from Syria (e.g. Weiss *et al.* 1993).

These changes in potential vegetation also carry fundamental implications for the interpretation of settlement clustering and possible polity formation along the Jordan Rift. As noted above, the three southern-most cluster localities on the Rift show repeated long-term occupations at settlements roughly around Jericho, Tall as-Saʿīdiyyah / Tall al-Mazār and Rehov / Pella. Not coincidentally, the southern end of the Jordan Valley shows the most consistent potential vegetation patterns through the Bronze Age and in the present. In contrast, at the northern end of the Jordan Rift, just south and north of the Sea of Galilee, settlement clusters shift more noticeably in location and degree of clustering (as indicated by RMS circles), most especially in the far north, intermittently involving Hazor.

This patterning is counter-intuitive, in light of the archaeological and historical prominence of Hazor and the gradient of increasing rainfall from south to north along the Rift. Despite enjoying generally greater precipitation, the northern Jordan Valley reveals a striking shift in potential vegetation between 3000 and 1500 BC. Simply put, the northern end of the Jordan Rift also features clearly discontinuous patterns of polity formation and dissolution closely coupled with demonstrable patterns of change in potential vegetation and the climatic and geographical variables that fuel these patterns. Thus, the reconstruction of ancient potential vegetation offers a robust avenue for broadened explanations of settlement dynamics that incorporate paleoenvironmental variability along the Jordan Rift and in the southern Levant more generally.

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