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The Role of Environmental Degradation in Long Term Settlement Trends in Wādī al-Ḥasa, West-Central Jordan

Introduction

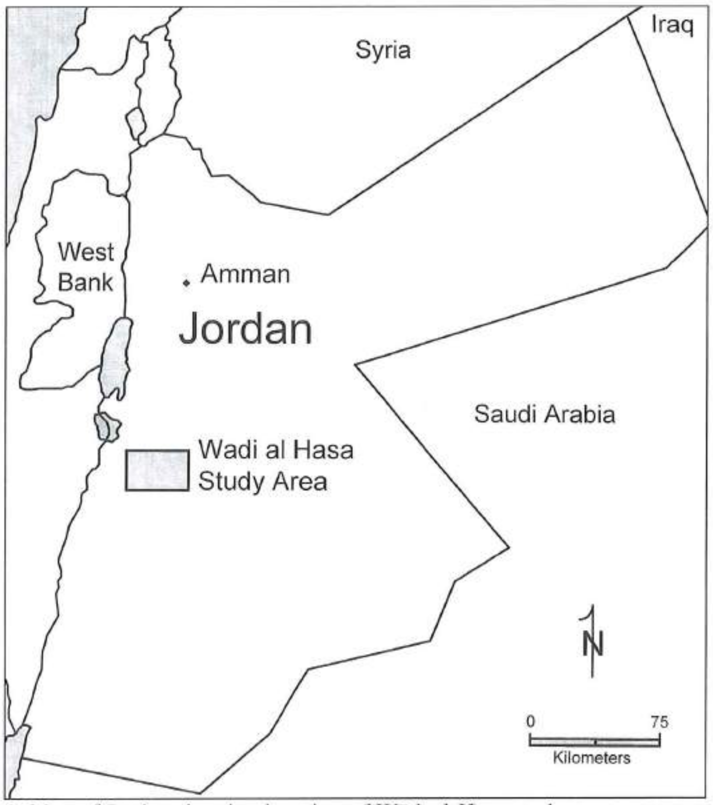
Long term human impact on the environment is a subject of considerable interest to archaeologists in the Near East (Bintliff 1982; Bottema 1990; Falconer and Fall 1995; Le Hourou 1981; Naveh and Dan 1973). In the present study I use archaeological and geographic data to evaluate hypotheses of human induced environmental degradation in the vicinity of archaeological sites along Wādī al-Ḥasa, Jordan.

Wādī al-Ḥasa is one of the largest drainage systems and only perennial watercourses in the southern Levant. It is located in west-central Jordan and flows from south-east to north-west draining from the Transjordanian Plateau into Wādī 'Arabah and the Dead Sea (Donahue and Beynon 1988; Schuldenrein and Clark 1994) (FIG. 1).

The Wādī al-Ḥasa and its environs have long been of importance to human populations. Throughout the Holocene the Wādī has been the location of critical permanent water sources, as well as one of a few easily passable routes from Wādī 'Arabah, and the Negev to the west, up to the Transjordanian Plateau, and trade routes to the east.

Archaeological survey has revealed the locations of more than 1400 sites ranging in age from the Middle Paleolithic to the Late Ottoman period along the wadi (Clark *et al.* 1992; 1994 and MacDonald 1988). The present analysis will focus on sites discovered on the survey of the south bank (MacDonald 1988), dating from the Pottery Neolithic through the Ottoman periods. These periods cover the time range during which people lived in settled communities and practiced agriculture and pastoralism. It is these activities that are typically thought to have posed the greatest threat to the natural environment during pre-industrial times.

The principle causes of anthropogenic environmental degradation in upland regions of the Near East are the removal of vegetative ground cover and disturbance of the structure of the topsoil or a horizon. This results from the harvesting trees and shrubs for fuel in various pyrotechnologies, and the introduction of domestic animals and plowing. These factors are thought to have augmented erosion by a combination of: 1) increasing the impact of rainsplash through the removal of ground cover, 2) inhibiting infiltration and increasing the velocity of surface runoff through soil compaction, and 3) causing positive feedback to these processes by removal of soil nutrients, and the introduction of goats and sheep, that together reduce the ability of vegetative ground cover to be restored.



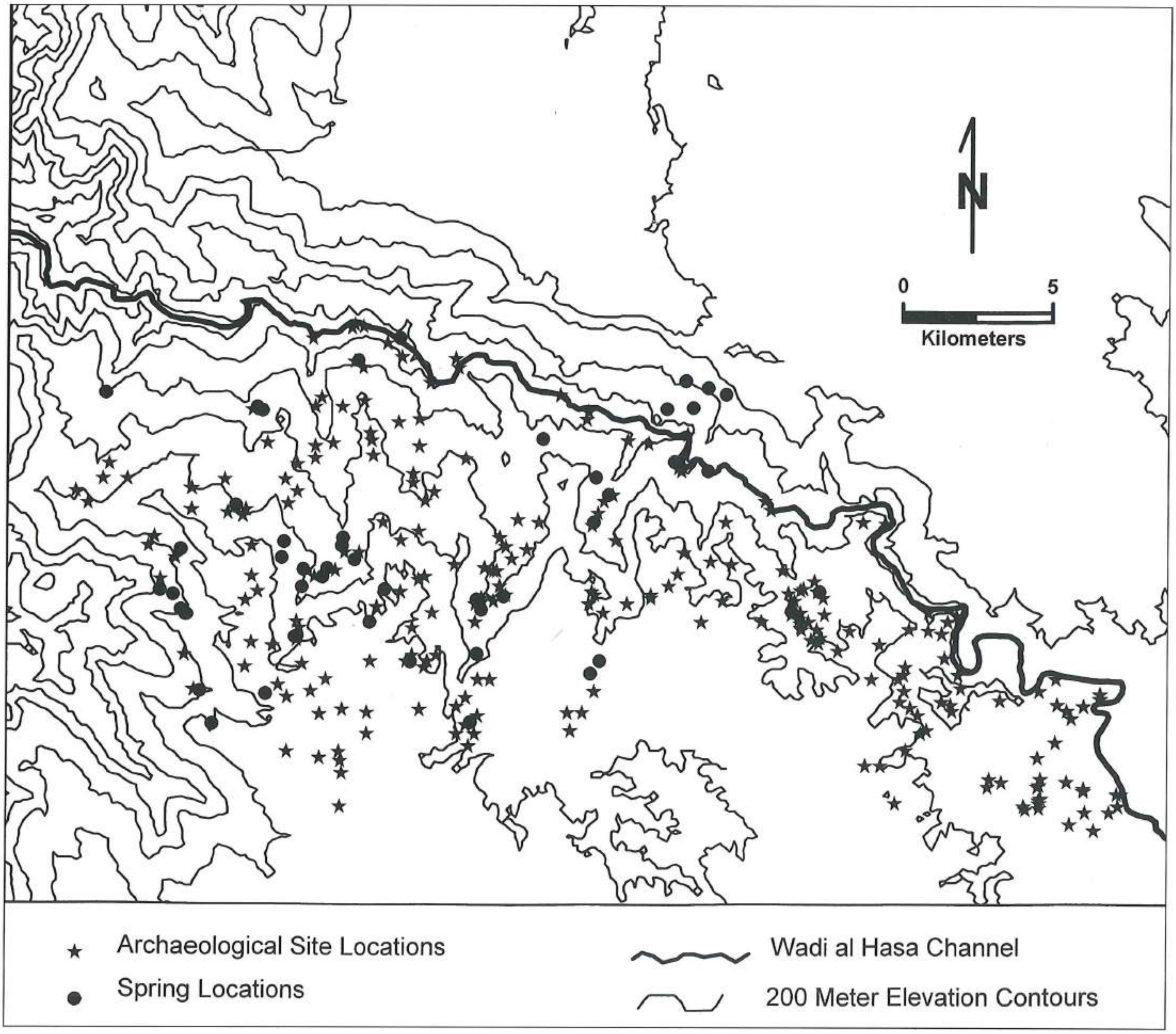
1. Map of Jordan showing location of Wādī al-Ḥasa study area.

In this analysis I address the spatial implications of diminishing local soil resources. I reason that, if the residents of Wādī al-Ḥasa have consistently degraded their environment through subsistence farming and pastoral activities, then the location of those activities would necessarily shift through time as resources were depleted. This situation may be stated in straightforward spatial terms. Significant degradation of local subsistence resources should lead to spatial segregation of site locations between one period and the next.

Analysis

My sources for archaeological information are the published tables of survey data provided by MacDonald (1988). Using these tables I compiled a MapInfo database of 341 sites dating to the appropriate periods (FIG. 2). My grounds for including a site were that the recorders interpreted it as indicative of local habitation or subsistence activity (e.g. village, farm, structures, etc.). I excluded anything that seemed indicative of other types of activity (e.g. tower, cemetery, fort, etc.). In a few cases I also excluded late-period site components comprised of only a few sherds (i.e. 1-3). Multi-component sites were recorded as a separate site for each period in order that they would be counted as near neighbors in statistical evaluations of between-period locations.

The first stage of analysis consisted of a series of spatial statistical evaluations of the site locations to determine whether there was between-period spatial segragation. I performed Nearest Neighbor, and Hodder and Okell's A



2. Map of Wādī al-Ḥasa study area.

statistics. These calculations indicated that significant segregation was present in most between-period distributions.

I used Kintigh's (Kintigh 1992) *NEIG* module in the *Archanal* package to perform nearest neighbor statistics on all 341 sites grouped by period. The nearest-neighbor coefficient provided by this analysis is a ratio of the actual average distance between the nearest neighbors among a set of points, and the expected average distance if the same number of points were randomly distributed (Kintigh 1990; Whallon 1974). The relevant results of the nearest-neighbor analysis on sites by period are shown in Table 1. Because of uncertainty about the exact area and boundary of the survey from which these data were collected, as well as general advice about the use of nearest-neighbor statistics (Kintigh 1990), the coefficients are only meaningful in a relative sense. Therefore, I chose to compare the between-type coefficients from temporally adjacent periods with the within-type coefficients from each period.

The results of this analysis indicate that in most cases (7 out of 9) between-period nearest-neighbor coefficients are greater than within-period coefficients. The exceptions are between periods Nabataean/Roman - Roman, and between Byzantine - Islamic. It is worth noting that the Nabataean/Roman, Roman and Byzantine periods were times of significant political change in this area but were each only 2 to 3 centuries long, compared to as much as 1 to 2 millennia for some of the other periods. Breaking them up into three periods may not reflect the time required to inflict significant damage on soil resources and necessitate relocation.

A student's t-test on the means of within-period versus between-period nearest-neighbor coefficients yields a probability of only 0.06. This indicates that, on the whole, there has been an unusual degree of between-period segregation over the last 8,000 years in Wādī al-Ḥasa. It says little, however, about the significance of any particular transition in settlement patterns.

The second statistic that I present here is Hodder and Okell's A, which is a measure of association or segregation between all points of any given type (Hodder and Okell 1978), and is recognized as particularly useful for identifying spatial segregation (Kintigh 1990). The A statistic is defined by Kintigh (1990: 174) as:

> "... the product of the two mean intratype distances divided by the square of the mean intertype distance. A value of about 1.0 indicates that distributions of the two types are spatially intermingled:...Values less than 1.0 indicate spatial segregation:.."

I used the *HOA* module in the *Archanal* package (Kintigh 1992), which allows for a Monte Carlo simulation using a large number of random runs to provide for a more realistic evaluation of the results. The between-period A statistics are provided in TABLE 2, along with the results

TABLE 1.

Nearest Neighbor Statistics

W/in Per	NN W/in Per	Btwn Per	NN Btwn Per
1	0.92	2&1	1.61
2	0.51	3&2	2.02
3	0.78	4&3	1.11
4	0.54	5&4	1.16
5	0.91	6&5	1.03
6	0.76	7&6	0.64
7	0.72	8&7	2.23
8	0.70	9&8	0.68
9	0.74	10&9	0.96

Key to Period Names
1= Neolithic
2= Chalcolithic
3= Early Bronze Age
4= Mid/Late Bronze Age
5= Iron Age
6= Hellenistic/Nabatean
7= Roman
8= Byzantine
9= Islamic
10= Ottoman

T-test Results

	Mean	Std.Dev.	t	df
NN_W/IN	0.73	0.14		
NN_BTWN	1.27	0.56	-2.65	8

p= 0.029

TABLE 2.

Hodder and Okell's A with 100 Random Runs			
Btwn Per	HOA	Ran. Mean	Std.Dev.
2&1	0.26	1.05	0.28
3&2	0.49	0.99	0.09
4&3	0.44	0.99	0.16
5&4	0.71	0.99	0.14
6&5	0.82	1.00	0.02
7&6	0.81	1.00	0.04
8&7	0.54	1.00	0.05
9&8	1.00	1.00	0.04
10&9	0.61	0.99	0.05

of 100 random runs. These statistics indicate largely the same segregation that was shown by the nearest neighbor calculations with the exception that they indicate the Hellenistic/Nabatean - Nabataean/Roman transition is only 1 standard error below the mean of 100 random runs, and hence may not be very significant. It is worth noting that these were also periods of relatively short duration as those noted above. The use of the Monte Carlo simulation allows for the interpretation of each particular transition with respect to random possibilities and indicates that individually, 6-7 out of 9 cases are unusually segregated, suggesting a significant rearrangement of settlements between specific periods.

Overall, the hypothesis of between-period segregation is convincingly supported by these statistical analyses. These results indicate that there have been numerous transition periods during which settlement patterns were significantly altered and people relocated to a different part of Wādī al-Ḥasa. They also indicate that, throughout the duration of agro-pastoralist subsistence activity in Wādī al-Ḥasa, there has been a significant tendency to periodically relocate to completely different areas. Yet there is not a clear indication of movement to or from any particular part of Wādī al-Ḥasa. Movement appears to be back and forth between the upper, middle and lower regions. This may be due to currently unknown aspects of a changing hydrology for example, or it may reflect the length of time required for key environmental conditions, such as soil, to recover. Interestingly, a Kmeans test of all site locations in Wādī al-Ḥasa indicates no clustering at all, suggesting that in the long term any area has had equal likelihood of being inhabited.

Conclusion

The results of the analyses conducted here support the hypothesis that a degraded local environment has long been a factor in the settlement strategies of Wādī al-Ḥasa inhabitants. The consistent segregation between sites from temporally adjacent periods indicates an unusual motivation to relocate periodically. Unlike the relatively low-relief bottomlands of the Jordan Valley, Wādī al-Ḥasa does not contain *tall* sites typical of long enduring occupations at a favorable location. Rather this area is typified by a large number of more ephemeral sites. These data are consistent with the idea that a thin and easily erodable soil was regularly diminished by the activities of devegetation, plowing, and trampling common to agriculturalists and pastoralists. The back and forth occupation and abandonment of portions of Wādī al-Ḥasa is certainly suggestive of a response to changing environmental conditions, but it is still equivocal with respect to the cause of environmental change.

As noted above, it may be that occilating climatic conditions rendered different parts of the Wādī arable at different times. While climatic variability could, and probably did, affect the hydrologic regime, it seems unlikely that the degree of variability occurring during the Holocene would have had a rapid and dramatic effect on soil development. The back and forth movement may have been related to the time necessary for the quality of soils to recover from a degraded state. The length of time necessary for such a recovery is still uncertain and remains an area in which archaeological research can be of use in the larger debate over human environmental impact.

Future directions for research on human/landscape relationships in Wādī al-Ḥasa must include more analysis of the geomorphological contexts of habitation and subsistence production sites. These analyses will be enhanced particularly by focusing on the qualities of soil productivity and erodability in the areas used in different periods, as well as the relationships to other resources such as water and transportation. The spatial statistical modeling discussed here indicates that the use of formal quatitative methods can be of considerable value in helping us develop our understanding of past human impacts on the environment.

References Cited

Bintliff, J. L. and van Zeist, W. 1982. *Paleoclimates, Paleoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory*. Oxford: British Archaeological Reports, International Series 133.

Bottema, S., Enjes-Nieborg, G. and van Zeist ,W. (eds), 1990. *Man's Role in the Shaping of the Eastern Mediterranean Landscape*. Rotterdam: Balkema.

Clark, G. A., Neeley, M., MacDonald, B., Schuldenrein, J. and 'Amr, K. 1992. Wādī al-Ḥasa Paleolithic Project - 1992: Preliminary Report. *ADAJ* 36: 13-23.

Clark, G. A., Olszewski, D., Schuldenrein, J., Rida, N. and Eighmey, J. 1994. Survey and Excavation in the Wādī al-Ḥasa: A Preliminary Report of the 1993 Season. *ADAJ* 38: 41-55.

Donahue, J. and D. Beynon, E. 1988. Geologic History of the Wādī el Hasa Survey Area. Pp. 26-40 in B. MacDonald *et al., The Wadi el Hasa Archaeological Survey 1979-1983, West-Central Jordan.* Waterloo: Wilfred Laurier University Press.

Falconer, S. E. and Fall, P. L. 1995. Human Impacts on the Environment During the Rise and Collapse of Civilization in the Eastern Mediterranean. Pp. 84-101 in D. W. Steadman and J. I. Mead (eds), *Late Quaternary Environments and Deep History: A Tribute to Paul S Martin.* Vol. 3. Hot Springs: The Mammoth Site of Hot Springs, South Dakota, Inc. Scientific Papers.

Hodder, I and Okell, E. 1978. A New Method for Assessing the Association Between Distributions of Points in Archaeology. Pp. 97-107 in I. Hodder (ed.), *Simulation Studies in Archaeology.* Cambridge: Cambridge University Press.

Kintigh, K. W. 1990. Intrasite Spatial Analysis: A Commentary on Major Methods. Pp. 165-200 in A. Voorrips (ed.), *Mathematics and Information Science in Archaeology: A Flexible Framework.* Studies in Modern Archaeology. Bonn: Holos.

___ 1992. *Tools for Quantitative Archaeology.* Tempe.

Le Hourou, H. N. 1981. Impact of Man and His Animals on Mediterranean Vegetation. Pp. 479-521 in DiCastri and Hooney (eds), *Mediterranean Type Ecosystems.* Berlin: Springer-Verlag.

MacDonald, B. 1988. *The Wadi el Hasa Archaeological Survey 1979-1983, West-Central Jordan.* Waterloo, Ontario: Wilfred Laurier University Press.

Naveh, Z. and Dan, J. 1973. The Human Degradation of Mediterranean Landscapes in Israel. Pp. 373-389 in F. D. Castri and H. A. Mooney (eds.), *Mediterranean Type Ecosystems: Origin and Structure*. Springer: Verlag.

Schuldenrein, J. and G. Clark, A. G. 1994. Landscape and Prehistoric Chronology of West-Central Jordan. *Geoarchaeology* 9(1): 31-55.

Whallon, R. 1974. Spatial Analysis of Occupation Floors II: The Application of Nearest Neighbor Analysis. *American Antiquity* 39: 16-34.