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Analysis

Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities

Stephan Barthel [a,b,c,*], Christian Isendahl [d]

[a] Department of History, Stockholm University, SE-106 91 Stockholm, Sweden
[b] Stockholm Resilience Center, Stockholm University, SE-106 91 Stockholm, Sweden
[c] The Beijer Institute of Ecological Economics, Royal Academy of Sciences, SE-104 05 Stockholm, Sweden
[d] Department of Archaeology and Ancient History, Uppsala University, SE-751 26 Uppsala, Sweden

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ABSTRACT

Food security has always been a key resilience facet for people living in cities. This paper discusses lessons for food security from historic and prehistoric cities. The Chicago school of urban sociology established a modernist understanding of urbanism as an essentialist reality separate from its larger life-support system. However, different urban histories have given rise to a remarkable spatial diversity and temporal variation viewed at the global and long-term scales that are often overlooked in urban scholarship. Drawing on two case studies from widely different historical and cultural contexts – the Classic Maya civilization of the late first millennium AD and Byzantine Constantinople – this paper demonstrates urban farming as a pertinent feature of urban support systems over the long-term and global scales. We show how urban gardens, agriculture, and water management as well as the linked social–ecological memories of how to uphold such practices over time have contributed to long-term food security during eras of energy scarcity. We exemplify with the function of such local blue–green infrastructures during chocks to urban supply lines. We conclude that agricultural production is not "the antithesis of the city," but often an integrated urban activity that contribute to the resilience of cities.

1. Introduction

Over the last two hundred years, modernity, innovation, and progress have been associated with the city. Based in ecosystems theory (Clements, 1916) and using Chicago as a case study, the Chicago School of urban sociology emerged in the 1920s and 1930s to establish a modernist understanding of urban life as an essentialist reality separate from rural life. This idea still permeates urban scholarship and mainstream perceptions of the constitution of cities but is untenable when taking a longer-term perspective to global urban history. The idea of cities as separate entities essentially detached from their broader life-support systems (Wirth, 1938) was strongly linked to major innovations in transportation technology as Chicago became an important hub in the US railroad network in the 1850s, enabling food transportation over great distances. It allowed Chicago to grow rapidly from a few thousand inhabitants in the 1850s to over 2 million in the early 1920s. Harvey (1990) has shown how industrial-era technological innovation, cheap and efficient travel, and economic growth (opening new markets, speeding up production cycles, and reducing the turn-over time of capital) catered for the first wave of space–time compression, which refers to those socio-economical processes that accelerate the pace of time and reduce the significance of distance. Hence, the modernist ideology underpinning the emergence of urban planning during the early decades of the 1900s distinctly separated local agricultures as obsolete in futuristic and normative understanding of the city as an autonomous social system (Eisenstadt, 1966).

Today, urbanization is in a second wave of space–time compression driven by internet, jet-travel, and globalized economies (Harvey, 1990). The accelerating pace at which urban life proceeds and the decreasing importance of geographic barriers and distances are qualitatively different in terms of their intensity and scope compared to even fifty years ago (Harvey, 1990; Sassen, 1991). However, space–time compression is an outcome of surplus energy of diminishing returns subsidized by fossil fuels (Strumsky et al., 2010; Tainter, 2011). Large cities mainly feed themselves by global food systems relying on fossil fuels (Curtis and Ehrenfield, 2012; Fraser and Rimas, 2010; McMichael, 2011) to sequester foodstuffs from the farthest reaches of the planet (Deutsch, 2004; Folke et al., 1997), often with detrimental environmental impacts (Fraser and Rimas, 2010; Steffen et al., 2011). While such high global connectivity between cities and remote food supplies can decrease cities' vulnerability to food shortages and build resilience during medium-severe crises (Ernstson et al., 2010), sudden severances of supply lines – that for instance peak oil scenarios threatens to levy – pose major threats to urban food security (Barthel et al., in press; Newman et al., 2009). We define food security broadly as the situation when people have physical and economic access to sufficient, safe, and nutritious food to meet their dietary

* Corresponding author at: Department of History, Stockholm University, SE-106 91 Stockholm, Sweden. Tel.: +46 763605705.
E-mail address: stephan.barthel@historia.su.se (S. Barthel).

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needs (FAO, 1996) and the food system as "the chain of activities connecting food production, processing, distribution, consumption, and waste management, as well as all the associated regulatory institutions and activities" (Pothukuchi and Kaufman, 2000, p. 113). We argue that the historical and archaeological record offers important insights on urban food systems that are not sponsored by fossil-fuel regimes. In this paper, we analyze food systems in pre-Industrial cities, addressing two main questions: How did people in cities of the past build food security? How did people in cities of the past cope with cuts in supply lines?

Different urban histories have given rise to a remarkable spatial diversity and temporal variation viewed at the global and long-term scales that are often overlooked in urban scholarship (Fletcher, 2009; Marcus and Sabloff, 2008; Sinclair et al., 2010; Smith, 2003; Storey, 2006). Comparing long-term urban histories in a global frame of reference suggests that a marked conceptual and physical separation between urban and rural sectors emerged largely as a consequence of modernist space–time compression (Barthel et al., in press). This paper explores food security resilience for urban people by comparing two distinct and unrelated historical metropolitan landscapes: the pre-Columbian Lowland Maya cities in Mesoamerica and medieval Constantinople in the eastern Mediterranean (Fig. 1). As temporal frames of analysis, we adopt a multi-scalar approach and look at both processes over the *longue durée*, the long-term, as well as *événement*, or historical events (Balée, 2006; Braudel, 1980). We present these two cases since they are the ones we are the most familiar with from previous research (Barthel et al., 2010b; Isendahl, 2002, 2010, in press; Ljungkvist et al., 2010). We argue that the similarities observed in these urban settings offer important insights that are not simply idiosyncratic but can be valid for understanding food security in cities more broadly, even though the sample size is inadequate for any nomothetic conclusions.

1.1. Social–Ecological Resilience of Urban Food Supply Systems: The Analytical Lens

Ecological resilience was originally conceived in forest ecology (Holling, 1973), linked to the interrelated behavior of sets of species over time in spatially defined areas (Folke, 2006). Social–ecological resilience is defined as the capacity to absorb shocks, utilize them, reorganize, and continue to develop without losing fundamental functions (Carpenter and Folke, 2006). Diversity has been put forward as an overriding principle of social–ecological resilience (Gunderson and Holling, 2002; Low et al., 2003). The evolutionary logic is that "diversity of species within the same functional group, superficially described as a redundancy, add resilience to that specific ecosystem function (e.g. pollination), because each species responds differently to a given disturbance" (Folke et al., 1996), as memories of past experiences are captured in the genetic pool of each species.

Since it informs future responses and renewal in relation to disturbances by drawing on different forms of memories, the capture and use of experiences – sometimes called learning – is another key principle of resilience. Analyzing features that brings "captured experiences" into periods of crises is one way to unpack temporal sources of resilience (Colding et al., 2003; Folke et al., 2003; McIntosh et al., 2000). One concept that deals with such temporal resilience dynamics is called social–ecological memory (Barthel et al., 2010a). Such memory also includes features of wider spatial importance for renewal after collapse (Bengtsson et al., 2003; Nyström and Folke, 2001). For instance, in the context of dramatic disturbance – such as natural forest fires or human forest clearance – resilience depends on three main factors: the diversity and quantity of surviving memory carriers within the disturbed area (large trees that survive fire or seeds that remain in the soil); the diversity of vectors (insects, birds, humans) that brings in new memory carriers (seeds, eggs, pollen), and the often human shaped physical morphology of the surrounding landscape, including migration routes and diversity of refugia from which memory carriers can be vectored back into the disturbed area, thus collectively forming a complex mnemonic infrastructure for resilience.

In an analysis of urban food supply systems we need to apply these principles of resilience in an inclusive manner, beyond the strict behavior of sets of species in an ecosystem. We use the above definition of resilience as a benchmark, but construe diversity and memory also of broader categories in social–ecological systems. Since urbanism has a multi-millennial history on most continents, it is evident that cities in a general sense are remarkably resilient systems as ways to organize large and complex human populations. It is illuminating that many ancient cities persisted to reach life-ages it is hard to imagine that any contemporary city in the United States will. Surely, there must be important insights for urban planning to gain from analyzing the resilience of past urban food systems over the long-term and in times of stress in the diverse urban archeological and early historical record. In a global framework, the diversity of types of cities and urban food systems forms an essential part of the explanation as to why the city in many senses has been a long-term "success story." But urban resilience must be assessed at several scales, from global and regional levels to individual cities and intra-city sectors. In the present analysis we scale down the level of analysis to individual case cities, applying social–ecological resilience as a lens for assessing the management of urban food resource security, but with reference to regional contexts and complex social networks.

One approach to investigate and compare urban resilience is to assess the degree of diversity in the options available to urban communities in relation to food resource production and distribution

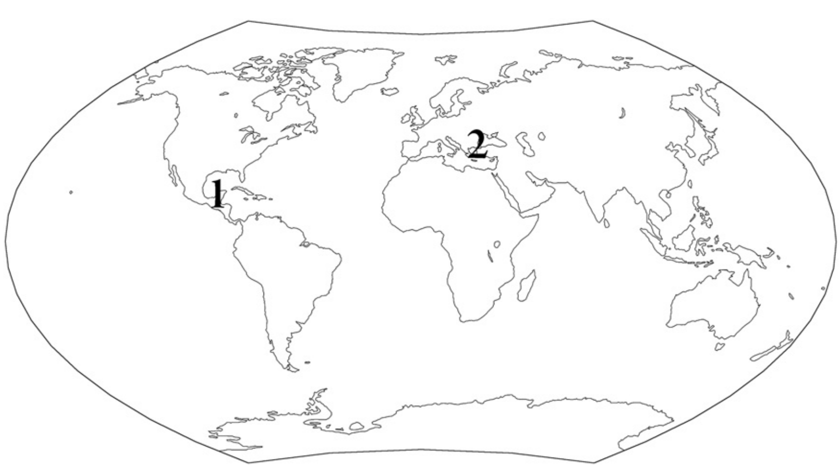

Fig. 1. Map showing the location of case studies: (1) the Maya Lowlands and (2) Constantinople.

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over the long-term and how this played out during severe crises (Barthel et al., 2010b, 2012). The different sets of available options we are focusing on here include (1) the diversity of food production systems in the total food resource framework; (2) the spatial distribution of primary food resources (local, regional, interregional); (3) trade networks and the capacity to trade for food; and (4) access to a diversity of mnemonic tools relating past experiences of how to produce and access food during chocks to the system. There are many and very different kinds of social–ecological mnemonic carriers, including not only species DNA and landscape morphologies and histories, but also social institutions, rituals, habits and practices, and in a broad range of documentation (Crumley, 2000; Nazarea, 1998). Here we choose the concept of social–ecological memory since it captures vital relations between humans and living ecosystems that affect the ability of people to respond to disturbance (Folke et al., 2003), defined as the means by which knowledge, experience, and practice about how to manage a local ecosystem and its services are retained in a society and revived and transmitted through time (Barthel et al., 2010a).

We test diversity and memory as principles of resilience in two cases of early pre-Industrial urbanism that are particularly well studied and from which there is sufficient data available on urban history and food support systems to allow assessments of social–ecological resilience: Constantinople and Maya cities, displayed in Section 2. Section 3 discusses urban resilience in the cases and compares these with industrial/modern and contemporary cities. We conclude with policy implications for future urban development regarding the crucial roles that local harvesting of food and water has had for urban resilience in distinctly different ancient cities.

2. Learning About Food and Water Security from Ancient Cities

2.1. Urban Agriculture, Gardening, and Water Provision in the Classic Period Cities of the Maya Lowlands

Pre-Columbian Lowland Maya civilization extended over the Yucatán Peninsula of southeast Mexico, Guatemala, and Belize. The Maya lowlands cover about 250,000 km^2 and form a heterogeneous environment in terms of topography, hydrology, soils, vegetation, and climate, from the tropical rainforests in the south to the semi-arid north-west coast (Fig. 2; Dunning and Beach, 2011). The prehistory of the Maya unfolded over several millennia with the initial development of states, cities, long-distance exchange networks, advanced technologies, and complex resource management systems by the first millennium BC. The long-term political and economic history of the lowlands suggests a complex series of cycles of growth, decline, and reorganization and numerous large, medium, and lesser cities emerged during the course of the Preclassic (1000 BC–AD 250), Classic (AD 250–1000), and Postclassic periods (AD 1000–1500). By the Classic period, the lowlands were politically divided between a number of different polities, ranging in size and form from sub-regional states to alliances of small-scale city-states. The longevity of urban histories varies greatly and there were cities of both relatively long (>1000 years) and short (~200 years) durations.

Despite temporal and spatial idiosyncrasies, most cities share a basic model of how to organize urban landscapes (Fig. 3). At the center is a core complex with buildings and spaces of elite residential and civic–ceremonial functions linked together by a network of causeways. It is surrounded by dispersed urban sprawl of residential household groups that cluster into neighborhoods around subsidiary civic–ceremonial buildings. The household group was the basic settlement unit of Maya cities and consisted of an elevated quadrangular basal platform on which houses were built on each side. The zone surrounding the platform was left un-built, creating a dispersed settlement pattern.

Scholars have addressed the dispersed pattern with supplementary explanations: (1) weak socio-political control unable to offset centrifugal tendencies in the population (Inomata, 2006); (2) data

Fig. 2. Map of the Maya lowlands on the Yucatán Peninsula showing the location of the Puuc sub-region. Present-day nation boundaries are indicated for orientation. Background: SRTM shaded relief map of Central America (http://www2.jpl.nasa.gov/srtm/central_america.html) modified by C. Isendahl.

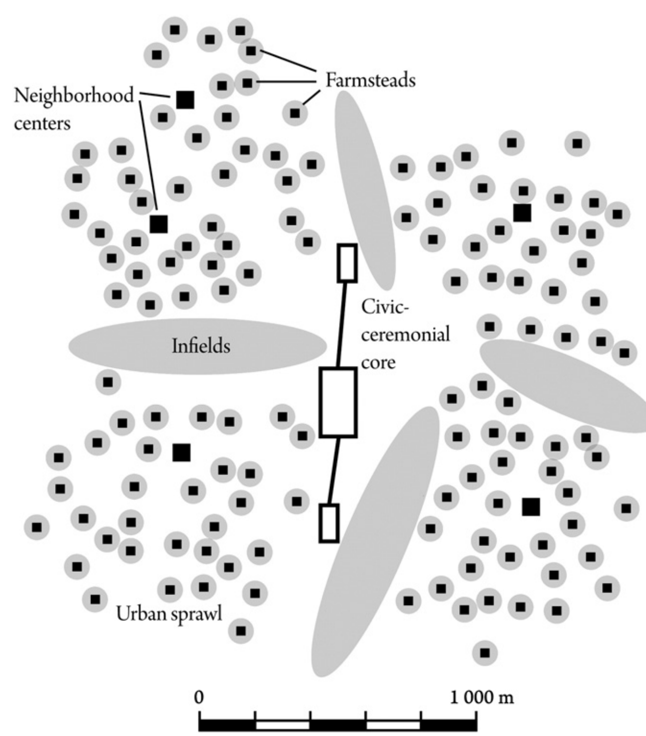

Fig. 3. Schematic model of the dispersed settlement pattern of a Classic Maya city. Urban sprawl was interspersed with garden areas around each farmstead. Larger open spaces were devoted to short-fallow or permanent infield agriculture. Garden and farming areas are shaded.

bias owing to incomplete recognition of subsurface evidence (Johnson, 1994); and (3) settlement patterning as an adaptive response that mimics the tropics' high ecological diversity and low individual species density (Scarborough and Burnside, 2010); but the overriding cause for the low-density pattern is (4) a function of that large urban sectors were devoted to agriculture (Drennan, 1988; Isendahl, 2010; Killion, 1992). The basic mechanism creating the low-density city was the clustering of composite household compounds and associated garden space, collectively forming a farmstead (Dunning, 2004). The process of expanding urban sprawl of clustering farmsteads produced "green cities" (Graham, 1999), "garden cities" (Chase and Chase, 1998), "forest gardens" (Ford and Nigh, 2009), or "agro-urban landscapes" (Isendahl, 2010, in press). Agrarian-based low-density early cities have been identified elsewhere, for instance in the ancient Khmer civilization of Southeast Asia (Fletcher, 2009) and among the Aztecs of Highland Mexico (Isendahl and Smith, 2011), but the phenomenon is inadequately investigated.

2.1.1. The Diversity of the Food Production Framework

Pre-Columbian Maya subsistence was agricultural-based, supplemented by hunting and collecting aquatic resources. Maya food producers did not keep large stocks of any domesticated animal. Contrary to a common stereotype of traditional Maya farming as long-fallow slash-and-burn cultivation of maize, beans, and squashes, farmers practiced a series of highly complex and diverse agrosystems-from the regional scale down to the individual field plot (Atran, 1993; Fedick, 1996; Flannery, 1982; Gomez-Pompa et al., 2003; Harrison and Turner, 1978; Killion, 1992; White, 1999).

Fedick (1996) uses the term "managed mosaic" to characterize the diversity and complex spatial distribution of Maya resource management systems. At the regional scale agrosystem diversity can partly be recognized as adaptations to spatially distinct environmental regions. For instance, in the humid south-eastern region of the lowlands, raised-field wetland cultivation extended over large sectors (e.g., Pohl, 1985, 1990; Turner and Harrison, 1983) and extensive agricultural terracing is found in hilly terrain (Chase et al., 2011). But the Maya practiced a series of other cultivation techniques, including garden agriculture, orchard farming of fruit trees, short- to long-fallow swidden cultivation, and agro-forestry. Moving down in scale to the total food resource framework available to individual cities, adaptation to environmental conditions cannot alone account for food security management. Rather, the inhabitants of each city drew on a variety of sources for sustenance, employing composite agrosystems that usually included most of these techniques, but that were balanced differently from place to place and changed over time according to environmental, economic, and socio-political conditions. For instance, at the Classic period city at Xuch in the Puuc region of the northwestern lowlands (Isendahl, 2002, 2006, 2010), city dwellers simultaneously produced food in urban farmstead gardens, in orchards, in short-fallow infields, in long-fallow outfields, and from agroforestry. In this region there were no topographical and hydrological conditions for agricultural terracing or wetland cultivation, which might have contributed to a higher degree of agrosystem complexity.

Although the detailed social organization of Maya societies changed and varied significantly over time and across space, these were horizontally and vertically complex societies, with the overwhelming majority of urban inhabitants being farmers. The production potential of urban farming varied from city to city owing to a series of interacting factors and is not well understood. For the Puuc region, ethnographic data and field experiments suggest that urban gardens, infields, and orchards alone could support between 5000 and 10,000 people (see Dunning, 1992, pp. 127–133).

2.1.2. The Spatial Patterning of Food Resources

Drawing on a variety of sources to form a multi-scalar total food resource framework, Maya agriculture was highly diverse and spatially complex regionally, sub-regionally, and within each city, down to the neighborhood and household levels. In the Classic and Postclassic northern lowlands, land tenure, food production, and surplus control seem to have been managed by four different administrative–social institutions (Isendahl, 2010; Roys, 1957): (1) the leadership of the city state; (2) the city and its leadership, paying tribute to the state leadership; (3) the urban neighborhood and its leadership distributing land use rights and coordinating tribute to the city; and (4) farmer households producing agricultural surplus for the neighborhood and autonomously managing farmstead gardens. When brought together and mapped out, the spatial patterning of the different components of the total food resource framework catered for a strategic system that could manage high biodiversity; a logic of agricultural practice that particularly condensed in the carefully tended farmstead garden (Dunning, 2004; Ford and Nigh, 2009; Isendahl, 2002, 2010, in press; Killion, 1992; Netting, 1993). Forming the basic building block of urban sprawl, the farmstead located key ecosystem services to cities, including food provisioning and supporting, regulating, and cultural services (Barthel et al., 2005). Thus, Maya urban gardens – contrary to how ancient urban gardens are often envisaged – were not palatial pleasure gardens for elites, but sites of agro-ecosystem services for household food security (Jansson and Polasky, 2010), managed by farmstead dwellers.

But farmstead gardens were not the only spaces for urban agriculture in Maya cities. For instance, in the Puuc region, large sectors of fertile soils devoid of settlement construction mark out city infields (Isendahl, 2010). The management of these infields was different from farmstead gardens in being under the control of polity elites, by way of a multi-tier lineage-based tributary taxation system. Such agricultural sectors were put under increasing pressure during the Classic period to maximize production and economically support the unsustainable growth of city and state systems in a strongly competitive regional political and economic climate, a condition which accounts for the collapse of cities in the Puuc during the 10th century AD (Isendahl et al., 2011). Hence, it was specifically the household farmstead compound that was resilient, held the key to urban food security, and eventually provided the capacity to reorganize, rather than urban agricultural production units of scale.

In the Maya lowlands, water management – involving a number of different aspects (technical, economic, political, symbolic, etc.) – was multi-componential, diverse across space, and shifted over time, in large parts owing to different hydrological conditions. In the Puuc – a seasonally dry region with no permanent natural water sources – two hydro-technological inventions designed to capture and store rainwater dominated water management: (1) large, open still-water reservoirs managed by neighborhood and city leadership and (2) small underground water cisterns. Water cisterns were typically constructed in the center of each residential architectural group and formed the main source of freshwater for domestic use of each household (Isendahl, 2011; Scarborough, 1998). Similar to the management of land and food, water provision and sustenance were bi-fold and involved both high- and low-level systems.

2.1.3. Trade Resources and Networks: Capacities for Food Allocation

The ability to move resources along trade networks and the energy cost of transport are an important aspect of urban food security. The Maya lowlands were interconnected by extensive social, political, and economic networks, as well as with other regions of Mesoamerica and Central America, and the Maya traded a variety of resources and commodities both short- and long-distance, including foodstuffs such as cacao, salt, and dried fish. However, as elsewhere in the pre-Columbian New World (except for in the Andes where llamas were used as draught animals), the Maya had no beasts of burden and they lacked wheeled carriers, making overland transport of bulk food staples energetically costly compared to in the Old World. Coastal transport was one important way to move goods, but the uneven spatial distribution and seasonality of passable rivers disconnected many inland cities and population centers from readily accessible waterway transport systems. In some polities, for instance at Caracol (Chase et al., 2011) and Cobá (Folan et al., 1983), the Maya invested in the construction of raised causeways that connected politically dependent cities in a network that facilitated transport and control of goods, and a system of depots from one city to the next may have been one important capacity to distribute food and increase sustenance security. However, the energetics involved in bulk transporting staples put a relatively high cost on trade, inhibited bulk staple exchange, and was a contributing factor to locate food production in close geographical proximity to consumers.

2.1.4. Social–Ecological Memory: Knowledge Capacities for Coping with Crises

Despite two millennia of cyclic urban growth, decline, and reorganization the farmstead compound conditioning the dispersed low-density settlement pattern reoccur largely throughout the pre-Columbian period. The spatial consistency and temporal longevity of the farmstead as the basic building block of Maya cities suggest that it held the key to the perseverance of management systems, retaining an ability to reorganize and collectively take shape within complex urban forms of settlement. Urban farmsteads offered food security capacity that contributed to the resilience of Maya cities.

For the pre-Columbian Maya farmer, knowledge of past land-use management was retained in practice, but it was also intentionally and unintentionally manifested in the landscape (Campbell et al., 2006; Schama, 1995), which functioned as a mnemonic framework; a composite, multi-dimensional protocol for resource management (Crumley, 2000). The farmstead garden concentrated agricultural knowledge and practice; owing to residential proximity it was usually the most carefully tended plot relative to other more distant fields available to an individual farmer (Netting, 1993), fertilized by the organic waste concentrated by city dwellers and used for plant breeding and experimentation, seed storage and buffering, and for managing plant diversity. Throughout Maya prehistory and into the historic period the farmstead garden was at the center of the Maya universe. Archeological settlement analyses suggest that urban planning and the use of space more generally followed the same principles that guided the establishment of gardens and field plots: a quadripartite pattern where the center represents *axis mundi*, a conduit between the tree dimensions of reality that the Maya perceived in their cosmology (Hanks, 1990; Isendahl and Liljefors Persson, 2011; Redfield and Villa Rojas, 1934; Taube, 2003). In this sense, the farmstead garden mapped out an entire life-world, forming a micro-cosmos and essential guiding spatial ontology.

2.2. Urban Agriculture, Gardening and Water Provision in Constantinople

Constantinople – founded as Byzantium in the mid-6th century BC, and the capital of the Roman cum Byzantine Empire from the 4th century AD until 1453 – when the Ottomans conquered it – demonstrates amazing resilience carrying the city through numerous periods of crises. In contrast to many other European cities of Late Antiquity and the Medieval period, it did not lose its key position for over a millennium, and subsequently continued as the capital of the Ottoman Empire. Byzantine Constantinople is a well-studied city (e.g., Haldon, 1990; Laiou and Morrisson, 2007; Mango, 2002), but researchers have not until recently found that one important aspect explaining urban resilience was a green–blue infrastructure that combined local production and storage of food and water within the boundaries of the city (Balicka-Witakowska, 2010; Barthel et al., 2010b; Ljungkvist et al., 2010).

2.2.1. The Diversity of Food Production Systems in the Total Food Resource Framework

Constantinople is a prime site of rich ecosystem services, strategically located by one of the narrowest parts of the Bosporus strait, with a temperate climate and rain falling all year; an explanatory factor for the long-term resilience of the city (Jansson, this volume; Jansson and Polasky, 2010; Ljungkvist et al., 2010; MA, 2005).

The area surrounding Constantinople included a diverse soilscape of varied fertility. The river Lycos ran through the town to form an important freshwater source, but the amount and quality seem not to have been satisfactory since rulers invested in channeling water into the city core from surrounding mountains (Crow et al., 2008). Water was consumed in large volumes not only for domestic consumption by city dwellers, but also in the cultural institution of bathing, and an extensive water supply system of aqueducts and reservoirs formed an impressive blue infrastructure, securing freshwater access (Balicka-Witakowska, 2010).

At its location, city inhabitants lived right next to the migration routes between the Mediterranean and the Black Sea of bonito, tuna, and other high-quality fish protein sources, earning the region the epithet the “Golden Horn” (Fig. 4; Başaran, 2008, p. 16; Dagron, 1995; Wilson, 2006, p. 136). But fish protein was a complimentary source of food; the most important staple foodstuff was grain.

Early on in Constantinople's history the main source of staples was bulk food imports of grain produced in the Nile Valley. Grain was not subject to price speculation in Constantinople; unlike other foodstuffs it was nationalized and bread was distributed for free. During Constantine's reign of the 4th century AD some 80,000 rations of bread were distributed daily (Balicka-Witakowska, 2010). The annual supply of grain was only partly distributed to mills and bakeries for immediate consumption; a significant share was stored in granaries as a buffer during years of low-yield harvest caused by the fluctuations of the Nile. Over the long-term, however, urban food security was more vulnerable to cuts in the supply system brought on by political shifts in the eastern Mediterranean, rather than climatic anomalies in the Ethiopian Highlands and eastern Africa – the sources of the Nile. In particular, the loss of Egyptian and North African territory to the Muslim expansion during the 7th and 8th centuries AD radically transformed the food supply system (Haldon, 1990), shifting food production and grain supplies to lower-level food production units known as *oikos* (household farmsteads or communities of farmsteads) located more closely to Constantinople, in Trachea and Thessaly (Magdalino, 1995).

Koder (1995) suggests that another important source of food for city dwellers was located even closer to home, identifying crop production in a 2 km broad zone outside the city wall and in areas just across from the city in the Bosporus and the Golden Horn (Fig. 4). One advantage of urban and near-urban agriculture is that a greater supply of organic nutrients produced by a concentrated population could be injected into the nutrient cycling of city garden plots, compared to agriculture in less densely settled rural sectors. Waste disposal within the metabolic system of Constantinople included a potential to provide effective fertilizers – organic human waste, rubbish, and manure from horse stables, pigs, chicken, and other livestock supplied farm fields and gardens with high-quality nutrients (Ljungkvist et al., 2010).

2.2.2. The Spatial Patterning of Food Resources

Although bread was distributed freely by the city leadership to citizens during times of riches, access to near-residential land for local food production ensured food security during harvest failures, regional political turmoil, or other reasons for cuts in grain imports from distant supply zones. In Constantinople, the ruling elite owned a major proportion of cultivable land (Frankopan, 2009), and although aristocratic urban gardens are usually thought of as palatial pleasure gardens and socially restricted parks, Byzantine Constantinople pleasure gardens seem to have been gradually replaced over time by farm fields and kitchen gardens for household needs (Constantinides, 1996). Particularly detailed descriptions of Byzantine vegetable gardens, grape fields, orchards, and keeping livestock like pigs and poultry in the city are found in

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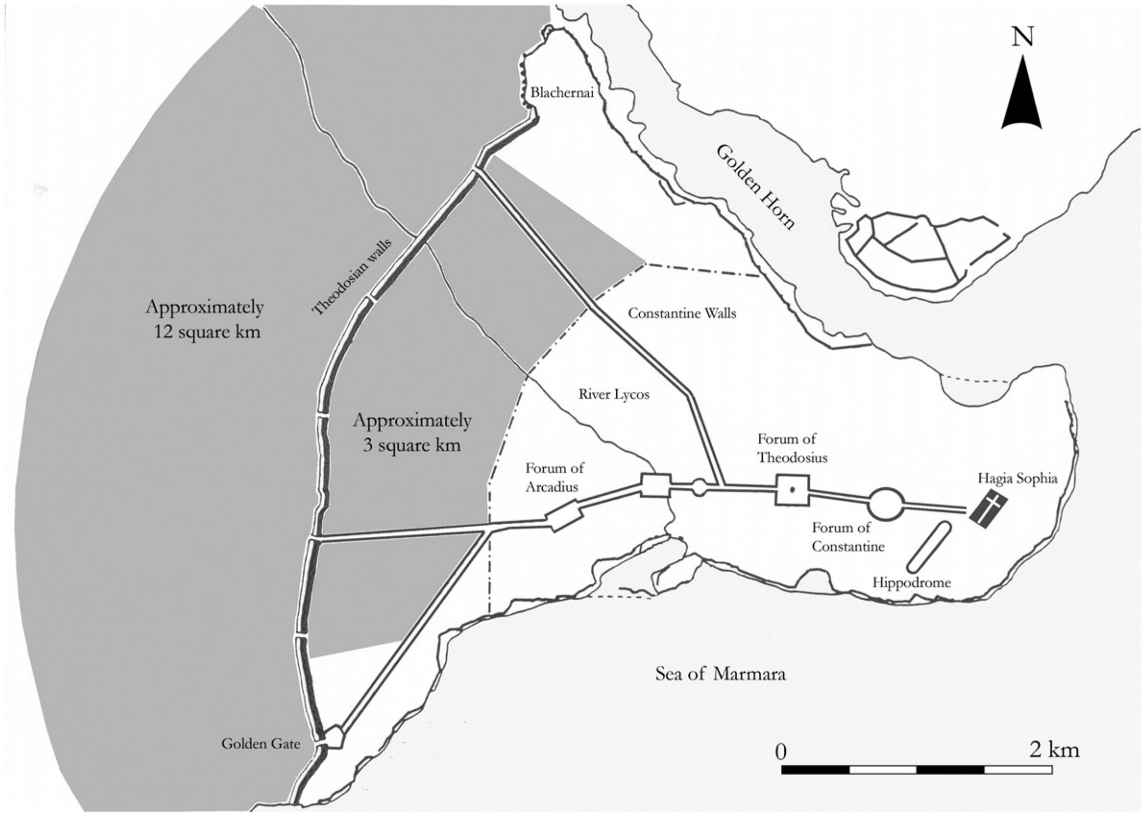

Fig. 4. Map of Constantinople, where areas used for fishing (Golden Horn) agriculture, gardening, horticulture and pasture are highlighted, in total 15 km^2 (marked in gray). From Ljungkvist et al. (2010).

historical documents from the 13th century until Ottoman conquest in 1453, at a period when recurrent sieges and loss of control of external breadbaskets put unfathomable pressure on city food sustenance (Constantinides, 1996).

Studying the siege of Constantinople by Bayezid I (1392–1402), Necipoglu (1995, pp. 160–161) shows how arable land within or just outside the city walls increased in value and yielded high prices during periods of stress to the external food supply system. Local urban agrosystems formed complex webs involving different social groups and varying organizational structures, from household gardening and animal husbandry to the management of large orchards and regular vineyards at a higher level of organization. The social composition of Constantinople was complex and multiethnic and different kinds of urban gardeners and farmers participated in food production, whether they cultivated their own land or were hired as laborers for monasteries or private large-scale landowners. People from the lower classes carefully tended kitchen gardens – the ultimate source of food security for the poor (Barthel et al., 2010b; Buchmann, 2009). Land ownership was divided between at least three main social groups (Frankopan, 2009; Ljungkvist et al., 2010): (1) the emperor and the aristocracy; (2) monasteries; and (3) landowning farmers (*oikos*). Land was also used for small domestic gardens managed by people from lower social strata.

Monasteries and the aristocracy owned most of the land, but it was in practice rented and farmed by smallholders. Constantinides (1996) provides a case of how a large tract of land owned by a monastery just outside the Golden Gate (Fig. 4) was managed by an aristocratic family, who supplied the monastery with vegetables. The aristocrats in turn rented out plots to families of the civic society. Through this "institution of sharing," land-owners such as the Church gained in prestige at the same time as insurance against food shortages was distributed throughout the social strata. But although local food produce was abundant in Constantinople – at least during certain intervals – the affluent lifestyles of the upper levels in the social hierarchy relied to the most part on imported foodstuffs.

2.2.3. Trade Resources and Networks: Capacities for Food Allocation

Feeding Constantinople, which at its Byzantine prime during the 6th century hosted a population of 500,000 (but which was in continuous flux owing to epidemics and war (Mango, 2002, p. 69)), required efficient sea and land transportation systems. Sea-borne bulk trade supplied grain, wine, and oil into the harbors of the city. Although these supply lines were subjected to the difficult winds of the eastern Mediterranean and the fluctuations of Nile river dynamics, the most severe threats to food security were social in nature.

Regional political, economic, and cultural conflicts between competing states of the Mediterranean and beyond were constant menaces to the survival of Constantinople ever since it was established as the imperial capital in the 4th century AD. Food supply lines required strong military power to secure sea and land transports. At its geographical location the city had an advantageous position to assume the key node in an extensive sea and land transport network. Constantinople was surrounded by water on all sides but one, where the great Constantine walls were erected in AD 324 (Fig. 4), and was relatively easy to defend. By keeping military control over the seas (Nicolle et al., 2007), the Byzantine navy secured an inflow of grain from Egypt and North African provinces by trading vessels averaging 40–50 tons in capacity (Balicka-Witakowska, 2010).

The most severe chocks to the urban food security of Constantinople were the sieges and blockades that occurred on average every 65 years or so (Table 1), cutting distant food- and water-supply lines. The most severe siege, at the end of the 14th century, lasted eight years but did not succeed in starving out the urban population (Ljungkvist et al., 2010). How was it possible to feed an urban population when the normal grain producing areas were lost and when importing food was difficult or even impossible?

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Table 1
Periods of extreme chocks on the food and water security of Constantinople. Modified from Ljungkvist et al., 2010.

Year AD	Loss of land, sieges and blockades
609	Usurper Nicetas takes control of Alexandria and probably the grain transports
619	The Sassanid takes Egypt
626	Avars and Sassanid besieging the town
642	Arabs conquer Egypt
674–678	First Arab siege
714	Second Arab siege
813	Bulgar siege
860	Siege by the Rus
1047	Usurper LEO Tornices besieging
1191	Seljuk–Petcheneg siege
1097	First crusade threatening the city
1204	Fourth crusade sacking the city
1261	City again in Byzantine control
1394–1402	8 years under siege by the Turks, Bayezid I
1422	Second Turkish siege
1453	Besieged and conquered by Mehmet

2.2.4. Social–Ecological Memory: Knowledge Capacities for Coping with Crises

Learning from a history of conflict and siege, the city invested heavily not only in military infrastructure but also in food and water supply systems and storage capacity. With at least four harbors and several major granaries the city had the capacity to receive and store large quantities of seaborne food staple bulk imports (Başaran, 2008; Laiou and Morrisson, 2007). Over longer sieges when city food supplies ran dry, urban planning and infrastructure had the flexibility to allocate space for food production within the boundaries of the city. Urban dwellers could also catch fish and shellfish. Hence, the city of Constantinople managed long-term diversity of options for food sustenance and security.

Adapting to a history of repeated sieges, a second city wall (the Theodosian wall) was erected in AD 414 some 1.5 km west of the old one (Fig. 4). The construction of the wall was not motivated by a need to expand settlement for a growing population, but by the necessities of protection from hostile forces, and to construct water cisterns and increase agricultural space (Balicka-Witakowska, 2010; Croke, 2005, p. 68; Koder, 1995). In AD 478 the Ostrogoths destroyed several aqueducts during a siege of the city, which – after the Byzantines had defeated the aggressors – ultimately resulted in that the city expanded its network of aqueducts and invested in a system of large water reservoirs in the area between the inner and outer city walls. With the capacity to store more than a million m^3 of water, the city never ran dry again (Balicka-Witakowska, 2010; Croke, 2005, p. 68). In addition to the water storage system, the 3 km^2 large area between the walls was allocated as a vast green common (see Colding and Barthel, this volume) used for cultivation and pasture (Koder, 1995; Ljungkvist et al., 2010). Including a 2 km broad buffer zone of farm fields immediately outside the Theodosian wall, the city used 15 km^2 of land in direct proximity to the urban zone for food production. Adding urban kitchen gardens throughout the city and fishing ground these urban food production zones combined had the potential to occasionally feed 300,000 people[1] (Balicka-Witakowska, 2010; Koder, 1995).

Bayezid I's eight-year long siege and blockade in the late 14th century was one of the greatest challenges in the city's history as it managed to cut off supply lines from both land and sea for a long period of time, putting the food security system and resilience of Constantinople to the test. Necipoglu (1995) describes how land and food prices rose dramatically and how inhabitants were hit by the lack of income and food. The patriarch encouraged citizens to put as much soil in the city under cultivation as possible, and although the wealthy had the means to buy food smuggled into the city, the poor relied entirely on food produced within the confinements of the outer city wall. Despite heavy pressure, the blockade did not succeed; many inhabitants suffered badly from malnutrition and hardship, but the city persevered and was not starved into submission as Bayezid I had intended (Ljungkvist et al., 2010; Necipoglu, 1995, pp. 165–166).

One important source of resilience was the experiences of agriculture and gardening that Medieval Constantinople had inherited from historical documents dating back to Late Antiquity and earlier. Monasteries and the state and city administration were institutions that were partly legitimized by reference to tradition, history, and ancient knowledge systems. For instance, *Geoponika* (Owen, 1805–06) is a 9th century AD collection of agronomic texts (some dating back to the Hellenistic period of the first few centuries BC) that formed part of a portfolio of memory-carriers (Barthel et al., 2010a; see also Crumley, 1994) of how to produce food in the city, including celestial and terrestrial omina (for instance about when to sow and harvest), viticulture (grape cultivation and wine production), oleoculture (olive cultivation and oil production), apiculture (beekeeping and honey production), veterinary medicine, fishpond construction, and many other agronomic and food producing skills (Barthel et al., 2010b). Such written accounts, in combination with other mnemonic features, maintained food production skills in Constantinople, forming part of a continuum of social–ecological memory that was built on over the *longue durée* history of the city.

3. Discussion

There are intriguing dissimilarities between these cases, the most striking being environmental frameworks, transport systems, and urban morphology. In Maya cities, food consumed within the urban confinement was to a significant extent also produced there, providing energy-efficient ways of producing food where both wheeled transport and draught animals were lacking. In Constantinople this was the case only when there were cuts in supply lines. However, both cases demonstrate that food and water security on regional to local scales are dependent on spatial access to proximate landscapes of food production and on systems that harbor autonomous food production at lower levels of social organization (see also Fraser and Rimas, 2010; Ingram et al., 2008; Sen, 1994; Watts and Bohle, 1993).

3.1. Diversity of Options in Food Security in Ancient Cities

The evidence from pre-Columbian Maya cities suggests that an energetically costly transportation technology discourage long-distance bulk trade in non-exotic food stuffs and favor proximate sources of food staples. The diversity of agrosystems also indicates that although urban farmstead gardens were largely constants of Maya cities, provided important sources of food to householders, and were instrumental in posting other important ecosystem services to the urban landscape, the production capacities of these could not alone generate surpluses to finance the high costs associated with maintaining urban functions – defined as the political, administrative, religious, economic and other activities and institutions in a city that affect a larger hinterland (Marcus, 1983) – and the complex social organization of the city (e.g., Tainter, 2011). Farmstead gardens primarily offered resilience capacity to the household and a source of agro-economic autonomy, but Maya farmers also practiced a series of other farming techniques by which labor and surplus production were directly and indirectly levied by city elites. Hence, Maya urban farmstead gardens formed part of more composite total food resource frameworks that included a diverse array of food sources.

Putting all eggs in one efficiency-basket within an energy regime is worrisome from a sustainability perspective since there is a clear trade-off between short-term efficiency and long-term resilience

[1] This figure must be used with caution, since this is extremely hard to estimate due to changing consumption patterns and changing dietary preferences.

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(e.g., Folke et al., 1996; Fraser, 2003; Holling, 1996; Holling and Meffe, 1996; Scheffer and Westley, 2007; Strumsky et al., 2010). The food sustenance of 6th century AD Constantinople, with a population of around 500,000, was heavily dependent on a highly complex food production and distribution system that involved a series of professional categories (farmers, traders, overland transporters, administrators, dispatchers, mariners, engineers, etc.). It formed in many ways an early precursor to the present global food industry and was ultimately administered and controlled by the state leadership (Ljungkvist et al., 2010). Despite the investments in technology for long distant trade, its history displays a clear phase-shift in the spatial strategy of food security during the 7th century AD, when the empire lost many of its grain producing provinces and suffered from reoccurring sieges.

After the 7th century crisis and the breakdown of the North African grain trade, the food supply system of Constantinople shifted to rely more on the rich ecosystem services of its regional hinterland. From this point onward individual *oikos* owned, rented, and managed farmland within the city, in close proximity to it, and at some distance (Magdalino, 1995). The second city wall provided highly valuable, protected space for urban food production as insurance to sieges (Koder, 1995), and investments in massive granaries, increasing harbor capacities, and an extensive water management system increased options for food security resilience during supply cut events that allowed the city to regain power relative to other urban centers (Ljungkvist et al., 2010).

In both Maya cities and Constantinople diversified total food resource frameworks with a considerable capacity of proximate food sources were keys to long-term urban resilience. At Constantinople, diversification of options demonstrably offered better insurance against chocks and powered large-scale shifts in the character and scale of urban metabolism. Although we must be careful not to attribute current concerns and motivations to people in the past (Smith, 2010) it seems it was in the general interest of decentralized self-organized food-producing communities to steward their land in ways that better could balance long-term sustainable returns with surplus production for the food markets of the city (see also Adams, 1978).

3.2. Social–Ecological Memories in Urban Blue–Green Infrastructures: Sources of Resilience

In the Introduction we outlined how social–ecological memory is a key indicator of resilience (Folke et al., 2003). It is difficult to know exactly when and how memory of food shocks in the deep past survived and how adaptive agricultural strategies were passed on in cities. The study of social or collective memory has of late become a focus for research in several fields (anthropology, archeology, history, psychology, and sociology), linking processes of recollection to modes of retention and loss within their historical, cultural, and economical contexts (Climo and Cattell, 2002; Connerton, 1989; Halbwachs, 1926; McIntosh et al., 2000; Misztal, 2003; North, 2005; Walsh, 1991). Research suggests that while only individuals can be said to remember sensu stricto, individual memory processes derive from social interactions and are facilitated by supra-individual means, sharing with others through different ways of communicating (stories, songs, material culture, landscapes, rituals, etc.) (Barthel et al., 2010a; Crumley, 2000; Nazarea, 1998, 2006; Schama, 1995). This discourse is especially interesting when addressing the role of crises, which can render more permanent memories, or in certain contexts, entirely suppress or eradicate them, for instance through genocide (Crumley, 1994; McIntosh et al., 2000).

Drawing on the general notion that acquisition of social memory typically follows crises (Berkes and Turner, 2006; Folke et al., 2003) makes it is reasonable to hypothesize that experiences of recurrent sieges and loss of territories urged people to create the local blue–green infrastructure of Constantinople, including its protective walls, forming tangible reminders of the power of local food production (Barthel et al., 2010b). Without such infrastructures, the 65-year intervals between sieges would probably have been enough to dissolve living memory about the rationale of locating agricultural production to the city. Ethnographical research demonstrates that experiences of participating in agricultural labor are carried between people and across cohorts: in rules-in-use, habits, stories, artifacts, and metaphors (Andersson et al., 2007; Barthel et al., 2010a; Colding and Barthel, this volume; McDaniel and Alley, 2005). As part of the complex mnemonic urban fabric of Constantinople, the blue–green infrastructure (city walls, agricultural spaces, water management technology, historical documentation and accounts, etc.) and the people engaged in its food production served the city well over the long-term. Memory carriers potentially increased food security, innovative capacities, and resilience by retaining successful subsistence competencies into its recurrent food crises (Barthel et al., 2010b).

In the diverse environments of the Maya Lowlands, Maya farmers similarly drew on experiences and folk knowledge of coping with stress and crises, recombining and elaborating a diversity of food production and water management systems. Food and water technologies, infields and gardens were subtly inscribed in the landscape syntax, and functioned as memory carriers from one generation to the next. Maya smallholders retained the farmstead garden as an autonomously managed and secure space – largely independent from higher-level socio-political control – where skills related to self-sufficiency in water and food was transmitted across generations. It was particularly in the farmstead garden – a condensed representation of both landscape and the wider cosmos – that agronomic knowledge and resources (e.g., tending practices and plant material) were manifested and conveyed. This was the corner-stone of Maya settlements that formed the basis for renewal, when higher order social structures collapsed.

3.3. Food for Thought: Insights from the Past and Self-Reflection

What general insights can urban scholars and practitioners use from ancient examples such as these? Owing to increasing uncertainties in the nexus of energy scarcity, biodiversity loss, and climate change, urban food security has of late become focus for research in several fields (Fraser and Rimas, 2010; Ingram et al., 2008; Nabhan, 2008; Steel, 2010). For instance, people living in Stockholm are estimated to be less than two weeks away from starvation after household and store supplies have been emptied, if the fossil-fuel dependent food system would collapse (Lindgren and Fischer, 2011).

In complement to the well-known resilience function of long distance trade when harvests fail owing to environmental anomalies and changes, the *longue durée* perspective applied here shows that urban food security can be built to manage *événement* chocks by keeping options open for producing and storing food and water in close spatial proximity to the consumers. Our results also bring the important insight of "grass-root," lower-level social forms of water and food management and locally situated social–ecological memories for transmitting practical knowledge between people and across generations, complementing centralized governance of long distance food trade, distribution, and storage.

Since the environmental history of the West demonstrates how urban gardens saved millions of people from starvation in cities during the 1900s, the social amnesia about the value of local solutions is surprising. For example, during World War I allotment gardens played a crucial part in supplying city people in Britain with vegetables, providing 2,000,000 tons of vegetables by 1918 (House of Commons, 1998). As part of the *Every Man a Gardener*-campaign, allotment gardens were planted in parks and sports fields – even at Buckingham Palace the earth was tilled to grow vegetables (Barthel et al., 2012; Crouch and Ward, 1988). After the war, the number of allotments declined abruptly, but green space was still ample when World War II sparked a new rush for local urban foods, not only in

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Britain but also across Europe and the US (Barthel et al., 2012; Gröning, 1996).

In contemporary cities, however, spaces and skills related to local food and water management are rapidly vanishing on a grand scale (Barthel et al., 2012; Merson et al., 2010; Rural, 2006). Eroded food security for the poor in the cities of Athens and Lisbon owing to the current financial crises, as well as the post-Soviet collapse situation in Cuba and among the emerging poor in eastern European cities are some reminders about the vulnerable food situations of city people when supply lines, for various reasons, are severed (Altieri et al., 1999; Round et al., 2010; Southworth, 2006). One of the most studied situations is the one on Cuba (Altieri et al., 1999; Buchmann, 2009; Wright, 2009). The US blockade in combination with the collapse of the Soviet Union in 1989 caused a shock on the supply lines of food, fertilizers, and oil, which was particularly difficult for the people of Havana. Ten years later, 400 horticulture collectives had been established in Havana, annually producing 8500 tons of vegetables, 7.5 million eggs, and 3650 tons of meat agro-ecologically (Altieri et al., 1999). Such urban food production strategies have not turned Havana into a wealthy city, but have helped to increase food security resilience in the face of a trade breakdown (Barthel et al., 2012; Buchmann, 2009).

As a self-reflection on our approach, it is evident that a sample size of two is not adequate for drawing nomothetic conclusions on strategies for urban food security. We do argue however that the similarity patterns we observe in these widely dissimilar historical, environmental, political, and economic settings offer important insights that can be valid for understanding food security in cities more generally. The dialogue of our findings with the more recent historical urban cases indicates that the patterns we describe are not idiosyncratic for Maya cities and Constantinople but have more general applicability. Future comparative research on a case-to-case basis will be needed to evaluate the validity of our conclusions from a much larger and more representative sample in order to make broad generalizations.

Early modernist urban sociology unintentionally developed an image of the city as an essentialist reality separate from life-supporting ecosystems, which has proved hard to rid and which continues to permeate urban policy and planning. In retrospective, this is ironic and paradoxical since the Chicago School built their urban models on ecosystem dynamics, particularly plant community succession models (Clements, 1916). This realization has made us reflective and cautious to our own application of ecosystem resilience theory to understand such complex and diverging phenomena as urban food systems (Cote and Nightingale, 2011; Holling, 1973; Odum, 1953). A major difference is that the *social*–ecological approach used here, which focuses on the dialectics between ecosystems and socio-cultural systems and human agency, specifically in relation to the resilience of food and water security systems, does not – as early modernist urban social sciences did – rest on the assumption that plant communities and urban systems share similarities in their change-dynamics towards states of equilibrium. To the contrary, we have included distinctly social characteristics such as power-relations, agency and contingency, technological innovation, and cultural values that shape the dynamics of complex social–ecological trajectories, for instance in the phase shift in the energy-food strategy of Constantinople.

4. Conclusion

The results outlined in this paper indicate that agricultural production is not "the antithesis of the city" – as modernist understandings of urbanity suggests – but is in many cases a fully integrated urban activity. That is why it is worrisome that spaces for urban food production are rapidly vanishing on a grand scale. Historically informed scholars are well aware of the current erosion of urban food security and recognize that urban food systems must be an issue of equal importance to other, "traditional" urban services, such as transport, electricity, entertainment, and sewage (Born and Purcell, 2006; Newman et al., 2009; Pothukuchi and Kaufman, 2000; Steel, 2010). The findings on food supply systems in ancient cities reported in this paper, as well as other contributions to this special issue on urban resilience, show that this cannot be achieved if regional and local ecosystem services are ignored.

A conclusion of this study for designing future urban resilience is the need to re-ignite urban minds about the close connection between urban people and their life-support systems. It is alarming that the opposite is currently happening. In the midst of the second wave of space–time compression, with 75% of the global population projected to be urban within a few decades, we are now experiencing a "global generational amnesia" about how to grow food (Colding and Barthel, this volume; Pyle, 1978). Community and allotment gardens are contemporary examples of urban "memory workers," which serve as living protocols for transmitting information about local climate, soils, and moisture regimes as well as about fluctuating populations of organisms, and which tend to emotionally connect people with local ecosystems (Andersson et al., 2007; Bendt et al., in press; Tidball et al., 2010). In light of the pressures of urban development and industry on ecosystems, an active civil society and critical scholars are preconditions for mobilizing the ability to protect urban green spaces, to support memory of how to grow food, and to re-imagine the city as a place where food can be grown.

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