Climate, Settlement History, and Olive Cultivation in the Iron Age Southern Levant

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In this article, we suggest a palaeo-climate reconstruction of the Iron Age based on pollen diagrams for sediment cores extracted from the center of the Sea of Galilee and from the Zeʾelim ravine on the western shore of the Dead Sea. We describe three pollen zones that roughly correspond to the Iron Age I, Iron Age IIA, and Iron Age IIB–C. Pollen Zone 1 (ca. 1100–950 B.C.E.) is characterized by high arboreal and olive pollen percentages in both records, representing relatively wet climate conditions and intense olive cultivation in the regions west of the lakes. Pollen Zones 2 (ca. 950–750 B.C.E.) and 3 (ca. 750–550 B.C.E.) are typified by a profound reduction in olive cultivation. Based on Mediterranean tree pollen percentages in the Sea of Galilee record and sediment characteristics in the Zeʾelim profile, climate conditions still seem to have been humid, albeit slightly less than in Pollen Zone 1. The low arboreal pollen in Pollen Zones 2 and 3 in the Zeʾelim diagram is probably the result of intense human influence on the natural vegetation in the Judaean highlands. The lowest olive pollen values during the Bronze and Iron Ages were documented in both records at ca. 700 B.C.E., possibly the outcome of depopulation as a result of deportation and the succeeding abandonment of olive orchards. These and other trends discussed in the article show that climate is only one of the factors that influenced settlement processes and economic trends in antiquity.

Keywords: palaeo-climate; Iron Age; pollen; Sea of Galilee; Dead Sea; olive orchards; olive oil

This article continues a series of recently published articles dealing with pollen evidence for climate conditions in the Levant during the Early Bronze Age (Langgut, Adams, and Finkelstein 2016), Middle Bronze Age I (Finkelstein and Langgut 2014), and Late Bronze Age (Langgut, Finkelstein, and Litt 2013). Here, we deal with the Iron Age (ca. 1100–550 B.C.E.), focusing on the southern Levant. Relatively detailed historical records and massive archaeological data make the Iron Age a reliable laboratory for discussing the balance between the impact of either environmental conditions or historical and geopolitical processes on expansion and contraction of settlement systems.

The study is based on pollen data collected from two sediment cores: one from the center of the Sea of Galilee and another taken from the Zeʾelim ravine on the western shore of the Dead Sea. These cores were studied in an unprecedented resolution of a sample every 25 to 40 years (compared with the usual procedure of samples every 100 to 200 years) and were subjected to rigorous radiocarbon dating. When necessary, we refer to two other pollen diagrams for the Rift Valley: Lake Hula (van Zeist, Baruch, and Bottema 2009) and Ein Feshkha (Neumann et al. 2007).1 We focus on three issues: changes in precipitation, transformations in settlement patterns, and olive cultivation.

1 Another pollen investigation was conducted on a sediment core from Ein Gedi (Litt et al. 2012). Though the Ein Gedi record was sampled in lesser resolution (sampled every 200 years vs. 30 to 40 years in this study), it provides results that are in line with the Zeʾelim evidence reported here.


Material and Method

Sampling and Chronology

Sea of Galilee. The drilling campaign was performed during the spring of 2010. It resulted in the recovery of an 18 m core from the bottom of the lake near Research Station A (see Fig. 1), covering almost the entire Holocene (Schiebel 2013). The time interval of the Bronze Age to the Iron Age comprises 5.5 m of the profile. This interval (composite depth of 458.8–1006.6 cm) was sampled for palynological analysis at 10 cm intervals (ca. 40-year time intervals between pollen samples [Langgut, Finkelstein, and Litt 2013]), while other sections were investigated in lower resolution (ca. 120 years between samples [Schiebel 2013: 26, appendix 6]).

The chronological framework of the Sea of Galilee record is based on an age-depth model, composed of nine radiocarbon AMS dates of short-lived samples (Langgut, Adams, and Finkelstein 2016: table 1). The Sea of Galilee sediment core is characterized by a relatively homogeneous lithology, with no evidence of any hiatus; thus, sediment deposition can be reliably considered as continuous.2 This is further supported by the uniformity in pollen concentration values throughout the record (Langgut, Finkelstein, and Litt 2013: fig. 2).

Zeʾelim. The sediment outcrop was extracted in the winter of 2010 from the Zeʾelim ravine, which dissects the Zeʾelim terrace located west of the Masada Plain on the southwestern side of the Dead Sea (Fig. 1). Sediments embedded in the lake during the Holocene were exposed in the last two decades due to a continuous, anthropogenically caused retreat of the lake (currently > 100 cm per year). The Zeʾelim riverbed drains the southern part of the Judaean Desert, carrying water and sediments that originate in the eastern flank of the central highland ridge (see Fig. 1). A detailed description of the stratigraphy, sedimentology, and palynology of the Zeʾelim sediment outcrop is presented in Langgut et al. 2014.

The chronology of this sediment sequence in the wall of the ravine is based on 11 radiocarbon AMS dates of short-lived samples (Langgut et al. 2014) and the identification of a textually recorded 8th-century B.C.E. seismic event (Kagan et al. 2011). The Zeʾelim profile covers the time interval of ca. 2500–500 B.C.E.—from the beginning of the Intermediate Bronze Age to slightly after the end of the Iron Age (Langgut et al. 2014; 2015). It was sampled for pollen analysis at ca. 5 cm intervals, which represent a few decades between samples. Since the sediment outcrop is located on the shore of the lake, different sediments were embedded within the sampling location as a result of changes in the lake levels. This enabled us to conduct a sedimentological investigation, which supports the palynological analysis (Langgut et al. 2014; see below). Yet the deposition of different lithological units, as well as the occurrence of hiatuses, results in an inconsistent pollen record. This prevented the construction of an age-depth model and led to some chronological uncertainties (Langgut et al. 2014).

Palynology

The palynological samples were processed using standard pollen extraction techniques (Faegri et al. 1989).3 One Lycopodium clavatum C. Linnaeus tablet was added to each of the sediment samples in order to calculate pollen concentrations: 6.8 sediment grams average were processed in the Zeʾelim samples, and 4.3 grams average in the Sea of Galilee samples.

The simplified palynological diagrams presented in Figure 2 are comprised of a group of natural Mediterranean trees4 (pinkish curve) and cultivated olive trees (green curve), together representing the relative frequencies of the total arboreal (vs. non-arboreal) pollen for the Bronze and Iron Ages; Figure 3 focuses on the Iron Age time interval (~ 1150–550 B.C.E.). The diagram was divided into pollen zones,5 based on significant changes in the pollen curves. The olive trees were combined with other Mediterranean trees, since they occupy almost the same ecological niches; this method was used in previous palynological studies from the region (Horowitz 1979: 193; Baruch 1986). Olive trees, like other Mediterranean trees, require at least 400 mm in order to thrive (see below). Already in antiquity, areas of Mediterranean forest/maquis had been replaced by olive orchards through human agency. The combined arboreal pollen curve is used in this study to trace changes in humidity (see Figs. 2, 3); high arboreal pollen percentages represent humid climate conditions and vice versa.

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2 For details, see Schiebel 2013; and Langgut, Adams, and Finkelstein 2016.

3 At least 500 terrestrial pollen grains were counted per sample. Pollen grains were identified to the lowest possible systematic level. A reference collection of Israel’s pollen flora (Steinhardt Museum of Natural History, Tel Aviv University), as well as pollen atlases (e.g., Reille 1995; 1998; 1999; Beug 2004) were used for identification. Detailed pollen diagrams are presented in Langgut et al. 2014 (Zeʾelim) and Langgut et al. 2015 (Sea of Galilee).

4 Within this group, only trees common to the Mediterranean vegetation territory were included; the majority among them are wind pollinated. The most dominant are evergreen (Quercus calliprinos type) and deciduous oaks (Quercus ithaburensis type). Other Mediterranean trees appear in lower percentages (e.g., Phyllyrea, Pistacia [pistachios], Pinus halepensis [Aleppo pine]).

5 Throughout this article, we use the conventional term “pollen zone,” which corresponds, in fact, to pollen period.
Fig. 1. (a) The position of the southern Levant; (b) the Sea of Galilee with the coring location near Station A; Lake Kinneret 1 is the sediment core studied in Baruch 1986; and (c) archaeological sites and the locations of sediment core extractions mentioned in the text, together with phytogeographic zones and rainfall isohyets characterizing the Sea of Galilee and the Dead Sea drainage basin (based on Zohary 1962 and Srebro and Soffer 2011, respectively). (Maps by I. Be-Ezra and M. Cavanagh)
Pollen Sources

Ze’elim. Most of the pollen of the Mediterranean trees as well as the Olea pollen represented in Figure 3b originated from the higher elevations of the eastern slopes of the Judean highlands, which are characterized by a Mediterranean climate. These wind-pollinated species were embedded within the Dead Sea mostly by the prevailing northwest wind and, to some extent, by fluvial transportation. The origin of the pollen grains was determined by (1) systematic study of recent pollen patterns in the Dead Sea area (Baruch 1993); and (2) quantitative analysis that traced direct and inverse correlations between the different fossil pollen taxa (Langgut et al. 2014). The study of recent pollen patterns was based on the calculation of the ratios of the extant vegetation in the Dead Sea area and the composition of present-day pollen rain for a given taxon (Baruch 1993). A matrix of the Spearman correlation coefficients between the fossil records of the two taxa was computed in order to uncover direct and inverse correlations in the abundances of the different taxa.

Sea of Galilee. To evaluate the sources of the pollen grains and changes in pollen distribution as a function of sampling location within and around the lake (e.g., inner part versus banks), several samples from the recent “pollen rain”—that is, the uppermost lake bottom sediments—were collected. The results showed that the extraction of the core from the inner part of the lake gives a reliable picture of vegetation cover in its vicinity. Most of the Mediterranean trees, including olive, originated from the mountainous Galilee due to the prevailing northwest wind (Langgut, Adams, and Finkelstein 2016: table S1, fig. S1). Uri Baruch (1986) also assumed that most of the pollen grains of Mediterranean elements that he identified within the lake (see Fig. 1b) were transported by the relatively constant northwesterly wind, while the Golan Heights pollen contribution is negligible.

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6 The study of recent pollen patterns was based on the calculation of the ratios of the extant vegetation in the Dead Sea area and the composition of present-day pollen rain for a given taxon (Baruch 1993).
7 A matrix of the Spearman correlation coefficients between the fossil records of the two taxa was computed in order to uncover direct and inverse correlations in the abundances of the different taxa.
8 Samples for recent pollen investigation were collected from the depth of 0–1 cm of the topmost lake sediments (see Langgut, Adams, and Finkelstein 2016: supplementary material).
To summarize, the pollen of natural Mediterranean trees and cultivated olive in the two palynological records derived mainly from the Mediterranean territories that lie west and/or northwest of the lakes: the mountainous Galilee, in the case of the Sea of Galilee, and the upper eastern flank of the Judean highlands, in the case of the Dead Sea. It seems that pollen grains from trees on the western side of the drainage divide (Fig. 1c) are not represented; this means that most of the pollen originating from the coastal plain, the Shephelah, the western Galilee, the Carmel Ridge, and the Jezreel Valley is not represented in the two records discussed here. Based on the regional prevailing northwesterly wind, it seems that the Hula Valley and the Golan Heights contributed only a little to the palynological assemblages recovered from the inner part of the Sea of Galilee.9 The Samarian hill country, although partially extending east of the drainage divide, is also underrepresented in both pollen profiles due to the direction of the prevailing winds. Only pollen that originated from southeastern Samaria can reach the Dead Sea with northwesterly winds.

Excursus: Olive Cultivation

The olive (Olea europaea) is a relatively slow-growing tree with fruit production starting five to six years after planting. It is mainly a wind-pollinated species; therefore, it releases large amounts of pollen in the spring (April–May, to compensate for the low pollination efficiency that characterizes wind-pollinated trees [Baruch 1993]). As a result, the pollen of ancient olive trees—both before and after domestication—is well recorded in regional pollen diagrams (e.g., Langgut et al. 2011; Litt et al. 2012).10 Olive trees have a strong response to cessation and resumption of cultivation, resulting in dramatic fluctuations in pollen production following abandonment or rehabilitation of orchards. Olea pollen is thus considered a reliable marker for identifying agricultural activities in antiquity (Langgut, Lev-Yadun, and Finkelstein 2014: 129–30). Well-managed, long-living olive trees can keep bearing fruit for hundreds of years (Zohary, Hopf, and Weiss 2012: 116).11 A mature olive tree has the unique ability to regenerate after traumatic conditions, such as fire, deforestation, overgrazing, and drought.

The success of olive trees—that is, their fruit yield—depends mainly on the amount of precipitation and/or moisture available in the soil. An olive tree can survive in environments with less than 200 mm of annual rainfall; yet, to be profitable, it requires at least 400–450 mm of annual precipitation. Modern orchards that receive 300–400 mm of rain are not profitable, while orchards that receive 200–300 mm rain annually yield fruit only every three to four years (Zinger 1985: 27–28). Olive trees thrive best in light, aerated soils, although they can succeed in a relatively large variety of soil types, as long as the soil is well drained. Where the soil is heavy and suffers from poor drainage, olive cultivation is rare (e.g., the northern Golan Heights, Beit Netofa Valley in the Lower Galilee). An olive tree usually prospers in a climate characterized by great differences in summer and winter temperatures. Hot conditions during the summer are required for oil accumulation and fruit ripening, while relatively low winter temperatures (but not sub-zero) are needed for bud differentiation. Flowering takes place on branches that developed in the previous year; therefore, the young growth has to survive low temperatures in winter as well as water shortages in summer in order to produce a good crop. Olive trees grow well in regions with low air humidity, where they are less vulnerable to disease and pests.

In accordance with the above-described conditions, olives in the Mediterranean Levantine region are most successful in the hill country and usually below 600 m above sea level, as freezing temperatures in the winter can destroy the yield. In the highlands, olive trees can succeed in patches of rich soil, where other crops are unprofitable due to limited space (Zinger 1985: 29–30). Lowland valleys with well-drained soils can also accommodate olive orchards, as can the coastal plains of the Mediterranean areas (Zinger 1985: 29–30). Yet the latter have usually been devoted to grain cultivation.

The pre-modern distribution of olives in Palestine (see, e.g., 1935 in Fig. 4) does not necessarily portray the situation in antiquity. For example, in the early 20th century, olive groves appear in very low frequencies in the Shephelah and the Jezreel Valley (see Fig. 4), while archaeological evidence points to a large number of olive oil extraction installations in Iron Age layers in these same areas (see below).

Results

In general, the Sea of Galilee arboreal pollen curve is characterized by many minor fluctuations, which reflect climate instability. Still, based on significant changes in the
Fig. 3. (a) The Sea of Galilee and (b) Zeʾelim simplified pollen diagrams focusing on the Iron Age and divided into pollen zones. (Graphs by D. Langgut)
pollen curves of the general Mediterranean tree taxa and cultivated olive trees, the Iron Age pollen diagram of the Sea of Galilee can be divided into three pollen zones (Fig. 3a; Table 1). The division of the Iron Age Ze’elim palynological diagram (see Fig. 3b) is more difficult, mainly because the section that corresponds to the Iron Age II seems to reflect intense human pressure on the natural environment; in other words, the low arboreal pollen values are probably a result of tree clearing. Therefore, it is not as good a proxy as the Sea of Galilee core for palaeo-climate reconstruction (Langgut et al. 2014). Yet the sedimentological study that was conducted on the same Ze’elim outcrop helps to illuminate the climatological situation (Table 2; detailed in Langgut et al. 2014 and Kagan et al. 2015). All things considered, though the interpretation of the Ze’elim data is slightly complicated, it generally follows the same trends that emerge from the Sea of Galilee pollen record and can therefore be divided into the same pollen zones.

Table 1. Percentages of Mediterranean Arboreal Pollen and Olive (Olea) Pollen for the Iron Age (Raw Data for Figure 3)

<table>
<thead>
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<th>Depth (cm)*</th>
<th>Arboreal Pollen (%)</th>
<th>Olive Pollen (%)</th>
<th>Degraded Pollen Grains (%)</th>
<th>Depth (cm)*</th>
<th>Arboreal Pollen (%)</th>
<th>Olive Pollen (%)</th>
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*Additional details regarding the depth of the Ze’elim (Dead Sea) and the Sea of Galilee records are available in Langgut et al. 2015.
Pollen Zone 1 covers the time interval ~ 1100–950 B.C.E. In the Sea of Galilee, it is characterized by maximum percentages of arboreal and olive pollen (up to 43.2% and 28.5% of the total pollen, respectively). Thanks to the increase in available moisture following severe dryness at the end of the Late Bronze Age (Langgut, Finkelstein, and Litt 2013), both the Mediterranean forest/maquis and olive orchards expanded. A similar increase in the values of Mediterranean and olive tree pollen was documented in the Zeʾelim record (28.0% and 8.9%, respectively; see Fig. 3b and Table 2) as well as in the Ein Feshkha palynological profile (Neumann et al. 2007).

Pollen Zone 2, which covers the time interval ~ 950–750 B.C.E., is characterized by a gradual decrease in olive pollen levels in both the Sea of Galilee and the Zeʾelim records (11.7–2.1% and 2.3–0.0%, respectively). The arboreal pollen exhibits opposite trends: In the Sea of Galilee, it retains the high frequencies that typified the previous zone, reaching 38.1%, while in Zeʾelim, it declines dramatically to a minimum of 0.5%. These data point to a developed Mediterranean forest/maquis and relatively humid climate conditions in the vicinity of the Sea of Galilee. The reconstructed depositional environment of the sediments in the Zeʾelim section in the Iron Age II is that of a deep lake (Langgut et al. 2014; Kagan et al. 2015), corroborating the occurrence of wet climate conditions. It therefore seems that the profound decline in the pollen of Mediterranean trees in the Zeʾelim profile is the result of human interference in the natural vegetation.

The pattern identified in the Sea of Galilee is evident in the Hula diagram: Olive pollen declines in the later stage of the Iron Age, while the common native Mediterranean trees, such as deciduous oaks, retain their high values (van Zeist, Baruch, and Bottema 2009: fig. 5). On the other hand, in the palynological record of Ein Feshkha, both olive and Mediterranean trees appear in the same levels, as was the case during the early phase of the Iron Age (Neumann et al. 2007).

Pollen Zone 3 corresponds to the later stage of the Iron Age II: ~ 750–550 B.C.E. The Sea of Galilee record exhibits a slight decline in arboreal pollen (not exceeding 29.4% of total pollen), representing moderate climate conditions, while a minor, gradual increase characterizes...
the olive pollen curve (6.5–1.2%). In this pollen zone, the Zeʾelim sequence portrays low values of both arboreal and olive pollen (not exceeding 5.1% and 2.6%, respectively), yet somewhat higher than in the previous zone. This represents a slight recovery of the Mediterranean forest/maquis together with minor expansion of olive orchards. This zone portrays the lowest arboreal and olive pollen percentages almost at the same time in both records: The lowest tree values are documented at ~ 750 b.c.e. in the Sea of Galilee, while in the Zeʾelim record, they are recorded about a decade earlier. The lowest Olea pollen in both records was identified at ~ 700 b.c.e. The deposition of the sediments in a high-lake environment at Zeʾelim (Langgut et al. 2014; Kagan et al. 2015) indicates a relatively humid climate.

Discussion

In what follows, we discuss climate conditions, settlement patterns, and olive culture in the southern Levant in the three pollen zones (periods) referred to above. Based on radiocarbon dating of Iron Age strata (e.g., Finkelstein and Piasetzky 2010; Toffolo et al. 2014), they roughly cover the Iron Age I, IIA, and IIB–C.

Pollen Zone I: The Iron Age I
(ca. 1100–950 B.C.E.)

In the Sea of Galilee core, this zone is characterized by the highest arboreal pollen in the Bronze and Iron Ages after the Early Bronze Age I12 and by high values of olives (see Fig. 3a). High frequencies of pollen from general Mediterranean tree taxa and cultivated olive trees are also evident in the Zeʾelim record (see Fig. 3b). These data imply a wet period, which significantly comes immediately after the very dry event at the end of the Late Bronze Age (ca. 1250–1100 B.C.E. [Langgut, Finkelstein, and Litt 2013]). The wet conditions in the Iron Age I seem to have influenced the settlement patterns throughout the southern Levant, especially in the southern and eastern steppe regions.

The wave of settlement in the highlands of Cisjordan could have commenced in the early days of the 12th century, if not slightly before; however, based on radiocarbon data for Shiloh and el-Ahwat (Sharon et al. 2007), its main phase took place in the late 12th and 11th centuries B.C.E. Observations regarding pottery collected during surveys seem to indicate that the settlement process started in the small valleys along the spine of the hill country and the Bethel-Gibeon plateau, as well as in the eastern flank of these regions—that is, in the desert fringe (Zertal 1994; Finkelstein 1995). These areas were chosen because they were amenable to a combination of dry farming and animal husbandry—the basics for the establishment of new farms and villages. While the wave of settlement in the highlands was probably initiated by the climate crisis and social upheaval in the later phases of the Late Bronze Age, its main phase took place under improved, wet conditions, which must have facilitated settlement activity along the desert fringe. This is also true for the wave of settlement in the highlands of Transjordan, especially for sites located on the eastern fringe. A good example is the relatively large Iron Age I site of Sahab, located 12 km southeast of Amman (Ibrahim 1987). The same holds true for settlement systems in western Syria, which facilitated the rise of the Aramaean kingdoms at the beginning of the Iron Age II.

A noteworthy phenomenon is the system of Iron Age I settlements in the Kerak plateau—that is, south of Wadi Mujib in Transjordan, an area that today receives

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12 For the Early Bronze Age I, see Langgut, Adams, and Finkelstein 2016.
ca. 300 mm of rain per year (Porter et al. 2014).\textsuperscript{13} Two significant sites in this system are the fortified strongholds of Khirbet Medeineh ʿAliya and Khirbet Medeineh Muʾarrajah. These sites, located along the eastern fringe of the region, date to the late Iron Age I (Routledge 2000; Finkelstein and Lipschits 2011; Porter et al. 2014). Considering the pottery evidence and radiocarbon determinations, Khirbet Medeineh ʿAliya was probably constructed during the 11th century and abandoned around the middle of the 10th century.\textsuperscript{14} This site features evidence of dry farming (Routledge 2000), despite its position east of the current line of permanent agriculture. Settlement activity in the Kerak plateau could have been promoted by copper mining in the area of Wadi Faynan in the Arabah, ca. 60 km to the south, as well as by transportation of copper to the north, along the King’s Highway (Finkelstein and Lipschits 2011). A climate that is wetter than what we see in this region today could have helped the daily subsistence economy, which was probably based on dry farming and herding. Copper mining in the area of Wadi Faynan\textsuperscript{15} could have been easier with a good flow of water in the ravines, which led from the Edomite plateau to the Arabah.

Two Middle Bronze Age sites are known in the Beer-sheba Valley, but no Late Bronze Age settlements. Sedentary activity in this region resumed in the Iron Age I, with the most evident sites being Stratum III at Tel Masos and Stratum IX at Tel Beersheba (Herzog 1994).\textsuperscript{16} Several of the Negev highland sites were first settled in the later phase of the Iron Age I (Fantalkin and Finkelstein 2006: 20). The Tel Masos–Negev highlands system (which peaked in the Iron Age IIA [see below]) was linked to the copper industry in the Arabah to its east (Fantalkin and Finkelstein 2006; Martin and Finkelstein 2013; Finkelstein 2014). But with no evidence of agricultural activity in the Negev highlands (Shahack-Gross and Finkelstein 2008; Shahack-Gross et al. 2014), grain must have come from areas farther to the north. Wet conditions could have promoted dry farming in the Beersheba Valley more broadly than today.

An exception to the picture presented above is the Judaean highlands, where settlement activity in the Iron Age I was still sparse. This shows that demographic expansion in the Iron Age I was also influenced by factors other than climate; the harsh rocky terrain of the region demanded great effort in clearing land for agriculture, and this could have deterred settlement activity in a period when more hospitable areas were still sparsely settled.

The Sea of Galilee pollen diagram portrays a dramatic increase in olive orchards starting in the very late 12th century and peaking in the first half of the 10th century B.C.E. As mentioned above, this is the highest representation of olives since the Early Bronze Age I. What could have caused this development?

The collapse of urban centers in northern Canaan at the end of the Late Bronze Age was followed by slow recovery of the main settlements. In the Late Iron Age I, between the late 11th and the middle of the 10th centuries B.C.E. (Toffolo et al. 2014), some of these places—in the valleys and Lower Galilee—grew to become major, prospering urban centers; this process may be interpreted as the revival of the Late Bronze Age city-state system (Finkelstein 2003). The main centers were Megiddo, Yokneam, Tel Keisan, Kinneret, and Tel Rekhash (= Bronze Age and biblical Anaharah). Most of these sites feature olive oil presses.\textsuperscript{17} Megiddo revealed olive presses from the Late Bronze Age III and Iron Age I (Frankel 2006), and Yokneam’s “Oil Maker’s House” dates to the late Iron Age I (Zarzecki-Peleg 2005). In addition, Megiddo’s Iron Age I layers produced an exceptionally high percentage of olive charcoal remains (Benzaquen 2017). Olives were also cultivated in the Beth Shean Valley. The largest percentages of olive charcoal and olive pits were documented at Tel Rehov for the Iron Age IIA (Liphschitz in press). At Tel Beth Shean, the Iron Age IB features high frequencies of olive charcoal remains (Baruch 2006; Liphschitz in press: table 52.4). More significant for our discussion are finds at the two sites located near the Sea of Galilee.

Kinneret is a large Iron Age I urban site, ca. 10 ha in size, located on the northwestern shore of the Sea of Galilee (Münger, Zangenberg, and Pakkala 2011). An olive oil press was found in Area U, and olive cultivation played a significant role in the economy of the site (Münger, Zangenberg, and Pakkala 2011: 80, 82). Tel Rekhash is located in Nahal Tavor, about 10 km southwest of the lake. The site prospered in the Late Bronze Age and Iron Age I (Hasegawa 2010; Paz et al. 2010). Five Iron Age I oil presses, an extraordinary number, were discovered there (Onozuka 2012). It seems, then, that the areas around both sites included significant territory devoted to olive orchards. The proximity of these two sites to the Sea of Galilee may account for the exceptional abundance of olive charcoal and olive piths at these sites.

\textsuperscript{13} For the survey of this region, see Miller 1991.

\textsuperscript{14} For the pottery, see Routledge 2000; 2008. For the radiocarbon evidence, see Porter et al. 2014: 135.

\textsuperscript{15} For Khirbet en-Nahas, see Levy et al. 2004; 2008.

\textsuperscript{16} For their updated chronology, see Herzog and Singer-Avitz 2004: 231.

\textsuperscript{17} See the summaries in Beeri 2008; and Onozuka 2012.
percentage of olive pollen recorded in the sediment core extracted from the lake. This is especially true for Kinneret, located close to where the sediment core of the Sea of Galilee was extracted. The land around Kinneret and Tel Rekhesh cannot be considered as one of the "classic" olive-growing areas in the traditional agriculture of pre-modern Palestine: In the early 1940s, the sub-district of Tiberias, which covered areas to the west of the lake, provided only 2–8% of the olive oil production in the country. Moreover, the olive oil presses in this territory were in the western sector, while the areas around Kinneret and Tel Rekhesh did not have even a single olive oil press (Government of Palestine 1942–1943). The olive presses unearthed at these sites testify to a different situation in the Iron Age I; a wetter climate in this period could have augmented the yield of their orchards. As for the basalt lithology around the two sites, post–Iron Age olive presses are known in the eastern Lower Galilee (Frankel 1999: maps 16, 31). The 108 olive oil presses dating to the Roman–Byzantine periods recorded at 60 sites in the basalt areas of the central and southern Golan (Ben David 1998) also demonstrate that olive trees can prosper in basalt soil. To summarize, it seems to us that a major expansion of olive orchards in immediate proximity to the Sea of Galilee accounts for the exceptional percentage of olive pollen in the sediment core from the northern part of the lake (see Fig. 1). What caused this expansion of olive horticulture near the Sea of Galilee, as well as in other areas in the north, such as the Jezreel Valley? Since the contemporary wave of settlement in the central highlands must have engaged in olive horticulture, at least in the late Iron Age I (Finkelstein 1995), and as olive oil was also produced at that time in the Shephelah (Bunimovitz and Lederman 2009), the overall production in the country seems to have been beyond the need of the local population. As for export, the main venue for southern Levantine olive oil in the Iron Age I seems to have been Egypt. The Nile empire must have imported olive oil from Canaan in the Late Bronze Age. Connections with Egypt were probably severed for a while after the Late Bronze Age collapse, but trade was revived a short while later during the days of the 21st Dynasty. Scarabs of Siamun (986–968 B.C.E.) at Dor, Megiddo, and Tell el-Far‘ah South and Egyptian pottery found in Canaan testify to these connections (Ben Dor Evian 2011). The palynological evidence from Tell Sukas on the Syrian coast corroborates this scenario: The Early Bronze Age II–Late Bronze Age time interval is characterized by high percentages of olive pollen, while a pronounced reduction in olive frequencies is documented starting at the beginning of the Iron Age I (Langgut, Adams, and Finkelstein 2016: fig. 4c; Sorrel and Mathis 2016: fig. 5a), possibly reflecting strong export to Egypt from the northern Levant in the Late Bronze Age, and then changing to the southern Levant in the Iron Age I. The scenario proposed here is related to the question of the regnal date of Shoshenq I, in whose time Egyptian interests in Canaan are indicated both textually (recently, Ben Dor Evian 2015) and archaeologically (the Shoshenq I Stele found at Megiddo). The date of his reign suggested by Thomas Schneider (2010)—962–941 B.C.E.—fits the above scenario better than the one advocated by Kenneth Kitchen (1986)—945–924 B.C.E.—as it opens the way to associate this pharaoh with the late Iron Age I sites. The Ze‘elim pollen diagram also shows an increase in olive pollen in the Iron Age I. Since the Hebron highlands are too high for olive growing (see above), because the Iron Age I settlement system in the Judaean highlands was weak, and inasmuch as pollen from olive orchards in the Shephelah was not likely to have reached the Dead Sea (on this, too, see above), one could argue that olive pollen was transported to the Dead Sea from the Sea of Galilee via the Jordan River. Another possible explanation for the Ze‘elim record is that olive pollen was carried to the lake from the area of Jerusalem and slightly to its north by northwesterly winds. Both of these explanations seem to be supported by the pollen diagram for Ein Feshkha—closer to the outlet of the Jordan into the Dead Sea than Ze‘elim, as well as to the area of Jerusalem—which exhibits an increase in olive pollen percentage during the beginning of the Iron Age I (Neumann et al. 2007: fig. 9). Pollen Zone 2: The Iron Age IIA and Early Iron Age IIB (ca. 950–750 B.C.E.) This period is characterized by the continuation of wet conditions but a dramatic reduction in olive pollen

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18 For Nilotic fish remains at Iron Age I sites in the southern Levant, see Van Neer et al. 2004.

19 The comparison of the Sea of Galilee olive pollen curve (Langgut, Adams, and Finkelstein 2016) with the Syrian (Tell Sukas) olive pollen record (Sorrel and Mathis 2016) provides a mirror image: The Sea of Galilee’s *Olea* pollen percentages retain low values from the Early Bronze Age II until the end of the Late Bronze Age, while at the beginning of the Iron Age I, around 1100 B.C.E., they increase dramatically. The northern olive record shows an opposite trend. In both Levantine records—south and north—periods of high olive distribution seem to point to export-oriented production, while periods of relatively low olive percentages indicate cultivation mostly for local consumption (Langgut, Adams, and Finkelstein 2016).
in the Sea of Galilee as well as in the Ze’elim records (see Fig. 2).

Evidently, the rise of territorial kingdoms in the region, starting in the second half of the 10th century, took place in conditions amenable to agricultural activity. This was advantageous to the nascent bureaucracies, which must have overseen the organization of surpluses, transportation of commodities, and agricultural specialization in certain localities. Still, in a world of rising kingdoms, international trade, and geopolitical considerations, climate is not the only factor dictating changes in settlement patterns. Perhaps the best example is the rise of Aramaean territorial kingdoms in western Syria, which can be understood as a “secondary state formation”—the result of the rising power of Assyria.

The decline of the early Moabite polity in the fringe area of the Kerak plateau around the middle of the 10th century or slightly later took place during a period of continuing wet conditions. Therefore, this development cannot be explained against the background of environmental change; rather, the reason should be sought in changing geopolitical circumstances. It seems that Egyptian intervention in the south during the early days of the 22nd Dynasty (during the reign of Shoshenq I), possibly aimed at monopolizing the copper industry in the area of Wadi Faynan, caused the transportation of copper to be shifted from a northerly direction through the King’s Highway in Transjordan to a northwestern course through the Beersheba Valley to the Mediterranean coast and Egypt. This brought about prosperity in the Negev and, in parallel, decline in the Kerak plateau (Finkelstein and Lipschits 2011; Finkelstein 2014).

In the Negev highlands, settlement activity peaked in the early to mid-9th century and declined in the second half of that century. Activity at the copper production sites in the Faynan area declined at the same time. Both processes took place during a period of continuing wet conditions. The decay of these southern settlements and their economic system was probably caused by the revival of copper transportation from Cyprus, which replaced the Arabah mines as the main source of copper for the Levant (Knauf 1995: 112–13; Finkelstein 2014).

Judah’s expansion into the Beersheba Valley during the late Iron Age IIA must have taken advantage of the improved climate conditions in the region. Yet this was probably not the prime mover behind the process. It seems that Judah’s expansion resulted from its alliance with Damascus following the campaign of Hazael to Gath. The Judahite strongholds in the valley—Arad and Beersheba—helped Damascus to repress copper production in the Arabah and replace it with Cypriot copper shipped to the Phoenician coast (Fantalkin and Finkelstein 2006; Finkelstein 2014).

While the Sea of Galilee curve in Figure 2a indicates continuing wet conditions in the 950–750 B.C.E. period, the Ze’elim record portrays diminishing arboreal pollen. This is probably due to the significant expansion of human activity in the Judaean highlands during the late Iron Age IIA (Ofer 1994)—that is, the 9th century B.C.E. One of the outcomes of this demographic expansion must have been the clearing of natural vegetation from the land. Indeed, the Ze’elim pollen diagram indicates increased grazing in the Judaean highlands (and probably Moab) at that time (Langgut et al. 2014).

Turning to olive horticulture, while adhering to our explanation for the peak in olive cultivation in the area of the Sea of Galilee in the Iron Age I (see above), the dramatic drop in olive pollen may be explained by the destruction of the late Iron Age I cities in the north, first and foremost Kinneret and Tel Rekhesh near the lake. In their stead, the Northern Kingdom could have promoted olive cultivation in the Samarian highlands; this is suggested by the Samaria ostraca of the first half of the 8th century B.C.E., which report shipments of oil from villages (royal estates?) to the capital (e.g., Niemann 2008). Yet the Samarian highlands vegetation is most probably not recorded in our pollen diagrams—neither for the Sea of Galilee (too far to the north) nor for the Dead Sea (too far to the south).

Another area where olive cultivation could have prospered is the western Galilee. Indeed, in the early 1940s, the districts of Nablus (Shechem) and Acre were the leading suppliers of olive oil in Palestine—together producing 40–45% of the yield of the country (Government of Palestine 1942–1943). Strong olive oil production in the western Galilee is portrayed in the Iron Age IIB olive oil industrial complex of Building 100 at Horvat Rosh Zayit (Gal and Frankel 1992). This area too is not represented in the Sea of Galilee palynological diagram (see Fig. 2a), as the olive pollen, borne by westerly winds, would most probably be blocked by the ridges of the Lower Galilee.

The low level of olive pollen in the Ze’elim core should come as no surprise. As noted above, the higher areas of the Judaean highlands do not allow for profitable olive cultivation (the elevation is too high and hence the winter nights are too cold). Indeed, unlike in the Samarian highlands, Iron Age olive presses are not known in this region. Even in later periods, the number of presses is marginal (Frankel 1999), and the same holds true for the situation in the 1930s and early 1940s (Government of Palestine...
Pollen Zone 3: The Iron Age IIB–C (ca. 750–550 B.C.E.)

This phase of the Iron Age is characterized by a slight reduction in arboreal pollen, low values of olive pollen in ca. 700 B.C.E., and a moderate increase in olive values thereafter—seen in both the Sea of Galilee and Dead Sea records. A decrease in the Mediterranean forest ca. 750 B.C.E. could have been the result of peak population growth in the Northern Kingdom (Broshi and Finkelstein 1992), which brought about deforestation in order to clear land for agriculture. Growth in the Mediterranean forest which followed in the 7th century B.C.E.—though moderate—may have resulted from the depopulations after Tiglath-pileser’s conquest in 732 B.C.E. (Younger 1998). Archaeological surveys show that many of the Iron Age sites in the Lower Galilee were abandoned as a consequence of the Neo-Assyrian takeover (Gal 1988–1989).

Low arboreal values in the Dead Sea during the second half of the 8th century do not reflect diminishing precipitation, as sediments along the lake were embedded in high lake levels (Langgut et al. 2014; Kagan et al. 2015). Rather, this must reflect the peak of settlement activity and hence deforestation in the Judaean highlands during the Iron Age IIB–C (Ofer 1994; Finkelstein and Silberman 2006). In this period, too, some of the settlement processes were dictated by geopolitical conditions, sometimes against the sheer logic of the environmental conditions. This is true first and foremost for the dramatic increase in settlement activity in the Edomite plateau and the Beersheba Valley—both probably related to prosperity created by the Neo-Assyrian-led Arabian trade; the main route from Arabia passed along these regions.

Turning to olive cultivation, the 8th century and especially the years around 700 B.C.E. in the north demonstrate a record low for all of the Bronze and Iron Ages. At least for the late 8th century, this could be another outcome of depopulation resulting from the Neo-Assyrian deportations and the ensuing abandonment of olive orchards.  

The Ze’elim graph (see Fig. 2b) represents continuing low values of olive pollen in the second half of the 8th century; the intensification of settlement activity in the Judaean highlands probably brought about the expansion of viticulture rather than olive orchards (in recent generations, this area has been devoted to growing vines). The archaeological data point to prosperity in olive oil production in the Shephelah—manifested in the olive oil installations found in late 8th-century B.C.E. Beth-Shemesh (Bunimovitz and Lederman 2009) and Tell Beit Mirsim (Eitam 1979), and possibly the large number of linum storage jars retrieved at Lachish (Lipschits, Sergi, and Koch 2011: 10). Yet, as explained above, Shephelah olive pollen is not likely to reach the Dead Sea.

The slight increase in olive pollen in the 7th century is intriguing. The intensification of olive culture in the Shephelah under Neo-Assyrian domination during the 7th century is attested in the unprecedented and intense olive oil production at Ekron, described as the largest olive oil industry in antiquity (Gitin 1990), as well as at Tel Batash (Mazar 1997: 262–63). Yet, as olive pollen from the Shephelah is unlikely to have reached the Dead Sea, explanations for this phenomenon should be sought elsewhere. The loss of the Shephelah following Sennacherib’s campaign in 701 B.C.E. must have promoted a reorganization of agricultural production in Judah in the years that followed (Finkelstein 1994). The Southern Kingdom could have attempted to develop olive orchards in those areas of the southern highlands that are not too high and hence make olive culture possible—for example, immediately to the east of the watershed. A certain increase in precipitation could have facilitated this endeavor.

Summary

The most significant results of this study are:

- The combination of the pollen evidence and archaeological data indicates a wet period and intense olive cultivation in the Iron Age I, especially in the later phase of this period (~ 1050–950 B.C.E.), possibly aimed at export of olive oil to Egypt.
- The low arboreal pollen values that characterize the ~ 950–550 B.C.E. time interval in the Ze’elim record most probably reflect settlement expansion and intense human influence (deforestation) on the natural vegetation in the Judaean highlands.
- An almost total disappearance of olive pollen ca. 700 B.C.E., documented both in the Sea of Galilee and the Ze’elim records, seems to be the outcome of depopulation as a result of deportations and the consequent abandonment of olive orchards.

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21 For the diminishing pollen yield in abandoned olive orchards, see Langgut, Lev-Yadun, and Finkelstein 2014.
Archaeological data indicate strong olive oil industries in the Shephelah of Judah, the highlands around Samaria, and the western Galilee in the Iron Age IIB–C; yet, as pollen in the southern Levant is transported mainly by westerly and northwesterly winds, and because of the barrier formed by the mountains of the Lower Galilee and Judaea, pollen from these regions is not represented in the Sea of Galilee and Dead Sea records.

With the rise of territorial kingdoms and the later domination of the region by empires, climate was only one factor in shaping settlement processes, even in the marginal areas of the southern Levant.

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