Toward a Socionatural Reconstruction of the Early Iron Age Settlement System in Jordan's Wadi al-Mujib Canyon

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Abstract: In the final centuries of the second millennium BCE, multiple well-defended settlements developed on the edges of the Wadi al-Mujib canyon in west-central Jordan. Archaeological evidence reveals that these communities practiced grain agriculture and animal husbandry. This agro-pastoralist economy sustained the settlements despite the prevailing semi-arid environmental conditions that limited the amount of available natural resources such as sufficient precipitation and adequate arable soils. Subsistence in these difficult conditions meant that producers were entangled in relationships with natural resources that were often in scarce reserve. Drawing on a socionatural perspective, this article examines the archaeological and paleoenvironmental evidence to reconstruct the recursive relationships between the settlements and their environment. Extensive human-induced impacts are difficult to identify in the currently available evidence, although producers' activities likely had short-term effects on the landscape. Additionally, environmental proxies indicate prevailing semi-arid conditions at the end of the second millennium. Two pollen cores have characterized the eleventh century BCE as a period of climatic fluctuation between moister and dryer conditions. This dynamic period coincides with the expansion of settlements throughout the al-Mujib canyon. While a moister climate would have created more ideal conditions for subsistence, the unpredictability in temperature and precipitation levels motivated producers to implement strategies that buffered them from food insecurities.

Keywords: agriculture; archaeology; environment; Iron Age; Jordan; pastoralism; semi-arid; socionatural

DEDICATION

One spring day in Jordan in 2003, Denyse invited me to accompany her team to Lahun where they were planning the site's development for tourism with Jordan's Department of Antiquities. She gave me a detailed tour of the site during our visit. In the late afternoon, we stood on the edge of the Wadi al-Mujib watching large dark clouds dumping rain as they travelled east through the wide canyon. I was so struck by the scene that I took a picture of the quiet storm (Fig. 1). That wet afternoon often springs to mind, either when excavating at nearby Dhiban during the hot summer, or describing the rugged semi-arid conditions of the al-Mujib canyon in my writings. That day with Denyse has, in a small way, led me to the ideas presented in this and other related publications. I am so thankful to Denyse for her commitment to Jordanian archaeology and history, and her support for the young scholar that I was when we first met.

Fig. 1. Spring precipitation in the Wadi al-Mujib, looking west from Lahun, 2003 (Photo : B. Porter).

INTRODUCTION

Archaeological investigations over the last several decades have determined that a series of small fortified agro-pastoralist settlements were founded along the edges of Jordan's Wadi al-Mujib and its tributaries in the final centuries of the second millennium BCE (most recently, NINOW 2004 ; 2006 ; PORTER 2013 ; ROUTLEDGE 2000 ; SWINNEN 2009) (Fig. 2). While some scholars have been eager to identify these settlements as evidence for an early Moabite kingdom like that described in the Hebrew Bible (e.g., Numbers 21-36) (FINKELSTEIN and LIPSCHITS 2011 ; GLUECK 1940 : 167-172), this author and his colleagues cite the lack of a regional settlement hierarchy, the limited levels of inter-settlement social and economic differentiation, and the fallibility of the biblical sources on Early Iron Age political history as reasons to interpret these settlements as part of a segmentary system of households fusing into small-scale communities (PORTER 2013 ; PORTER *et al.* 2014 ; ROUTLEDGE 2008). Furthermore, current evidence suggests that these settlements were not established in one simultaneous episode, but were instead founded and abandoned over the course of nearly two centuries between the late-thirteenth and mid-tenth centuries BCE (PORTER 2013 : 62, 66-67 ; ROUTLEDGE 2004 : 112-113). The location of these communities on the edges of the wadi's steep canyons can partly be explained by their communities' desire for food security. These locations were also desirable because they were adjacent to the moist riparian zones at the canyon bottoms where aquifer-fed streams created ideal conditions for agro-pastoralism (LEV-TOV, PORTER, and ROUTLEDGE 2010).

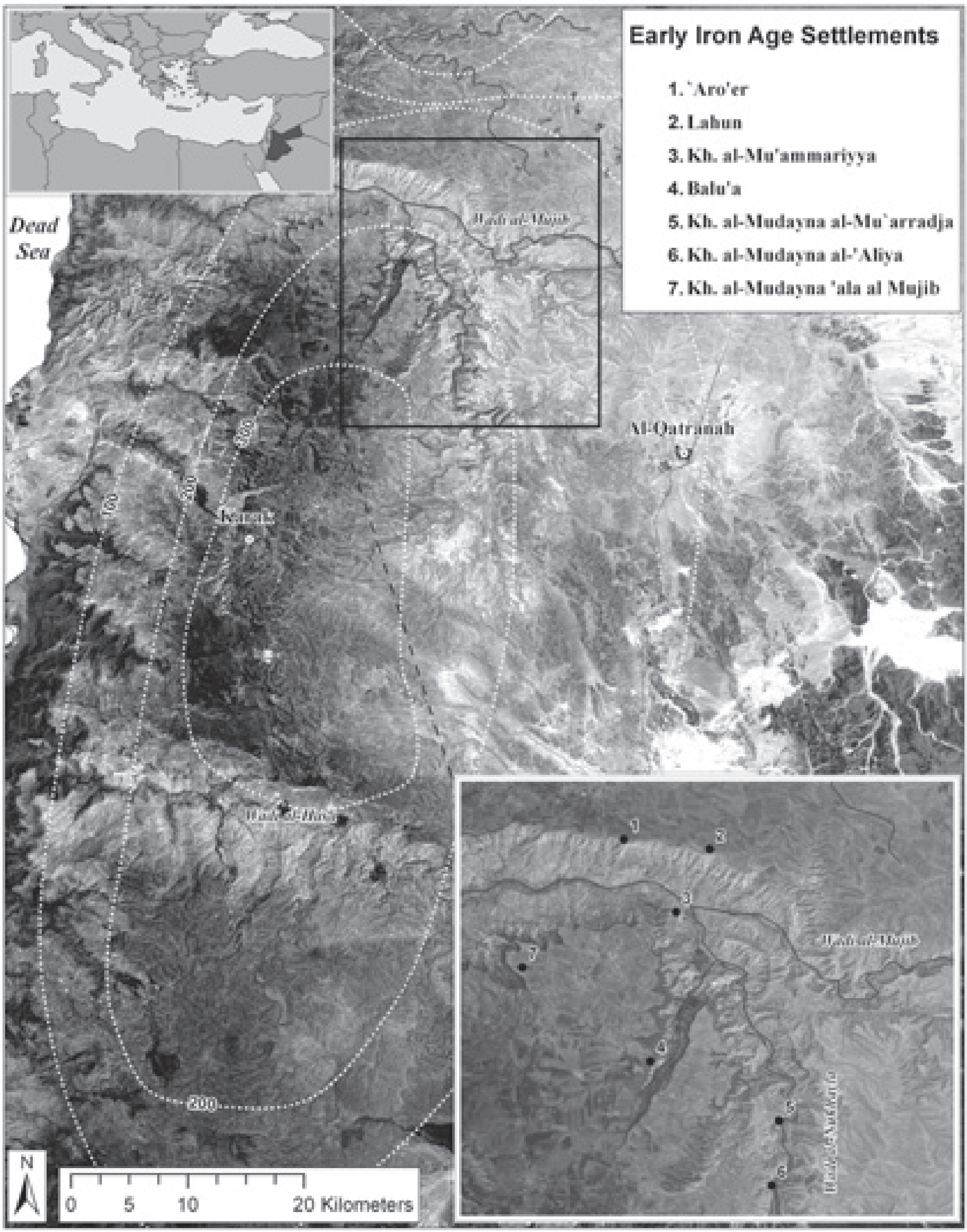

Fig. 2. Map of Jordan's Karak and Dhiban Plateaus noting Early Iron Age settlements next to the Wadi al-Mujib (Image: A. Wilson).

The al-Mujib settlements are today located in a semi-arid transitional environment between a degraded Mediterranean zone on the west and an Irano-Turanian zone on the east. Weather field stations throughout west-central Jordan demonstrate that the region experiences the cool wet winters and hot dry summers typical of Mediterranean climates. Annual precipitation levels recorded between 1960 and 1989 at Hmud, 3.5 km west of the al-Mujib canyon, was a mean of 283 mm; at Qatrana, 20 km southeast of the canyon, average levels were a mean of 90.12 mm (EL-NAQA 1993: Tables 3 and 5). These amounts are barely adequate for rain-fed grain production. Soil quality also varies with Red and Yellow Mediterranean soils on the Dhiban and Karak Plateaus' western half, eventually giving way to Yellow Steppic soils of an Irano-Turanian Zone that are inadequate for agricultural production, but make sufficient grazing grounds for pastoralism (CORDOVA 2007). Today, grain and fruit production can be found in patches on the eastern half of the plateaus as well as on the small colluvial benches that line the al-Mujib canyon's sides. A thin riparian zone snakes through the bottom of the canyon where small aquifer-fed streams can be used throughout the year. Modern settlements still use technologies that were first implemented by the region's preindustrial societies such as water cisterns carved into bedrock and stone terrace walls to shore up soil beds. Modern producers have also employed new technologies that were obviously unavailable to earlier landscape users. Crop fertilizers, pesticides, and drought-resistant seeds reduce the chances of low crop yields, while trucks and mechanized pumps move water from natural and artificial reservoirs to fields to supplement precipitation. Driving the construction of these agricultural systems is, of course, a persistent issue in modern Jordan's economic development – the need to meet domestic food demands for a growing population that inhabits a country with limited water and arable land.

When studying the al-Mujib canyon's modern semi-arid landscape, one should be cautious not to assume that past producers subsisted in similar marginal conditions. Indeed, paleoenvironmental research over the past several decades has documented natural- and human-induced changes in the environment throughout the Levant (CORDOVA 2007; ISSAR and ZOHAR 2004; ROSEN 2007). Research specifically in Jordan has determined that the earliest hominid Pleistocene settlements 900,000 years ago subsisted in a cool, moist landscape consisting of fluvial lakes abundant in animals and naturally growing plants (OLSZEWSKI 2008). This landscape extended throughout what is today Jordan's eastern deserts where relic oases still remain around Azraq. Woodlands covered the Dhiban and Karak Plateaus at this time (CORDOVA 2007: 62-94). Starting around 12,000 years ago, during the transition from the Pleistocene to the Holocene, the Levant entered a period of aridification that led to the retraction of this fluvial environment. Increased temperatures and lower precipitation rates during the Early Holocene did not stop – and in fact, may have encouraged (MCCORRISTON and HOLE 1991) – settlement intensification during the Neolithic and Early Bronze Age periods. These periods of demographic growth and agricultural intensification instigated landscape degradation, particularly forest clearing for fuel and agricultural land, and erosion from intensified use of soils for food production (CORDOVA 2007). By the time the first al-Mujib communities were founded in the final centuries of the second millennium BCE, the Holocene landscape of west-central Jordan was already a degraded shadow of a formerly lush Pleistocene environment. Later episodes of agricultural intensification during the Classical and Islamic period throughout the Southern Levant further contributed to soil erosion and deforestation while prevailing semi-arid conditions continued to have a drying effect on the landscape (ROSEN 2007).

This macro-reconstruction of Jordan's environment says little, unfortunately, about the precise conditions the Early Iron Age al-Mujib settlements faced at the end of the second millennium BCE. The archaeological evidence suggests that the settlements took several steps to buffer their agro-pastoralist systems against drought and famine. Excavations at al-Mudayna al-ʻAliya, for instance, have documented storage bins throughout the settlement that could house food for both humans and animals (ROUTLEDGE 2000) (Fig. 3). While such archaeological proxies do speak to a general anxiety with unpredictable semi-arid environmental conditions, the evidence reveals little about the specific conditions to which producers responded. Nor do they say much about what impacts the al-Mujib settlements made on the potentially scarce naturally available resources in the surrounding landscape. This article therefore draws on a combination of archaeological and environmental evidence to reconstruct the recursive relationships between Early Iron Age communities and their environment. This reconstruction is unfortunately partial due to the quality and quantity of the available proxy data, a point that will be discussed in more detail below. Indeed, this is only a first, rather than a final, statement that should be revised as more, and more sophisticated, archaeological and environmental evidence becomes available to future researchers.

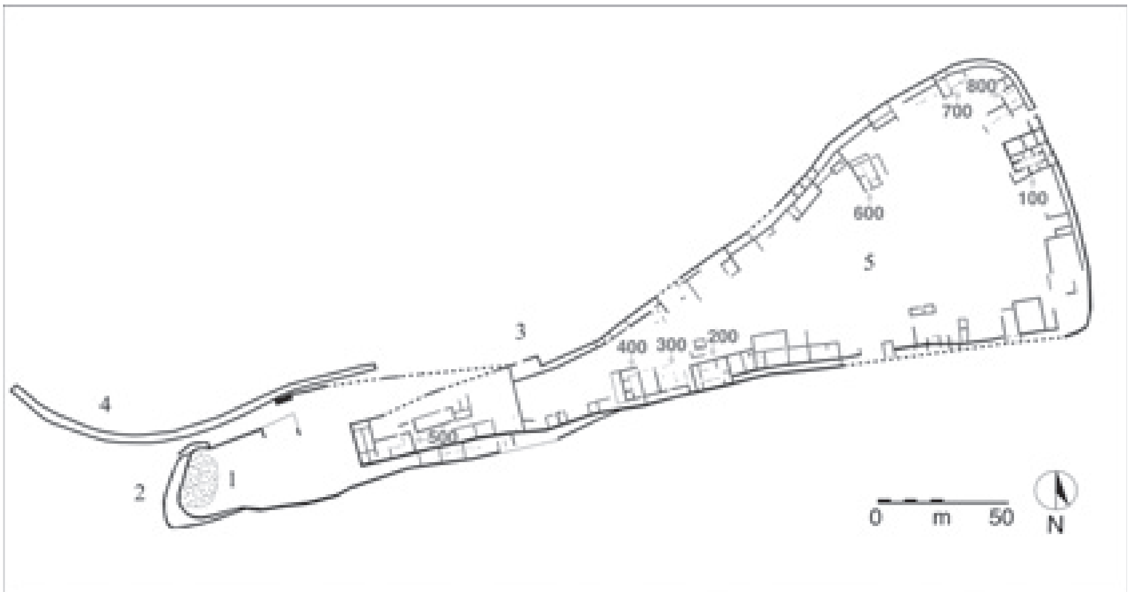

Fig. 3. Map of al-Mudayna al-ʻAliya denoting Buildings 100 through 800 : tower (1), moat (2), a possible gated entrance (3), paved pathway (4), and courtyard (5) (Image : B. Routledge).

THE SOCIONATURAL SYSTEM OF EARLY IRON AGE WEST-CENTRAL JORDAN

Archaeologists have recently joined their colleagues in the environmental sciences in calling for a more balanced understanding of the relationship between human populations and the environments they inhabit (FISHER, HILL, and FEINMAN 2009 ; MCINTOSH, TAINTER, and MCINTOSH 2000). Earlier research paradigms that saw past societies either as victims or destroyers of environmental conditions have given way to perspectives that place humans and the environment within socionatural systems that seek a state of equilibrium as they consistently adapt to natural and human-induced impacts (GUNDERSON and HOLLING 2002). Archaeological research has concentrated on the participation of expansive political polities in socionatural systems in order to examine the impacts that the development of intensified agrarian economies had on landscapes and how the environment's response to such human-induced changes created a feedback loop that promoted or limited producers' successes (e.g., WILKINSON *et al.* in KOHLER and VAN DER LEEUW 2007). Still other scholars have discovered that a society needs not be organized as an empire or a state to participate in socionatural systems. Less expansive societies, such as the Pueblo societies of the American Southwest (GUMERMAN and GELL-MANN 1994), can make iterative impacts on their landscape through agriculture, irrigation, and herding. Once the degradation of naturally available resources (e.g., water, grasslands, soils) reaches a particular limit, or less optimal climatic conditions persist, such small-scale societies must adapt to new conditions or abandon the landscape for more ideal conditions (PORTER 2013 : 13-37).

The relatively small size of the al-Mujib settlements should therefore not lead one to assume *a priori* that early Iron Age producers were less abusive toward the landscape. Rather, such impacts should be investigated using whatever direct and indirect evidence is available. Archaeological excavations in different settlements indicate that agriculture and pastoralism (or, agro-pastoralism) was the principal mode of production. Faunal and paleobotanical evidence from al-Mudayna al-'Aliya reveals that producers emphasized goats over sheep, and barley over wheat, an arrangement often chosen by producers subsisting in semi-arid conditions (LEV-TOV, PORTER, and ROUTLEDGE 2010 ; PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2013 : Tables 1 and 2). The extent to which this agro-pastoralist system was intensified during the Early Iron Age is a key question for determining the short-term and long-term impacts on the landscape. Geographers have observed that the intensification of agricultural economies in marginal zones can lead to the over-exploitation of naturally available resources and landscape degradation through practices such as overgrazing, aggressive planting, and irrigation (DOOLITTLE 1988). Such corrosive activities can leave signatures in the archaeological and environmental record that are available for analysis (MORRISON 1994).

The fact that preindustrial producers living on the Eastern Karak Plateau in the millennia before and after the Early Iron Age developed agro-pastoralist economies suggests that economic intensification was possible here despite the semi-arid steppe conditions. Landscape surveys (e.g., MILLER 1991 ; PARKER 2006) and settlement excavations have determined that the Eastern Karak Plateau witnessed five periods of agricultural intensification, albeit different in scale and organization (reviewed in PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2014 : 144-146). During the Early Bronze Age II-III period (*c.* 3100-2300 BCE), nucleated agro-pastoralist settlements were larger compared to the Early Iron Age (CHESSON, MAKAREWICS, KUIJT, and WHITING 2005; JONES 2006). Four later episodes, in the Iron Age IIC (the 7th-6th centuries BCE) (ROUTLEDGE 2004: 192-201), Nabataean-Early Roman (*c.* 100 BCE-106 CE), Late Roman through Byzantine (c. 284-551 CE) (PARKER 2006), and Middle Islamic (*c.* 1250-1516 CE) (BROWN 1984) periods, occurred while the Karak Plateau was under the sway of external empires, the Assyrian, Roman, Byzantine, and Mamluk Empires, respectively. In each instance, settlement is characterized by a combination of military forts and dispersed farmsteads and towers extending to the very edge of the desert margins. Evidence for agro-pastoralist practices (e.g., CHESSON, MAKAREWICS, KUIJT, and WHITING 2005; PARKER 2006; ROUTLEDGE 2004: 192-201) reveals a diverse food economy designed to feed a larger population as well as produce for regional markets.

These earlier and later instances of economic development indicate that intensification was possible on the Eastern Karak Plateau under the right political and economic conditions. The organic and inorganic evidence recovered from Early Iron Age settlements, however, suggest that agro-pastoralism was substantially less intensive compared to earlier and later periods of settlement. The faunal evidence sampled from multiple buildings at al-Mudayna al-ʻAliya reveal that domestic sheep (*Ovis aries*) and goat (*Capra hircus*) herds were limited in size. This size was likely determined by households that balanced their short-term preferences for primary products such as meat with their long-term needs for secondary products such as milk and animal hair. The amount of available labor may have also determined herd size. The settlements likely followed a common pattern in pastoralist economies in which households cooperate by appointing a small number of individuals to manage herding duties collectively in order to free up labor for other projects. Other animals used for traction or long-term transport of goods such as cattle, various equids, and camels, were kept in limited numbers (LEV-TOV, PORTER, and ROUTLEDGE 2010: Table 1). The paleobotanical evidence likewise suggests grain, fruit, and legume production was designed to meet the immediate consumption needs of each settlement's human and animal population (PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2013: Table 2). Nearly all sampled buildings possessed well-protected storage installations, some of which contained charred plant remains at various stages of processing and cleaning. Altogether, the available evidence strongly suggests that the economies of the al-Mujib settlements were relatively low in their intensity and were principally oriented toward meeting each community's subsistence needs. There is currently no substantial evidence that settlements participated in regional markets or redistributive economies organized by broader political entities (contra FINKELSTEIN and LIPSCHITS 2011).

Societies operating at subsistence levels could still have an impact on their surrounding environment, of course (ERICKSON 2006). One proxy for human-induced landscape degradation in the Mediterranean Basin and ancient Near East is the erosion of agricultural sediments (VITA-FRINZI 1969; more recently, CASANA 2008). The consistent plowing and irrigation of fields over time disrupts topsoils, making them susceptible to movement through different erosional processes. These actions, along with the abandonment of terraced fields on slopes, leads to a pattern in which agricultural soils are deposited in valley and canyon systems like the al-Mujib system. Geologic research throughout western Jordan has identified erosional episodes that have created large colluvial deposits on the edges of steep wadi cliffs (CORDOVA 2007). Close study of these deposits reveals that they were transported at key moments when humans intensified their exploitation of landscape resources during the Upper Pleistocene and Holocene Eras. Humans first began to intensively use Jordan's natural resources when newly sedentary Pre-Pottery Neolithic B settlements initiated domestic agricultural production, forest removal, field plowing, and animal grazing. This landscape degradation resumed again during the Early Bronze II, the next period of intensified landscape use. Cordova has argued convincingly that the impacts that occurred during these periods were so substantial that landscape resources such as forests and soils never recovered. Societies that would follow the Early Bronze over the next four millennia inherited a deforested, eroded landscape in which most major degradation had already occurred. Later episodes of intensification during the Classical and Islamic periods only destroyed whatever limited resources that were left to exploit. In other words, there was very little left for the Early Iron Age settlements of the al-Mujib to destroy by the time they settled the area in the late second millennium BCE.

One additional area where the Early Iron Age settlements may have transformed their environment is the thin wadi riparian zone at the bottom of the al-Mujib canyon. Underground aquifers discharge water into streams here that gradually drain north and then west into the Dead Sea. The ponds that form alongside the streams offer places where pastoralists can water their herds throughout the year. These ponds are also natural gathering points for wild animals that communities hunted, trapped, and fished to supplement their diets. The analysis of faunal evidence from al-'Mudayna al-'Aliya identified an assortment of wild animals including bony fish (*Osteichthyes*), heron or stork (*Ardeidae/Ciconiidae*), assorted birds, red deer (*Cervus elaphus*), and a large number of freshwater crabs (*Potamon potamios*) (LEV-TOV, PORTER, and ROUTLEDGE 2011 : Table 1). These ponds could also be used to water small fields where agriculturalists could plant in alluvial deposits consisting of materials that had been previously eroded from the plateaus and carried downstream. Paleobotanical analysis of carbonized plant remains found in household storage bins at al-Mudayna al-'Aliya identified different weed species mixed with various grains that were either in an earlier stage of processing or were meant for animal fodder (PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2013 : Table 3). Such weeds (e.g., *Cardamine cf. hirsuta*) grow in moist soils like those found in the riparian zone below the settlement (SIMMONS 2000 : 44). This evidence strongly suggests that producers organized agricultural production around the riparian zone's resources, possibly using flood-water farming techniques. One additional likely use of the riparian zone was ceramic vessel production. Petrographic and neutron activation analysis of ceramic assemblages from multiple al-Mujib settlements have determined that vessels were produced using local resources (PORTER 2007 ; ROUTLEDGE *et al.* 2014). Clay, fuel, and water – all materials necessary for vessel shaping and firing – are available in the riparian zone, making it the most ideal location for ceramic production. Finally, organic materials such as reeds and rushes could also be gathered in the riparian zone and transported to settlements for use in building construction (e.g., roofs) (ROUTLEDGE 2000 : 53-54).

Fig. 4. The canyon riparian zone below al-Mudayna al-ʻAliya in July, 2011 (Image: B. Porter).

Altogether then, there is a significant amount of evidence indicating that Early Iron Age producers drew on the naturally available resources in wadi riparian zones beneath their settlements. Despite this evidence, there is little sign that their impact on natural resources was so great that it instigated irreversible changes in the landscape. Rather, the riparian zone's current conditions suggest that the area has been resilient despite its use over the past three millennia. The author has observed an abundance of wild animals during numerous research transects through the riparian zones between al-Mudayna al-Muʻarradja and al-Mudayna al-ʻAliya over the past fifteen years. Such animals include birds, fish, and small deer, many of which appear in al-Mudayna al-ʻAliya's faunal taxa list. These species co-exist alongside modern pastoralists who herd animals and farmers who use mechanized agricultural techniques such as small-pump irrigation to grow grains and fruits. Most conspicuous is the currently thriving freshwater crab population that lives in and near the ponds and slow-moving streams. These crab communities have persisted for at least three millennia despite their desirability as a food resource during the Early Iron Age and later time periods.[1]

1 The author and his colleagues are completing a project using biometrics and isotope evidence to reconstruct the Early Iron Age and modern crab populations in the al-Mujib canyon riparian zone (PORTER, FARAHANI, and MILLER 2013).

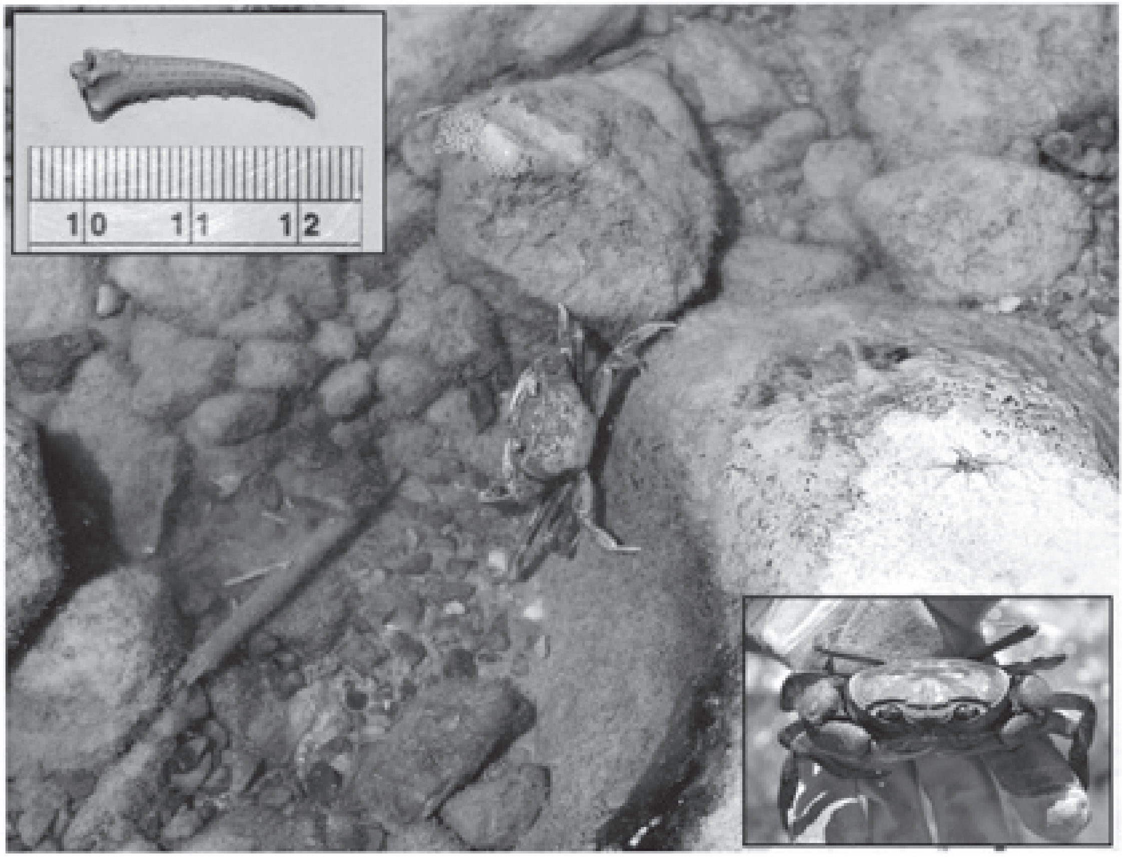

Fig. 5 : A freshwater crab (*Potamon potamios*) observed in the riparian zone below al-Mudayna al-'Aliya in July, 2011 (Photo : B Porter). A crab pincer excavated in Early Iron Age contexts at al-Mudayna al-'Aliya is shown in the upper left corner (Photo : C. Morgan, S. Jagani, and A. Farahani).

The currently available evidence therefore suggests that the al-Mujib settlements made little or no irreversible impacts on their environment. Substantial degradation – soil erosion and deforestation, for instance – had already taken place in earlier millennia, leaving natural resources crippled and scarce by the end of the second millennium BCE. Early Iron Age producers likely made small, iterative impacts on this fragile landscape that are difficult to detect in the available geologic and archaeological evidence, such as reducing remaining forests, overgrazing on wild plants, and hunting and trapping desirable animals. Some of these resources were resilient enough to regenerate in the centuries after the Early Iron Age settlement system ceased in the mid-tenth century BCE.

MEASURING CLIMATIC CONDITIONS WITH ENVIRONMENTAL PROXIES

Even though the Early Iron Age settlements appear to have had only a limited impact on the al-Mujib canyon's resources, their subsistence practices were nevertheless structured by west-central Jordan's environment. Western Jordan had already entered a long-term phase of increased aridity at the beginning of the Holocene around 12,000 bp, so that by the time the al-Mujib settlement system began toward the end of the second millennium BCE, producers were required to adapt to dry conditions that had been in place for millennia. Yet Mediterranean semi-arid zones like those in west-central Jordan fluctuate significantly in inter- and intra-annual precipitation and temperatures. An abundant year of moisture can be followed by several years of below average amounts, as twentieth century CE data from weather stations positioned throughout the region indicate (EL-NAQA 1993). If this variability in annual temperature and precipitation levels during the past century are any indication of patterns in earlier centuries, then producers no doubt faced substantial uncertainty in growing conditions and resource availability at each stage of the agricultural cycle. These anxieties in part explain the emphasis that the al-Mujib settlements placed on grain storage and other features that bolstered food security.

Is it possible to have a more refined understanding of paleoclimatic conditions at the end of the second millennium BCE? Environmental proxy records recovered from locations around the Southern Levant are somewhat helpful. Because it is obviously impossible to observe past climates first-hand, environmental scientists depend on archives of organic and inorganic evidence whose presence and character are proxies for prevailing conditions during the period in which they were deposited. The number and kinds of Holocene Era records has grown in the past few decades due to growing scholarly and public interest in climate change. While powerful tools for reconstructing paleoclimates, environmental proxy data must be queried cautiously, and a wide range of geographic and taphonomic issues must be considered. For instance, the Levant throughout the Holocene has consisted of a collage of climatic microzones that vary significantly in temperature and precipitation levels. Factors that determine these differential conditions include altitude above sea level, proximity to the Mediterranean coastline, and location in precipitation dispersal patterns, among many others. This diversity also suggests that proxy evidence dating to the same time periods may produce different and possibly contradicting results. Caution should therefore be exercised when extrapolating proxy evidence from one well-documented area (e.g., the Dead Sea, Lake Kinneret) to areas where environmental archives are limited or absent.

This is precisely the challenge one encounters when using Southern Levantine proxies to reconstruct paleoclimatic conditions in west-central Jordan. Except for pollen records in west-central Jordan's Wadi al-Walla geological deposits (CORDOVA 2007: Fig. 5.4), all other Middle and Late Holocene proxy records originate from locations north, south, and west of the al-Mujib canyon corridor that today demonstrate climatic conditions that are different from west-central Jordan. West-central Jordan's uneven precipitation levels are partly determined by its location east of the Levantine Central Highlands and the Jordan Rift Valley. Precipitation clouds moving from the northwest to the southeast must climb the Central Highlands, leading them to discharge most of their moisture before descending again into the Jordan Rift Valley. If clouds do not accumulate new moisture as they climb out of the valley, there is limited precipitation available for them to discharge in west-central and southern Jordan. Consequently, proxies from areas that receive higher average amounts of precipitation may mask drier conditions in areas within rain shadows.

One must therefore proceed cautiously when using Southern Levantine proxy records to reconstruct climatic conditions at the end of the second and the beginning of the first millennia BCE.[2] Collectively, records indicate that, like today, the Early Iron Age Southern Levant possessed a Mediterranean climate with cool wet winters and hot dry summers. Isotope data from $\delta^{18}O$ levels from speleothems in Soreq Cave, Israel (BAR-MATHEWS and AYALON 2004 : Fig. 12) and Eastern Mediterranean ocean cores (SCHILMAN *et al.* 2001, 2002), however, reveal that precipitation amounts were generally lower than today's annual levels. A closer look at several proxy records indicates that the end of the second millennium BCE was indeed a period of significant climate change in the Eastern Mediterranean (DRAKE 2012 ; RIEHL *et al.* 2012 ; ROBERTS *et al.* 2011). Precipitation curves reconstructed from the isotopic composition of Soreq Cave speleothems indicate that starting after 1500 BCE, precipitation levels were generally lower than previous Early and Middle Holocene levels, with some minor fluctuations in amount (BAR-MATTHEWS, AYALON, and KAUFMAN 1998).

Palynology, the analysis of pollen evidence, can offer a higher resolution understanding of the paleoclimatic conditions during the final centuries of the second millennium BCE. Lower percentages of tree pollen in cores can identify arid phases in climatic conditions. Lowered precipitation levels, warmer temperatures and deforestation through human activities, it is assumed, contributes to this reduction in forest levels in the landscape. Conversely, a rise in oak (*Quercus calliprinos* ; *Quercus boissieri*) and olive trees (*Olea europaea*) is interpreted as a proxy for wetter, cooler conditions. Pollen cores from around the Southern Levant, including those from Lake Hula (BARUCH and BOTTEMA 1999 ; VAN ZEIST and BOTTEMA 1982), Lake Kinneret (BARUCH 1990 ; LANGGUT, FINKELSTEIN, and LITT 2013), Birkat Ram (SCHWAB *et al.* 2004), Ein Gedi (LITT *et al.* 2012), Ghab (YASUDA, KITAGAWA, and NAKAGAWA 2000), Tweini (KANIEWSKI *et al.* 2010) and along the Dead Sea's west shore (LANGGUT *et al.* in press ; NEUMANN *et al.* 2007, 2010) provide insights into vegetation patterns. One challenging issue with these pollen cores is that most use a limited number of radiocarbon dates to fix strata to chronological years, a point made recently by LANGGUT, FINKELSTEIN, and LITT (2013 : 151 ; cf. LANGGUT *et al.* 2014). It is therefore often difficult to make observations about paleoclimatic conditions within specific shorter time spans.

Two recent cores, one from the bottom of the Lake Kinneret (LANGGUT, FINKELSTEIN, and LITT 2013), and one from sediment profiles in the Ze'elim Gully on the west side of the Dead Sea (LANGGUT *et al.* 2014), are rare exceptions, however. Organic materials were selected at key intervals along each core and then dated using AMS radiocarbon techniques, yielding higher than normal chronological precision on the recovered pollen evidence dating to the end of the second millennium BCE. Patterns observed in both cores identified evidence for increased aridity between 1250 and 1100 BCE. The Lake Kinneret core demonstrated a shrinkage in Mediterranean trees and olive trees, reaching a minimum of 13.5 percent and 1.8 percent, respectively (LANGGUT, FINKELSTEIN, and LITT 2013). The Ze'elim Core likewise demonstrated evidence for increased aridity during this period (LANGGUT *et al.* 2014). Sediments were deposited in a terrestrial, rather than a fluvial, en-

2 See CORDOVA 2007 ; ISSAR and ZOHAR 2004 ; and ROSEN 2007 for syntheses of Middle and Late Holocene environmental conditions.

vironment, indicating that there was a significant drop in the Dead Sea's shoreline. This drop is likewise symptomatic of arid conditions, as a decrease in precipitation would have reduced the amount of water discharging into the Dead Sea from surrounding wadi canyons and gullies. This period of aridity coincides with a dramatic regional upheaval that occurred in the late thirteenth and early twelfth centuries BCE throughout the Eastern Mediterranean that saw the collapse of the Mycenaean Kingdoms in the Aegean, the Hittite New Kingdom in Anatolia, and a weakening of New Kingdom Egypt's control of the Southern Levant (WARD and JOUKOWSKY 1992).

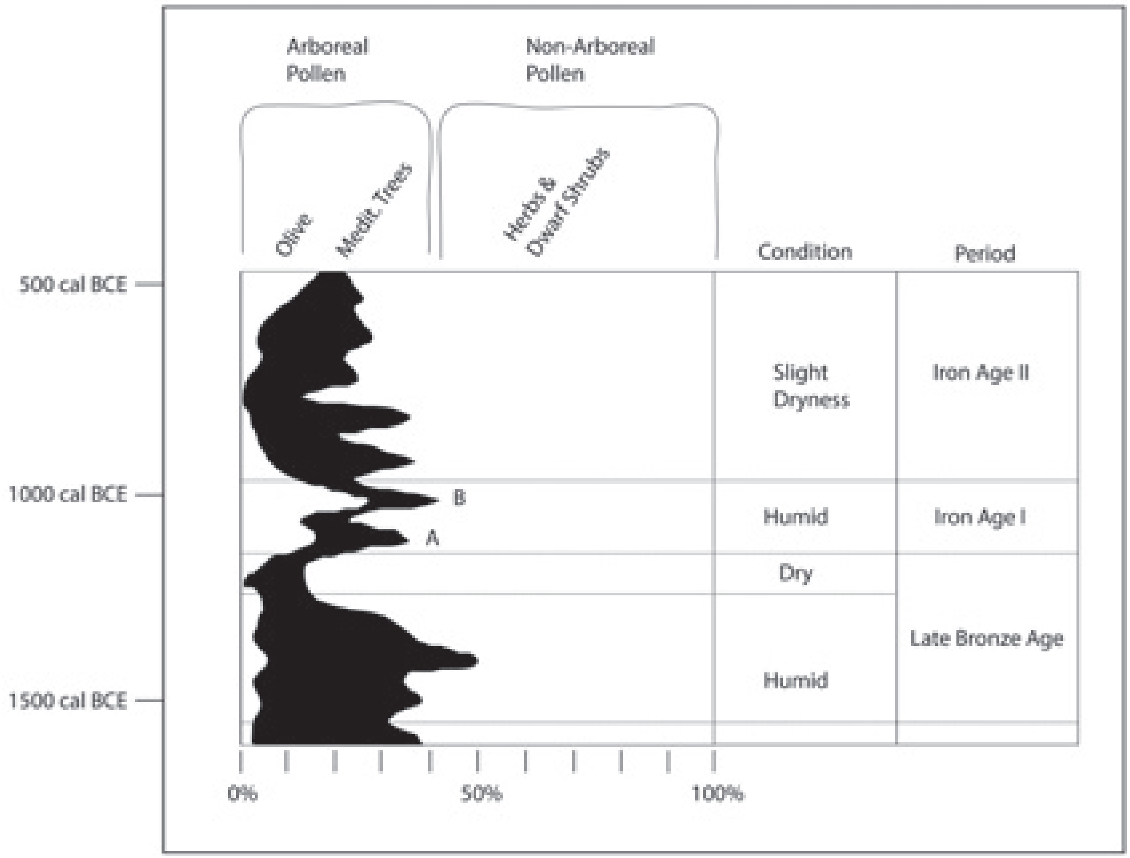

Fig. 6 : A selection from a pollen core from Lake Kinneret (adapted from LANGGUT, FINKELSTEIN, and LITT 2013). (A) and (B) indicate increases in Mediterranean tree and olive tree pollen that point to increases in cooler and wetter conditions.

These pollen cores are particularly interesting when considering the development of the Early Iron Age settlement system in the Wadi al-Mujib canyon. An examination of published ceramic vessel evidence reveals that the system developed over a two-century period. Currently published evidence from Lahun (SWINNEN 2009) suggests a date of occupation as early as the late thirteenth century BCE, while settlements located further south in the canyon (e.g., al-Mudayna al-Mu'arradja and al-Mudayna al-'Aliya) were founded in the eleventh century BCE. AMS radiocarbon dating of organic samples (n=29) indicates that al-Mudayna al-'Aliya was occupied for no more than a century, ending at some point in the first half of the tenth century BCE.[3] This gradual extensification of settlements through the canyon was a consequence of community fissioning due to demographic pressures, territoriality, and the need to exploit new resources deeper in the canyon riparian zone (PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2014). If indeed the Lake Kinneret and Ze'elim cores are correct in their identification of a return to cooler and wetter conditions in the eleventh century, then it is tempting to interpret these extensification episodes as producers responding to shifting environmental conditions. Indeed, a more evenly distributed settlement pattern would result in more evenly distributed use of natural resources between settlements. Although these cooler and wetter changes in climate may have motivated a shift in settlement strategies, it may still have required producers to adapt to unpredictable conditions. A close look at pollen levels in the Lake Kinneret core suggests that eleventh and early tenth century climatic conditions oscillated between wetter and drier conditions (Fig. 6). An increase in the relative percentages of olive tree and Mediterranean tree pollen in the early eleventh century indicate that wetter and cooler conditions replaced the warmer and drier conditions of the previous twelfth century (A). This recovery lasted only for a short period before conditions became drier and warmer once again. Granted, the relative percentage of pollen during this mid-eleventh century arid phase does not appear to have been as dry and warm as twelfth century conditions. Conditions once again became wetter and cooler toward the end of the eleventh and the beginning of the tenth century BCE (B) until changes once again occurred later in the century. The Ze'elim core shows similar changes in arboreal and olive tree pollen during the eleventh century BCE (LANGGUT *et al.*, 2014 : Fig.2).

This new palynological evidence for dynamic changes in climatic conditions in the Early Iron Age leads one to ask to what extent did these changes structure the al-Mujib settlement system ? Initial wetter and cooler conditions in the early eleventh century may have motivated the extensification process southward into the al-Mujib canyon. The settlements would have already established a subsistence infrastructure by the time drier and warmer conditions returned mid-century. Producers adapted their agro-pastoralist practices as drier conditions limited crop yields, increased evaporation levels at watering holes, and reduced some wild plant and animal populations. Buffering strategies likely included enhancements in storage strategies, such as an increase in animal fodder to feed herds once grazing lands were depleted in the late summer months. Producers could also modify butchering practices to control the rate of meat consumption, especially when grain sources were growing scarce. However, the grain storage facilities found in nearly all buildings at al-Mudayna al-'Aliya were likely the most important buffer against food scarcity during drier climatic conditions. Paleobotanical analyses of charred plant remains recovered in these bins indicate that producers stored a combination of cereals, fruits, and legumes for both animal and human consumption (PORTER, ROUTLEDGE, SIMMONS, and LEV-TOV 2014 : Table 1). These shifting climatic conditions likely took place so gradually over time that producers did not recognize

[3] Bayesian modeling using OxCal places al-Mudayna al-'Aliya's building construction phase between 1105 and 1016 BCE (p=2 sigma). Final settlement abandonment is based on burnt organic evidence excavated in storage bins in buildings 100 and 500. This evidence is modeled between 1001-921 BCE and 1011-941 BCE, respectively (p=2 sigma).

these changes during their everyday routines. Short-term conditions, such as inter-annual precipitation and temperature variability, probably remained a principal way of measuring relatively ‘good’ and ‘bad’ years, since producers likely operated on time horizons of two to three agricultural cycles. But if drier conditions continued to prevail for several cycles, there would come a point when such difficult circumstances became normative for producers, causing them to tacitly shift their practices and strategies to maintain the resilience of their subsistence economy.

CONCLUSION

The currently available environmental and archaeological evidence reveals that the socionatural system that developed in the Wadi al-Mujib during the Early Iron Age was complex and dynamic. The Early Iron Age al-Mujib settlements likely made short-term impacts on what was already a desiccated landscape. However, the shifting climatic conditions played a key role in structuring subsistence practices in individual communities. As mentioned earlier, this socionatural reconstruction of the Early Iron Age settlement system will hopefully be improved as new evidence is collected in the coming decades. Several settlements (e.g., al-Mudayna al-Mu‘arradja) require additional excavation beyond what took place in the latter half of the twentieth century. Better settlement plans need to be made using the digital cartographic and remote sensing technologies now available. Geophysical technologies such as ground penetrating radar (GPR) are now more affordable, and can illustrate building designs and positions under the right geological conditions. Alongside non-invasive documentation, several intriguing research questions call out to be answered through archaeological excavation and analyses. More AMS radiocarbon dating of organic evidence from secure contexts is needed in order to determine the dates of each settlements’ founding and abandonment with more precision. Botanical and faunal evidence need to be recovered from more settlements in order to measure the diversity of agro-pastoralist subsistence strategies in the region. These materials should be analyzed in great detail so that producers’ entanglements with landscape resources can be understood in more detail. As this research unfolds over the next several decades, the al-Mujib settlement system will continue to illustrate how Early Iron Age societies responded to as well as shaped the new political, economic, and environmental conditions that occurred between the upheavals of the twelfth century BCE and the emergence of Levantine polities in the early first millennium BCE.

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