Byzantine–Early Islamic agricultural systems in the Negev Highlands: Stages of development as interpreted through OSL dating

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An extensive survey followed by OSL (optically stimulated luminescence) dating of loess accumulation in agricultural terraces at six Byzantine and Early Islamic sites in the Negev Highlands revealed clear stratigraphic and chronological sequences. Traditionally dated to the 1st–7th centuries A.D., results from the present study demonstrate that the construction and use of largescale agricultural systems took place in the 4th–11th centuries A.D. This new chronology provides the framework for a more precise interpretation of the circumstances of construction and demise of largescale agriculture in the Negev Highlands. The agricultural fields were exploited continuously, yet ancient farmers had to confront the environmental hazards of occasional intensive floods, successive years of drought, and a constant process of loess accumulation and erosion. The constant maintenance and repair of fields necessitated an investment of labor. However, it seems that the expansion of ancient agriculture was part of the natural growth and development of Byzantine settlements in the Negev, and not the outcome of planned government enterprise. The agricultural systems were abandoned in the course of the 11th century A.D. and sporadically reused by pastoral nomads.

Keywords: agricultural terraces, OSL dating, Negev, Byzantine–Early Islamic periods, Levant

Introduction

Ancient agricultural systems in the Negev Highlands cover more than 30,000 ha of cultivated plots dammed with stone built terraces, alongside extensive channels designed for collecting runoff water from hillslopes and from occasional intensive floods in wadis (FIGS. 1, 2). The impact of the systems on the desert landscape attracted scholarly attention as early as the 19th and early 20th centuries (Robinson and Smith 1841: 281–284; Palmer 1871: 367; Woolley and Lawrence 1914–1915: 32–36). With the intensification of modern archaeological research in the Negev, these systems have been the target of several comprehensive studies (Glueck 1956, 1959, 1960, 1965; Aharoni *et al.* 1960; Mayerson 1960; Negev 1986; Rubin 1990). The Negev Emergency Survey (1979–1989) provided further data on the agricultural fields and related settlement sites (Avni 1992, 1996; Baumgarten 2004; Haiman 1986, 1991, 1993, 1999; Lender 1990; Rosen 1987, 1994). The ancient agricultural fields were also studied from their hydrological, geomorphological, and botanical aspects with specific attention to the mechanisms of conveying water into fields, the processes by which arable soil accumulated, and the nature of the agricultural crops grown (Zohary 1953; Even-Ari *et al.* 1982; Kedar 1967; Yair 1983; Rubin 1990: 73–104; Bruins 1986). These detailed studies formed the basis for a typological classification of agricultural systems and suggested a wide chronological framework. Some scholars have dated the beginnings of agriculture in the Negev to the Bronze and Iron Ages (ca. 4th to 1st millennia B.C.) (Even-Ari *et al.* 1982: 100–111; Aharoni *et al.* 1960) and expansion during the Nabatean and Roman (ca. 1st and 2nd centuries A.D.) periods (Negev 1986). While the existence of agrarian societies in the Negev Highlands during the Iron Age is debatable (Haiman 2003; contra Shahack-Gross and Finkelstein 2007), most studies connect the major expansion of agriculture in the region to the penetration of settlement during the Roman and Byzantine periods (1st–6th centuries A.D.) (Negev 1986; Tsafrir 1996; Rubin 1990). The present study addresses the questions of chronology and interpretation of the agricultural settlements in

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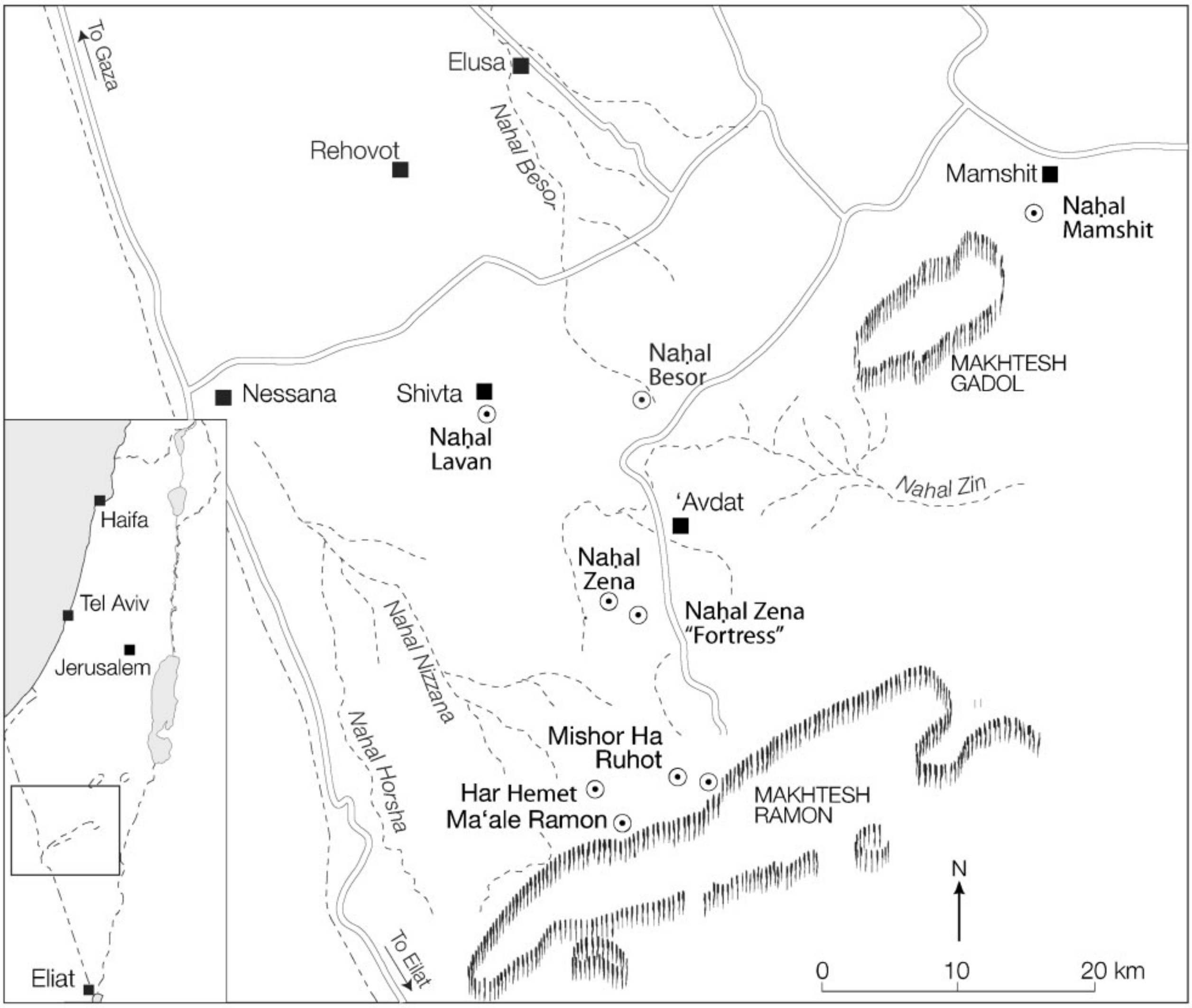

Figure 1 Map of the Negev Highlands with the study areas and other sites mentioned in the text indicated.

the Negev Highlands through an interdisciplinary research project focusing on six sites in the region. Agricultural terraces were analyzed and dated using optically stimulated luminescence (OSL).

Geomorphological and climatic background

The Negev Highlands encompass uplifted terrain between the central Sinai Basin in the west and the Dead Sea Transform in the east. The region is composed of monoclinal ridges of limestone and dolomite of lower Cretaceous to Eocene epochs that form a hilly and rocky desert landscape, in which arable soil is present only in the valleys. Its current climatic conditions place the region within the hot Saharo-Arabian desert, with a mean annual temperature of 17–19°C, depending on the elevation. The average annual precipitation ranges from 120 mm in the north to less than 80 mm in the south; the annual evaporation is 2000–2500 mm and the aridity/humidity index P/PET (annual precipitation to potential evapotranspiration ratio) is 0.16–0.06. These data are based on measurements from stations at Beer Sheva and Sede Boqer from 1970 to 2002 (Kafle and Bruins 2009).

The origin of the soil in the Negev Highlands is a mixture of fragments of local rock and finegrain sediments—mostly silt and clay, which were brought by dust storms from the Sahara and Sinai deserts (Avni *et al.* 2006; Crouvi *et al.* 2008, 2009). Based on evidence from the southern and central Negev, it was concluded that the accumulation of dust began approximately two million years ago. It is documented by finegrain loess sediments trapped in large valleys deposited within the Arava, Zehiha, and Sede Zin formations dating to the Early Pleistocene period (ca. 2.6–0.76 mya) (Avni 1998; Ginat 1997; Avni and Zilberman 2007). However, most of the aeolian sediments currently found in the Negev Highlands date to the last glaciation phase (ca. 73,000–18,000 B.P.). These sediments created an almost continuous alluvial cover ranging from four meters thick on hilltops to one meter thick on the slopes, and six to ten meters thick in the river valleys (Crouvi *et al.* 2008). With the transition to the latest interglacial period (ca. 18,000–15,000 B.P.), finegrain sediments gradually eroded out of the drainage basins (Avni 2005; Zilberman 1992). The first phase of erosion included secondary sedimentation of alluvial deposits washed from the steep slopes into the valleys, which amassed to a thickness of several meters. Remains of these sedimentary entities are still visible at numerous sites in the Negev Highlands (Avni *et al.* 2006, 2012).

Soil erosion and gullying continued during the Holocene epoch, undermining the alluvial section through heads of ravines and gullies, creating vertical headcuts 2–4 m in height (Avni 2005). The floodwater flows through the headcuts down the valley, concentrating in narrow channels, and resulting in an increased erosive power that acts against a substrate of practically unconsolidated, fine grain alluvial sediments and loess soils. These eroded fine sediments were redeposited in relatively wide segments of the valleys, and they sometimes accumulated in the valleys. The reduction of the erosive processes and the irrigation of these segments by runoff enable deep percolation of water leading to rich floral biomass (a rich assemblage of shrubs and annuals) and agricultural potential. The coexistence of soil and floodwater enabled the establishment of agricultural activities in the desert regions of the Levant during the late Holocene that were based on runoff harvesting techniques. Ancient farmers utilized the well-preserved soils in the valleys and constructed agricultural installations in which soils were redeposited. These installations combated soil erosion in unprotected segments of the drainage basins. Following the abandonment of the agricultural systems, erosion increased behind the terraces, causing the features to collapse. Consequently, agricultural zones that had been cultivated in ancient times were no longer viable.

Historical and archaeological context

Early explorations of the Negev Highlands revealed the remains of five large settlements: Mamshit (Mampsis-Kurnub), ʻAvdat (ʻAbde-Oboda), Rehovot (Ruheibeh), Shivta (Sobota-ʻSubeita), and Nessana (FIG. 1) (Woolley and Lawrence 1914–1915; Negev 1977, 1988, 1993; Rubin 1990). Shivta and Nessana were extensively explored in the 1930s (Baly 1935; Colt 1962), yet only the excavations in Nessana were fully published. The discovery of the Nessana archive, containing numerous administrative documents written between A.D. 512 and 689, provided a major source for understanding the local history of the Negev in the Byzantine period and the daily life of the local agrarian society (Kraemer 1958; Rubin 1990). Additional largescale excavations were conducted at Shivta, ʻAvdat, and Mamshit during the 1960s, but these have yet to be fully published (Negev 1986, 1993). All settlements were extensively developed during the Byzantine period, expanding in area and population and maintaining large agricultural networks offsite (Negev 1977; Mayerson 1960; Rubin 1990).

Figure 2 Typical terraced-dammed fields above and below a terrace wall.

Archaeological research underscored the connection between the villages and agricultural fields nearby, and the Nessana papyri provided valuable information on the size and social organization of the agricultural systems, the division of water rights, and the types of crops grown (Kraemer 1958; Mayerson 1960; Rubin 1990: 73–100). The ancient fields yielded different kinds of grains and legumes, particularly wheat and barley, and were also renowned for their olives, grapes, and date and fig orchards (Kraemer 1958; Mayerson 1960: 14–21; Rubin 1990: 86–99). Additional botanical finds from the excavations at Nessana yielded almond, peach, and walnut seeds (Mayerson 1960: 15). A recent study of pigeon dung samples found in an ancient dovecote near Shivta bolstered the evidence of locally grown figs, grapes, olives, and dates (Ramsay and Tepper 2010). Ancient olive trees have survived in terraced fields throughout the Negev Highlands, which provide additional clues relating to horticultural practices (Ashkenazi *et al.* 2011).

The systematic mapping of agricultural systems identified their structure and spatial relationship with adjacent settlements (Kedar 1967; Even-Ari *et al.* 1982; Haiman 1995; Ashkenazi *et al.* 2012). The fields appear in different forms: small dams extending across narrow streambeds (FIG. 2); medium sized fields across larger wadis, and large farmsteads spread over sizeable arable areas and delimited by formidable stone walls. Nevertheless, basic questions regarding methods of construction, development stages, duration of use, and the timing and circumstances of the collapse of these sophisticated systems were not clarified.

The problem of chronology

The dating method for ancient agricultural systems has been explored at various sites around the Mediterranean, suggesting different approaches for establishing the time of construction and function of terraces (Davidovich *et al.* 2012: 193–194). As terraced fields are one of the most typical features in agrarian societies in many ancient cultures (e.g., Marcus and

Stanish 2006), the question of accurate dating of the fields and their relation to nearby settlements has been crucial for the reconstruction of settlement intensification and demise. While numerous studies addressed these topics in the settled areas of the Mediterranean basin, only a few targeted the arid fringe zones, where runoff desert agriculture was extensively developed (Barker *et al.* 1996), and few researchers considered OSL dating to be a reliable tool (Barker 2007).

A major obstacle in dating agricultural systems was that pottery collected within the features had only limited ultility for establishing the chronology, as it was not found in situ but embedded in the alluvial fills washed from the slopes and accumulated behind stone built terraces (Alcock *et al.* 1994; Davidovich *et al.* 2012: 194). In addition, construction techniques, stratigraphy, and even radiocarbon dating had their own limitations in establishing a reliable chronology (Davidovich *et al.* 2012: 193–194). As a consequence, the ancient agricultural fields could not be dated accurately through conventional archaeological methods.

The chronological framework of the agricultural systems in the Negev Highlands was traditionally established by ascribing the fields to nearby settlements that were dated through archaeological surveys and excavation. For example, small fields at Ramat Matred were ascribed to the Iron Age (Aharoni *et al.* 1960), large cultivated plots around ʻAvdat to the Nabatean and Roman periods (Negev 1986), areas in the vicinity of Rehovot, Shivta, and Nessana to the Byzantine period (Mayerson 1960; Rubin 1990), and fields in the western and southern fringes of the Negev Highlands to the Early Islamic period (Haiman 1995; Avni 1996).

Based on his excavations at ʻAvdat and Mamshit, Negev (1961, 1986) connected the beginnings of agriculture in the Negev Highlands to the end of the Nabatean kingdom in the second half of the 1st century A.D. In his opinion, the decline of an international caravan trade forced King Rabael II to adopt new strategies for survival, shifting from commerce and caravan trade to agriculture. This interpretation was based on his reading of several Nabatean inscriptions found near ʻAvdat, supposedly mentioning the construction of dams (Negev 1961). However, this has been refuted by other scholars who interpreted the inscriptions differently (Naveh 1967).

The traditional view is that the agricultural regime of the Negev Highlands reached its zenith during the Byzantine period, particularly in the 6th century A.D., though the involvement of a central government in the expansion of settlement to the fringe areas of Palestine has yet to be clarified (Tsafrir 1996). A controversial interpretation suggested that the massive construction of agricultural systems reflected an attempt of the Byzantine imperial authorities during the 5th and 6th centuries to enhance local biomass and to increase the potential grazing areas for sheep and goat herds in the Negev Highlands in order to win the support of local pastoral nomads (Nevo 1991). However, most interpretations suggest that the expansion of settlement into the arid zones of the Negev was an outcome of population pressures in settled areas to the north and the increased demands for Palestinian wine in the western Mediterranean (Tsafrir 1996; Kingsley 2001; Decker 2009; Pieri 2005).

While some scholars established the 7th century as a period of collapse, linking it to the Arab conquest of A.D. 634–640, recent research concluded that settlement declined much later in the Early Islamic period (Avni 2008). The expansion of settlement into the western and southern fringes of the Negev Highlands during the 6th–8th centuries A.D. was firmly established by surveys and excavation (Avni 1996, 2008; Haiman 1995). As in the vicinity of the main settlements in the central and northern Negev Highlands, these villages and farmsteads were surrounded by extensive agricultural fields that were tentatively dated to the Byzantine and Early Islamic periods, relying on dated finds in nearby settlements rather than on finds from the fields. The suggested demise of settlement and related fields has since been pushed into the middle of the 8th century (Haiman 1995) or even later in the Abbasid period (Avni 2008).

Research Context, Methods, and Sampling Strategies

The accurate dating of agricultural terraces using OSL addresses several questions, among them the establishment and the cessation of agricultural systems in the Negev Highlands within the local cultural and political contexts of the 1st millennium A.D. Was the end of the agricultural regime associated with the penetration of Arab groups into southern Palestine or was it a prolonged, "bottom up" process, connected to settlement changes within the region? A related issue concerns the involvement of the central government in the creation of such agricultural systems. Was the expansion of settlement in the Negev Highlands an outcome of a government initiative or was it associated with an internal process of settlement expansion to the marginal regions of the Near East? The possible impact of climatic fluctuations should not be ruled out. In the early 20th century, the American geographer Elsworth Huntington proposed that climate change was the central agent influencing settlement change in the Near East. He associated the growth and collapse of desert runoff agriculture with environmental changes (Huntington 1911). Since then the question of climatic fluctuations is raised as a possible explanation for the growth and collapse of the agricultural regime in the Negev Highlands and other fringe regions of the Near East during the 1st millennium A.D. (Issar 1998; Issar and Zohar 2004; contra Rubin 1989).

The methods employed to address these questions combine archaeological and geomorphological analysis with extensive use of OSL dating in order to reconstruct the chronological framework for the operation of the fields and to evaluate the impact of anthropogenic and environmental agents on their construction and maintenance. Such interdisciplinary research was conducted at six sites located in different areas of the Negev Highlands. The study of each site included microgeomorphological analyses of loess accumulation and erosion in agricultural fields, calibrated with a number of OSL dates from accumulated loess sections, and incorporated with archaeological observations on stratigraphic phases of construction, maintenance, and long term use of the systems. The combination of data obtained from each method allowed a better understanding of the operating mechanism and internal development of the fields in each system. The study of accumulation and erosion in terraces provided a basis for a reevaluation of environmental and climatic conditions in the Negev Highlands during the Byzantine and Early Islamic periods, compared to the present conditions, allowing preliminary conclusions regarding the climatic stability of the region during the last two millennia.

The six sampled sites were selected according to their regional context and their distance from nearby large settlements (FIG. 1). Two are located in the immediate hinterlands of Mamshit (Nahal Mamshit) in the eastern highlands and Shivta (Nahal Lavan) in the western highlands. Both settlements were extensively excavated revealing archaeological sequences from Late Roman and Byzantine times (Mamshit) and from Byzantine and Early Islamic times (Shivta). Two sites are located in the outer hinterland south of ʻAvdat. One is associated with a small Byzantine period farmstead and the other is located next to an Iron Age site. The possibility of an earlier phase of agricultural exploitation was raised at both sites and the OSL dating was employed to address this question. The last two sites represent fringe areas in which small agricultural fields were constructed. The Nahal Besor site, north of ʻAvdat, is located next to an Early Islamic village, which represents the latest phase of permanent settlement in the Negev Highlands. In the Har Hemet-Mishor Haruhot area, a sparsely inhabited region and one of the southernmost locations that practiced desert runoff agriculture, which included shallow terraces spread out along wadis, perhaps representing shifting agriculture practiced by local pastoral nomads.

The sampling strategy addressed differences in the shape and size of the terraces. Two sites (Nahal Mamshit and Nahal Lavan) consist of large cultivation plots in plains adjacent to wide basins, and two others (Nahal Zena and Nahal Besor) are located along secondary narrow valleys consisting of relatively short terraces. While Nahal Mamshit and Nahal Lavan represent large scale networks that extend over a vast area near large settlements in the region, the systems south of ʻAvdat incorporated medium sized fields. Those in the outer fringe are much smaller and required less investment of labor in their construction.

OSL dating

Field methods

OSL dating measures the time elapsed since the last exposure of quartz grains to sunlight (Aiken 1998). Quartz grains in the ancient agricultural fields are aeolian in origin and were blown onto limestone hilltops and slopes by storms as loess (Enzel *et al.* 2003; Crouvi *et al.* 2008). These grains were later transported downslope by rain and accumulated behind stone built walls. After burial within the agricultural fields, the sediment was not exposed to light, except perhaps between the plow zone at the surface to a depth of ca. 20 cm. Thus, OSL can be used as a dosimeter to pinpoint the time when the accumulation of a specific sediment horizon began.

Samples for OSL dating were taken from terraced fields at the six sampled sites (FIG. 1; TABLE 1). The samples were collected from loess that accumulated behind terraces and sampling was carried out by drilling vertically from the top of the terrace downward or horizontally into the sides of the eroded terraces (FIGS. 3, 4). This sampling strategy is necessary for obtaining reliable results, as drilling reaches sterile sediments that constitute the natural substrate on which agricultural fields were built. Such samples would yield dates that are too old and unrelated to the construction phase of the terraces. Therefore, when exposures of eroded terraces were not available, drilling was first carried out in the anthropogenic soil accumulated behind the terrace wall to reach underlying natural sediment, which is characterized by the frequent appearance of fluvial gravels. After establishing the depth of accumulation of anthropogenic soil above the natural fluvial-alluvial sediment, a second drilling between 50–100 cm from the first was used to sample for OSL dating, and the deepest sample was taken from ca. 10 cm above the expected depth of the underlying sediment. Such a sample provides a minimum age for the beginning of terrace building at that site.

The modern surface of the sediment in the terraces has probably been plowed, mixing older with younger sediments. To avoid contamination, samples were taken from below the plow horizon, estimated to be ca. 20 cm. Quartz grains could have also infiltrated

Table 1 OSL dating results of archaeological terraces.

Sample	Location	Depth (m)	Field γ (μGy/a)	Grain size (μm)	K %	U (ppm)	Th (ppm)	Ext. α (μGy/a)	Ext. β (μGy/a)	Total dose (μGy/a)	No. of discs	De (Gy)	OD (%)	Age (years before 2008)
Mamshit														
MM-5	Lower terrace, middle	0.22	552	88–125	0.54	1.40	4.00	7	626	1184±61	19/20	1.76±0.09	29	1480±110
MM-6	Upper terrace, top	0.08	912	88–125	1.08	2.50	6.80	12	1187	2110±98	20/20	1.64±0.11	26	780±60
MM-7	Upper terrace, middle	0.25	1061	88–125	1.03	2.80	6.80	12	1191	2264±112	19/20	3.296±0.12	12	1440±90
MM-8	Upper terrace, base	0.40	1018	88–125	1.03	2.50	6.60	11	1149	2178±108	16/20	3.32±0.12	25	1520±90
Nahal Lavan														
LVN-7	Lowermost terrace, top	0.33	892	74–125	0.60	3.60	4.10	13	944	1849±95	17/19	1.88±0.06	19	1020±60
LVN-2	Lower terrace, top	0.65	964	88–125	0.64	3.30	4.00	12	928	1904±101	13/18	3.43±0.11	29	1800±110
LVN-1	Lower terrace, base	2.50	943	88–125	0.55	2.70	3.40	10	780	1733±98	15/19	3.13±0.09	17	1810±110
LVN-4	Middle terrace, top	0.25	886	74–125	0.60	3.60	4.00	13	942	1841±94	17/19	2.00±0.06	17	1080±60
LVN-3	Middle terrace, base	2.50	836	88–125	0.60	3.10	4.10	11	879	1726±89	15/19	6.91±0.30	60	3800±260
LVN-6	Upper terrace, top	0.37	884	74–125	0.71	2.80	3.80	11	911	1806±94	18/18	1.70±0.10	24	940±70
LVN-5	Upper terrace, base	1.70	853	88–125	0.67	3.10	4.70	12	940	1804±91	18/19	2.94±0.16	24	1630±120
Nahal Zena														
NZN-3	Terrace I – top	0.30	920	88–125	0.83	1.720	4.660	8	895	1823±95	14/14	2.00±0.15	5	1100±100
NZN-6	Terrace I – middle	1.00	872	88–125	0.61	1.750	4.80	8	752	1632±93	18/18	2.21±0.10	18	1360±100
NZN-2	Terrace I – base	2.10	806	88–125	0.75	1.630	5.030	8	838	1622±76	11/14	2.36±0.26	40	1460±170
NZN-9	Terrace II – top	0.60	806	88–125	0.42	1.650	3.30	7	574	1387±85	13/18	2.29±0.09	29	1650±120
NZN-8	Terrace II – middle	2.10	823	88–125	0.71	1.900	4.60	9	835	1666±87	16/18	2.18±0.07	18	1310±80
NZN-7	Terrace II – base	2.90	776	88–125	0.71	1.80	5.10	9	840	1627±83	17/18	2.39±0.10	18	1470±100
NZN-13	Terrace III – top	0.30	776	88–125	0.85	1.900	5.40	9	949	1734±82	15/17	2.02±0.08	33	1160±70
Nahal Zena (Iron Age “Fortress”)														
NZE-21	Top	0.60	753	88–125	0.66	1.70	3.90	7	741	1501±80	18/18	1.76±0.08	17	1170±80
NZE-22	Middle	0.75	766	88–125	0.61	1.70	4.00	7	710	1483±81	18/19	2.51±0.08	12	1700±110
NZE-23	Base	1.05	819	88–125	0.70	1.70	4.50	8	781	1608±87	17/19	2.65±0.05	15	1650±90
Upper Nahal Besor														
NAY-1	Top	0.37	857	88–125	0.91	1.80	5.50	9	956	1822±91	14/19	0.70±0.02	26	380±20
NAY-2	Middle	0.67	829*	88–125	0.91	1.80	5.10	8	947	1784±34	20/20	1.24±0.04	15	690±30
NAY-3	Base	0.84	808	88–125	0.83	1.70	5.40	8	888	1704±86	16/19	1.87±0.06	27	1100±70
Upper Nahal Zin														
Mishor Ha-Ruhot 1														
YA-3	Base of terrace	0.50	729*	88–125	0.53	1.90	4.30	8	688	1425±31	11/11	4.07±0.40	20	2850±290
Mishor Ha-Ruhot 2														
YA-36	Up-terrace	0.20	514	88–125	0.52	1.50	4.00	7	625	1146±41	18/19	1.35±0.06	26	1180±70
YA-37	Pre-terrace	0.30	514	88–125	0.60	1.60	4.90	8	711	1233±41	17/19	2.41±0.09	15	1950±100
Ma’ale Ramon														
YA-30	Early sediment	0.45	512	88–125	0.83	2.20	6.40	10	947	1496±45	19/19	1.55±0.06	14	1040±50
YA-31	Late sediment	0.25	617	88–125	0.77	2.00	5.80	9	895	1522±44	28/28	0.99±0.11	58	650±80
Har Hemet														
YA-34	Up-terrace	0.20	390	88–125	0.49	1.40	3.80	6	588	984±32	20/20	1.46±0.10	27	1460±110
YA-35	Down-terrace	0.20	337	88–125	0.59	1.40	4.40	7	684	1029±34	19/20	1.76±0.14	38	1560±110

Notes: Ages were calculated with 5% moisture content. γ + cosmic dose rates are from field measurements, except for samples marked with an *, where γ + cosmic dose rates were estimated from the concentration of the radioelements and burial depth. # of discs=number of aliquots used for De calculations out of those measured. OD=overdispersion, a measure of the scatter within a sample. De and errors were calculated using the central age model (Galbraith *et al.* 1999). Errors on the concentrations of K, U, and Th are 1%, 5%, and 10% of the values, respectively.

Figure 3 Sampling sediments for OSL dating vertically into the terrace infill. The auger barrel head is covered by a large, opaque black plastic sheet, while the sediment brought up by the auger is placed into a smaller black bag.

Figure 4 Horizontal sampling for OSL dating into the face of an eroded sediment infill of a terrace and the underlying Holocene gravel.

from above by bioturbation. This would produce dates that are younger than the time of sediment deposition, and so it was accounted for by thorough sampling.

Laboratory methods

Very fine sand quartz grains (75–125 μm) were extracted from the samples in a laboratory under a dim orange light using routine procedures (Porat 2007). After grain size analysis using wet sieving, the carbonates were dissolved using HCl. The rinsed and dried samples underwent magnetic separation to remove heavy minerals and most feldspars. Consequently hydrofluoric (HF) etching was used to dissolve any remaining feldspars and etch the outer part of the quartz grains. The purified quartz grains were mounted on 10 mm aluminum discs using silicon spray as an adhesive. The equivalent dose (De) values were determined on 18–20 aliquots for most samples, measured using the OSL signal and the single aliquot regenerative (SAR) dose protocol (Murray and Wintle 2000).

Dose rates were calculated from field and laboratory measurements. The gamma and cosmic dose rates were measured in the field using a calibrated portable gamma scintillator, while the alpha and beta dose rates were calculated from the concentrations of the radioactive elements U, Th, and K, measured by ICP-MS or ICP-AES (Porat and Halicz 1996). In this arid region, average water contents were estimated at 5±2%. TABLE 1 lists the field and laboratory data for all samples dated by OSL. The dates mostly range from 1800 B.P. for sediments at the base of the terraces to 380 B.P. at the top of a terrace at Nahal Besor (Avni *et al.* 2012). Scatter within the dates is due to incomplete resetting of the OSL signal in the quartz grains in sediments when they were transported to and deposited in the fields. Most likely the main agent of resetting was plowing; even if the sediment reached the field with some residual signal, as long as it was within the plow zone it would be mixed and exposed to sunlight on at least an annual basis. Only after burial at greater depths would the sediment be safe from bleaching.

Rough sedimentation rates can be guessed at from the continuously raised height of the terrace walls, which needed to accommodate the necessary amount of irrigation water. The height of the major terrace walls range between 1 and 6 m, and the duration of use of the fields is estimated as 400–700 years, giving accumulation rates of 0.25–0.7 cm per annum. Thus, a grain of quartz could have been in the bleach/plow zone 30–80 years before it was finally buried, and OSL provides minimum ages for cultivation of that particular level in a terrace.

Results

Nahal Mamshit

The agricultural system is located on the shallow plain, ca. 700 m from the outlet of a deep gorge and 2 km east of Mamshit, the largest Roman and Byzantine settlement in the northeastern Negev Highlands. The fields, built on a natural alluvial terrace south of the streambed, extend over an area of ca. 12 ha. In addition, smaller cultivation plots were located across secondary steep wadis that descend from a rocky ridge to the east of the plain (FIG. 5).

The accumulation of loess in the agricultural fields was dated by OSL showing that anthropogenic deposition occurred between the 3rd–4th centuries and the 11th century A.D. Three stratigraphic phases were identified within this period. The early system, constructed when the main streambed was at a slightly higher level than the present, was preserved only in limited sections because of severe erosion and later alluvial covering. It seems that the anthropogenic deposition of loess behind the stone built walls of the early system was minimal (up to 1 m) and

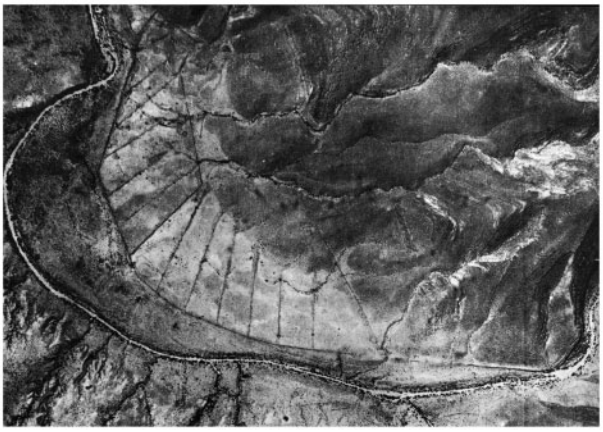

Figure 5 An aerial view of the Nahal Mamshit system (after Even-Ari *et al.* 1982: fig.74).

functioned for a relatively short period of time. The agricultural terraces of the early phase were constructed on top of a natural alluvial terrace consisting of limestone and dolomite pebbles from blocks derived from the walls and banks of a rocky canyon and its tributaries and of flint pebbles of the Hazeva formation whose outcrops are scattered in the dammed valleys and throughout the nearby plains. The early system was delineated by low stone walls and its lower part was installed parallel to the main wadi channel, which cut into the ancient natural alluvial terrace. The lower part of the system consisted of a number of dams built of low stone walls and included a solid wall that retained the diversion channel from adjacent Nahal Mamshit.

In the second phase, a massive dam was built near the outlet of the Mamshit gorge, from which a diversion channel extended southwards to the fields. This dam was completely washed away by later floods and only meager remains could be discerned. The catchment point from the streambed to the large diversion channel was at a slightly higher level than the channel's present flow level; hence the streambed has been downcut by ca. 1.5–2.0 m since the Byzantine period. The diversion channel, which extended from the outlet of the gorge ca. 400 m southward, was delimited by a solid wall. Its level was raised several times as a result of driven loess that accumulated in and around the channel and often blocked it. The channel's destination was a series of broad leveled terraces, including large, wide sluices (passages on the upper part of the terraces) that could have controlled considerable amounts of floodwater. In the second phase of the agricultural system the streambed was already downcut to its present depth. It seems that this stage was also short term due to the increased accumulation of sandy loess conveyed into the fields that clogged the channel.

In the third that final phase, the agricultural fields were built directly on top of the earlier second phase plots. The large diversion channel was abandoned and the supply of irrigation water to the fields was based on diverting runoff from a series of small drainage basins located on nearby slopes. These rocky basins consist of hard carbonate units of the Judea Group—the Netzer, Shivta, Derorim, and Tamar formations—which produce greater amounts of runoff even from small drainage basins of less than 2 sq km. A series of dams diverted water from the slopes and basins to a diversion channel leading to the upper fields of the third phase. The upper dam in this system was particularly notable for its large construction stones. Parts of the main diversion channel, leading from the dam and collecting water from additional basins, were quarried and excavated to a depth of more than 3 m in order to create a suitable downward gradient for the floodwater. The channel, ca. 2 km long, diverted floodwater to the highest point of the system and henceforth directly into the agricultural fields.

OSL dating of soil samples in the agricultural terraces revealed that the upper terrace was constructed in the 5th century A.D., and that loess accumulated behind the terraces from the 6th century A.D. onwards (TABLE 1). The two earlier phases of the system could not be reliably dated; however, it seems that these were only slightly earlier than the late phase and perhaps were constructed in the 4th century A.D. and functioned until the 5th or 6th centuries. It appears that the people tasked with the maintenance of the fields and diverting channels in the first two phases were confronted with difficulties. The early farmers had to cope with the hazards of accumulating loess and massive soil erosion. The abandonment of the large diversion channel from the Mamshit gorge was probably caused by a combination of a blockage and torrential flooding that destroyed the diversion dam. Thus, the third phase of the system employed a different strategy of water supply by collecting floodwater from secondary basins and avoiding the high volume torrential floods in the Mamshit gorge. The latest date retrieved from the upper sediments in the third phase revealed that the use of this system continued until ca. A.D. 1200, which is much later than those obtained from other regions of the Negev Highlands (see below). It may represent a local late reuse of the original Byzantine fields or rather indicates that fields were in constant use throughout the Early Islamic period. This chronological framework is inconsistent with archaeological finds from the nearby Late Roman and Byzantine settlement at Mamshit, showing that settlement declined in the 7th and 8th centuries A.D. (Negev 1988, 1993; Avni 2008). A continuous use of agricultural systems in the vicinity of the deserted town could link the cultivation of the fields to a nomadic population that may have continued to reside in this area of the Negev Highlands during the Early Islamic period.

Nahal Lavan

The agricultural systems of Nahal Lavan are among the largest and most impressive in the Negev. Nahal Lavan drains the slopes of the Matred Plateau and the western ridges of the Negev Highlands. The systems cut through hills of Cenomanian and Turonian age hard limestone and contribute to the formation of intense floods. The narrow streambeds in the southern sections of Nahal Lavan open into a broad alluvial valley south of Shivta, on which extensive agricultural systems were developed. These consist of massive terraces (up to 5–6 m high) that formed a significant section of Shivta's agricultural hinterland during the Byzantine and Early Islamic periods (Even-Ari *et al.* 1982; Baumgarten 2004).

One of the largest agricultural systems in Nahal Lavan is located ca. 3 km south of Shivta, where a series of high retaining walls formed a large field system adjacent to the main streambed (FIG. 6). The system is composed of large fields located on ancient natural terraces to the north and south of the streambeds. This area was studied by Even-Ari *et al.* (1982: 109–112), who defined three main phases of development and claimed that the fields were fed by diverting water from the main stream. As in Nahal Mamshit, the main problem facing the ancient farmers was the combination of large scale loess deposition which necessitated constant height-ening of terraces and the high velocity flooding in the main stream which destroyed sections of adjacent fields.

The detailed reexamination of the Nahal Lavan agricultural system revealed many secondary phases of reinforcement and modification to terraces and retaining walls, indicating an ongoing process of maintenance and repair. A thick layer of loess continued to accumulate behind the terraces and was periodically washed away by powerful winter floods. The fields were irrigated by two parallel sources: a large diverting channel that collected water from the main stream of Nahal Lavan, starting ca. 1.5 km upstream from the main system of terraced fields and a dense network of small channels that collected water from the rocky slopes near the fields. The collecting area was further extended by channels that diverted runoff from neighboring catchments areas.

OSL dates from sediments retained behind the terrace walls indicate consistent and prolonged use of the agricultural systems between the 3rd and 11th centuries A.D. Seven OSL samples were collected from various levels in the anthropogenic loess accumulation. The dates demonstrate that sediments were deposited directly on the ancient gravely natural terrace formed ca. 19 kya B.P., deeply incised into loess deposited along Nahal Lavan during the Late Pleistocene glacial phase (ca. 70–20 kya B.P.) (Avni *et al.* 2012). The beginning of anthropogenic loess accumulation on top of this gravely unit was dated to the 3rd century A.D., whereas the upper accumulations were dated to the 11th century A.D. (TABLE 1).

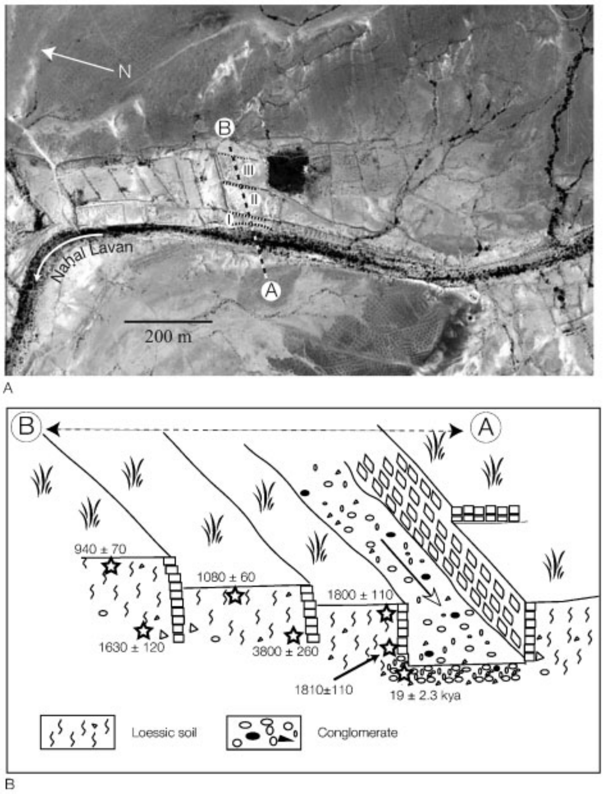

Figure 6 Nahal Lavan: A) A Google Earth image of part of the Nahal Lavan system showing the wadi bed and archaeological terraces. Section A–B crosses three terraces parallel to the wadi, marked as I–III; B) Schematic cross section (A–B in FIG. 6A) showing the stratigraphic relationship between terraces I–III, the underlying old gravel, the modern wadi bed, and the OSL ages (star symbols). The arrow in the wadi bed marks the drainage direction. Note that the age for the sample from the underlying gravel is in thousands of years (kya).

The fields were used for ca. 800 years and were abandoned in the 10th or 11th century. The terraces were breached and a long process of erosion and soil removal began which continues to the present day. This chronological framework corresponds to the archaeological findings in Shivta, showing that the settlement endured into the latter part of the Early Islamic period (Baly 1935; Avni 2008). It seems that the residents of Shivta and the surrounding villages continued to cultivate plots in Nahal Lavan throughout the Early Islamic period. The continuity of use in the large systems at Nahal Mamshit and Nahal Lavan and their abandonment around the 11th century provide evidence in support of an alternative chronology for the decline of the Negev agricultural

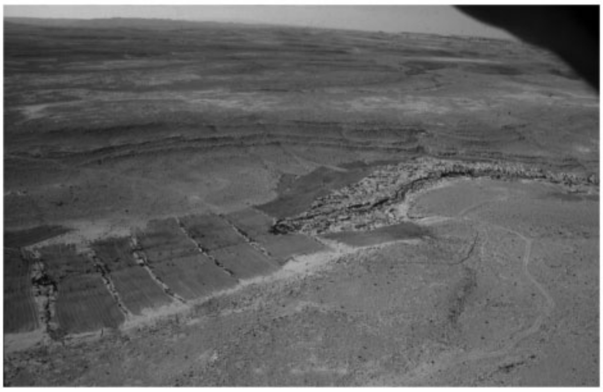

Figure 7 An aerial view of Nahal Zena. Note the terrace walls and plowed fields.

Figure 8 A typical eroded terrace in Nahal Zena.

hinterland, correlating it with the general decline of Palestine and other regions in the Near East during this turbulent period (Avni in press; Ellenblum 2012).

Nahal Zena

Nahal Zena is located ca. 8 km southwest of ʻAvdat, on the northern slopes of the Eocene rock formations of Har Nafha (FIG. 1). It has a relatively small, 5 sq km drainage basin compared with Nahal Mamshit and Nahal Lavan. The agricultural system examined here is composed of 150–300 m wide fields created by loess deposits and a network of terraces built across the streambed extending along a ca. 1000 m area (FIG. 7). A small site dating to the Iron Age and the Byzantine periods was found next to the fields (Lender 1990: 95–99). The intensive cultivation was connected to the Byzantine period remains, and so, forming part of the agricultural hinterland of ʻAvdat.

The agricultural system in the higher southern section includes numerous 2–3 course constructed dams situated across a moderate flow channel. The central section consists of larger dams, 10–12 courses high, constructed across the wadis in order to reduce the intensity of the floodwater. The lower northern part of the valley is narrow, ca. 30–40 m wide, and surrounded by rocky slopes. The bottom terraces are made of massive walls 1.2–1.5 m wide, consisting of two rows of medium size stones with gravel fill between them. The cultivated plots, built on both banks of the active channel, were delineated by stone walls and irrigated by diversion channels that transported water from the main stream to the fields. A number of terrace fills were sampled for OSL dating, revealing that the accumulation of soil behind built terraces began in the 3rd–4th centuries A.D. and ended around the 10th century A.D.

Stratigraphic analysis identified five phases in the accumulation. In phase one, the earliest identified remains are small segments of walls built of large stones buried beneath 3–4 m of loess accumulation, perhaps representing an early phase of farming at the site. This phase and the remains of the Iron Age settlement located nearby could not be correlated, but the fragmentary walls exposed in the eroded sections of the streambed may represent an earlier phase of agriculture in this area. For phase two, the construction of the main system of terraces began in the early 6th century A.D. This dating is consistent with pottery found at the site. During phase three, the agricultural system was in use until the 10th century, including a continuous process of terrace raising due to the accumulation of loess behind the walls. The construction of large terraces, the installation of the dams in the lower section of the system, and the large dam built in its lowest part attest to the attempts of ancient farmers to protect their fields from erosion by high velocity floods. In phase four, the fields were abandoned in the late 10th or 11th century and the large dam in the lower part of the system was breached. Massive backward gullying destroyed the fields and terraces and washed away the loess accumulation. Phase five shows that following the abandonment of the main system, there were cursory attempts to renovate the terraces to halt soil erosion. These were characterized by a casual reconstruction of destroyed terraces that involved a small investment of labor and were probably implemented by modern pastoral nomads who practiced sporadic cultivation.

Based on archaeological analysis and OSL dating, the geomorphological processes at Nahal Zena can be reconstructed as follows. The construction of the first terraces across the broad flow channel resulted in rapid loess accumulation behind the terraces reaching ca. 0.5 cm per year. This necessitated continuous maintenance, including a gradual raising of dams (FIG. 8). At the same time ancient farmers were preoccupied with the constant cleaning of diversion channels to prevent alluvium from collecting in them. The large accumulation of loess together with the constant need to repair damage required ongoing maintenance, likely creating an intolerable burden on local farmers. The decline of the Nahal Zena system in the 10th century might be connected to an inability to deal with the processes of both soil accumulation and destructive erosion.

Nahal Zena Iron Age "Fortress"

The possible connection between agricultural fields and nearby settlements from the Iron Age II period (10th–9th centuries B.C.), a highly debated topic in the archaeology of the Negev Highlands (Haiman 2003; Bruins 2007; Bruins and van der Plicht 2005; contra Finkelstein 1984; 1995; Shahack-Gross and Finkelstein 2007), was examined at another nearby site located in the upper tributaries of Nahal Zena. The "Nahal Zena fortress," an Iron Age II site located on the edge of a broad wadi plain, includes a massive structure with solid walls and casement rooms surrounded by residential dwellings (Lender 1990: 80–82; Cohen and Cohen-Amin 2004: 63–67) (FIG. 9). The ca. 100 m wide valley next to the site was extensively dammed with low stone terraces. Unlike most of the terraces in the region, these were built of large stones. The OSL dates retrieved from the loess deposits in the terraced fields indicate that these were first used not earlier than the 4th century A.D. The upper level of accumulation was dated to the 9th century A.D. (TABLE 1).

Despite the proximity of the ancient fields to the nearby Iron Age site, no evidence was found of their use during this period, leading to two alternate conclusions: either the Iron Age local population did not engage in agriculture, thus all the existing fields are of a later date, or perhaps there was a large scale erosive phase between the Iron Age and the Byzantine period that washed away earlier loess accumulations leaving no identifiable remains. As the extensive agricultural activity of the Byzantine period obliterated possible evidence of agriculture from earlier periods, further research and sampling is required in order to address the question of early agriculture in this region.


Figure 9 Nahal Zena Iron Age "fortress" walls with adjacent terrace walls and plots in the foreground. These terraces were sampled for vertically for OSL dating (see FIG. 3A).

Upper Nahal Besor

In order to evaluate the latest phases of agricultural exploitation in the Negev Highlands, another site was sampled where ancient fields were connected to a well-dated Early Islamic village. This settlement, located north of ʻAvdat, is a small valley on the upper tributaries of Nahal Besor (FIG. 1). It included a number of dwellings and agricultural installations, all built along the bottom of a slope facing a terraced wadi. The site was inhabited between the 7th and the 10th centuries A.D. (Ben Michael *et al.* 2004; Avni 2008). A number of agricultural installations, sheepfolds, granaries, and water cisterns were documented adjacent to the settlement.

The nearby agricultural system includes a series of low dams built across the valley, which amassed loess soil 0.8–1.0 m deep. An OSL sample from the lower part of the accumulation was dated to the 10th century A.D. (TABLE 1), the middle phase was dated to the 14th century, and the upper part of the loess deposits was dated to the 17th century. The later dates seem to be exceptional compared to other sampled sites. A tentative interpretation suggests that the fields were constructed in the Early Islamic period and used in conjunction with the nearby settlement. After the abandonment of the settlement, the terraced fields were maintained by local pastoral nomads who employed them for seasonal agriculture. If this was the case, it may indicate ongoing use of the fields from the Byzantine period to early modern times. The continuity of agricultural activity may also be associated with the revival of agricultural settlements in Palestine during the Mamluk and the early Ottoman periods (14th–17th centuries), but further research is required to clarify this, as no evidence of medieval settlements was retrieved during intensive surveys carried out in this area (Cohen 1981, 1985).

Upper Nahal Zin: Har Hemet and Mishor Ha-Ruhot

Several agricultural systems were investigated on the plateau north of Makhtesh Ramon (Mishor Ha-Ruhot). The terraces extend across wide plains in the upper tributaries of Nahal Zin and Nahal Nessana, where low intensity floods occasionally occur. Most terraces consist of undressed fieldstones, one or two courses high, which retain the accumulation of loess soil behind the manmade stone terraces. This soil, which is a result of anthropogenic intervention, is only 0.3–0.5 m. deep. This layer was deposited directly on the Late Pleistocene natural loess soil and gravel sequence (41 ± 5 and 13.6 ± 3 kya B.P.) (Avni *et al.* 2012). Another small system is located in a narrow stream on the slope of Har Hemet not far from an Iron Age site.

The OSL dates obtained from four agricultural systems in this area reveal long chronological sequences spanning the Iron Age to the early modern period. One sample, at Mishor Ha-Ruhot 1, obtained from a section of a shallow terrace, yielded an early date of 2850±290 B.P., which corresponds with the 10th–9th centuries B.C. settlement phase in the Negev Highlands. However, as this is the only early (Iron Age) OSL date obtained from an agricultural context in the Negev Highlands, it does not clearly indicate Iron Age terrace farming in the region. Other dates are consistent with large scale agricultural exploitation in the region between the 4th and 11th centuries. One sampled site (Ma'ale Ramon) shows late use in the medieval period between the 11th and 15th centuries. The shallow and ephemeral nature of the terraced fields in this region suggest that they represent construction by local pastoral nomads who adopted the practices of the more developed agricultural fields farther north.

Construction, Operation, and Decline of Agricultural Systems

The rise and demise of ancient agriculture in the Negev Highlands presents a clear chronology, which was obtained through combined archaeological analysis and OSL dating. Fields were constructed not earlier than the 3rd or 4th century A.D. and they were used continuously until the 10th or 11th century A.D. The question of earlier phases of agriculture in the region, particularly during the Iron Age, requires further research.

The development of the agricultural regime in the Negev Highlands with its sophisticated terraced fields and water collecting system seems to be a gradual process that was established independently in different regions, rather than the outcome of a government enterprise carried out over a short period of time throughout the region. While the early stages of use in the large systems at Nahal Mamshit and Nahal Lavan were dated to the 4th century A.D, those in Nahal Zena were established later in the Byzantine period during the 6th century. Similar to other Mediterranean agrarian societies, the expansion of agricultural systems in the Negev Highlands was connected to the economic system of the Byzantine world, rather than to the older indigenous Nabatean realm, which flourished in the fringe areas of the Levant between the 2nd century B.C. and the 2nd century A.D. (Rubin 1990: 163–180; Erickson-Gini 2012; contra Negev 1977, 1986). It is noteworthy that similar large scale agricultural systems in southern Jordan, for example at Wadi Feinan, Jebel Haroun, and Humayma (Barker 2007; Eadie and Oleson 1986), were dated to earlier periods, particularly the 1st and 2nd centuries A.D. However, the chronology of agricultural fields in these areas is mostly based on circumstantial evidence, i.e., their relation to nearby dated sites and the pottery found within the fields (which may have been carried with the loess deposits from other locations), rather than on the accurate dating of soil deposits. The flourishing agriculture in southern Jordan is well attested in the Petra papyri from the 6th century (Frosen 2004) and it seems that like in the Negev, its large scale development was a result of intensive settlement during the Byzantine period (Nasarat *et al.* 2012). Recent OSL and radiocarbon dating of agricultural systems near Petra demonstrate continuity through the 9th and 10th centuries A.D. (Beckers *et al.* 2012). The detailed work conducted at Wadi Feinan (Barker 2007) reveals a unique agricultural system of an earlier date than those prevailing in the Negev Highlands and it seems to us that it represents the exception rather than the rule.

Based on a study of the sites presented above, we suggest the following reconstruction for the life cycle of ancient agricultural systems in the Negev. The first stage included large scale construction of stone dams and terraces across flow channels of small and medium sized wadis ("streams of the first and second order" [Kedar 1967]) or on wadi terraces along the bank of the flow channel of a large stream (e.g., at Nahal Mamshit and Nahal Lavan). The dams were constructed on subsoil composed of loess sediments and natural alluvial gravels, which provided the substrate for the agricultural fields. Fine grain loess was washed from the slopes and deposited behind the terraces, improving the sediment mixture and rapidly transforming it into arable loess soil. It seems that the first concern of ancient farmers was to increase water flow into the fields and not the creation of additional arable soil (Even-Ari *et al.* 1982; contra Kedar 1967). In the second stage, concurrent with the terracing of the wadis, a system of smaller channels constructed on the nearby rocky slopes increased runoff from the slopes into dammed areas. In addition, diversion dams built across larger wadis carried water to fields built on side terraces. Finally, following the initial construction and deposition of loess behind terraces, ancient farmers were engaged with the arduous and continuous process of maintenance. This included raising the terraces in response to the accelerated accumulation of loess deposits behind them, cleaning and renovating the channels leading to the fields, and repairing the large diversion dams that would burst as a result of occasional torrential floods. All of these required a constant investment of manual labor.

The demise of the fields seems to have been associated with the deteriorating economic and political conditions and with the accelerated deposition of loess which required additional maintenance. The decline of the international wine market following the 7th century A.D. was a serious blow to the local economy in southern Palestine (Mayerson 1985; Rubin 1990: 89–90; Decker 2009) and it also affected the Negev Highlands agricultural systems. Nevertheless, most of the fields were maintained for another three centuries, perhaps shifting to local markets in central Palestine. It seems that the long term impact of the economic decline affected the resilience of the local society. Farmers could not cope with the destruction of terraces and dams and the fields were gradually neglected and abandoned. The abandonment of agricultural systems in the Negev Highlands is established with OSL dating. Most fields were maintained until the 10th and 11th centuries and ceased to be used only with the final abandonment of nearby settlements. Apparently this process was not connected to climatic fluctuations, as suggested by Huntington (1911), but rather to the economic and political instability in Palestine during the 11th century.

While historical accounts of the first half of the 11th century noted construction activities in the cities, most infrastructure was in a state of decline by this time. Archaeological research in the major urban centers of Ramla, Tiberias, and Caesarea indicates that the settlement crisis peaked in the third quarter of the 11th century with the decline of these cities. Although large settlements were not completely abandoned, they were reduced in size and population (Avni in press). This slump was particularly evident in rural settlements and villages on the periphery. The Negev Highlands and the Judean Desert were abandoned and farmland was left to wither.

What led to this downward spiral that culminated in the collapse of village settlement? This subject has not been adequately studied, but it appears to be linked to a combination of factors clearly manifested in the archaeological record. Political insecurity, protracted wars between the Fatimids and the Abbasids, and an onslaught of Bedouin raids served to weaken and eventually destroy the foundations of urban and rural life in Palestine (Gil 1992: 230–252). The Bedouin tribes from central Arabia and North Africa who infiltrated many parts of the Middle East in the 10th to 11th centuries were significant part of process (Fraenkel 1979).

A series of severe earthquakes in Palestine (particularly notable were the earthquakes in 1033 and 1068) contributed to the disintegration of the settlement network. While previous earthquakes left considerable damage in their wake, they did not lead to complete abandonment of settlements. The social and economic decline of the 11th century created a situation in which the local population did not have the resources to rebuild and get back on their feet (Avni in press). In addition to earthquakes, Palestine also experienced many years of drought. The problem was particularly severe between 1050 and 1070. Perhaps it was this combination of natural disasters that triggered the collapse of settlement in the Middle East in the second half of the 11th century, as recently suggested by Ellenblum (2012).

Conclusions

The reevaluation of ancient agricultural fields in the Negev Highlands provides new information about their technological and chronological aspects, focusing on three important topics. These include a clearer chronological framework for the initial construction, expansion, and abandonment of the agricultural systems; a better understanding of the technological aspects of operation of the fields; and the geomorphological factors affecting their function. This new chronology suggests a continuity of settlement in the Negev Highlands up to the 10th and 11th centuries A.D., contradicting previous estimates of collapse in the 7th–8th centuries A.D. The role of local societies in construction and maintenance of the systems demonstrates that the expansion of agriculture was part of the natural growth and development of Byzantine settlements in the Negev and was not the outcome of government planning. Although supported by ecclesiastical and imperial authorities, the Negev settlements were dependent on agriculture as a major factor in the local economy. Similar to the agricultural fields in North Africa, the Negev regime provided for the needs of local inhabitants, but also produced a large surplus that was exported outside the region. Lastly, environmental conditions in the Byzantine and Early Islamic period were similar to the present in terms of soil accumulation and erosion. There may have been small differences in precipitation but these are insignificant and would not have affected runoff agriculture in the arid regions of the Negev.

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