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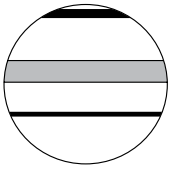

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Intensification of production in Medieval Islamic Jordan and its ecological impact: Towns of the Anthropocene

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Abstract

Medieval Islamic archaeology in Jordan is relevant to the 'Anthropocene' discourse because of state investment in intensive land use, including irrigation and diversion of local agricultural economies from subsistence crops to cash crops. Archaeology offers a deep-time perspective on these issues. Previous archaeological and historical studies indicate that major centers of Medieval agriculture deteriorated at some point during the 15th century, in part because of state economic withdrawal and this impacted land use. In this paper, we use phytoliths to understand agricultural practices of Medieval Hisban (Mediterranean vegetation zone), Tawahin as-Sukkar, Khirbet as-Sheikh Isa, and Beidha (semi-arid region of the Jordan Valley) to offer new insights into state agricultural policies in relation to ecological and environmental history. Our results show control of irrigable land by subsistence farmers gave them resilience and contributed to sustainable farming. However, state-managed agricultural systems expropriated irrigable land, emphasizing production of cash crops for state revenue, thus reducing sustainability and putting pressure on the landscape. Sugarcane production replaced cereal cultivation and led to wood fuel burning, enhancing landscape erosion. Phytoliths from Beidha indicate that intensive agricultural production extended to marginal areas with the use of irrigation, thus creating greater human impact on sensitive environments.

Keywords

Anthropocene, complex societies, environmental history, Medieval, phytoliths, political ecology, pre-industrial economies

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Introduction

In 2002, a new term was introduced to current environmental research as a new definition of the era we live in, the 'Anthropocene' (Crutzen, 2002). The idea that human activities are altering the natural landscape led to the recognition of anthropogenic influences as significant geological forces. A succession of causal events such as land-use changes, subsequent deforestation, and fossil fuel burning associated with population growth, vast urbanization processes, and agricultural intensification were emphasized as a new natural and cultural setting of 'anthropos' and his environment.

According to Crutzen (2002), the epoch of the Anthropocene started with the Industrial Revolution (AD ~1850). During that time, large concentrations of greenhouse gases such as CO_2 and CH_4 increased in the Earth's atmosphere. The rise of greenhouse gases at a global scale was emphasized and was directly related to a vast population growth and the burning of fossil fuels to the industrial activities. The global scale assigned to the Anthropocene became a challenge for researchers who try to identify global forces as having agency in history, perceiving humanity as a 'force' of impact in cross-cultural, multi-spatial, and multi-temporal contexts. Robin (2013) correctly identifies this process as difficult and points out that in order to inform global change, scientists who are interested in anthropogenic change should appreciate the contribution of history and archaeology to the Anthropocene debates. Although the main idea of the Anthropocene is that human activities have caused global changes in ecological, social, and political terms, historical and archaeological case studies of the pre-Industrial and Industrial era put emphasis on the local effects of human actions as well (Rull, 2013). Looking at climate change and its human dimensions outside of the traditional Industrial view as Ruddiman proposed will lead to the development of heuristic models of local and regionally specific human–environment interactions (Robin and Steffen, 2007), a civilized view of climate change (Rosen, 2007). Soon after Crutzen (2002) introduced the Anthropocene era with the Industrial Revolution, Ruddiman (2003) offered an alternative view of the Anthropocene, based on data from methane emission levels over the past 5000 years. He proposed that the onset of this new era began thousands of years ago. He and others (Fuller et al., 2011) cited evidence for methane emissions from rice cultivation in wetland areas, and methane input from livestock during middle and late-Holocene, in southeast Asia. They showed that atmospheric methane would have increased between 2500 and 2000 BC, given the growth of wet-rice lands and accelerated with the introduction of cattle after 3000 BC, reflecting later Holocene methane emission levels. Their main point was that early pre-industrial and agricultural activities and their impact on the environment were of a larger

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Table 1. Early, middle, and late Islamic Empires (after Walker and LaBianca, 2003).

Early Islamic (Umayyad, Abbasid)	Middle Islamic (Fatimid, Ayyubid, early Mamluk)	Late Islamic (late Mamluk, Ottoman)
600–1000 CE	1000–1400 CE	1400–1918 CE

scale than what was thought according to the industrial view. Within this theoretical framework, the economic investment of Early Empires and early industrialization in and outside Europe was proposed as a new focus of research on the Anthropocene.

In this paper, we present a case study from Medieval Jordan showing the environmental impact of the Mamluk state on semi-arid landscapes with the introduction of a cash crop economy including large-scale grain cultivation and sugarcane production. With this case study, we demonstrate how the industrialization and intensification of agriculture during the Mamluk period in Jordan affected small-scale communities and potentially their local environments because of state agricultural investment.

Pre-industrial Medieval societies of the Middle East: The 13th century World System

The development of an international trade economy that extended from northwest Europe to China during the 13th century marked an industrial and commercial revolution, which is of a particular interest to the pre-Industrial Anthropocene discourse (Abu-Lughod, 1991 [1989]). An expansion of industry and agricultural production driven by trade took place in the Medieval world, such as the development of Chinese metallurgy and paper making in the 12th century which expanded to the West by the 16th century. The Middle East was an important part of this commercial network where early Islamic Empires flourished and contributed to the development of this 'industrial' and commercial World System from the 7th to the 14th century (Table 1). This World System (Wallerstein, 1974) consisted of economic subsystems, including the region of Southern Levant.

The Medieval Islamic states (Table 1) collaborated with the western European and the Far Eastern subsystems on the basis of the production and export of agricultural products such as cotton, flax, and sugarcane and their industrial processing on industrial units that were established and maintained by the state (Abu-Lughod, 1991 [1989]). At the same time, one of the highest profit agricultural sectors of the Islamic states' economy in the region was the production of grains for local and export market and constituted the financial foundation of the Islamic states (Walker, 2008, 2009). The impact of this imperial agricultural investment and land management practices on the Medieval societies and landscape of Southern Levant offers an excellent historic case study of the pre-industrial Anthropocene era.

The effects of the cash crop political economy of Medieval Islamic states on the society and the environment peaked during the 13th and 14th centuries under the Mamluk rule (AD 1260–1516). This is one of the most interesting periods of study that can give great insights into changing human–environment relationships, shaped by agricultural intensification, cash cropping, and expansion of intensive agricultural production into semi-arid regions. Egypt during the 13th and 14th centuries largely invested in grain production, primarily wheat, and in two major industries: textiles that depended on the cultivation of cotton and flax, and sugar refining that depended on the cultivation of sugarcane. Both industries and the production of grains for export linked rural production and expansion to an 'industrial' economy which was highly dependent on state control and demanded the 'mobilization of peasant labor through the corvée (forced labor on the irrigation system)' (Abu-Lughod, 1991 [1989]: 232).

Sugar was grown in Egypt and South Syria, and sugar-refining factories were established on the plantations during that time. The scale of this industrial activity was immense if we consider that in Cairo alone 66 sugar refineries were in existence. In addition, in the 13th and early 14th centuries, Egypt largely invested in sugarcane production in the region of Jordan, and Sultans and amirs developed financial interests in the Transjordan as a whole. The sugarcane industry was a particularly very profitable enterprise in well-watered areas such as the Jordan Valley, and mills have been attested archaeologically in the Madaba Plains and Ajlun region (Walker, 2003). Egypt and Syria were providing other Arab countries, as well as Italy, southern France, Catalonia, Flanders, England, and Germany, with refined sugarcane during the Mamluk period until the 15th century when European sugar-refining techniques improved and the Levantine sugar industry declined when the Mamluk state declined as well (Abu-Lughod, 1991 [1989]).

Research that examines local state investment and changes in land use, water systems (irrigation), and climate as factors that transformed settlement shifts documented in the archaeological and historical records places Islamic archaeology in the Anthropocene discourse. This paper focuses on aspects of local-scale human influence on the natural environment related to the industrialization and intensification of agriculture during the Mamluk period in Jordan. The intensification of agriculture relates to bi-seasonal agricultural practices and diversification which were introduced in the early Islamic periods and continued into the Mamluk era. Also, industrialization of agriculture refers to the introduction of the sugarcane industrial agriculture.

The project focuses primarily on issues of large-scale grain production and the establishment of a new plantation economy of sugarcane production. It aims to examine how small-scale communities adapted to large-scale changes such as financial and political reforms of Mamluk state and to the potential change of their local environments due to climate and state agricultural investment. In the next section, we discuss two major economic reforms in Mamluk Jordan that directly affected the rural population and their environment. The first one is the *iqta'* system, and the second one is the privatization of estate lands and their endowment as *waqfs* for revenues that supported both institutions in Egypt and trade. These processes are very important and highly related to the Anthropocene discourse. These reforms define the relationships between the rural population and the state with the environment and the potentials of the rural population for adaptation to a new cash crop economy. The state policies reduced the flexibility and resilience of the environment at the time and as a consequence the potential for resilience of the subsistence farmers (Laparidou, 2014).

Islamic archaeology and the Anthropocene discourse

Surveys and historic account information that focus primarily on macro-level changes of state economy and demographic patterns (Kareem, 2000; King, 1992; MacDonald, 2009; Yassine, 1988) suggest a model of economic decline at the end of the 14th century in Jordan. An increase in settlement was driven by the establishment of the Mamluk rule (mid-13th century) and the resulting agricultural and administrative investment by the state. Extensive agrarian investments during the Mamluk period in central Jordan and Ajlun region contributed to the direct demographic growth

and agricultural revival of the region (Walker, 2011) as a result of the implementation of the *iqta'* system. Also, archaeological surveys indicate that many Mamluk era sites were established on marginal areas of Jordan such as the southern Jordan Valley and northeast Arabah (MacDonald, 1992).

Prosperity was evident particularly at the areas of the central plains of Madaba where investment in large-scale production of grains took place, and in the Jordan Valley an area of large plantations of sugarcane. The Northern part of the country witnessed a flourishing of agricultural and economic wealth as well. These state-level economic, agricultural investments sustained many towns and villages in the 13th and 14th centuries (Walker, 2004a, 2004b). Economic and demographic prosperity was followed by a period of settlement decline during the end of the 14th and 15th centuries, a phenomenon that in the literature is called 'the period of Mamluk state decline'. According to this model of economic decline, the direct response of the Medieval people to the withdrawal of Mamluk rule was the abandonment of their permanent settlements and a shift to a more nomadic way of life (Kareem, 2000; MacDonald, 2009). Both historic accounts and archaeological surveys give evidence for a lack on investment by Mamluk state in security, infrastructure, and agriculture at the 15th century, indicating a breakdown of the state politically and militarily (Walker, 2011, 2012).

However, recent surveys and excavations conducted on geographically and historically distinct regions of Jordan, the central plains and the North of the country, suggest that some areas especially in the North did not follow the trend of 'decline' and remained viable and strong in population and agricultural investment throughout the 15th and 16th centuries, up until the present day (Ames, 2012; Porter et al., 2010; Walker, 2005, 2012; Walker and LaBianca, 2003). This led to a new direction of research on the Political Ecology of Medieval Jordan that considers regional differences of state-level investment and village-level economies in distinct geographical areas. This new research is based on historic documents and excavations and suggests that state agricultural activity and exploitative strategies employed by the Mamluk state must have affected local Medieval communities and their environs. However, archaeological evidence testifies that local communities did not abandon their regions but were reformed, dispersing and shifting to a small-scale agricultural economy of small plots of grain and orchards (Walker, 2012).

The Mamluks invested in the area of Jordan in order to serve their financial and administrative interests on selected regions according to geographical, natural, and human resources (Walker, 2003, 2007a, 2007b). The main element of the Islamic state's agricultural investment was the *iqta'* system. *Iqta'at* were grants of primarily land tax in lieu of salaries in the Mamluk period, and they were the main system used to pay army officers. They were evaluated at the time by grain yields which were produced on state-controlled lands and supported the state financially through agricultural production for profit and export (Walker, 2007a, 2007b).

Most of these landed estates that were dedicated to the production of cash crops were located near wadis (seasonal streams) and their tributaries at the Jordan Valley and the orchards of the well-watered North at the Sawad region (Walker, 2003). They were used for the cultivation of water-intensive crops particularly in the area of the Jordan Valley, as well as along the major highways and near springs (Walker, 2003). Generally, these were the main cultivated areas, and agriculture was practiced on marginal, rain-fed lands for agriculture (marginal for crop production). The latter comprises the majority of Jordanian land with the exception of the Jordan Valley. Among the regions of Jordan where irrigation agriculture was practiced with the exploitation of distant water by *qanats* were the Jordan Valley (Ghor area) and the Yarmouk/Irbid region (Lightfoot, 2000). The local environment of Medieval Jordan was altered and consequently so were local custom and peasant economy because Jordan's rich farmland was exploited to support the *iqta'* system that Mamluk government inherited from the Ayyubids. An enterprising officer, in order to maximize his revenues, would invest in his estate (*iqta'*) in order to squeeze out a greater salary. Most though, did not and, were not actively involved in the management of their *iqta'at*. The *iqta'* was managed by local managers, the *muqta's*. The *iqta'* was not the private property of the *muqta'*, and he did not necessarily have a moral interest in the management of the plot. The *muqta'* resided on the *iqta'*, but he did not have to be present all the time. He was responsible for water management issues and tax collection, sometimes with the assistance of agents (*wakils*). In addition, it was his responsibility to overview the cropping and harvest processes and was able to intervene between arguments among peasants on crop and water management issues. The general view of agricultural manuals and historic records is that local custom prevailed in that process, meaning sowing time, rotation of crops and harvest, or water management. However, that was not the case for the most profitable *iqta'at*. There the state made its presence more noticeable during harvest and at the threshing floors. The one exception was the sugar plantations. They are called plantations as they transformed traditional crop rotation, water sharing, and labor organization. There the *muqta'* was monitoring the cropping and harvest processes (Walker, 2011: 196–197). While mismanagement and further abuses of the peasants and their environment were possible, this was not the case necessarily if the person who purchased the land and subsequently endowed it was a local farmer or member of the rural elite (Walker, 2011).

The effects of Mamluk political economy on the society and the environment of Medieval Jordan

According to Walker (2003), during the period of the Mamluk plantation economy, although local custom prevailed in matters of cropping harvest and processing in Medieval Jordan, this did not apply for the sugar estates. Sugar production was closely monitored and became predominant over other crops and traditional water sharing agreements. The production of sugarcane interrupted traditional crop rotation and the planting of summer crops. Also, large investment in grain production to maximize profit for the *muqta'* on *iqta'* land would conflict with traditional agricultural practices. According to the Mamluk and Ottoman registers, local farmers returned to traditional agricultural practices in all regions only in the 16th century, after the collapse of the *iqta'* system (Walker, 2011).

Under the *iqta'* system and during the periods of the privatization of the *iqta'at*, the new landowning class that emerged did not have the same sense of responsibility toward local society and local lands. Agricultural practices during the 13th and 14th centuries on the most fertile lands of Jordan were driven only by profit. The environmental implications of this large-scale state agricultural investment, for both sugarcane and wheat production in a semi-arid region such as Jordan, could have been immense. Sugar cultivation is demanding in terms of water resources and fuel which is required for processing (Galloway, 1989). This could have led to deforestation of state land and consequent erosion of soil cover.

In private or individually held land, the individual would have made decisions on cropping according to markets and environmental factors, grazing land tends to be freed up for cultivation, and there are significant financial incentives for the individual to invest in the land through terracing or irrigation (Palmer, 1998; Rosen, 2007). Cash crop farming and periods of reduced rainfall may have caused environmental degradation and crop failures during the Mamluk rule (Walker, 2008). Due to deforestation,

there must have been alluviation in the valleys leaving bare hills as visible today across Jordan (Rosen, 2007). Both the sugar industry and the production of grain surplus replaced a traditional agricultural economy with a cash crop economy that in combination must have caused stress to the local environmental settings. A diversified agriculture shifted to a specialized regime and was profit-driven in Egypt and southern Syria in the 13th and 14th centuries (Walker, 2003). Wheat from Jordan supplied Cairo and Damascus in times of want, and grain fields here constituted some of the most dependable financial support of the state since the Ayyubid period (Walker, 2009). The largest fields were on the open plains of central and southern Jordan.

This new cash crop economy, and in the case of sugarcane a plantation economy, must have affected the long-term health of the environment. According to historic documentation, the new mono-cropping system did not allow for the traditional two-crop rotation agriculture to prevail, which allows for the alteration of winter crops with summer legumes and vegetable in order to replenish soil nutrients (Walker, 2009). Thus, reduced fertility of the agricultural land, deforestation, and accelerated erosion processes may have been the consequences of the 13th century political economy of pre-Industrial Mamluk Empire in Jordan, which collapsed during the 15th century.

The contribution of historical and archaeological data analysis to the Islamic period Anthropocene discourse

Recently, several archaeological projects on administrative, industrial, and rural sites were initiated in Jordan. They aimed to explore local Medieval political economies and to reconstruct local land-use histories at different geographic regions of Jordan. As a result, more data became available for the life and organization of the Medieval economic centers and villages (Porter et al., 2010; Walker, 2003, 2005).

The Mamluk political economic reforms of land management and ownership of agricultural land, namely the *iqta'* system, and the privatization of state lands and their endowment as *waqfs* for revenues that supported both institutions in Egypt during the cadastral survey of al-Nasir Muhammad in 1313 shaped the relationship between the state and local population and dictated middle Islamic social transformations in Jordan. Communities of the well-watered areas in the North part of Jordan and areas with access to state investment on irrigation systems did not abandon full-time settlement at the end of the 14th century (Walker, 2003, 2005). In contrast, communities in semi-arid regions of the Jordanian plains and southern parts of Jordan were more dependent on rain-fed agriculture. Accordingly, the latter groups relied on state support for bad years of inadequate rainfall. As such, at the end of the 14th century, the peasants of southern and central Jordan were at higher risk of food shortage in the absence of state support and adopted an internal migration buffer strategy. One response of local communities to the decline of the state was the dispersal of populations from the larger villages. Villagers migrated to the safer hill country of the plateau margins (Walker, 2004a, 2004b, 2007a, 2007b, 2012).

Archaeology and history can greatly contribute to the reconstruction of micro-level cultural changes that refer to village-level economy and how the latter might have varied locally because of state-level economic reforms. In particular, the analysis of micro-botanical and macro-botanical evidence from excavations at Medieval villages that contain stratified domestic deposits dating to the phases before and after the Mamluk rule (12th–16th centuries) across different environmental zones could detect regional patterns of subsistence strategies and responses of the rural population and the environment to political and natural stress. Such information on village-level Medieval agricultural economy is not clarified in historic sources and archaeological work on Medieval Jordan and is directly related to the Anthropocene discourse. Phytoliths provide direct evidence for the reconstruction of village-level and state-level agricultural regimes and for the ways that Early Empires affected the subsistence strategies of the commoners and their natural environment.

Study area

Analysis of sites and micro- and macro-botanical data analysis

Tawahin as-Sukkar and Khirbet as-Sheikh Isa. Tawahin as-Sukkar and Khirbet as-Sheikh Isa are located in the Ghor Valley and were thriving centers of Mamluk agricultural economy (Jones et al., 2002) (Figure 1). The former is one of the largest sugarcane factories in Jordan, with two mills, a boiling room, and additional wheat mills, while the latter is a Medieval village located within walking distance from the factory. The latter is a Medieval village that has an outstanding stratigraphy and rich Medieval occupation surfaces. The earlier stratigraphic layers date to the Byzantine period. Also, there are two layers of Umayyad and Abbasid occupation and three phases of Mamluk occupation. The Ottoman settlement is located approximately 5 km east of the site. The Mamluk occupation is the most dominant, and this is directly related to the presence of the sugar production and processing factory. The sugarcane industry declined in the mid-14th century, and according to historical sources, it is not mentioned at all after the 15th century. This is an important site that offers a unique case study of Mamluk state industrial and agricultural economy and is important for understanding the impact of early industrial development on the landscape and environment of the Southern Levant that predates the European Industrial Revolution.

Tawahin as-Sukkar and Khirbet as-Sheikh Isa: Sampling contexts and justification. At these sites, samples came from the excavated stratified domestic deposits that date to the phases before and after the incorporation of the region under the Mamluk rule and the sugarcane factory deposits. A pile of ash next to the factory will offer direct evidence for the continuous use of fuel in the region for the century in which the factory was in use. This is a unique opportunity to collect information on the agricultural economy that sustained the Medieval villagers (that most probably were the working labor of the neighboring industrial unit) and its impact on the environment before and after the abandonment of the factory. These samples will provide botanical evidence for the dichotomy of the village-level agricultural sustainability of this community versus the state pressure for profit with a view to understanding the impact of these opposing goals on the environment.

Beidha. The Medieval village of Beidha (15th–16th centuries CE) is located 4.5 km north of Nabataean Petra, at c. 1020 m above mean sea level (Figure 1). It is situated within the alluvial valley created by Wadi el-Ghurab, which reaches Wadi-Araba in less than 2 km downstream of the site (Rambeau et al., 2011). In this environmental zone of the southern sandstone mountains (Cordova, 2007) between the Mediterranean highlands of Jebel Shara and arid lands of Wadi-Araba, the alluvial valleys of Beidha provided a shelter for its inhabitants. Springs near the site are that of Ain-Musa and Dibadiba, 4 and 3 km away from Beidha, respectively, and steppe-type vegetation is predominant (Rambeau et al., 2011). With a mean annual precipitation varying between 170 and 200 mm, agriculture at Beidha is rather opportunistic depending on annual rainfall and snowfall levels (Rambeau

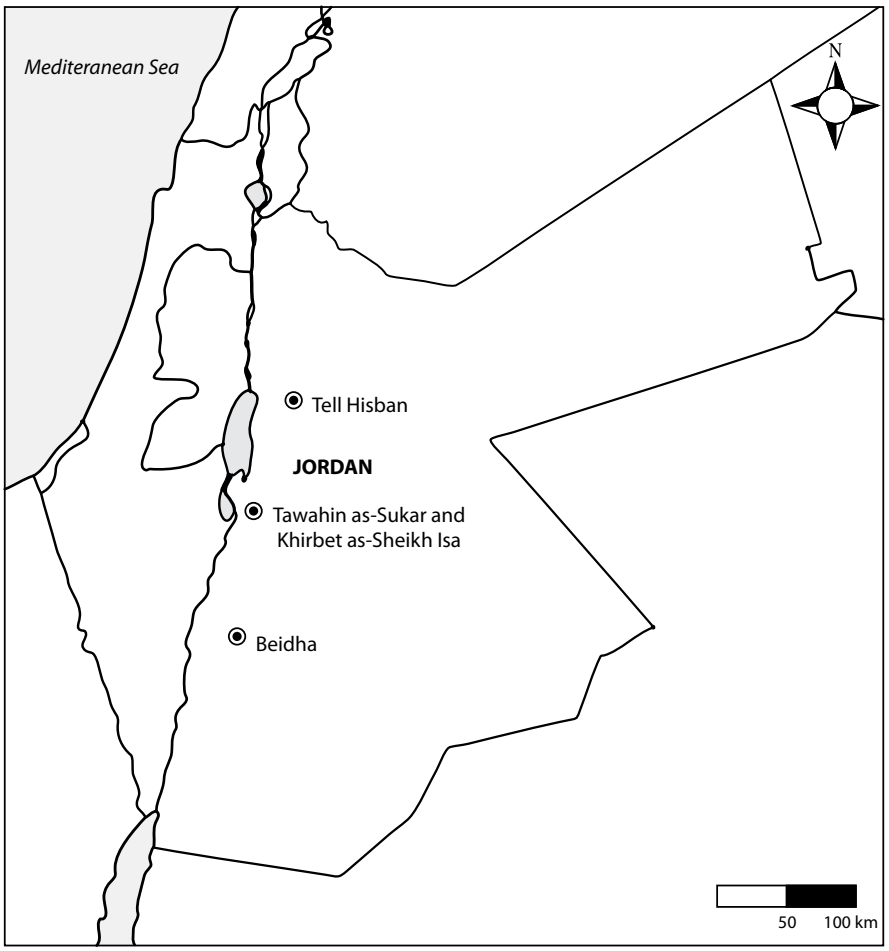

Figure 1. Study area (courtesy of Monica Ramsey).

et al., 2011). The soils of the area are limestone and sandstone mixed soils that do not retain rainwater. Although it has been reported in the literature that agriculture at Beidha was assisted by canal irrigation and use of cisterns systems, the annual precipitation and soil conditions offer rather uncertain conditions for village-level agricultural economy (Bikai et al., 2005; Cordova, 2007). This village serves as a good example of how state-supported communities expanded into marginal farming environments and how village-level agricultural practices could have had lasting impacts on the localized ecology of those areas that extend into the present day.

Beidha: Sampling contexts and justification. The excavated Medieval site revealed three phases of occupation and a complex of rooms, courtyards, and architectural features such as animal pens, storage pits and a storage room, pottery workshops, *taboons* (ovens), and re-furbished beaten earth surfaces of courtyards. According to Sinibaldi (2010, personal communication), occupation surfaces indicate repeated kinds of actions on the same areas and thin stratified deposits indicate a short time-span of occupation. This could correspond to a short term but repeated occupation of the site by agro-pastoralists that depended on their livestock. The analysis could show whether the local community could sustain a subsistence agricultural economy and their adaptive economic strategies to cope with agricultural uncertainty in the absence of state-level support during bad years of inadequate rainfall. Our analyses suggest that the peasants intensified their production via irrigation at a village-level through runoff-water farming and the use of cisterns in the vicinity of the site. They could use an agro-pastoral economy to buffer against the uncertainty of local low crop yield during dry years, and villagers could count on the exchange of animal by-products for grain. The population of Beidha could make due in years of higher rainfall, but probably relied heavily on state support during a series of drought years.

Tell Hisban. The historic site of Tell Hisban is located southwest of Amman overlooking the Madaba Plains region and is located approximately 25 km from Amman (Figure 1). The site is on a strategic historical location on a caravan route of the Medieval Islamic period from Damascus to Mecca and near historically documented rich agricultural lands. The natural water resources of Wadi Majar, Wadi al-Marbat, and the Jordan River and an annual rainfall of 500 mm along with the presence of rich soils make for a productive natural environment (Walker and LaBianca, 2003). The wadis are largely spring-fed. The nearest major spring to the site is ‘AynHisban, which is 2 km away. Archaeological remains testify a Byzantine town, an Umayyad and Abbasid domestic and defensive use of the Tell (Early Islamic *qasr*), and a continuous growth and re-use of structures until the early 14th century. It is identified in historical sources as an agricultural and market center of the Mamluk period that produced fruit, vegetables, nuts, sugar, and wheat for exports to Cairo. It became the capital of Balqa from AD 1309 to 1356 when finally the administrative center was moved to Amman (Walker, 2003). The summit of the site was the administrative and residential area of the governor, and the Medieval village was located on the slopes around the summit. During the 14th century, the site of Tell Hisban, although it is located in this fertile region of Jordan, would have been greatly impacted by the pressure on local agricultural production to maximize profit for the *muqta’*. Due to the vast urbanization of the area and the apparent population growth, the amount of land cultivated may have increased, most probably

Table 2. Single-cell or multi-cell morphotypes used to identify crop-processing stages' by-products.

Plant part	Single-cell	Multi-cell
Unidentified husk (late stage by-product, if free-threshing wheat was produced)	Long dendritic	2–5 conjoined single-cell insufficient for identification
Wheat husk (late stage by-product if free-threshing wheat was produced)		Rosen (1992)
Barley husk (late stage by-product)		Rosen (1992)
Sedge stem (Cyperaceae) (mainly used as fodder and dung presence indicator)	Long rods	Long smooth conjoined single-cell of varied width and attached visible cones
Wild grass husk unidentified (early stage by-product, mainly used as fodder and dung presence indicator)		Echinate, dendritic, sinuate, and zigzag pattern of conjoint cells. Papillae varied in size and shape with high number of pits above 17–18
Grass leaf/stem	Long smooth	Long smooth multi-cell
Cereal straw (early stage by-product)		Rosen (1992)

accompanied by deforestation. The state depended on the local produce of wheat for export not only to Cairo and Damascus but also to other areas of Jordan and may have pushed this administrative center, its inhabitants, and its natural surroundings to the limits. We do not know whether the lands of Hisban constituted an *iqta'* although this is highly likely (Walker, 2011).

The original Hisban team in the 1970s suggested that the site was abandoned after Timur's invasion in the early 1400s. Ottoman tax registers indicated that by the end of the 16th century, there were no permanent residents on site and that it was occupied maybe on a seasonal basis. However, recent excavations and phytolith data report evidence of re-used structures and secondary contexts such as hearths and storage bins and local agricultural production that date to the 15th century (Laparidou, 2013; Walker, 2012). Similar patterns of continuous occupation are suggested by excavations in the neighboring Medieval rural village of Tell Dhiban (Ames, 2012; Fatkin et al., 2011; Porter et al., 2010). However, the site of Tell Hisban was supporting the local catchment or other broader areas with grain for almost a century under the safety net of state support until the 14th century. The Mamluk empire could force the local population to maximize production for profit and could shelter and support the villagers during periods of drought or bad years. However, when the Mamluk state withdrew its administration investment, the local population lost its support during lean years. State support came in all the following forms. Towns (*madinahs*) such as Hisban, Salt, Karak, and Irbid were rural capitals of Jordan which were the basic administrative units. The state transformed them into major economic centers and castle cities that overlooked the surrounding farmland and villages. They functioned as administrative and military centers, and the state enhanced agricultural development, security for regional exchanges, jobs, and new markets. The state invested in the construction of the citadel at Hisban, in the 13th century, invested in not only defensive works but also other infrastructure such as roads, storage facilities, and water works (Walker, 2011: 139) Thus, economic prosperity and rural rejuvenation resulted in the creation of a very strong town in the 14th century that controlled 300 villages (Walker, 2011: 142). Also, according to 16th century registers, tax authorities discriminated between villages and towns (such as Hisban) and were assigned different tax rates based on differences between the town, that is, whether they had a major market, in which case the town had to pay the *baj bazar* (Walker, 2011). This loss of support was particularly problematic when the plains around the settlement were degraded and depleted.

Tell Hisban: Sampling contexts and justification. We sampled contexts at villagers' farmhouses and animal pens, as well as the 14th century Governor's storeroom and the 16th century re-used citadel. In this paper, we investigate controlled food distribution and large-scale storage of irrigated crops versus small-scale household level storage. Botanical analysis will test a potential replacement of a market-based agriculture in the 14th century with a small-scale subsistence farming and agro-pastoral local economy that could have sustained a local community at the turn of the 15th century.

Methods of analysis

The methods used in this project in order to identify the impact of Medieval Industrial activities on the environment and on village-level subsistence strategies depend on the potential of phytoliths and macro-botanical data for plant and crop identification. Also, analysis of crop-processing stages' indicators (Table 2) and identification of irrigation signals are useful in order to infer intensification of production and help reconstruct the effects that Medieval industry had on risk-buffering mechanisms of Medieval peasant communities. Macro-botanical remains from the sites and contexts presented in this paper were collected as well as phytoliths, but have not yet been analyzed. However, we may suggest that both hulled and naked grains were produced during the Mamluk period, in Jordan. Fatkin et al. (2011) presented the results of macro-botanical analysis on samples that derived from the Medieval rural site of Dhiban, which is located near Tell Hisban on the Madaba Plains. Both hulled and free-threshing grains were present on site. This is important for interpreting husk phytoliths present on the sites analyzed in this paper, as they will be considered an early stage by-product of potentially free-threshing wheat, based on the presence of free-threshing wheat (*Triticum aestivum/durum*) in the contemporary Mamluk village of Dhiban (Fatkin et al., 2011).

Phytoliths are particles of amorphous silica that are formed with the absorption of ground water by the plants when living. Silica (opal) is deposited in and around the cells of plant epidermal tissue, and the shapes of these cells define phytoliths morphology. For the purposes of archaeological analysis and interpretation, the recovery and identification of two major types of phytoliths are necessary: single-cell and multi-cell phytoliths (Rosen, 1999). Single-cell phytoliths are individual cells formed within the plant and multi-cell phytoliths are conjoined single cells that form silica skeletons of adjacent cells of the epidermal tissue of grasses (Rosen and Weiner, 1994).

The two major economic plants used for identification and analysis in this study are wheat and barley, given that their identification is possible using specific morphological criteria of multi-cell phytoliths (Rosen, 1992, 1993). As they are a main staple and, in the case of wheat, a cash crop of the period of study, their identification is crucial in order to trace the influence of the state and state economic interests, and impacts on the environment and society through the establishment of a cash crop economy and in the case of sugar estates, a plantation economy.

In addition, using phytolith analysis it is possible to determine whether agricultural crops identified on sites under study were produced locally before and after Mamluk rule. This is possible

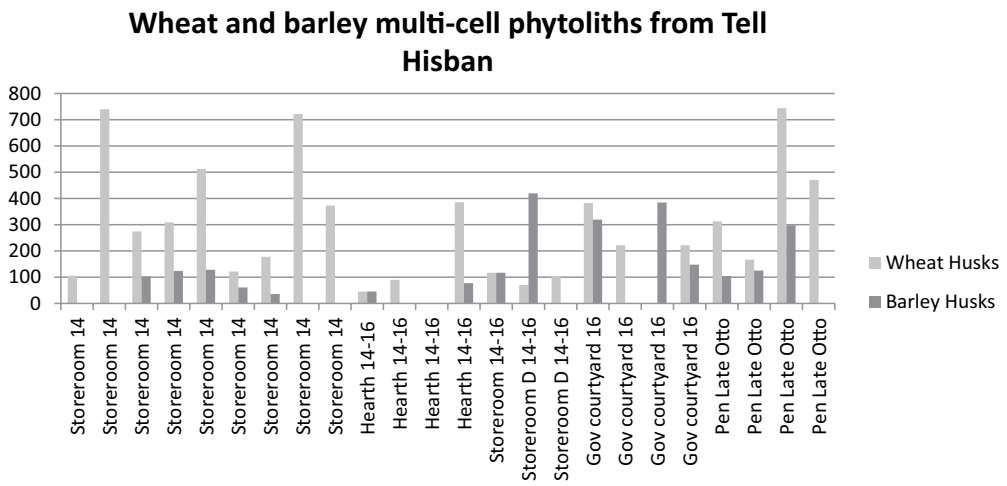

Figure 2. Agricultural production at Tell Hisban, Jordan.

because phytoliths are diagnostic of different plant parts such as the stem and husk, and they can be used as indicators of crop-processing stages' by-products. Crop-processing stage can be determined by the proportions of cereal grain, cereal chaff, and weed seeds in the sample (Bogaard et al., 2005; Jones, 1984, 1987). Positive correlation coefficient graphs of weeds/straw, husk (wheat and barley)/straw, and husk/weeds indicate local production (Harvey and Fuller, 2005; Hillman, 1981, 1984; Jones, 1992, 2002). Macro-botanical data will also help to explore the crop-processing impact in sample composition, but the assemblages from the sites under study have not yet been analyzed. These methods of analysis are used in order to identify local production and to describe sustainable agriculture of cereal crops during periods of state control (13th and 14th centuries) and during periods of 'decline' (end of 14th and 15th centuries).

Also, the analysis will explore whether local subsistence farmers employed intensified agriculture in the absence of state support during bad years of inadequate rainfall via irrigation. Phytoliths can be used as evidence of past irrigation systems based on multi-cell phytolith size, and the intensification of production could be inferred (Jenkins, 2009; Madella et al., 2009; Mithen et al., 2008; Rosen and Weiner, 1994; Weisskopf et al., 2014). In order to identify what were the main economic plants and crops, multi-cell phytoliths are used. Limitations of crop and plant identifications through phytoliths will be assisted by macro-botanical analysis and vice versa. Phytoliths can be used to identify major economic crops such as maize (Pearsall, 1978, 1987; Piperno, 1984, 2001, 2003; Piperno and Flannery, 2001); Poaceae family cereals, some wild cereals, and dates (Rosen, 1992, 1993; Rosen and Weiner, 1994); rice (Harvey and Fuller, 2005; Pearsall et al., 1995); millets (Harvey and Fuller, 2005; Houyuan et al., 2009); Cucurbitaceae family plants (Piperno et al., 2000); and a number of Cyperaceae family plants (Ollendorf, 1992). Dicotyledonous plants (woody shrubs and trees, fruits, and pulses) offer limited identification potential (Bozaarth, 1992).

Preliminary results

This preliminary data analysis shows the potential of phytoliths and the sampling strategy adopted for this study to explore the industrial and agricultural economy in Medieval Jordan. It also shows the potential of the analysis to identify similarities and/or differences of the subsistence economy in different regions in Jordan and the heavy impact of the Medieval industry and economy on the environment and the local communities. This analysis is an example of a study on an earlier beginning to the heaviest impact of the Anthropocene, earlier than the European Industrial Revolution. The three distinct cases of Medieval sites in favorable but risky environmental regions for agriculture offer excellent examples of analysis on 'towns of the Anthropocene'.

Tell Hisban

It appears through the phytolith record of multi-temporal contexts of Tell Hisban that wheat remained the most common and important crop in the periods studied, and also that wheat production was local, as suggested by the presence of chaff versus its absence which might indicate the supply of clear grain from elsewhere. The local, heavy investment and intensification of production of grain, particularly wheat (Figure 2), are reflected in the phytolith record as a marker of the continuous intensified agriculture under Mamluk rule in the region of Tell Hisban.

The influence of the state and state economic interest and control is reflected in the phytolith evidence for irrigated wheat and barley, the two main staples and cash crops that Hisban was distributing across Jordan and to Cairo and Damascus (Figure 2). The Mamluk state economic interests contrasted with the Jordanian peasant sustainable systems and must have led to a pronounced impact on the environment due to imperial and soil exhausting agricultural regimes. The flexibility and resilience of the peasants depend on their autonomy to invest in strategies of adaptation that minimize their risk. These are social networks and redistribution of labor, mixed cropping, dispersal of fields, migration, growing of a range of crops such as summer crops, fruits, and vegetables, reliance on intercropping and livestock, which serves as a repository of grain surplus, and more. The choice to shift between intensive/traditional agriculture that does not require large labor input and minimizes risk and between intensive agriculture that requires greater labor input but offers greater security due to the production of surplus offers a variety of cultural resilient mechanisms to the agricultural communities (Halstead, 1990; Halstead and Jones, 1989).

In the case of Mamluk Jordan, the direct impact of the implementation of the *iqta'* system was that peasant became landless and was much more restricted to practice traditional agricultural regimes under the pressure for increased annual yields for the *muqta's*. The true cushions for the environment and the peasants, a moral traditional agricultural economy, and a system of risk minimization strategies were taken away as a possibility from peasant communities under the new cash crop economy.

The data for an intensified production of wheat and barley (Figure 2) suggest that peasant had to deal with a degraded environment after centuries of extensive ploughing and the interruption of the fallow periods during imperial agricultural regimes.

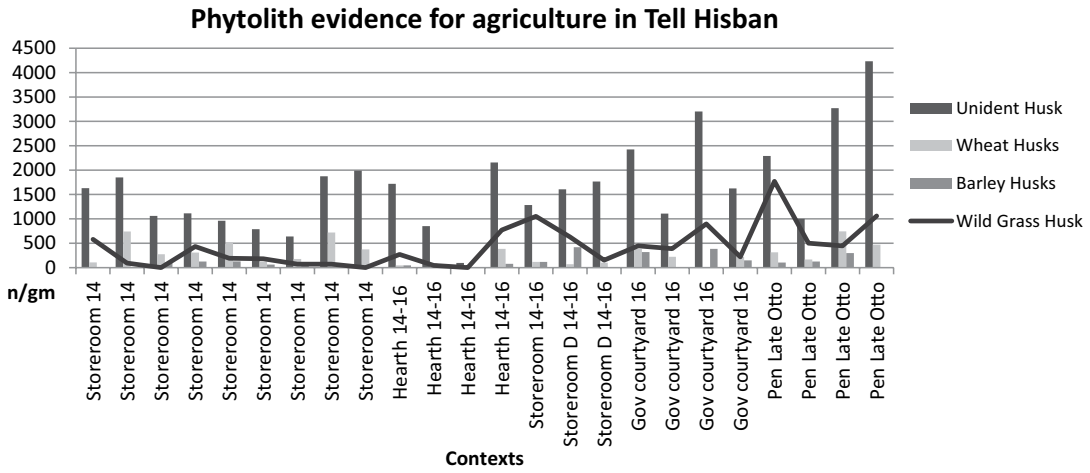

Figure 3. Phytolith evidence for agriculture in Tell Hisban, Jordan.

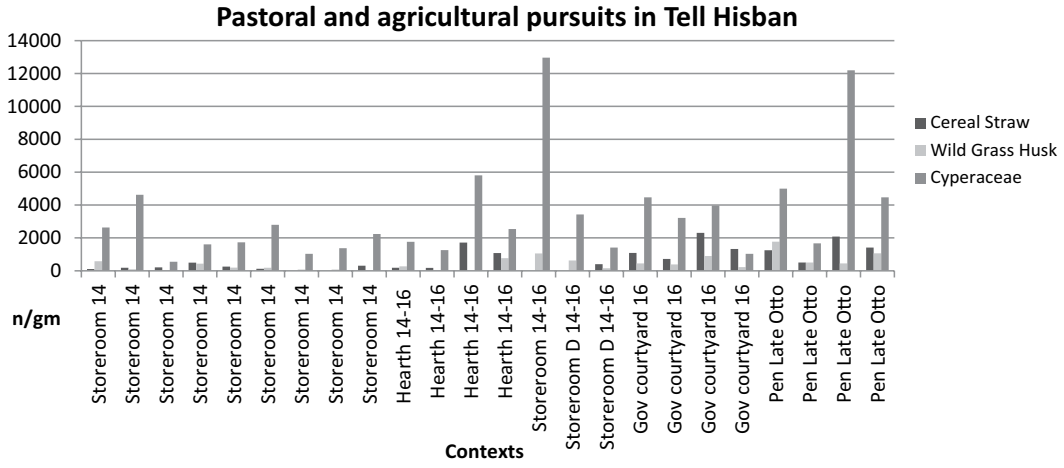

Figure 4. Phytolith evidence for pastoral and agricultural pursuits in Tell Hisban, Jordan.

They most probably had a shelter of state support during the mid-13th and early 14th centuries. But local communities and the local environment of Tell Hisban during the late 14th and 15th centuries may have faced the challenge of areas of depleted soils, that lost their capacity to retain moisture and flooded in the events of heavy rains after extended periods of drought (Butzer, 1982). Peasants may not have been able to cope with periods of extreme climatic events without the support of the state, as Mamluk imperial agriculture inherited to them a dry-depleted soil. The phytolith record as depicted in our results picks up the presence of dung possibly used as fertilizer (Figure 3).

When straw is found along with high densities of some grains and wild husks, ethnographic and archaeobotanical records have been used to identify the presence of fodder and/or dung (Charles, 1996; Hillman, 1981; Tsartsidou et al., 2007; Van der Veen, 1999). Furthermore, based on ethnographic studies conducted in northern Jordan by Palmer (1998), animals are mainly fed the wheat chaff and straw as well as barley among other crops. High densities of straw, wheat, barley, and weeds in the samples derived from the hearth could imply that animal dung may have been used for fuel (Figure 4).

During periods of loose state support and after depletion of soil took place during prolonged periods of intensified cultivation, agricultural areas of Tell Hisban may have turned to areas of very low fertility. Subsistence level farmers may not have been able to invest in large-scale fertilizers such as manure to support the recovery of the soil, especially for periods with a lesser state investment in local agriculture (Butzer, 1982). Evidence of dung for fuel or manure may indicate an environment under stress and the need for intensification of production because of imperial regimes.

Diversification of production is one major aspect of this analysis, a parameter that could be easily picked up through the botanical data and utilized toward the identification of intensified production. For example, palm single-cell phytoliths were present in one sample derived from the hearth, but the low counts cannot be taken to infer local cultivation for consumption of dates (*Phoenix dactylifera*) based on current analysis. This will be the focus of future analysis using phytolith and macro-botanical data to explore the variety of crops produced and consumed on the sites studied. For instance, the identification of scalloped phytoliths in the samples of Tell Hisban as observed in current analysis will be incorporated into this analysis for the identification of the Cucurbitaceae family (Piperno, 2006). Indicators of a diversified agriculture under the political control of the Mamluk state and the plantation economy established at the capital of Tell Hisban could suggest a more sustainable and resilient agricultural economy at a village-level versus the state pressure for profit and the fact that people exploited diverse ecological zones during the periods of study.

Beidha

The main cereal crops identified in the samples analyzed from the Medieval village at Beidha were wheat and barley. However, the latter is present in very low concentrations. Also, in general, densities of multi-cell phytoliths are very low as well as densities of single-cell forms.

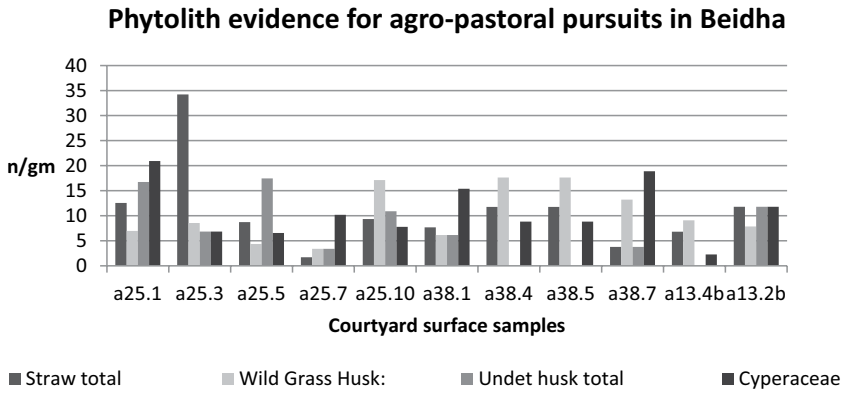

Figure 5. Phytolith evidence for pastoral and agricultural pursuits in Beidha, Jordan.

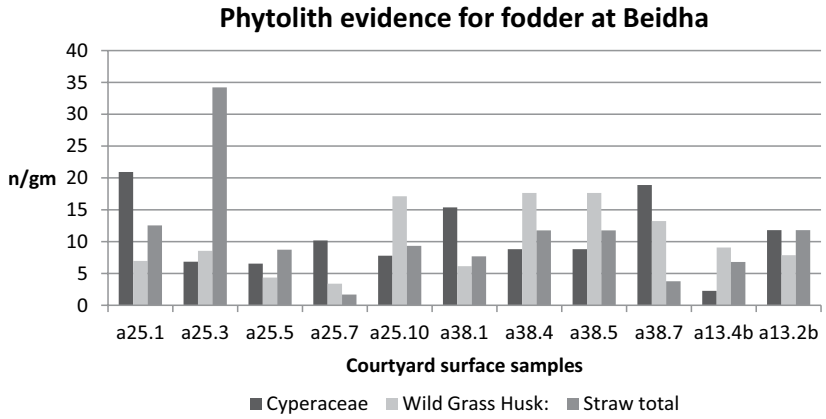

Figure 6. Phytolith evidence for fodder at Beidha, Jordan.

Large multi-cell forms of wheat or barley husks consisting of more than 10 cells are low or absent from the assemblage. Surprisingly, large concentrations of cereal straw, including large conjoined multi-cells of more than 10 single cells, are present across the whole area of the courtyard along with a strong presence of weed grasses. Wheat seems to be the most abundant crop, but because of low densities it cannot be suggested that it was cultivated as a main crop at the site at that stage of analysis (Figure 5). When more contexts will be analyzed from the site of Medieval Beidha, further conclusive comments will be very interesting.

These observations are of great importance to the Anthropocene discourse. First, it seems that the state allowed settlement into the fragile marginal ecological settings at Beidha and allowed for an agricultural community to establish there. According to Bikai (2006), houses may have been established during the Crusader period to accommodate agricultural workers, but no archaeobotanical analysis was conducted in order to have an estimate of the exploitation of the local environs under a strong state control from the Crusader period until the late Mamluk period. It is important to explore the data for intensified agriculture of cereals in this marginal area and envision how these fragile ecologies were altered profoundly and permanently.

The inhabitants at Beidha seem to have most probably cultivated their own crops via irrigation, as the presence of large multi-cell straw phytoliths indicates, and they had access to primary crop-processing by-products (Table 2). This suggests an agricultural investment by the state in this drier, marginal area of Jordan throughout the middle–late Islamic periods. This could be done through runoff irrigation and the use of cisterns and could be a sustainable method of production of cereals for local subsistence farmers.

Second, evidence of straw, weeds, and husks present on site shows traces of fodder or dung from the courtyard (Figure 6). Thus, the population of Beidha may have adopted an agro-pastoral economy, with straw being an imported good from better watered regions to sustain their animals during bad years. They could profit by an agro-pastoral economy and were buffered against the uncertainty of local low crop yield during the dry years of the three occupation phases identified and during periods of absent state control.

This is a very important aspect to consider as a way that state agricultural economy affected the local environment of Beidha through its exploitation for profit from the Crusader period until late 14th century. Also, we must consider the problems which local communities may have faced, given the degraded and heavily exploited environment at the turn of 15th century when state had collapsed and withdrawn its support to the villagers. In Beidha, an area which receives much lower precipitation compared with the Madaba Plains and Karak Plateau and which has soils that are not clay rich and do not retain moisture, such an imperial investment in agriculture would have devastating effects on the community and the environment.

Tawahin as-Sukkar and Khirbet as-Sheikh Isa

The data for phytolith analysis from the Medieval village of Khirbet as-Sheikh Isa and the industrial unit of Tawahin as-Sukkar, one of the largest sugarcane factories of the region, offer a great deal of information on Medieval Industrial and agricultural economy as an example of the great impacts of the Anthropocene.

Tawahin as-Sukkar. Data collected from six layers of waste deposits at the sugarcane factory and analyzed for phytoliths provide information on the use of fuel when the sugarcane industry flourished. Our early results clearly show that most of the phytoliths representing fuel use come from dicot plants (Figure 7).

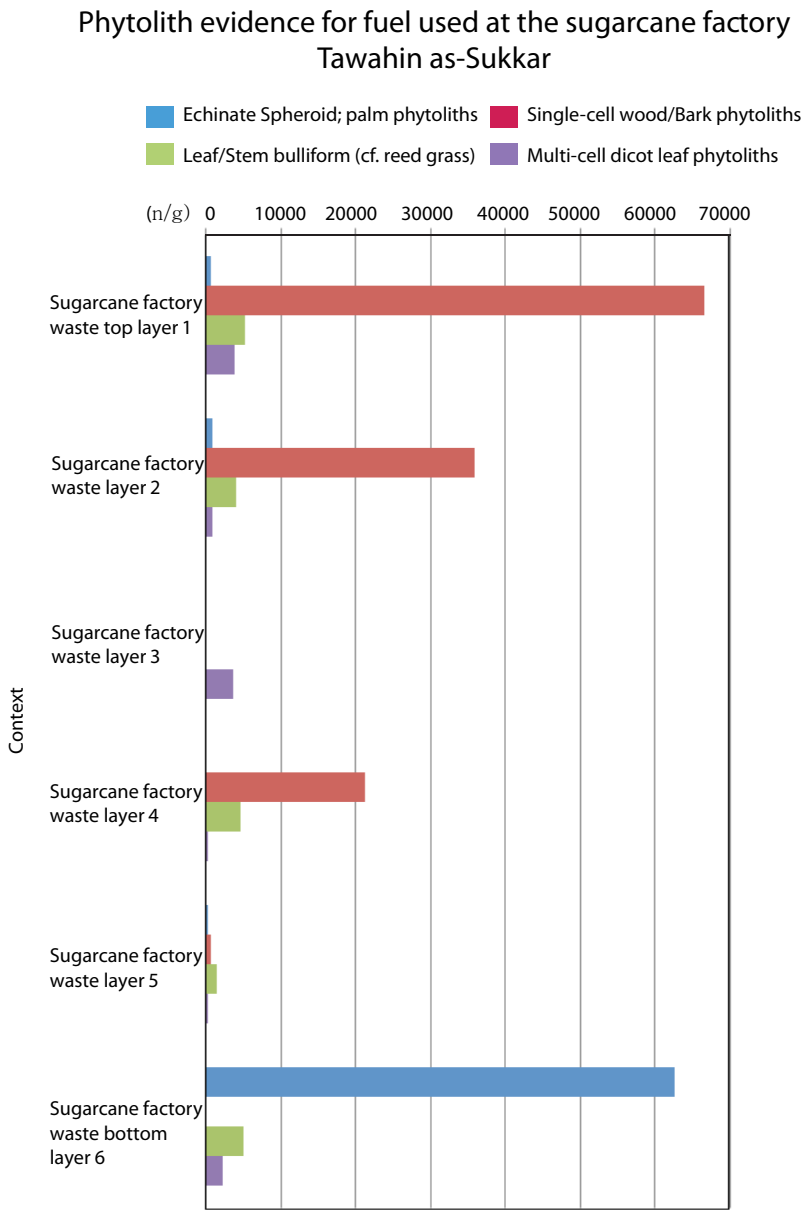

Figure 7. Phytoliths of fuel used at the sugarcane factory.

Certain phytoliths that derive from dicot leaves such as polyhedral multi-cell forms and 'jigsaw puzzles' are present in the samples (Bozaarth, 1992). They indicate the use of trees and/or shrubs available in the region for fuel (Figure 7). Tsartsidou et al. (2007) during an ethnographic study in Greece showed that the 'jigsaw puzzle' phytolith forms are produced by deciduous and nondeciduous trees, legumes, and shrubs and that they are likely to be formed in regions of humid climate, high precipitation, and/or heavy irrigation. However, looking at the absolute counts of dicot leaves and wood/bark phytoliths present in our samples, it is obvious that the inhabitants of the site were using a larger amount of wood and bark for fuel, compared with dicot leaves. The presence of dicot leaves may suggest that leaves could be attached to the wood used for fuel and/or from shrubby plants used for tinder.

In addition, our analysis shows that leaves and other parts of palms (*Phoenix dactylifera*) were also used for fuel at the sugarcane factory. Interestingly, there is a notable increase in the absolute counts of echinate spheroid phytoliths from palms in one of the industrial waste's layers, while the counts of dicot phytolith forms in that layer are considerably lower. For some reason, it seems that either a certain activity taking place at the factory required the burning of palms or maybe dicot leaves and/or wood and bark were not available in the amounts needed for processing sugarcane at the factory for a certain period of time. Perhaps palms were an alternative source of fuel, and it also seems to be a dominant species in the environment surrounding the sites. This is indicated by the high absolute counts of palm phytoliths in both the sugarcane factory waste deposits and the domestic deposits in the Medieval village nearby. Also, reed grasses seem to be a source for fuel as well, but not as prominent as palms and dicot plants (Figure 7).

Overall, early results of our analysis on data from this pile of industrial waste next to the factory offer direct evidence for the continuous use of wood for fuel in the region for the century in which the factory was in use. These early results and analyses, which are still in progress, help us envision the ways that state pressure for profit impacted the environment because of a plantation economy for sugarcane production that was established in the region for almost a century.

Khirbet as-Sheikh Isa. The samples that derive from the domestic deposits of the Medieval village adjacent to the factory offer valuable information relevant to the Anthropocene discourse. First, they provide information on the impact that the monocropping, sugarcane plantation economy had on the local environment. Second, they provide information on the village-level

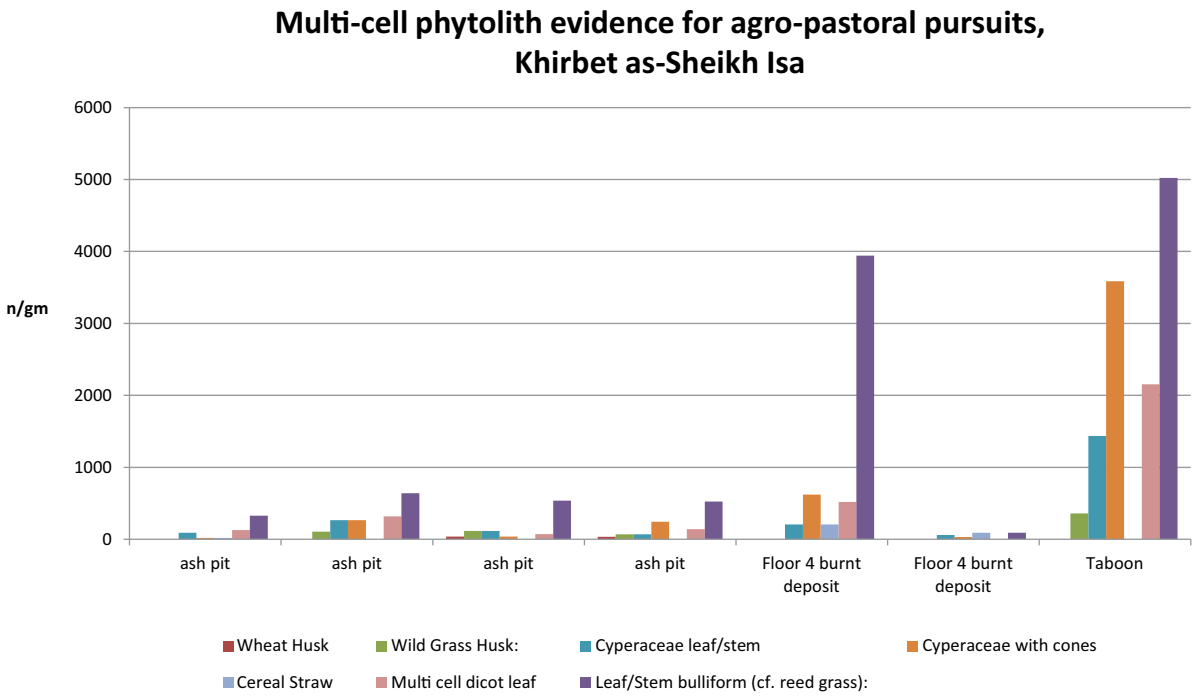

Figure 8. Agricultural and pastoral pursuits in Khirbet as-Sheikh Isa.

economy of the local peasant communities, who were the workers employed at the factory.

The study of phytoliths from these deposits shows very low counts of wheat and cereal straw, in all samples, while barley is totally absent (Figure 8). State-controlled economic practices related to the sugar plantations did not allow for the widespread cultivation of wheat or barley, major staples of the Mamluk period in Jordan, or for the cultivation of plants of the Cucurbitaceae family. This community might not have depended heavily on the agricultural production of the two main cereal crops. However, the phytolith data from burnt features such as the ash pit, the *taboon*, and burnt deposits on floor surface (Figure 8) were rich in phytoliths of wild grasses, sedges, and dicot leaves. Limited numbers of husks of irrigated, large multi-cell wheat silica skeletons were also found in the ash pit. These data point to the extensive use of dung for fuel in the village of Khirbet as-Sheikh Isa (see discussion of dung fuel use in the 'Tell Hisban' and 'Beidha' sections) (Charles, 1996; Hillman, 1981; Palmer, 1998; Van der Veen, 1999). It is likely that the inhabitants of Khirbet as-Sheikh Isa were relying on a small-scale agro-pastoral economy and were depending on the cultivation of wheat, possibly in small irrigated plots. In general, this analysis could indicate that while the sugarcane factory was in use, sugar plantations took over the environment and altered the ecologies of this fertile and important region for agriculture profoundly.

Sugar cultivation interrupted the traditional planting schedule in the region of Ghor. As a result of this, local communities must have suffered a great decrease in resources such as wheat and barley which were the main staples at the time as well as after state withdrawal. People would have been unprepared to adjust to the state withdrawal during the late 14th century, a state that sustained the big agricultural and industrial sector of sugarcane for a century. Sugar production was closely monitored by the *muqta'* and often the Sultan himself and replaced other crops and customary water sharing agreements (Walker, 2011). The intensive cultivation of this labor and water-demanding crop would have led to a greatly depleted environment.

Conclusion

The phytolith assemblages analyzed for this paper offer new and direct evidence for local-scale human influence on the natural environment related to the industrialization and intensification of agriculture during the Mamluk period in Jordan.

Phytolith assemblages from the sugarcane factory show the use of wood/bark for fuel, and this implies that multiple scales of deforestation and land clearance were required to support the production and processing of the sugarcane for almost a century. The Medieval Industry in Jordan suggests an earlier beginning to an accelerated impact on the environment than the European Industrial Revolution. The phytolith data from the neighboring village of Khirbet as-Sheikh Isa indicate that the influence of the state economic interests on sugarcane production contrasted with small-scale peasant sustainable agrarian systems and imply an accelerated impact on the environment due to the heavy exploitation of fertile soils of the Jordan Valley for the production of sugar. Phytolith data from the site of Tell Hisban and the Medieval village of Beidha show that intensified production of wheat and barley took place during the 14th century and expanded into areas that were marginal for cereal production. Our analysis points to the fact that the state allowed settlement into fragile marginal ecological zones during the 14th century, which may have altered those ecologies profoundly and permanently. The analysis also shows that peasants adopted an agro-pastoral economy at the village-level and buffered themselves against the uncertainty of low crop yields during bad years as well as during the period of large state agricultural and industrial investment.

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