# Mid-to-Late Holocene Agricultural System Transformations in the Northern Fertile Crescent: A Review of the Archaeobotanical, Geoarchaeological, and Philological Evidence

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The region of the northern Fertile Crescent experienced dramatic changes in the political and cultural life of its societies during the mid-late Holocene period (approximately 3000–1000 calibrated years B.C.). The range of these changes in terms of agricultural production, as well as their interrelationship with climate, is poorly understood. We review and highlight the transformations of agricultural systems, and what might have triggered them, through an interdisciplinary approach based on archaeobotanical, geoarchaeological, and philological data from a series of archaeological sites in northern Mesopotamia. The archaebotanical record suggests changes in crop cultivation at the transition from the Early Bronze Age to the Middle Bronze Age (MBA). The general pattern of the MBA manifests itself also in the Late Bronze Age sites, whereas the Iron Age sites reveal changes such as the extension of free-threshing wheat occurrence and a return of flax. These changes have been set in comparison to fluctuations of the stable carbon isotope composition in seeds and to the dynamics of irrigation networks documented by pedosediment profiles in the field, as well as by textual sources. According to the evidence, a number of reasons can be considered responsible for societal change during the Bronze Age, such as changing climatic and environmental conditions, increasing societal, political, and economic complexity, population growth and related problems of sustainability and warfare, which were all interwoven through feedback mechanisms. Whether we call these developments "collapse" or "recommencement" remains a matter of opinion.

## 1. INTRODUCTION

Transformations of agricultural systems may have occurred for many reasons, the most commonly established of which is climate change, which has been intensively discussed for the past two decades regarding questions on the sustainability of our world's economy (e.g., *Stern* [2007] and others). Transformations of human systems are, however, inextricably related to changes in human society and culture. There is common agreement upon the role of historical and sometimes archaeological information in the expansion of consciousness and, in particular, in the understanding of societal and cultural changes and their laws of causality. In western civilizations, causality research includes determinisms, which are generally coined by the disciplines involved

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in the study [*Riehl*, 2009b, 2012a, 2012b]. As recent studies, however, on agricultural change in the past suggest, causality research has to take multiple causes, feedback mechanisms, and reciprocal amplification into account to develop realistic models [*Riehl*, 2009b]. When considering agricultural change today and in the past, we need to abandon the search for single causes in the development of ancient societies and instead integrate environmental, economic, and social factors into the causal chain. This involves an integrative and interdisciplinary approach that we present below.

Our approach of using multiple lines of evidence includes (1) the analysis of archaeobotanical crop data from 114 archaeological sites in Upper Mesopotamia in order to reconstruct ancient crop production patterns, as well as (2) stable carbon isotope analysis of ancient cereal grains as a proxy of past water stress on crop species which would have affected yields, (3) the evaluation of geoarchaeological records to detect ancient land use, and (4) the textual evidence from cuneiform sources on ancient crop management. Taken together, these information sources permit a well-balanced reconstruction of the interplay of environmental and social factors of agricultural transformation processes.

The historical sequence considered here roughly dates between 3000 and 1000 calibrated (cal) years B.C. When attributing absolute dates to historical events mentioned in different textual sources, we follow the "Middle Chronology" (MC), which most likely needs to be lowered by circa 50 years after 2100 B.C., depending on the assumed length of the "Dark Age," but only by about 20 years or less before circa 2150 B.C. It is assumed that MC more or less equals radiocarbon dates. Throughout the text, we differentiate between radiocarbon data as B.C. placed behind the year and historical data according to the "Middle Chronology" as MC placed before the year (for a detailed discussion over the dispute of middle versus short chronology in ancient Near Eastern Archaeology, see the works of *Pruzsinzsky* [2009] and *Mebert* [2011]).

Another terminology note: We avoid using the term "collapse" in our own interpretation due to any of its vague or negative connotations [cf. *Tainter*, 1988; *McAnany and Yoffee*, 2010; *Riehl*, 2012a].

### *1.1. Changes in the Political, Cultural, and Economic Life (Circa 3000–1000 cal years B.C.)*

Textual evidence and numerous finds from archaeological excavations directly or indirectly emphasize the role of political and cultural factors in the development of agricultural production. Some archaeologists even attribute causality to agriculture for the decline of early societies. Agricultural mismanagement through overexploitation may be assumed [*Hole*, 2007], which followed an agglomeration of production in specific ecological regions and simultaneous socioeconomic restrictions, disabling adaptation to changing environmental conditions through increased social complexity [cf. *Wilkinson*, 1997]. Despite the existence of a large amount of historical information, a systematic investigation of the interrelationship of agricultural development and political change is still pending.

*1.1.1. Flourishing and declining of city-state networks during the Early Bronze Age.* A period of ruralization with only small administrative centers in northern Syria and southeast Anatolia, marked through the end of the Uruk expansion (the final prehistoric cultural sequence of Mesopotamia between 3900/3700 and 3100/2900 B.C.), has been described by *Akkermans and Schwartz* [2003] for the beginnings of the Early Bronze Age (EBA) (around 3000 B.C.). Local traditions reemerged, and rural communities, characterized by economic specialization, were integrated into a larger economic network. Archaeologists refer to high cultural diversity as occurring throughout the entire region, a situation that some researchers attribute to the north-south gradient of precipitation resulting in rain-fed agriculture in the north and irrigation in the south [cf. *Jas*, 2000]. According to some scholars, this led to the existence of smaller cities in the north with higher populations in the outlying villages, compared to the south [*Van De Mieroop*, 2003].

Generally speaking, cities of various rank evolved after roughly 2900 B.C. in Upper Mesopotamia and Syria. City-state indicates an accumulation of political power through agricultural surplus production. Cooperation between independent cities has been documented [*Van De Mieroop*, 2003]. Early administrative structures and the appearance of cuneiform writing in the middle of the third millennium B.C. are indicators of a complex organization within the city-state, as defined by the largest capital cities (like Tell Brak, Tell Khuera, or Tell Hariri/Mari). The network of city-state stretched from lowland Sumer to Upper Mesopotamia and even to Syria (Tell Mardikh/Ebla) [*Sallaberger*, 2007, 2012a].

The texts discovered at Tell Beydar reveal the best evidence for the internal communal organization of the city-state. Studies of these documents show that the central organization included all or at least the large majority of the inhabitants of the city. Agriculture was organized as collective labor of the urban center and of dependent smaller settlements [*Sallaberger and Ur*, 2004]. This organization corresponds largely to the one known from lowland Mesopotamia, despite the differences in irrigation, which are well documented in the south. Collective labor included the central allocation of human resources, draft animals (donkeys, oxen), and tools for work in the fields. At the time of harvest, practically the whole population of a settlement was obliged to cooperate. The grain was stored in communal granaries and distributed to the population according to status, profession, sex, and age. The central organization also controlled the large animal flocks of sheep and goats that were handed over to herdsmen [*Sallaberger*, 2004]. Communal organization included craftsmen who were given their wages in grain, whereas some human resources were directly linked to the royal palace (e.g., metal and textile production, military officials, royal court). The secondary settlements contributed to the upkeep of the state by delivering grain, caring for royal animal herds (especially equids), and offering labor service in state projects or military expeditions. The communal organization documented also at Ebla or pre-Sargonic Mari (before 2350 B.C.) can be seen as a typical feature of the society and economy of early Mesopotamia that lasted through the third millennium.

The system of city-state came to an end when the accumulation of power in a few centers such as Mari, Ebla, Nagar, or Akkad led to wars of unprecedented intensity. Centers like Ebla, Mari, or Nagar were destroyed around MC 2330–2320 and paved the way for the military success of Sargon of Akkad (MC 2353–2314) [*Sallaberger*, 2007, 2012a].

For Upper Mesopotamia, the end of the early city-state meant a strong reduction in urban settlements for the last third of the third millennium, with only a few centers of continuous importance at the northern fringe of the Jezirah plain [cf. *Ristvet and Weiss*, 2005]. The few remains of administrative archives from these sites (Tell Mozan/Urkesh, Tell Brak/Nagar, Tell Leilan/Shekhna) indicate the continuation of a similar communal organization of resources and labor as in the preceding period, at least at the urban centers. This, however, has to be evaluated against the general reduction of urban settlement in Upper Mesopotamia in the late third millennium and, at the same time, the appearance of nomadic people, the Amorites. The evidence "suggests an ethnogenesis of Amorite nomads meaning that a changing lifestyle of the former urban inhabitants of Upper Mesopotamia towards nomadism also included the adoption of the language of the nomads, Amorite" [*Sallaberger*, 2007, p. 450].

Mari, located on the Middle Euphrates, was able to recover after its destruction by Sargon of Akkad, becoming, like Ebla, a leading power during the period of the Third Dynasty of Ur, which ruled in Mesopotamia (MC 2110–2003). The regions of Upper Mesopotamia and Syria covered by the study presented here never became parts of the state of Ur, though good diplomatic relations existed with the dominant centers, foremost among them being Mari and Ebla, followed by Urshu, probably in the region of Gaziantep, and Shimanum, which was probably located in the Upper Tigris region at the Tur Abdin. Mari and Ebla continued to be the dominant centers of the region, even after the fall of the Third Dynasty of Ur (MC 2003). They were able to maintain good relations with Ur's successor Isin [*Sallaberger*, 2007].

*1.1.2. Competition for power between small states and agricultural underproduction in the Middle Bronze Age.* Upper Mesopotamia and Syria are characterized by continuous change in both political regimes and economic structures throughout the Middle Bronze Age (MBA) (circa 2000–1500 B.C.), the period of the Amorite kingdoms. Rivalry and political conflict were as numerous as before [*Klengel*, 1992; *Heimpel*, 2003], and a general trend had developed within the entire area, namely, competition for power between small states gathered around the more influential powers: Qatna, Yamkhad (Aleppo), Mari, Upper Mesopotamia or Assur, Babylon, Ešnunna, Larsa, and Elam (from Syria in the northwest to Iran in the southeast). In central Anatolia, the Old Hittite kingdom was gaining in power.

Whether these processes changed the economic organization cannot directly be detected in the archaeological or the textual record. It has been speculated that under Hattusili I, the Hittites expanded southward with the aim of acquiring larger cereal fields in northern Syria than available in their own country [*Van De Mieroop*, 2003]. In the west, new influential cities, such as Qatna, developed during the MBA. The geopolitical role of Ebla seems to have shifted the seat of the rulers of Yamkhad in the early MBA to the old cultic center of Aleppo. For Babylonia, there is no indication of economic decline in the first three centuries of the second millennium. Mari, in the middle Euphrates region, maintained its economic and political power [cf. *Charpin and Ziegler*, 2003]. Its economy was strongly influenced by interaction with nomadic pastoralists [cf. *Fleming*, 2004]. Mari also played an important role in trade [*Stol*, 2004], but its subsistence economy was mainly based on extensive irrigation agriculture in the Euphrates and Khabur region.

The archives of the palace of Mari during the reign of Zimri-Lim (early MC eighteenth century) inform us on institutional practices of agriculture based on thousands of legal and administrative texts and letters from the viewpoint of the palace [*van Koppen*, 2001]. The dominant role of palace estates and households of officials, and the absence of temple households, is a feature that the institutional agriculture of Mari shares with other Upper Mesopotamian states of this time period (e.g., Tell al-Rimah, Shekhna). The officials in charge were personally and financially accountable to the palace for successful production. Officials were also responsible for managing access rights to irrigation water. The *ikkaru*, "farmer; leader of a plough team," managed the basic work units in order to meet production goals and was responsible for communication with the administration.

Generally, as evident from the texts as well as from the archaeobotanical remains, the main cereal was barley (*še'um*), though evidence also exists for wheat species (*kibtum* and possibly *burrum*). Mari's agriculture did not so much lack arable land, as it did sufficient manpower. This point, along with the issue of contemporary political conflicts, led to local underproduction [*Lafont*, 2000], forcing the palace to acquire barley on the market. This explains why military commanders were responsible for the organization of additional personnel for the harvest [*van Koppen*, 2001]. Shortages in the labor force are also known for other Mesopotamian societies, e.g., the Middle Assyrian Empire in the north or the Ur III period in southern Mesopotamia.

The end of the MBA is marked by the Hittite attack on Yamkhad in northwest Syria and the sack of Babylonia in MC 1595. Although this led to a complete transformation of political structures, with a power vacuum opening up in formerly dominant regions, some scholars have pointed to a continuous transition to the LBA in the material culture [*Akkermans and Schwartz*, 2003]. This is especially true for the region we focus on here, where states like Qatna, Yamkhad/Halab (Aleppo), Hana, Mittani, and Hatti continued to exist, even gaining in importance. Mittani, the state in the region with a primarily Hurrian population along the Upper Tigris and in Upper Mesopotamia, became the dominant power in northern Mesopotamia and Syria. Hana, the kingdom at the Middle Euphrates, lost its power, and the region became part of the long-lived Kassite state of Babylonia that had arisen after the fall of Babylon (MC 1595, but later in absolute chronology) in the so-called "Dark Age," when, according to the texts, resources from Babylonia came almost to an end. The economic and agricultural consequences of these political upheavals are difficult to grasp due to the almost total disappearance of relevant written sources. Apparently, the loss of the connection to Babylonia in its "Dark Age" played an important role, since Babylonian scholars were vital for the dissemination of writing in the regions to the west. One may recall that Babylonian scribes were active especially in the early periods at Hattusa or that writing was apparently little used in the state of Mittani, which flourished in the "Dark Age" of Babylonian culture between MC 1595 and the fourteenth century. The spread of cuneiform in the fourteenth to thirteenth centuries both at palaces (like Alalakh IV) and in private households (Meskene/Emar, Ekalte) may not only be taken as evidence for a flourishing economy but also for renewed contacts with Kassite Babylonia.

*1.1.3. Globalization, warfare, and political decline during the Late Bronze Age (LBA).* During the LBA (circa 1500–1200 B.C.), Syria, the region between the Mediterranean Sea and the Euphrates, became a focus of interest for three large political powers: first, the Hurrian state of Mittani, which flourished between the sixteenth and the early fourteenth century; second, the Hittite state of Hatti from Anatolia, especially after the successful conquests of Suppiluliuma I in the mid-thirteenth century B.C.; and third, the Egyptian pharaohs who entered inner Syria from the Mediterranean coast between the fifteenth and thirteenth centuries. Before 1340 B.C., Egypt and Mitanni competed for control over the region; after that date, when Mitanni was turned into a vassal of the Hittite king, Egypt and Hatti competed for control over the Mitanni state. By 1300 B.C., the Hittites had expanded their system of vassal states as far south as Qadesh, culminating first in the battle with Egypt in 1274 B.C. and finally with the peace treaty between Hatti and Egypt in 1259 B.C. [*Van De Mieroop*, 2003].

We can consider this from a wider perspective, since contacts overseas were extended to also include islands like Cyprus or Crete after 1500 B.C. The cultures of Syro-Mesopotamia were seemingly linked to a maritime trading system, which enabled far-reaching economic and cultural exchange. This was both a sign of, and a means for, the international character of a large number of territorial states from western Iran to the Aegean, from Anatolia to Nubia [*Van De Mieroop*, 2003]. Van De Mieroop describes five zones of political unification and centralization of power that experienced a period of prosperity during the LBA. Besides Egypt, Hatti, Mittani-Assyria, and Babylonia, he also includes the Middle Elamite Kingdom in western Iran. Within these regions, several cities and their hinterlands were tied together by economic integration, while the regions, themselves, seem to have maintained a coherent trade network that resembles the later aims of internationalization and globalization, of course not free of rivalry. An exception to this trend toward larger regional political units was Syro-Palestine where the basic system of small states concentrated around a single city persisted [*Van De Mieroop*, 2003]. These small states survived as allies of the larger political powers.

The decline of Hatti and the important cities under its control around 1200 B.C. has been explained through the attacks by the so-called "Sea Peoples," by rebellion in the territories in the west and by possible crop failures. Similarly, the end of the Mycenaean culture in the eastern Mediterranean has been attributed to internal conflict, population movement, and warfare. It has been assumed that economic decline may have played a causal role in the collapse of LBA civilizations. It is most likely that complex interactions between political and ecological factors were responsible for these massive supraregional changes. How these changes influenced agricultural organization still remains relatively unclear. A bioarchaeological specification of economic decline has so far not been determined.

The "Dark Age" following the end of the LBA varied in duration within the different regions. In Assyria, which survived the 1200/1180 B.C. breakdown of the LBA systems, a period of decline lasted from the early eleventh century until circa 935 B.C. Little is known about this period, but it seems clear that an almost complete restructuring of the society must have taken place due to large-scale nomadization, migration, internal population movements, and technological and trade network changes, while there is also evidence for continuity, e.g., the maintenance and restoration of the Lower Khabur and Middle Euphrates canals by local rulers [*Fales*, 2008]. With the beginning of the first millennium B.C., the political situation in the Near East had become more stable, and a new network of states arose, which becomes tangible in the ninth century B.C. by written records again.

Beginning with the campaigns of Ashur-Dan II (934–912 B.C.) and Adad-nerari II (911–892 B.C.), Assyria successfully started the reconquest of Upper Mesopotamia. Shalmaneser III (822–811 B.C.) has finally conquered all of Upper Mesopotamia. Phoenicia, Israel, the Aramean, and the Neo-Hittite states, Urartu and Babylonia, were forced to pay tribute. Tiglat-Pileser III (744–727) terminated a short period of stagnation. He and his successors subjugated nearly all of the ancient Near East including Babylonia, the Levante, and parts of Egypt, Anatolia, and western Iran.

Features of the Neo-Assyrian agriculture are the planned distribution of rural labor forces, the installation of large-scale irrigation systems, and a centralized program of rural land settlement policy [*Bernbeck*, 1993; *Bagg*, 2000; *Morandi Bonacossi*, 2008]. The dense rural population was able to produce more agricultural goods to feed the dramatically increased urban population in central Assyria [cf. *Wilkinson et al.*, 2005].

### *1.2. Environmental Change (Circa 3000–1000 cal years B.C.)*

Despite general sparseness of pollen reservoirs and low preservation rates for pollen in the Near East, palaeoclimate proxy data sets have created a solid framework of Holocene climate history.

A period of increasing moisture, with the beginning of the Holocene, ends around 5000 B.C., when a general trend of increasing aridity starts which has, among others, been linked to orbital parameters and was probably associated with a southward shift of the Intertropical Convergence Zone [*Wanner et al.*, 2008]. Despite this global component, it is, however, clear that regional diversity played a role in the particular climate effects in the different geographic regions.

Anthropogenic impact during the Bronze Age played a greater role in vegetation development than it did during the early Holocene, a fact which makes interpretation of the palaeoclimate proxy data more complex [*Roberts et al.*, 2004]. This has been overcome by including stable isotope data [e.g., *Wick et al.*, 2003], allowing for differentiation of climatic and human factors in the degradation of the vegetation.

Rapid climate change events (RCC) considered to be global, occur in a larger number of distant regions and generally can be related to Bond cycles. For our study here, two RCCs are relevant, the "4200 B.P. event" (Bond cycle number 3), which has been related in the Near East with the transition from the Early to the MBA [*Staubwasser and Weiss*, 2006], and the climate changes between 1200 and 900 B.C., which correlates with the "Dark Age" between the LBA and the Iron Age (IA).

In the most relevant palaeoclimate proxy archives, including the speleothems from Soreq Cave [*Bar-Matthews and Ayalon*, 1998, 2011] and pollen and stable oxygen data from Lake Van [*Wick et al.*, 2003], for the geographic area considered here, the 2200 B.C. climate change indicates more a long-term shift to more arid conditions than an event. At Van, change in the data is rather visible in the pollen, with a strong reduction in oak and other tree species, than in the oxygen isotope record [*Litt et al.*, 2009]. As discussed above, this could be the result of anthropogenic impact on the vegetation. However, occurring simultaneously with the "4200 B.P. event," the lake level of Kinneret decreased [*Hazan et al.*, 2005]. The lake level at Van also decreased after 2000 B.C. [*Lemcke and Sturm*, 1997; *Wick et al.*, 2003], and carbonate cutans on objects from southern Anatolia stopped growing around this time [*Pustovoytov et al.*, 2007a, 2007b].

Chronological discrepancy in the appearance of drier conditions, generally linked to internal methodological problems of dating, could alternatively be related to time differences in the abandonment of EBA settlements, which started earlier in the Euphrates than in the Khabur region [*Kuzucuoglu and Marro*, 2007; *Riehl and Bryson*, 2007].

In the Levant, modern precipitation values were within a similar range of 350–580 mm as those since 5000 B.C., as calculated by *Bar-Matthews et al.* [1997]. According to Bond's data, a global cooling event between 1200 and 700 B.C. (Bond cycle no. 2) [*Bond et al.*, 2001] should have affected wider areas and might also have had an impact in the Near East between the end of the LBA and the IA II. This corresponds well with the stable oxygen isotope data from Lake Van where increasing aridity is visible within this sequence [*Litt et al.*, 2009]. Aside from probable chronological problems, the data imply regional variability with more stable moisture conditions in the Levant and stronger fluctuations inland in southern Turkey during the transitional period from the Bronze to the IA.

The "1200 B.C. hypothesis" of increased aridity in northern Mesopotamia between 1200 and 900 B.C. of *Neumann and Parpola* [1987] goes back to Carpenter's local model on the discontinuation of Greek civilization [*Carpenter*, 1966], which was supported by archaeoclimatological models [*Bryson et al.*, 1974; *Bryson*, 2005]. *Neumann and Parpola's* model [1987], which includes a causal argument for drought, famine, and social problems leading to political collapse, correlates with the Van record. Recently, *Rohling et al.* [2009] suggested that the cooling period at the end of the LBA adversely affected the agricultural quality in the northern and northeastern regions of the Aegean, thus triggering end-of-Bronze Age migrations. *Rohling et al.* [2009] emphasize that the Minoan eruption, which has been radiocarbon dated to 1627–1600 B.C. [*Friedrich et al.*, 2006], is not causally related to their RCC, which they date to 1500–500 B.C. While the former date would be more indicative of a chronological relationship with the end of the MBA, the latter covers major parts of the LBA and the IA.

## 2. METHODS

We reviewed multifaceted evidence from archaeobotany, geoarchaeology, and philology with the goal of developing a holistic view of the economic developments between 3000 and 1000 B.C. (Figure 1).

Results on crop cultivation patterns are heavily based on an archaeobotanical database in which more than 16 million seed records were gathered from archaeobotanical publications on archaeological sites in the Eastern Mediterranean and the Near East. A reduced version of this database can be found at www.ademnes.de. Crop proportions and ubiquities have been calculated within the database, and archaeobotanical distribution maps were created with ArcGis. Further data derives from our own archaeobotanical work at a number of sites, such as Tell Atchana [*Riehl*, 2010a], Tell Mozan [*Riehl*, 2010c], Tell Halaf [*Riehl and Deckers*, 2008], Emar [*Riehl*, 2010b], Qatna, Tell Fadous [*Riehl and Deckers*, 2011], Zeraqon [*Riehl*, 2004], and Troy [*Riehl*, 1999].

As the nature of archaeobotanical data carries with it a number of interpretative problems to crop distribution patterns [*Riehl*, 2011], an independent method was considered necessary to reveal whether climate fluctuations may have affected the crop yields and thus adaptive human behavior in crop production.

Stable carbon isotope analysis has been in use for some time at archaeological sites in order to facilitate investigations regarding water stress on crop plants during their grain-filling period [*Araus et al.*, 1999, 2001; *Ferrio et al.*, 2005; *Riehl et al.*, 2008; *Fiorentino et al.*, 2008]. Despite complex causes of variation [*Dawson et al.*, 2002], increased water stress accounts for the largest part of $\delta^{13}$C variation in arid to semiarid environments [*Tieszen*, 1991].

Carbon isotopes of the archaeological barley remains were measured in $\delta^{13}$C Vienna Peedee belemnite ‰. The changes over time in atmospheric $CO_2$ ($\delta^{13}C_{air}$) composition had to be considered when samples from different periods and, in particular, when ancient and modern sample values were compared. Discrimination of $\delta^{13}$C ($\Delta^{13}$C) was conducted with a transfer function [*Farquhar et al.*, 1982, 1989]. Values of $\delta^{13}C_{air}$ are available from ice-core projects in Greenland and Antarctica [*Barnola et al.*, 2003]. According to ancient $\delta^{13}C_{air}$, the following $\delta^{13}C_{air}$ values were used for the calculation of discrimination: for the EBA, −6.3/−6.4, for the MBA and LBA, −6.5, and for the modern samples, −8.

A relatively comprehensive series of geoarchaeological studies, including geographic information system (GIS)-based analysis of satellite imagery and modeling, has been published and helped with the identification of settlement and land use patterns as aspects of early economic systems in some regions of the Near East [*Goldhausen and Ricci*, 2005; *Wilkinson*, 1997, 2003; *Wilkinson et al.*, 2007; *Deckers and Riehl*, 2008; *Altaweel*, 2008]. The selective nature of such studies requires continuous and systematic research on land use changes by integrating available environmental data, the results from geoarchaeological fieldwork, GIS-based analyses of satellite images, and the application of agronomic models, by combining these data with palaeoclimatological, archaeological (environmental and architectural), and philological data.

The rich textual record of cuneiform tablets, which has been estimated to number more than 500,000 texts [*Streck*, 2010], covers a broad range of information related to agriculture that has not yet been systematically analyzed. For our study, it was necessary to focus on grain, wine, fiber, and oil species, which are the most important crops mentioned in texts written in Sumerian and Akkadian.

The cuneiform record usually provides indirect information about agriculture. No guidelines exist for the farmer, at least not for Upper Mesopotamia (for the southern alluvium see the work of *Civil* [1994]). The most important sources are administrative documents, i.e., lists of incoming and outgoing goods, and tabulations of the goods in stock that were issued by communal organization. The very existence of administrative texts is a sign of complex organization concerned with the distribution of goods or the management of labor within its specific sphere of responsibility. Such documents stem from communal organizations within the city-state of the third millennium [*Ismail et al.*, 1996; *Milano*

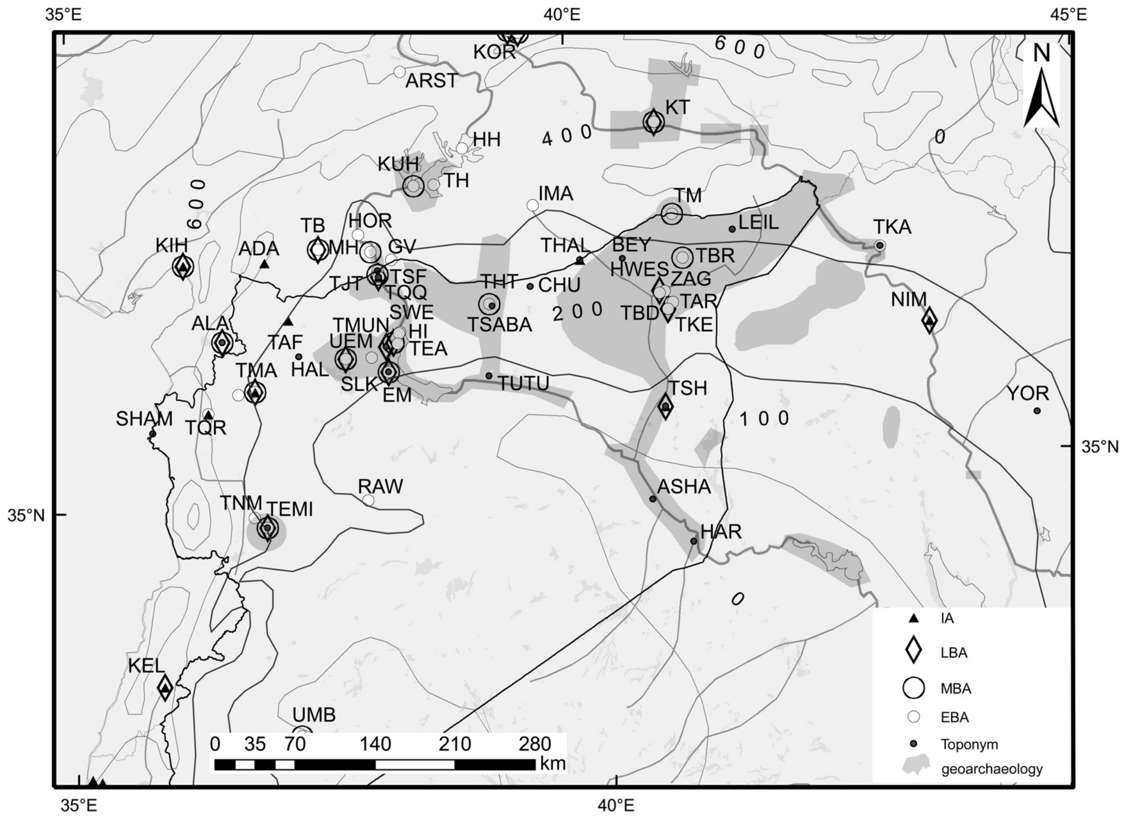


**Figure 1.** Overview of the study area with archaeological sites from different periods that produced archaeobotanical data. Toponyms from the cuneiform sources and regions where geoarchaeological research has been conducted are shown. Isolines represent isohyets; information on geoarchaeological surveys mostly derives from *Wilkinson* [2000] and our own investigation. Visible site codes represent the following localities: ADA, 'Ain Dara; ALA, Tell Atchana; ARST, Arslantepe; ASHA, Tell Ashara; BEY, Tell Beydar; CHU (Tell Khuera), EM (Emar), GV (Gre Virike), HAL (Haleb/Aleppo), HAR (Tell Hariri/Mari), HH (Hassek Höyük), HI (Hajji Ibrahim), and HAD (Tell Hadidi; hidden), HOR (Horum Höyük), HWES (Tell Hwes), IMA (Imamoglu), KEL (Kamid el-Loz), KIH (Kinet Höyük), KOR (Korucutepe), KT (Kenan Tepe), KUH (Kurban Höyük), LEIL (Tell Leilan), MH (Mezraa Hoyük), NIM (Nimrud), RAW (Tell al-Rawda), SHAM (Tell Ras Shamra), SLK (Tell Selenkahiye), SWE (Tell es-Sweyhat), TAF (Tell Afis), TAR (Tell al-Raqa'i)], TB (Tilbeshar), TBD (Tell Bderi), TBR (Tell Brak), TEA (Tell el-Abd), TEMI (Tell Mishrifeh/Qatna), TH (Titriş Höyük), THAL (Tell Halaf), THT (Tell Hammam et-Turkman), TJT (Tell Jerablus Tahtani), TKA (Tell Karrana), TKE (Tell Kerma), TM (Tell Mozan), TMA (Tell Matsuma), TMUN (Tell Munbāqa),TNM (Tell Nebi Mend), TQQ (Tell Qara Quzaq), TQR (Tell Qarqur), TSABA (Tell Sabi Abyad), TSF (Tell Shiukh Fawqani), TSH (Tell Shekh Hamad), TUTU (Tell Bi'a), UEM (Umm el-Marra), UMB (Umbashi), YOR (Yorgan Tepe/Nuzi), and ZAG (Tell Zagan).

*et al.*, 2004] such as the organization of a palace like in MBA Mari (MC eighteenth century) (cf. references in the work of *Charpin* [2004]) or in MBA and LBA Alalakh [*Dassow*, 2008; *Zeeb*, 2001] or from the provincial administration of Assyria [*Röllig*, 2008; *Radner*, 2004; *Jakob*, 2003]. Many administrative texts provide exact data, e.g., the precise amount of grain delivered to a granary from various persons. Within an archive, both the numbers and the types of products are consistent and can be used to reconstruct a larger picture of a city-state's agriculture. Common, everyday documents, though, presuppose a certain degree of knowledge of the available structures, of the terminology used in the texts, of the function of the persons, who are listed mostly by their names only, or of the role of various settlements. Furthermore, the administrative documents were issued for specific purposes like the calculation of grain for seeding or for the feeding of animals. Researchers today face two essential problems. They must tackle the difficult terminology of Akkadian, the Semitic language of Mesopotamia and adjacent regions from the late third to the first millennium, and of Sumerian, the language of the first script, which strongly influenced the cuneiform writing especially in its earlier periods. They must not only reconstruct the administrative structure behind the names of the documents, but also use the documents in such a way as to contribute to current investigations. Despite these imperfections, administrative texts are the best textual sources for uncovering details into the economies and societies of the ancient world.

These sources, however, are absent in regions and/or in periods where writing was less widespread. The states located at greater distances from Mesopotamia often used writing only or mainly within the palace, and thus, only the central palace administration, including the management of the royal treasury, is documented (e.g., Middle Elamite writing). Furthermore, even in the case of widespread writing such as at LBA Meskene/Emar [*Arnaud*, 1986] or Tall Munbaqa/Ekalte [*Mayer*, 2001], we are missing administrative texts, perhaps because large sectors of the economy were not organized collectively or because the documents were simply not found. We do have at our disposal private legal documents that only indirectly hint at the agricultural context, e.g., the acquisition or heritage of vineyards or fields [*Mori*, 2006].

As the historical survey has made clear, periods of dramatic change are followed by "Dark Ages" with an absence of written sources. The historical and philological investigation will therefore never permit a direct investigation of ongoing changes, and even if sources were to exist, they would not document the change of a system, but only a particular situation. In terms of philological and historical research, on changing agricultural systems in the Syro-Mesopotamian realm, describing these sites or regions and these periods as exactly as possible becomes our most important task. Only a bird's eye perspective will allow us to discover long-term trends. Inclusion of the geoarchaeological and the archaeobotanical records helps us to estimate regional differences of the various archives more precisely. For a few sites, both philological and archaeobotanical evidence has been published, e.g., for the thirteenth/twelfth century. Tell Sheikh Hamad (texts [*Röllig*, 2008], archaeobotany [*van Zeist*, 2001; *Frey and Kürschner*, 1991]). In some cases, relevant texts and palaeobotanical samples may stem from the same site and period, but have not been published with equal measure. Examples include the twenty-fourth century Tell Beydar/Nabada with published texts [*Ismail et al.*, 1996; *Milano et al.*, 2004], but archaeobotany is still to be published or Tell Khuera (texts [*Jakob*, 2003], archaeobotany to be published). In most cases, however, there is no textual equivalent to the archaeobotanical study of a site.

Despite these methodological problems, administrative texts are invaluable documents for any research on the economies or societies of a given time period.

## 3. RESULTS

### *3.1. Agricultural Transformations in the Archaeobotanical and Stable Carbon Isotope Record*

Considering the two transitional sequences that have been related to major climate fluctuations, the Early to MBA transition and the LBA to IA transition, results on agricultural transformations during the former sequence have already been published [*Riehl*, 2008, 2009a, 2011; *Riehl et al.*, 2008].

The overall result of these studies demonstrates a reduction in the presence, proportion, and ubiquity of water-demanding species comparing EBA and MBA data sets. Other, more stress-tolerant species, such as barley (*Hordeum vulgare*), increase in abundance throughout time. Today, a dominance of barley is a common feature in arid and semiarid environments due to its short reproduction cycle, which protects the crop from extensive drought stress. Although the ubiquity of free-threshing wheat (*Triticum durum/aestivum*) is generally high in the Bronze Age, suggesting routine usage in ancient households as a highly esteemed component in human diet, proportions are low in contrast to barley. In the MBA, free-threshing wheat in Syria is recorded with even lower proportions than in the EBA sites. This is notable in view of the fact that free-threshing wheat has comparatively higher water requirements than barley. Garden pea (*Pisum sativum*), which has comparatively high water requirements, is widespread and occurs with relatively high proportions during the EBA, particularly in northern Syria, i.e., in an area with higher mean annual precipitation (>400 mm). During the MBA, it occurs particularly in the part of Syria west of the Euphrates in a probably wetter area, better suiting the water demand of the pulse crop. Stress-tolerant bitter vetch (*Vicia ervilia*), which is reported as a crop with considerable drought adaptation, but is not a part of the human diet today, played a comparatively minor role in EBA plant production. However, it occurs with higher proportions in at least some of the MBA sites. Linseed (*Linum usitatissimum*) also occurred more often and with higher frequencies during the EBA farther to the east in northern Mesopotamia. It virtually disappeared in the MBA. Seed flax is raised under a wide range of conditions, but it is particularly intolerant of salinity and high temperatures in terms of normal seedling growth, while fiber flax requires abundant moisture during the growing season. It has been argued that flax disappeared with the end of the EBA because yields no longer justified the production costs [*Riehl*, 2009a]. Grape (*Vitis vinifera* L. ssp. *vinifera*) was cultivated over a large area during the EBA, although it occurs in larger proportions mainly in areas with modern mean annual precipitation above 400 mm. Cultivation during the EBA seems to have been practiced south of the natural distribution of the wild progenitor (*V. vinifera* ssp. *sylvestris*). Allowing for fewer analyzed MBA sites, grape cultivation generally seems to have been reduced during this period, particularly in the central part of northern Syria.

In summary, the archaeobotanical crop patterns indicate a disappearance or reduction in drought-susceptible species, particularly in flax, garden pea, and grape in many areas of the Near East from the EBA to the MBA, while drought-tolerant species tend to increase or remain unchanged. These results correlate with increased water stress during the MBA as has been recognized in the stable carbon isotope data from barley remains in a number of sites [*Riehl et al.*, 2008] (Figure 2).

Transformations in agricultural patterns can also be observed between the LBA and the IA in many places throughout the Near East by new crop species appearing on the scene, such as cotton (*Gossypium* sp.), pomegranate (*Punica granatum*), and cucumber (*Cucumis sativus*) [*Riehl and Nesbitt*, 2003]. Sesame (*Sesamum indicum*) appears more regularly in the archaeobotanical record than before, but as we discuss below, there is a discrepancy between the archaeobotanical and the philological record.

Changes in persisting crop species are particularly visible in free-threshing wheat and grape ubiquities, which are generally increased in the IA compared to the previous period. The rich new spectrum, as well as the more water-demanding species already established in the LBA, was possible most likely due to the use of irrigation. That irrigation was an important factor in agricultural production is not only known from the textual evidence but also indicated in the archaeobotanical remains. At Emar, for example, the wild plant remains contain an increased number of salinization indicators during the LBA, implying continuous irrigation of crops [*Riehl*, 2010b].

This argument correlates with the stable carbon isotope record available from a couple of sites, such as Troy and Tell Shiukh Fawqani, where there is only a slight difference in stable carbon isotope values from LBA and IA samples, which might also be related to irrigation. It has to be noted that at Troy, the settlement was abandoned between roughly 1000 and 700 B.C. At Qatna, on the other hand, increased water stress could be recognized in the IA barley grains, compared to the LBA remains.

### *3.2. Evidence of Transformations of Agricultural Systems in the Geoarchaeological Record*

In theory, transformations of agricultural systems over time should be found documented in the geoarchaeological record; in practice, however, their identification in the modern landscape is problematic. Their context can be destroyed by erosion and overlain by accumulating sediments [*Wilkinson*,

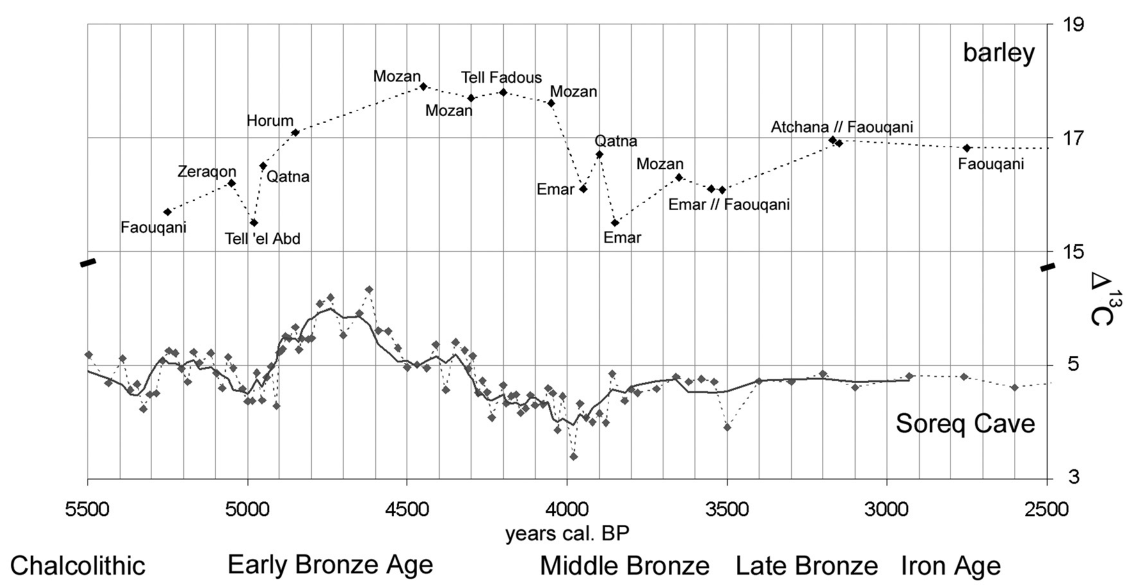


**Figure 2.** (top) Stable carbon isotope values for archaeobotanical barley grains from different sites and (bottom) stable carbon isotopes from Soreq Cave (values have been converted into $\Delta^{13}C$ to enable direct comparison between both records).

2003]. Furthermore, they can become less recognizable through diagenetic alteration. When they are found in the landscape, the chronological context might still remain unclear. Nevertheless, two lines of geoarchaeological evidence are worth mentioning in connection with the mid-Holocene to late Holocene transformations of agricultural systems in the northern Fertile Crescent (Table 1).

First, multiple sedimentological findings at archaeological sites in northern Mesopotamia, as well as within a broader context of the eastern Mediterranean, indicate a distinct change in the regime of water streams at the transition from the third to the second millennium B.C. Relatively stable, moderately strong water flows gave way to increasingly rare, erratic, and stronger flows, which suggests an aridification tendency, in general, and/or more frequent droughts. At Kazane Höyük in the Harran Plain (SE Turkey), the sediment profiles indicate relatively high moisture availability, stable water streams, and even swampy environments during the Chalcolithic and the EBA, whereas the MBA contexts show stream downcutting and drying out of swamps [*Rosen*, 1997]. Similar results have been obtained for the nearby site of Titriş Höyük [*Rosen and Goldberg*, 1995]. In Wadi Jaghjagh (North Syria), a decrease in stable flow is assumed after 2500 B.C. [*Deckers and Riehl*, 2007]. Furthermore, at Tell Brak (North Syria), the early to mid-Holocene channels, terminating presumably in the second millennium B.C., present a contrast to deeper and narrow channels after 1000 B.C. [*Wilkinson*, 2003]. Studies in the wadis al-Walla and ash-Shallalah (Jordan) have demonstrated a high water stand, valley aggradation, and floodplain stability at 3500–2500 B.C., followed by floodplain destabilization and incision at 2500–2000 B.C. [*Cordova*, 2008]. Sedimentological evidence from the Jordanian plateaus of Madaba and Dhiban reveals an almost identical picture [*Cordova et al.*, 2005]. An incision of streams occurring at the same time has also been found in the plains surrounding the Dead Sea [*Donahue et al.*, 1997]. All these observations correspond to a trend of relatively rapid aridification trend roughly around 2000 B.C.

**Table 1.** List of Mid-Holocene Geoarchaeological Phenomena Discussed in the Text

| Authors | Location | Period in B.C. | Observed Phenomena |
|---|---|---|---|
| *Cordova et al.* [2005] | wadis al-Walla and ash-Shallalah | 3500–2000 | high-water stand, valley aggradation and floodplain stability |
| | | 2500–2000 | floodplain destabilization, incision |
| *Frumkin and Elitzur* [2002] | Dead Sea | 2500–2000 | rapid drop of water level |
| *Donahue et al.* [1997] | wadis in the Dead Sea plain | 2500–2000 | incision |
| *Cordova et al.* [2005] | river terraces on the Madaba and Dhiban Plateaus | 2500–2000 | incision |
| *Parker and Goudie* [2008] | lake sediments and sand dunes in the SE Arabian Gulf | before 4000 | lake sediments, C3-dominated savannah |
| | | 4000–2000 | lake sediments, C4-dominated grassland |
| | | after 2000 | active sand dunes |
| *Rosen* [1997] | alluvial sediments, channel fills, Kazane Höyük | Chalcolithic-EBA | steady channel flows, swampy environments |
| | | MBA | stream downcutting, drying out of swamps |
| *Kühne* [1990] | ancient canal system, Middle and Lower Khabur | New Assyrian, seventh century | |
| *Wilkinson et al.* [2010] | hollow way fills, Tell Brak | circa 2000 until today | filling since 2/3 ka B.C., wearing down before that, most probably in the third millennium B.C. or slightly earlier |
| *Wilkinson* [1999] | cultural layers and sediments, Kurban Höyük | 4000 | spring context |
| | | mid-third millennium | well structure |
| | Mari texts | early second millennium | inhabitants of Tuttul (near Raqqa) complain about high water withdrawals at Zalpa upstream |
| *Rosen and Goldberg* [1995] | sediment sections, Titriş Höyük | late third/early second millennium | flow becomes more erratic |
| *Deckers and Riehl* [2007] | sediments, Wadi Jaghjagh | circa 2500 | decrease in stable flow |

and/or, more specifically, the "4200 B.P. event." The latter has been suggested as possibly triggering the late EBA societal collapse in northern Mesopotamia [*Weiss et al.*, 1993] and has since become the subject of debate [*Dalfes et al.*, 1997] with an array of additional proxy evidence having been found for this environmental change in the Near East [*Bar-Matthews et al.*, 1997; *Cullen and DeMenocal*, 2000; *Staubwasser et al.*, 2003; *Pustovoytov et al.*, 2007b; *Riehl et al.*, 2008]. A broader scale of the aridification trend is demonstrated by the simultaneous disappearance of lakes and sand dune activation on the Arabian Peninsula [*Parker et al.*, 2006]. Although landscape changes at the EBA to MBA transition that are visible in the geoarchaeological and sedimentological record in the northern Fertile Crescent mostly involve natural features (channel fills, etc.), they do suggest a restructuring of the regime of landscape moisture supply, which should have had a significant impact on agricultural systems.

The second line of geoarchaeological evidence comprises the finds of artificial, land use-related structures in the landscape and their evolution over time. At Kurban Höyük (SE Turkey), it has been established that the water tables were higher in the mid-fourth millennium B.C., while a water hole or a spring provided water supply to the settlement. This water source most probably became exhausted due to dropping groundwater level, and an artificial well was then dug in the mid-third millennium B.C. [*Wilkinson*, 1999]. Furthermore, the development of some artificial negative relief features obviously ceased around the late third and early second millennium B.C. and gradually filled with sediments. One of the features represents the so-called "hollow ways" (synonyms: holloways, sunken lanes). A hollow way is defined as a "road or track running in a natural or man-made hollow deepened through wear caused by prolonged usage or the raising of the ground on each side" [*Darvill*, 2008]. This term established itself in archaeological literature over the last decade or two to describe the linear structures, primarily in Mesopotamia, leading radially from one common center (usually a tell) and extend through the modern landscape over many kilometers [*Wilkinson*, 1993, 2003; *Ur*, 2003]. It is important to emphasize that for most of Mesopotamia today, there are no or very few distinct hollow ways in the sense of definition given above. To the observer on the ground, the relief between tells appears almost perfectly flat, and the long linear depressions can be detected only indirectly (i.e., by vegetation or standing snowmelt water) or in satellite images [*Wilkinson*, 2003]. However, these landscape features seem to have been true hollow ways in the past.

The hollow ways at Tell Brak experienced a certain evolution, that is, they first were incised and then replenished by several layers of fill, the oldest of which contained pottery shards from the third millennium B.C. [*Wilkinson et al.*, 2010].

The later layers contained ceramic fragments of successively decreasing age toward the modern land surface. This suggests that the hollow ways, having once been intensively used (most probably as roads), lost their original importance after the turn from the third to second millennium B.C. The continuous, nonabrupt formation of fills suggests that the surrounding fields and presumably the hollow ways, themselves, were still in use at later times rather than having been completely abandoned. Another type of negative relief feature is enclosed depressions around tells. They represent a typical element of a tell landscape and are assumed to have been the mud-brick quarries for extracting structural material for the tell [*Wilkinson*, 2003]. The depressions, otherwise called "city ditches," might also have had secondary functions, for which a number of hypotheses have been put forward (see *Pustovoytov et al.* [2011] for a review). For one of those city ditches, around Tell Mozan (NE Syria), a similar pattern of the development as for the hollow ways discussed above have been found [*Pustovoytov et al.*, 2011].

The youngest radiocarbon date from the depression base immediately below the fill was about 2.5 ka cal years B.C., suggesting that the fill accumulation started about that time or shortly thereafter. The formation of the horizon of secondary carbonate accumulation in the exposed soil profile started as early as 1 ka cal years B.C., which marks the phase of stabilization of the land surface. Although more data are needed to deduce the accumulation rate of the fill, it appears that its formation took place between 2.5 and 1 ka B.C. The evolution of the city ditch bears testimony to an end of loam extraction (at least at the study location), which, in turn, may be linked to a decline in settlement growth. Tell Mozan, however, survived well into the LBA, with the formation of fill in the depression possibly indicating continuous agricultural activities.

In general, geoarchaeological evidence, though promising, remains very local in terms of landscape reconstruction. Additionally, it is highly intriguing to find parallels (or contradictions) between the geoarchaeological record and textual and iconographic sources. However, the uneven distribution of the sources does not allow us to produce straightforward conclusions. Our sources for the third millennium originate from the Khabur region, while documents from the eighteenth century city of Mari at the Middle Euphrates prevail where irrigation was a commonly used devise. The inhabitants of Tuttul (near modern Raqqa), for example, complained about high water withdrawals at Zalpa, lying upstream on the Euphrates in the early second millennium B.C. [*Wilkinson*, 2003], an indication of a legal conflict that occurred concerning water rights. The representations of shaduf (a seesaw-like water extraction tool consisting of a bucket and a counterweight fixed at the ends of a long swinging pole) are found on Mesopotamian seals starting at circa 2400 B.C. [*Bagg*, 2000], pointing to the importance of irrigation technology in southern Mesopotamia.

### *3.3. The Transformations of Agricultural Systems in the Textual Record: The Presence and Absence of Crops (Cereals, Wine, Sesame, and Linseed)*

Cereals form the basis of ancient Near Eastern agriculture and thus figure prominently both in the textual and in the archaeobotanical record. The terms for cereals in Sumerian and Akkadian were identified in the groundbreaking work by *Hrozný* [1913]. Since then, further philological research has largely corroborated his identifications (see the articles in the *Bulletin on Sumerian Agriculture*, e.g., cereal crops: *Powell* [1984]; oil plants: *Postgate* [1985], *Waetzoldt* [1985]; sesame: *Stol* [1985b]; beans, peas, lentils, and vetches: *Stol* [1985a]; legumes: *Maekawa* [1985]).

Excavations have uncovered more textual material since the times of *Hrozný* [1913], with the new texts including other terms for grains as well. Hrozný had identified the three main cereal crops, "barley" (Sumerian *še*, Akkadian *še'u*), "emmer" wheat (Sumerian *zíz*, Akkadian *kunāšu*), and "wheat" (Sumerian *kìb*, Akkadian *kibtu*), which is considered as free-threshing wheat. The dominance of barley in all periods corresponds with the archaeobotanical record. The textual evidence generates a model of Mesopotamian societies that are basically barley-producing societies, due to climatic and sociopolitical factors. Collective agricultural production within a "top to down" decision-making structure may have favored monocultures, i.e., barley monocultures. In addition, the single farmer was expected to produce barley to fulfill his liabilities even in periods without a collective mode of production.

The philological work necessary for a proper understanding of the sources, so that they can be used in this interdisciplinary study, may be demonstrated by the following example on the terminology of wheat species. Generally speaking, the argument deals with the difficult question whether different terms denote different crops or are simply local expressions for the same crop. Any differentiation, however, lies on the basis to detect large-scale developments. An administrative document from Tell Beydar (approximately MC twenty-fourth century [*Ismail et al.*, 1996]) lists numbers (perhaps indicating the number of days for work in the field or for the harvest) together with three crop species: 5400 ŠE "barley," 1240 $\text{SIG}_{15}$, and 1240 ZÍZ "emmer" (NB: the font type ŠE indicates the use of a logogram for "barley" based on Sumerian *še*, which was read differently in the local Akkadian dialect, probably *še'um*). Two interpretations are possible: Either $\text{SIG}_{15}$ is simply another term used locally for "wheat," which was called *kìb*/*kibtu* in southern Mesopotamia, or $\text{SIG}_{15}$ identifies another cereal other than "wheat." In the latter case, a remarkable variation in the standard cereal species would then be evident. Considering the archaeobotanical evidence, the most common cereal species during the period under consideration are barley, emmer, and free-threshing wheat.

Emmer (ZÍZ) was mainly used as fodder for animals in MC twenty-fourth century Beydar. Besides barley, emmer was given to sheep, nanny goats, and oxen, which were fed before slaughter, and to "plough oxen" and even birds as well. Donkeys, however, were always fed barley, and especially, the donkeys of the ruler's entourage were richly fed with barley.

In the archaeobotanical record of the second millennium B.C., emmer strongly decreases in proportions, although it remains ubiquitous within many archaeological sites. There is very little textual evidence for "emmer" (ZÍZ) from the Middle Assyrian (fourteenth to thirteenth century) and from the Neo-Assyrian period (eighth to seventh century), an indication of its continual decline in use.

$\text{SIG}_{15}$ appears only in the single cited text from Tell Beydar (twenty-fourth century), and there is no information on its use. The term turns up more often in the slightly later "bread and beer texts'" from Palace G at Ebla (twenty-fourth century), which document the expenditure of food for persons present in the palace. According to the Beydar text, it must be a cereal species and not a specific preparation type. In consideration of the archaeobotanical evidence, $\text{SIG}_{15}$ may denote a specific free-threshing wheat, such as *T. durum*.

$\text{SIG}_{15}$ does not appear as such in second millennium sources from the region dealt with here. Ancient Mesopotamian vocabularies inform us that $\text{SIG}_{15}$ was read *ḫišlētu*, literally "the crushings, grindings," in Akkadian. In the mid-second millennium, texts from Nuzi/Yorgan Tepe situated east of the Tigris in the region of Assyria, *ḫišlētu* appears in the same texts together with *kibtu* "wheat." Thus, we are dealing with two different sorts of wheat at Nuzi, and given the equation of $\text{SIG}_{15}$ = *ḫišlētu*, it is reasonable to assume that $\text{SIG}_{15}$ denotes another type of wheat other than *kìb*. In this case, *kìb* would have been cultivated in southern Mesopotamia, $\text{SIG}_{15}$ in northern Mesopotamia, perhaps corresponding to *T. aestivum* (*kìb*/*kibtu*) and *T. durum* ($\text{SIG}_{15}$/*ḫišlētu*), respectively.

Whereas Presargonic Tell Beydar and Ebla (both MC twenty-fourth century) know the term $\text{SIG}_{15}$, another cereal, *burrum*, appears in Old Babylonian (mainly first half of MC eighteenth century) texts of the region, from Mari and Tuttul in the middle Euphrates Valley, to Chagar Bazar in the Khabur triangle and to Tell al-Rimah southeast of the Jebel Sinjar. The term also does not appear in southern Mesopotamian texts discussed by *Hrozný* [1913]. *Burrum* appears together with ŠE "barley" and ZÍZ "emmer" in Tell al-Rimah, and it may plausibly be identified as a free-threshing wheat species; furthermore, *burrum* is perhaps the word that stands behind the logogram $\text{SIG}_{15}$ in the third millennium texts or at least later replaces the archaic $\text{SIG}_{15}$.

The investigation has led to the identification of two hitherto unidentified words for "wheat" (archaic $\text{SIG}_{15}$, *burrum*); they may well denote another species than the one used in the south (*kìb*/*kibtu*). However, the archaeobotanical evidence of hexaploid (*T. aestivum*) and tetraploid free-threshing wheats (*T. durum*) is problematic due to the fact that the two species are only discernible on the basis of their chaff remains, which were often not considered in early archaeobotanical work (for details, see the work of *Riehl* [2011, p. 155]). The available evidence indicates a marked concentration of tetraploid free-threshing wheat in the upper Khabur region for the third millennium B.C. (thus = $\text{SIG}_{15}$, *burrum*?), while hexaploid species occur everywhere else (thus = *kìb/kibtu?*). The second millennium evidence is too scarce from which to draw any valid conclusions. More detailed research is needed to confirm the new identifications. The problem of the presence of einkorn, for which no native term has been proposed, must also be addressed. Only carefully controlled old and, if possible, new identifications will allow a much better use of the cuneiform documentation from the region.

Another crop category relevant for environmental change includes oil plants, linseed, and sesame, respectively.

Linseed occurs regularly in the Near Eastern archaeobotanical record starting at Pre-pottery Neolithic A Mureybet (circa 10.000–8.800 B.C.). Written evidence for linseed, called *gu* in Sumerian and *qû* in Akkadian, derives mainly from southern Mesopotamian sources [*Waetzoldt*, 1983]. Linen, the textile made from linseed fibers, which is attested since around 7000 B.C. in Anatolia [*Potts*, 1997], is *gada* in Sumerian (third millennium) and *kitû* in Akkadian (second to first millennium). But there is a single writing that proves that *kitû* in the thirteenth century B.C. Tall Sheikh Hamad/*Dūr-Katlimmu* means the flax plant [*Cancik-Kirschbaum*, 1996, pp. 106–111]. That both *qû* and *kitû* are Sumerian loanwords in Akkadian is an expression of the cultural continuity in Mesopotamia. Although linseed is mentioned in the textual sources, e.g., at seventeenth century B.C. Mari, its consumption is not documented, and linseed oil was apparently unknown in ancient Mesopotamia [*Waetzoldt*, 1983].

The rarity of linseed is directly related to the fact that wool was the dominant raw material for textile production as early as the Chalcolithic period [*Algaze*, 2008]. With less than 10% of the produced textiles, linen appears with much lower frequency in the written record than does woolen products [*Potts*, 1997], and linen textiles never seem to have acquired the same importance as they did in Egypt [*Waetzoldt*, 1983].

Although the textual evidence is limited and deriving particularly from southern Mesopotamia, a decrease of flax cultivation seems likely to have occurred in the second millennium B.C. The rare presence of a few linen garments in lists of textiles in the early second millennium (e.g., at Tell al-Rimah), or the import of linen in the first millennium, for example, as tribute from Syria to the Neo-Assyrian empire (934–609 B.C.), does not necessarily imply local production. Developing a more refined methodology for quantifying the proportion of linen textiles within various contexts is essential before we can draw definitive conclusions on the development of flax production from the third to the second millennium.

The plant cultivated for oil production in lowland Mesopotamia was sesame, a term related to Akkadian *šamaššammū*, and Sumerian *(še-)ŋeš-ì*, literally "(seeds of the) oil plant" [*Powell*, 1991]. Before the IA, sesame is archaeobotanically only recorded from EBA Abu Salabikh [*Charles*, 1993] and from LBA Tall Sheikh Hamad [*van Zeist*, 2001]. It appears, however, in the cuneiform sources as having been cultivated in Mesopotamia as early as the third millennium B.C. [*Stol*, 1985b, 2010; *Waetzoldt*, 1985; *Bedigian*, 1998, 2004].

Although sesame oil was used regularly for body care, and thus appears frequently in the textual record (e.g., at Old Babylonian Mari, Tell al-Rimah, etc.), the sources from Upper Mesopotamia and Syria are practically silent about its cultivation.

The textual evidence for olives corresponds with the natural distribution of the species, which is limited to the coastal areas of the Mediterranean [*Zohary and Hopf*, 2000]. In Mesopotamia, olive oil appears therefore as a good imported from the west [*Stol*, 2003–2005]. Recently, morphometric and biomolecular analyses have provided more insight into the emergence of cultivars [*Terral et al.*, 2004; *Breton et al.*, 2009], though the local beginnings of systematic use of domesticated species are still debated. The plausible argument of increased find numbers as an indicator of established olive cultivation places the beginnings into the EBA or in some places even the Chalcolithic.

Written evidence of large-scale olive cultivation comes from Ebla/Tell Mardikh in the MC twenty-fourth century, where the term used is GIŠ.Ì, literally "wood of oil." In the second millennium, the Akkadian term was *serdu*. Interestingly, Ebla seems to have been at the eastern fringe of the region where olives were cultivated, and in remarkable quantities (an annual production of 170,000 L [after *Archi*, 1991,

p. 219]). Ebla would send olive oil in small quantities to the courts of allied states, selling or delivering it as tithe for the Euphrates trade to the mighty city of Mari.

The common beverage in Mesopotamia was beer produced from barley. However, in Upper Mesopotamia, there is plenty of evidence for the consumption of wine (for the cuneiform evidence, see *Powell* [1996]). "Wine" is *ŋeštin* in Sumerian, *karānu* in Akkadian, but at Emar, the word *ḫamru* was used, written KAŠ.GEŠTIN (the signs meaning "the beer of the grape"). The overall proportions of wine and raisin (*muziqu*) [see *Postgate*, 1987] production are, however, unknown. At MC twenty-fourth century Tell Mardikh/Ebla, vineyards existed both near Ebla and in the surrounding countryside [*Milano*, 1996].

Interestingly, wine had to be bought at the contemporary cities of Nabada/Tell Beydar [*Ismail et al.*, 1996] and at Mari [*Sallaberger*, 2012b]. This could indicate that wine was not produced at Ebla. Alternatively, it could demonstrate that the organizations from which the available documents derive did not dispose of their own vineyards, since these were, for example, kept by the palace.

In the Old Babylonian period, the MBA, especially MC late nineteenth/eighteenth centuries B.C., we find plenty of evidence for wine consumption in Upper Mesopotamia, for instance from the archives at Mari (Tell Hariri), Tell al-Rimah, and Shekhna (Tell Leilan). Since it was significantly more expensive to produce grapes than barley, wine was the beverage of the upper social strata. The wine jars found listed in the texts, however, could have been imported from elsewhere. At Mari, wine trade became a source of income since the palace took 10% of every shipment as a tax on the Euphrates trade [*Finet*, 1974–1977, pp. 123–124; *Michel*, 1996, pp. 407–408]. At Mari, various qualities of wine are documented, such as wine "of good quality," wine "of second quality," "old" wine or "red" wine. The latter one implies that different phenotypes of grapes were cultivated.

Most wine with origins explicitly named did not come from the Middle Euphrates, though we do have evidence for viniculture in the region upstream of Terqa (Tell Ashara) [*Stol*, 2004, p. 870].

The main center of wine production in Upper Mesopotamia should have been Karkemish (Tell Jerablus). We do not have explicit evidence for local cultivation of grape, but the low prices for wine from Karkemish suggest its cultivation there [*Powell*, 1996, p. 108]. Other centers of wine production include Ugarit (Ras Shamra), Shubat-Enlil (Shekhna, Tell Leilan), the land of Apum (the greater region of Tell Leilan), and the landscape of Ida-Maras (region on the Upper Khabur or in the Khabur triangle [*Vincente*, 1991, pp. 299, 305, 310; *Powell*, 1996, pp. 115–116]. To summarize, grape cultivation during the EBA and MBA was concentrated on the banks of the Euphrates south of Karkemish, the hilly regions south of the Taurus Mountains, the Upper Khabur, and the region of Jebel Sinjar, which corresponds well with the natural distribution of the wild progenitor species [*Zohary and Hopf*, 2000].

Wine cultivation is known from LBA I Alalakh [*Dietrich and Loretz*, 1969] and from LBA II Ashtata with its capital Emar (Tell Meskene) [*Mori*, 2006], Karkemish, and Ugarit. In the Middle Assyrian Empire, wine continues to be used as the beverage of the upper class. There is one single Middle Assyrian text in a private collection that mentions a vineyard presumably somewhere in the Lower Khabur valley [*Fales*, 2010, p. 77].

The situation radically changes in the first millennium documentation from the Neo-Assyrian Empire. Textual evidence points to large vineyards in Upper Mesopotamia with tens of thousands of plants in the regions of the Balikh Plain and the Jebel Sinjar. Wine production occurred in the region of Guzana (Tell Halaf) in the Khabur triangle, in the hilly regions of the Jebel Sinjar and the landscape of Izalla (presumably the Dibek Dagi in the eastern edge of the Tur Abdin). Zamua, in the vicinity of modern Kirkuk, was famous for its wine as well [*Powell*, 1996, p. 115]. Still wine was the beverage of the upper social strata, although becoming a regular part of cultic ceremonies [*Powell*, 1996, p. 119] and the everyday beverage of professional soldiers. The per capita consumption of wine, however, is documented as having been low [*Powell*, 1996, p. 121].

The renewed interest in wine cultivation in the Balikh and Khabur region is surely a sign of a more dense agricultural exploitation of the region in Neo-Assyrian times in order to fulfill the rising demand for wine in the center of Assyria. Since there is evidence that the state was involved in the cultivation of the countryside, and with evidence from the late seventh century Harran census [*Johns*, 1901] showing the probable concern of royal estates with large vineyards in the region of Harran, it seems likely that the rise in cultivation of grapes was commissioned by the crown itself.

## 4. DISCUSSION

Looking at the geoarchaeological, archaeobotanical, and philological data, we find clear patterns linking evidence to known changes in the environment and the political and cultural life of the region under study.

The evolution of city-state after 2900 B.C. in the Khabur region, which was accompanied by the accumulation of political power through agricultural surplus production and cooperation between independent cities and the continuous centralization of power, was followed by the fall of the

Akkad Dynasty shortly before 2100 B.C., which is frequently discussed in relation with the climate change event of 4200 B.P. [*Weiss et al.*, 1993; *Weiss and Courty*, 1993; *deMenocal*, 2001; *Bar-Matthews and Ayalon*, 2011; *Kuzucuoglu and Marro*, 2007]. The chronological resolution of palaeoclimate proxy data, however, differs from historical time resolution, and the regional variations in the dating of climate fluctuations render the relationship between climate effects and population developments into a problematic issue [cf. *Roberts et al.*, 2008; *Riehl and Bryson*, 2007]. We need to keep in mind that the label of "4200" for the mid-Holocene climate fluctuation is not an exact dating, as the correlation of different palaeoclimate proxy archives is limited due to the methodological problems arising from differences in the material dated (see various contributions of *Battarbee and Binney* [2008]). This is particularly the case when we consider that climate fluctuations are trends between two peaks, which were experienced by ancient populations more as a relatively long sequence of minor fluctuations ("creeping normalcy" as introduced by *Diamond* [2005]). Chronological resolution of historical state development is much higher, which makes a probable correlation between climate fluctuations and historical events difficult. Phases of economic growth and increasing population, such as during the reign of Ur III, as well as various examples of settlement abandonment, are within the time frame of the "4200 B.P. event."

Despite the problem of linking historical development to climate fluctuations other than catastrophes, the general climate trend of increasing aridity after 5000 B.C. [*Wanner et al.*, 2008], which was superposed by regional climate effects starting at around 2200 B.C., has often been considered responsible for state collapse. Within the whole historical sequence, warfare, destruction of prominent political centers, opposition, and rebellion are frequently reported and are generally accepted as signs of collapse. Famine, inflation, and problems with taxation are also among the most frequently mentioned reasons. Generally, high-energy needs for surplus production and development of technological and organizational complexity [*Tainter*, 1995; *McIntosh et al.*, 2000] are considered as important problems for maintaining the societal status quo, and this seems to be reflected in the agricultural developments observed in the archaeobotanical and the philological data.

Due to fieldwork methodology, the archaeobotanical evidence provides only low chronological solution, usually showing only general differences between the EBA and the MBA assemblages on the supraregional level. A reduction in the presence, proportion, and ubiquity of water-demanding crop species is visible when comparing EBA and MBA assemblages. At the same time, water stress signals inferred through $\delta^{13}C$ in barley grains are more frequent in MBA assemblages. This correlates with the geoarchaeological record of a change in the regime of water streams at the transition from the third to the second millennium B.C. from relatively stable, moderately strong water flows to stronger, more rare, and erratic flows in a number of places, suggesting a trend toward aridification, in general, and/or more frequent droughts. These trends suggest a restructuring of the regime of landscape moisture supply, which should have had a significant impact on agricultural systems.

Regional differences in these patterns exist (e.g., between the Khabur and the Euphrates, and the western, more Mediterranean regions), but can only be discussed within more detailed studies [*Riehl and Bryson*, 2007; *Riehl*, 2012a].

The absence of the term KIB/*kibtu* for the hexaploid form of free-threshing wheat in the Beydar evidence may be explained by a lack of large-scale irrigation, whereas the tetraploid form would have generated greater yields than the hexaploid in this area. This would correspond with the archaeobotanical record of the third millennium, where tetraploid free-threshing wheat occurred in larger amounts in the Khabur region though hexaploid free-threshing wheat is found particularly in places were irrigation is assumed.

Despite a general correlation of the archaeobotanical with the philological record, discrepancies occur as well between both records, as in the case of sesame, which according to the texts was already an important crop in the EBA, though not preserved in most archaeological sites due to the physiological character of the seeds. There is, however, no textual evidence that any adaptations in sesame cultivation were conducted throughout time. Differently for linseed, although also an oil crop, it seems to have been used only in textile production, but even there in a very restricted manner.

Between 2000 and 1500 B.C., internal political change was greatly caused by the Amorites, who seized power over a number of urban centers. It seems probable that Amorite ways of life held consequences for animal husbandry. Other earlier centers regained economic and political power, and even new centers, such as Qatna, developed during the MBA.

The end of the MBA is accompanied by warfare in many regions, particularly the Hittite attack on Yamkhad in northwest Syria and the sack of Babylonia. Many powerful cities disappeared, and there was also a discontinuation of administrative and scribal practices as the levels of economic and cultural activities decreased. Textual evidence becomes scare, reflecting the emergence of a "Dark Age." Fewer archaeological sites and less archaeobotanical data are available.

There is a trend, however, of greater regional water stress on crop species and, consequently, a greater concentration on more drought-tolerant species, as outlined above. The comparatively small body of textual evidence, especially from southern Mesopotamia, unequivocally confirms the decrease of flax cultivation in the second millennium B.C. compared with the earlier periods. Although there is almost no written evidence for the cultivation of flax, and generally woven textiles were made of wool, the available sources support the assumption that linen and linen textiles were imported in small quantities, by trade or tribute during the second millennium B.C. The import of the end product was thus more efficient than local production of the source crop, supporting earlier interpretations of the disappearance of linseed from MBA archaeobotanical assemblages [*Riehl*, 2011]. A climate shift toward more arid conditions would have led to decreasing yields of flax, which has high water requirements. An additional factor may have been autotoxicity, which is the fact that plants of the same species react negatively to the metabolic products of the previous generation. In flax, this leads to a cultivation interval of several years on the same plot of earth before reasonable yields can be expected again. It is unknown whether ancient farmers were aware of this problem. The effect, however, should have been clearly recognized as strongly reduced yields in the second year, leading to either a shift to other cultivable land or, in the worst case, to an abandonment of the crop, in general. In this case, climate would have only acted as an additional factor.

Another correlation of the archaeobotanical with the philological data is the development of second millennium emmer production, which appears significantly regressive in the textual evidence and is economically meaningless since Late Bronze II. There is contemporary evidence, though, for irrigated wheat production (*kibtu*; presumably *aestivium*; see above). This has often been related to the development of markets and the mass production of barley [*Nesbitt and Samuel*, 1996].

Most of the settlement centers disintegrate with the end of the LBA due to political conflict and economic decline (e.g., crop failures, rebellion against taxation). It is most likely that complex interactions between political, ecological, and climatic (Bond event no. 2) factors were responsible for these massive supraregional changes. Another "Dark Age" following the end of the LBA was of varying duration and lasted in Assyria until 935 B.C. Very little is known about the centuries between 1100 and 900 B.C., but it seems clear that an almost complete restructuring of society must have taken place due to migration, internal population movements, and technological and trade network changes [*Van De Mieroop*, 2003]. But there is also textual evidence for continuity, e.g., the restoration of the irrigation systems of the Lower Khabur and Middle Euphrates [*Fales*, 2008] or the maintenance of many urban centers in Upper Mesopotamia under Aramean supremacy.

During the IA, a number of new crops appear in the archaeobotanical assemblages, most of them requiring irrigation in areas of irregular and low rainfall. Changes in persisting crop species are particularly visible in free-threshing wheat and grape ubiquities, which occur generally more often in the archaeobotanical record of the IA, and which is confirmed by the textual evidence of numerous vineyards in the IA of Upper Mesopotamia. The larger body of textual evidence from the first millennium also reveals more linen textiles than in the second millennium. Still, the evidence is almost exclusively for the import of linen as tribute from Syria to the Neo-Assyrian Empire (934–609 B.C.). Only later, during the Neo-Babylonian period, do we find evidence for more frequent linen cultivation [*Waetzoldt*, 1983]. Olive is not frequently mentioned in ancient texts, but the import of olive oil from the west is attested [*Faist*, 2001; *Stol*, 2003–2005, p. 33], corresponding with the archaeobotanical record.

The importance of irrigation is known from the textual evidence and is indicated in the archaeobotanical remains, where wild plant remains contain an increased number of salinization indicators [*Riehl*, 2010b]. A local increase in the water supply, either through precipitation or irrigation, is visible in the IA $\delta^{13}C$ values. At many other sites, however, there is no such signal.

## 5. CONCLUSION

Available archaeobotanical, philological, and geoarchaeological data of northern Mesopotamia show that climatic fluctuations at the end of the EBA correlate with the regional abandonment of settlements, the reduction of crop species with higher water requirements, and an increased water stress in barley. At the transition from the LBA to the IA, there are locally higher water stress signals in the IA, but also increasingly more water-demanding species, which can best be explained by an improvement in agricultural technology and irrigation techniques.

The archaeobotanical, geoarchaeological, and philological evidence confirm that a number of reasons, including feedback mechanisms, must have been responsible for the developments occurring at the end of the EBA and the LBA. The complex organization, which is necessary to sustain redistribution systems, such as in EBA northern Mesopotamia, was challenged through climate fluctuations and increasing aridity. Surplus production required high-energy input through labor, probably increasing throughout time by population growth and thus becoming increasingly difficult to sustain, as documented through shortages in the labor force for agricultural production. The endeavor to maintain such systems was related to the accumulation of power, which often ended in warfare between the different centers, with all its negative consequences.

Despite many difficult methodological issues, the following synthesis can be developed, based on our body of evidence for observable agricultural transformations in northern Mesopotamia between 3000 and 1000 B.C.

During the EBA, the aim of surplus production appears together with increasingly drier conditions toward the end of the EBA and the beginning of the MBA, consistent with the 4200 B.P. event. This led to decreasing yields, opening up new perspectives with probable economic change through an ethnogenesis of Amorite nomads. The continued reliance on surplus production during the MBA coupled with increased water stress, as indicated in the stable carbon isotope and geoarchaeological evidence, was answered by a relative shift from demanding and labor-intensive crop species to more stress-tolerant species, barley in particular. However, a shortage in human resources resulted in continuous economic decline on the political level, consequently leading to political instability, the competition for resources between states, and occasional warfare. This seems to have continued into the LBA. With the new network of states emerging at the beginning of the IA, agricultural production rejuvenated, with a considerable amount of new crop species being introduced and a comeback of more demanding crops occurring, such as grape. The combined archaeobotanical and stable carbon isotope evidence suggests that this can be traced to advances in irrigation technology for some places in northern Syria. For other, more southern, places, such as Qatna, increased water stress indicated problems in agricultural production, which may have been related to locally increased aridity.

These developments illustrate the difficulty in using the term “collapse” in relation to changing conditions. The end of one system almost always brings options for evolution or transformation. Despite climate changes and the visible restructuring of the landscape, particularly in relation to water resources and management, the development of agricultural systems spanning the cultural sequence considered here demonstrates continuous adaptation rather than collapse.

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