Chapter 3
Civilization and Landscape Dynamics in the Mediterranean from the Neolithic to the Roman Era

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Abstract This chapter examines the long-term anthropogenic transformation of the Mediterranean Basin, tracing the co-evolution of human civilizations and ecological systems from the Neolithic to the Roman Era. Challenging linear narratives of environmental degradation, it identifies three distinct structural "ruptures" in the geometry of human impact. The first rupture, the Neolithic Transition, is characterized by the "functional replacement" of wild megafauna with domestic herds and the rise of synanthropic niches. The second rupture, marking the Bronze Age, introduced "urban metabolism," shifting the ecological footprint from diffuse village-based extensive systems to concentrated, intensive resource extraction nodes vulnerable to climatic fluctuations like the 4.2 ka event. The third rupture, spanning the Iron Age and Roman periods, established "connectivity" as a primary ecological vector, facilitating biotic globalization, habitat fragmentation through infrastructure, and marine pollution. Integrating zooarchaeological, archaeobotanical, and ancient genomic data, this study argues that the structural dynamics of the modern "Polycrisis Era" were embedded in the Mediterranean ecosystem millennia ago, defining the region as a cumulative cultural landscape.

Keywords Niche construction · Urban metabolism · Connectivity · Biotic globalization · Mediterranean anthropocene

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3.1 Introduction

The Mediterranean Basin, recognized as a global biodiversity hotspot with exceptional endemism (Médail & Quézel, 1999; Myers et al., 2000), has served as a critical ecological refuge and a crossroads of continents over vast stretches of time. During the cooler glacial phases of the Pleistocene glacial-interglacial cycles, its coastal corridors and southern peninsulas acted as vital "refugia" for many species (Médail & Diadema, 2009; Taberlet et al., 1998), including hominin populations, both Neanderthals and early *Homo sapiens*, ensuring their survival and facilitating subsequent dispersals (Bailey et al., 2008; Dennell et al., 2011; Finlayson, 2008). Comparative zooarchaeological records suggest that during these periods, the ecological footprints of Neanderthals and early *Homo sapiens* were remarkably similar, characterized by localized exploitation strategies that remained within the bounds of natural regenerative cycles (Finlayson, 2008; Stiner, 1994).

A distinct ecological divergence emerged only later with *Homo sapiens*, marking a fundamental transition from passive niche adaptation to active "niche construction" that would eventually restructure the entire biotic community (Boivin et al., 2016; Smith, 2007). This divergence with the arrival of *Homo sapiens* was not due to mere biological presence, but through a radical shift in subsistence strategy. The true ecological rupture occurred with the Neolithic Transition. Unlike their Paleolithic predecessors who adapted to the landscape, Neolithic communities began to adapt the landscape to themselves. The transition from foraging to the settled agrarian regime is widely considered to have marked the onset of systematic niche construction. This is characterised by land use for wheat and, later, olive cultivation, the alteration of hydrological cycles, and the acceleration of soil erosion rates far beyond natural baselines (Hooke, 2006; Ruddiman, 2013). This "slow but sure" transition over six millennia fundamentally re-engineered the Mediterranean ecosystem, setting the stage for the Anthropocene long before the industrial era (Ruddiman, 2013).

The subsequent, even more profound turning point arrived with the development of urban centers and the rise of complex civilizations. While agriculture dispersed human pressure across the landscape, urbanization concentrated it into geographically small yet intensely powerful nodes, creating a distinct "urban metabolism" (Hughes, 2014; Kennedy, 2006). Cities such as Rome, Athens and Alexandria demanded vast resources. These included wood for fuel and construction, metals for tools, and large quantities of food, all of which had to be sourced from ever-increasingly distant hinterlands (Harris, 2013; Morley, 2002). This process intensified resource depletion, such as severe deforestation and soil erosion, often driven by the massive fuel demands of metallurgy and shipbuilding (Hughes, 2014; Walsh et al., 2019). Moreover, these urban centers generated unprecedented levels of waste and radically altered coastal and riverine ecosystems via port construction and modified flows, leading to early instances of heavy metal pollution in harbor sediments (Le Roux et al., 2005; Marriner & Morhange, 2007). Furthermore, these centers became critical vectors for the introduction of non-native species, including both intentional archaeophytes and unintentional synanthropes like rodents, profoundly

challenging the fragile equilibrium of the Mediterranean ecosystems (Galil, 2009; Michaux et al., 1990).

However, this history of anthropogenic pressure presents a paradox central to understanding the Mediterranean as a Global Biodiversity Hotspot. Today, the region is recognized as one of the most altered hotspots on Earth, with only 4.7% of its primary vegetation remaining unaltered (Geri et al., 2010). Yet, this millennia-long history of fragmentation and disturbance has also acted as an evolutionary catalyst. Human-induced habitat heterogeneity, manifesting as a mosaic of fields, pastures, scrublands, and forests, has been demonstrated to lead to an augmentation of intraspecific adaptive variation, culminating in periods of pronounced differentiation during the Holocene era. Therefore, the history of civilization in this region is not merely a singular narrative of degradation but a complex interplay of destruction and co-evolution. The Mediterranean landscape, as we recognize it today, is a prime example of a "cultural landscape," where the resilience of ecosystems has been repeatedly tested and reshaped by the escalating pressures from human activity. This provides a context for the challenges of the current Polycrisis Era.

3.2 The First Rupture: From Holocene Stability to Neolithic Transformation

The ecological history of the Mediterranean is often narrated as a linear degradation, yet the transition from the Pleistocene to the Holocene represents a complex shift in ecological functions rather than mere destruction. While hunter-gatherer societies had been modifying their environments for millennia through the use of wildfire and selective hunting, their impact remained relatively localized and bounded by the carrying capacity of natural ecosystems (Blondel, 2006; Turner et al., 2010; Zeder, 2025a).

However, the shift from these transient modifications to permanent landscape engineering was not immediate. It was rooted in a profound demographic and behavioral transformation: the adoption of sedentism. Before humans could systematically alter the biotic community through agriculture, they first had to alter their own spatial relationship with the land. To understand the magnitude of this ecological rupture, one must first examine the complex climatic and social drivers that compelled mobile populations to anchor themselves to specific landscapes.

Many explanations have been proposed to account for the adoption of a sedentary lifestyle by humans. Early theories, such as the Oasis Theory, linked this transition in Southwest Asia primarily to climate deterioration, with the suggestion that shrinking habitable areas forced people to settle in limited refuges (Braidwood, 2008). However, this view is now considered to be reductionist. It is an observed fact that climatic fluctuations at the end of the Last Glacial Maximum established the environmental preconditions for sedentism. However, it is evident that climate alone cannot provide a comprehensive explanation for the observed shift. Contemporary

scholarship highlights the equal, if not more significant, role of social and cognitive factors in this regard. A number of factors were identified as playing a central role, including the demand for surplus to support competitive feasting (Hayden, 1990), the need for social cohesion through communal rituals as seen at Göbeklitepe and Çatalhöyük (Dietrich et al., 2017; Hodder, 2018), and demographic pressures. Consequently, the transition to sedentism was probably a multifaceted process, whereby societies that were driven by evolving social and symbolic imperatives capitalized on climatic opportunities.

At the end of the Last Glacial Maximum, during a climatic amelioration known as the Bølling–Allerød Pollen Period, the glaciers retreated, precipitation increased, and forest vegetation expanded (Byrd, 2005; Moore & Hillman, 1992). During this period of favorable climatic conditions, groups known as the Natufians became sedentary in the Levant around 13,000 BC, relying heavily on plant gathering and hunting (Belfer-Cohen & Bar-Yosef, 2002). About 2000 years later, the Late Natufians shifted back to a semi-sedentary lifestyle as cold and arid conditions returned with the onset of the Younger Dryas Pollen Period, a rapid climatic reversal characterized by cooler temperatures and increased aridity. In Anatolia, settlements in the Upper Tigris Basin such as Körtiktepe, Boncuklu Tarla, Çemka Höyük, Hasankeyf Höyük, Hallan Çemi, and Demirköy attest that hunter-gatherer-fisher communities maintained fully sedentary lives from the Younger Dryas period into the subsequent Pre-Pottery Neolithic A (PPNA) period, relying on the intensive exploitation of wild resources despite not yet practicing agriculture (Benz et al., 2015; Erim Özdoğan, 2011; Kodaş, 2023; Miyake et al., 2012; Rosenberg, 2011a, 2011b). After the Younger Dryas, climatic amelioration during the Preboreal period enabled the widespread emergence of Neolithic settlements across the Levant and Anatolia (Belfer-Cohen & Bar-Yosef, 2002; Byrd, 2005; Hodder, 2021; Moore & Hillman, 1992; Özbaşaran et al., 2022; Zeder, 2025b). Although no direct genetic evidence of early plant domestication exists, it is suggested that these adaptations began in the Mediterranean climatic zone during the Late Natufian (Belfer-Cohen & Bar-Yosef, 2002; Byrd, 2005). Archaeological and bioarchaeological remains from Neolithic sites clearly show the intensive development of agriculture (Byrd, 2005; Zeder, 2025b). This shift was likely catalyzed by climatic stressors such as the Younger Dryas and enabled by the subsequent climatic amelioration of the early Holocene. With the advent of the "Neolithic Package," the human relationship with the Mediterranean ecosystem transformed from one of adaptation to one of active modification (Zeder, 2025b).

However, this modification was not limited to the cultivation of cereals and pulses, nor was it the result of a simple, unidirectional expansion from a single Levantine core. Recent ancient DNA studies have fundamentally reshaped our understanding of this transition, revealing that the Neolithic Transition was driven by genetically distinct populations across Southwest Asia (Lazaridis et al., 2016). In regions like Central Anatolia, archaeogenomic evidence points to a strong continuity between local hunter-gatherers and early farmers, suggesting that sedentary lifestyles were often adopted locally rather than merely introduced by incoming migrants (Feldman et al., 2019).

The most ecologically potent component of this era was arguably the domestication of livestock. This development marked a departure from merely harvesting the landscape's energy to actively managing its trophic levels. As these farming communities established themselves across the Mediterranean basin, they acquired a suite of herbivores—sheep, goats, cattle, and pigs—either through local domestication or exchange networks (Zeder, 2025b). This introduction did not occur in a biological vacuum; rather, it initiated a profound reorganization of the grazing niche, setting the stage for a "functional replacement" of the region's native megafauna.

3.2.1 The Functional Replacement of Herbivores

One of the most profound, yet often overlooked, ecological impacts of the Neolithic was the restructuring of the Mediterranean large mammal herbivory niche. The early Holocene landscape was originally maintained by a guild of wild megaherbivores and ungulates, including the aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*). These species acted as ecosystem engineers, influencing vegetation structure through selective browsing and grazing patterns that varied seasonally.

As human populations expanded, hunting pressure on these wild populations intensified, leading to local declines. However, humans did not leave this ecological niche vacant. In a process of functional replacement, the declining wild herbivores were substituted by domesticated counterparts (Garcés-Pastor et al., 2022). This substitution is visibly documented in the zooarchaeological record of key Anatolian and Levantine sites. For instance, faunal assemblages from sites like Çayönü and Çatalhöyük reveal a gradual but distinct shift: a decrease in the diversity of wild remains and a corresponding surge in the frequency of caprines (sheep and goats) and cattle, marked by demographic profiles (culling of young males) typical of herd management (Arbuckle et al., 2014; Hongo et al., 2009).

The primary agents of this new ecological regime were mainly domestic sheep (*Ovis aries*) and domestic goats (*Capra hircus*). Archaeogenetic and zooarchaeological studies have pinpointed their domestication to specific regions within the Fertile Crescent, followed by a rapid westward dispersal. Ancient DNA analysis indicates that the domestic goat was derived from the Bezoar ibex (*Capra aegagrus aegagrus*), with distinct domestication processes occurring in the Zagros Mountains (e.g., Ganj Dareh) and potentially Eastern Anatolia (Naderi et al., 2008; Zeder & Hesse, 2000). Genomic studies reveal that early domestic goats in the Neolithic were genetically structured, reflecting the distinct identities of their human herders, before being homogenized by later millennia of exchange (Daly et al., 2018). Similarly, domestic sheep, likely descended from the Asiatic mouflon (*Ovis gmelini*), appear in the archaeological record of Southeastern Anatolia and the Middle Euphrates valley by the Pre-Pottery Neolithic B (PPNB). High levels of diversity in modern sheep lineages suggest a complex domestication history involving broad population dynamics rather than a single bottleneck event (Chessa et al., 2009; Demirci

et al., 2013). Furthermore, a recent ancient DNA study (Kaptan et al., 2024) points to Central Anatolia as a distinct domestication center for sheep, highlighting the multi-regional nature of this process.

The rapid westward dispersal of these domesticates represented more than a migration of species; it signaled the expansion of a new metabolic regime. By insulating these herds from natural predation and buffering them against climatic stochasticity, Neolithic communities were able to maintain ungulate densities far exceeding historical baselines. Consequently, the grazing pressure shifted from a diffuse, seasonally fluctuating force typical of wild herds to a concentrated, persistent driver of landscape change managed by human agency.

This substitution was not ecologically neutral. Unlike wild herds, whose movements were dictated by seasonal resource availability, domestic herds were subjected to anthropogenic grazing pressure that was often intensive and localized. This pressure acted as a potent selective filter on the circum-Mediterranean vegetation and flora. Continuous grazing and browsing suppressed forest regeneration, thereby favoring the spread and assembly of grazing-tolerant plants and sclerophyllous shrublands, such as maquis and garrigue. The alternative biome states theory suggests that herbivory and fires are major determinants of world's vegetation in many ecosystems, shaping current vegetation states (Pausas & Bond, 2020). Dating back to the Miocene, the invasion of Irano-Turanian plants into the eastern Mediterranean is also a significant event that has contributed to shaping the plant diversity of the region (Manafzadeh et al., 2014), while human activities during the Holocene may have further facilitated this colonization. However, the outcomes of this restructuring were complex and not solely characterized by degradation. While erosion and deforestation were significant consequences of overgrazing in many areas, moderate and light grazing regimes engineered unique biodiversity-rich "cultural landscapes" that persist to this day (Bahar & Tavşanoğlu, 2024). Traditional agro-silvo-pastoral systems, exemplified by the dehesa or montado, emerged as high-biodiversity habitats mimicking natural savannas. Unfortunately, these open habitats are often considered degraded; however, the positive relationship between biodiversity and wild (pre-Neolithic) and domestic (post-Neolithic) mammal herbivory in these habitats suggests that domestic herbivory plays an important role in sustaining these ecosystems (Tavşanoğlu & Bernardi, 2024). By integrating trees, pasture, and livestock, these systems support high alpha and gamma diversity, demonstrating that the "open" character of the Mediterranean is a direct legacy of this functional substitution—a landscape engineered by the metabolic needs of the Neolithic Transition.

3.2.2 The Rise of Synanthropes: The Shadow Ecosystem

The Neolithic transition involved more than just the intentional domestication of crops and livestock; it created entirely new biological niches that facilitated the spread of "synanthropes" which are the species that live in close association with humans, often to their own benefit. The establishment of permanent settlements and

the storage of surplus grain created a stable, year-round food source and a buffered microclimate that did not exist in the wild. This anthropogenic environment acted as a powerful evolutionary magnet, initiating what Zeder (2012) describes as the "commensal pathway" to domestication.

The primary beneficiary of this new niche was the house mouse. Zooarchaeological evidence from the Levant demonstrates a competitive exclusion event coinciding with sedentism: as humans settled, the wild-foraging Macedonian mouse (*Mus macedonicus*) was rapidly displaced by the house mouse (*Mus musculus domesticus*), which was pre-adapted to exploit human food stores (Weissbrod et al., 2017). By the Pre-Pottery Neolithic B (PPNB), this commensal relationship had become so entrenched that *Mus musculus* began to stow away on early maritime expeditions, colonizing islands like Cyprus alongside human farmers. This process is termed "passive transport" (Cucchi et al., 2012).

Similarly, the house sparrow (*Passer domesticus*) underwent a profound physiological transformation to adapt to the "Neolithic niche." Genomic studies reveal that commensal sparrow populations, unlike their wild counterparts, possess distinct adaptive variations in the *AMY2A* gene, which is responsible for starch digestion. This suggests that the human shift to a starch-rich diet (cereals) exerted a strong selective pressure on local bird populations, driving the evolution of a companion species capable of thriving on anthropogenic surpluses (Ravinet et al., 2018).

The proliferation of these grain-thieving animals inevitably triggered a trophic cascade within the settlement walls, attracting predators. The ancestor of the domestic cat, the African wildcat (*Felis silvestris lybica*), was likely drawn to early farming villages by the high density of rodents. Unlike livestock, cats were not deliberately herded; rather, they "self-domesticated" by tolerating human proximity in exchange for easy prey. Ancient DNA analysis confirms that distinct *F. s. lybica* lineages dispersed from the Near East into Europe alongside the expansion of farming communities (Ottoni et al., 2017). The discovery of a cat buried with a human at the Neolithic site of Shillourokambos in Cyprus (c. 9500 BP) provides the earliest concrete evidence of this unique, mutually beneficial relationship, predating Egyptian depictions by millennia (Vigne et al., 2004). Thus, the Neolithic village did not just reshape the landscape outside its walls, but it also created a complex "shadow ecosystem" within them, comprised of species whose evolutionary trajectories became irrevocably tied to human civilization.

3.2.3 The Domestication of the Landscape: Fruit Trees and Ornamentals

Many fruit and other ornamental plants have also been widely cultivated throughout the Mediterranean Basin, providing another contribution to human-shaped landscapes. Among these species, iconic perennial crops such as olive (*Olea europaea*), fig (*Ficus carica*), grapevine (*Vitis vinifera*), almond (*Prunus dulcis*),

and pomegranate (*Punica granatum*) have not only supplied durable food products but also structured land use through orchards, terraces, and agroforestry mosaics. Archaeobotanical evidence indicates that olive and fig horticulture was practiced by ca. 7000 years ago in the Jordan Valley, including contexts outside natural habitat of the wild olive; consistent with deliberate cultivation and pruning-based management (Langgut & Garfinkel, 2022). Although the Pleistocene glacial-interglacial cycles continuously affected the distribution of wild olive trees across the Mediterranean Basin, wild olive lineages had already diversified long before the Last Glacial Maximum (Besnard et al., 2013). Genetic and fossil pollen evidence suggests that domestication of olive trees from the wild variety occurred in the Levant region, and then, domestic olive distributed across other regions of the Mediterranean Basin as the civilization spreads (Barazani et al., 2023; Besnard et al., 2013; Langgut et al., 2019). At broader spatial and historical scales, arboriculture expanded westward during the Late Neolithic, Chalcolithic, and Early Bronze Age, and by the 1st millennium BC, the joint arrival and diffusion of fruits such as grape, olive, fig, almond, and pomegranate helped underpin commercial agrarian systems where wine and oil became key commodities (Pérez-Jordà et al., 2021). These long-lived tree-crop systems are repeatedly identified as "iconic" elements of Mediterranean cultural landscapes, historically managed over centuries and shaping multifunctional land mosaics and local cultural identities (Wolpert et al., 2020). In parallel, emblematic ornamentals such as Mediterranean cypress (*Cupressus sempervirens*) have been intentionally planted for millennia; the columnar forms were used since Greek and Roman times to shade gardens and cemeteries and to form windbreaks along roads, leaving a conspicuous, linear signature on coastal and urban Mediterranean scenery (Caudullo & de Rigo, 2016).

Therefore, the "First Rupture" was not merely a change in the human economy but a radical reorganization of the Mediterranean biotic community. By replacing wild herbivores with domestic ones and creating niches for commensal species, Neolithic societies initiated a process of biological homogenization and functional redirection that would accelerate over the millennia that followed. However, up to this point, the anthropogenic footprint was largely "extensive" and spread diffusely across a landscape of autonomous farming communities. The resilience of this village-based mode of existence would soon be tested by demographic saturation and abrupt climatic instability. The transition from the Neolithic to the Chalcolithic and Bronze Ages would witness a fundamental shift in the geometry of impact: from the dispersed village to the hyper-concentrated city-state. This new era would not only intensify resource extraction through centralization but would also expose these emerging complex societies to a new vulnerability: the systemic shocks of the "Polycrisis Era."

3.3 Urbanization and the Concentration of Impact

Following the Neolithic dispersal, the next major ecological threshold was crossed during the Late Chalcolithic (LC) and Early Bronze Age (EBA) with the rise of central authorities and city-states (Frangipane, 2017; Sagona & Zimansky, 2015). This era marked a spatial reorganization of anthropogenic pressure: as populations migrated from rural hinterlands to emerging urban centers (Özdoğan, 2023), the ecological footprint of humanity shifted from being diffuse and extensive to being concentrated and intensive.

3.3.1 The Centripetal Force of Urbanization

The crucial shift toward resource centralization began during the LC period, driven primarily by the emergence of sophisticated, hierarchical Mesopotamian urban systems (Frangipane, 2017; Lawrence et al., 2022; Rothman, 2016; Sagona & Zimansky, 2015). This process occurred during the gradual transition from the Middle Holocene wet phase to the Late Holocene dry trend (Lawrence et al., 2022). The energy demands of these rising city-states created a vast "centripetal force," as their newly formed elites sought not only raw materials but specific prestige goods to legitimize their rising social status (Algaze, 2005; Lawrence et al., 2022; Rothman, 2016). This demand spurred the expansion of long-distance trade networks, thereby transforming the Upper Euphrates Valley (documented at sites like Arslantepe) into a critical frontier (Frangipane, 2017). In this region, the dynamics of settlement were particularly fluid, with the area often forming a contested region between stronger polities (Wilkinson et al., 2012). In this zone, the centralized Uruk influence from the south met the dynamic, mobile Kura–Araxes culture expanding from the Southern Caucasus (Frangipane, 2017; Sagona & Zimansky, 2015).

This entire period coincided with a major long-term drying trend across the Fertile Crescent, punctuated by episodes of increased cooling and aridity, placing heightened pressure on rain-fed agricultural systems (Lawrence et al., 2022). The process intensified into the EBA. The long-term trend towards increasing aridity meant that early urban centers, heavily reliant on dry farming in regions like Northern Mesopotamia, faced profound challenges, making small rainfall fluctuations critical to agricultural productivity (Lawrence et al., 2022; Wilkinson et al., 2012).

Simultaneously, the demand for metal became the chief catalyst for interaction and resource reorganization across the Anatolian frontier (Frangipane, 2017). This demand was driven by the elite requirement for visible symbols of authority (e.g. metal headdresses, diadems, and ceremonial weaponry) which became essential for maintaining social hierarchy (Frangipane, 2016; Sherratt and Sherratt, 1991). New metallurgical technologies intensified, particularly during EBA II, requiring systematic exploitation and organization of mining and distribution from sources like the Black Sea coast (Efe & Fidan, 2006). Consequently, the extraction of these ores

and the fuel required for smelting them linked the ecological degradation of the hinterlands directly to the political stability of the urban center (Lehner & Yener, 2014).

The non-centralized Kura–Araxes communities (c. 3500–2500 BCE) played a crucial, mobile intermediary role, channeling essential resources, including metal, animal byproducts (wool, dairy), and potentially wine, from the northern highlands into the increasingly demanding Mesopotamian-linked trade spheres (Rothman, 2016). The period of Late Uruk expansion (c. 3650–3150 BC/5600–5100 BP) coincided with a significant rapid climate change event (5.2 ka event, c. 3550–3050 BC), which contributed to an overall decline in urban sites in Northern Mesopotamia, though many communities proved resilient and adapted their subsistence strategies (Charles et al., 2010; Lawrence et al., 2022). For instance, although some sites like Tell Brak experienced partial abandonment, inhabitants were able to adapt their crop procurement system to the climatic aridification (Charles et al., 2010).

This period of intense expansion of exchange networks and population flow, evidenced archaeologically by trade routes, is mirrored by ancient DNA analysis, which documents a trend toward regional genetic homogenization across Southwest Asia. Notably, this gene flow began in the Late Neolithic and intensified during the LC/EBA, driven by substantial population movement originating in the Southern Caucasus/Iran (Koptekin et al., 2023; Lazaridis et al., 2016; Skourtanioti et al., 2020). This genomic landscape also offers insights into the social mechanisms of authority; specific kinship strategies, such as patrilocality and female exogamy, likely underpinned the consolidation of these elite groups, facilitating the accumulation of wealth and power across generations (Penske et al., 2024). This systemic organization meant the ecological footprint shifted from being diffuse to concentrated, resulting in intense ecological strain near urban nodes to fuel construction and industry (Charles et al., 2010; Wilkinson et al., 2012), fundamentally altering the relationship between urban metabolic units and their exploited hinterlands (Rothman, 2016).

3.3.2 Urban Metabolism and the Chronologies of Crisis

The concentration of populations and political power into fortified centers created a distinct and historically unprecedented "urban metabolism" (Hughes, 2014; Kennedy et al., 2007). Unlike the systems of Neolithic villages, these Bronze Age city-states functioned as highly dynamic open systems, requiring constant, massive inflows of energy and matter (e.g., timber, charcoal, ore, and grain) and exporting entropy in the form of waste and landscape degradation (Lehner & Yener, 2014).

Crucially, this metabolic intensification is not only an archaeological inference but is also legible in paleoecological archives. Across the Mediterranean, Holocene pollen syntheses document recurrent reductions in arboreal cover and increases in disturbance- and cultivation-linked taxa, consistent with a shift from more closed-canopy woodland states to heterogeneous agropastoral mosaics and secondary shrublands in many sub-regions (Sadori et al., 2013; Woodbridge et al., 2019). The most

visible scar of this metabolism was deforestation. The intensification of metallurgy in the EBA, driven by elite demand for weapons and regalia, necessitated large-scale, fuel-intensive metallurgical production. Estimates suggest that smelting a single kilogram of copper required dozens of kilograms of charcoal, translating to the clearance of vast tracts of woodland (Hughes, 2011). Pollen records from the period document a sharp decline in deciduous oak (*Quercus*) forests and a corresponding rise in disturbance-adapted, sclerophllous vegetation (maquis) and anthropogenic indicators like olive and vine (Ruiz & Sanz-Sánchez, 2020; Sadori et al., 2025). More generally, Mediterranean palynological overviews frame this as a recurrent Holocene pattern: forest openings (climate- and/or land-use-driven) can be followed by expansions of evergreen sclerophylls and other disturbance-tolerant assemblages, while economic taxa (e.g., *Olea*) and cultivation signals track phases of intensified land use. High-resolution palynology from the southern Levant specifically links Early Bronze Age socio-economic dynamics to detectable changes in regional vegetation and olive horticulture trajectories, underscoring that "urban metabolism" often reorganized vegetation through both fuel demand and agro-horticultural expansion (Langgut et al., 2016). This was not merely a change in scenery; it was a functional destabilization of the hydrological cycle. The removal of forest cover around mining centers and urban nodes accelerated soil erosion, leading to increased sediment loads in river systems and the rapid alluviation of coastal deltas, permanently altering the Mediterranean coastline (Degeai et al., 2024; Engel et al., 2009).

The Trap of Complexity This ecological restructuring came with a heavy price of systemic rigidity. While the complex administrative hierarchies and storage systems of the Bronze Age allowed for higher population densities, they paradoxically reduced resilience. Unlike the mobile foragers or autonomous Neolithic farmers who could migrate in response to environmental stress, urban populations were "tethered" to their heavy infrastructure and rigid trade networks. This vulnerability became existential when set against the volatile climatic history of the Holocene and the systemic risks inherent in highly interconnected urban systems (Capuzzo et al., 2018; Kemp & Cline, 2022; Scheffer et al., 2023; Tainter, 1990; Weiberg & Finné, 2018).

The connection between climate and demography had already been demonstrated by the 8.2 ka BP event (c. 6200 BCE). This abrupt cooling and aridification phase acted as a demographic pump, likely triggering earlier population movements from the Levant and Mesopotamia toward regions further north and west, as well as into the Southern Caucasus, other regions of Anatolia, and the Aegean (Flohr et al., 2016; Weninger et al., 2006). From the vegetation side, high-resolution pollen records in the northern Mediterranean (e.g., the Balkans) show that intervals overlapping the broader 8.2 ka anomaly can coincide with woodland decline and steppe/grassland expansion, i.e., an ecological opening of landscapes that could have altered the "cost" and opportunities of farming dispersal and land-use establishment (Van Vugt et al., 2025). These movements populated the regions that would later give rise to complex polities. However, by the Early Bronze Age, these societies had expanded into marginal rain-fed zones, betting their survival on a climatic stability that was about to end (Riehl, 2009; Wilkinson, 1997).

The 4.2 ka Rupture The inherent fragility of this urban metabolism was brutally exposed by the 4.2 ka BP event (c. 2200 BCE). A severe, multi-century megadrought disrupted the agricultural surplus that sustained the specialized bureaucracy and craft industries. In regions reliant on rain-fed agriculture, such as the Upper Euphrates and inland Anatolia, the impact was catastrophic (Weiss, 2016). The rigid centralized systems, unable to downscale their metabolic demands quickly enough, faced systemic collapse (Weiss, 2017). Paleoenvironmental reconstructions also indicate that this interval can register as a vegetation stress episode in parts of the Mediterranean, with forest declines in some sub-regions and conditions conducive to enhanced disturbance and fire-vegetation feedbacks (Burjachs & Expósito, 2015; Di Rita & Magri, 2019). In Mesopotamia, synthesis work similarly argues that late third-millennium BCE hydroclimatic deterioration was sufficient to depress natural vegetation and therefore likely agricultural productivity; exact magnitudes and pathways varying by local water management and exposure (Cookson et al., 2019). Although the effect was not uniform in the region, archaeological layers from this period often show abandonment, destruction layers, or a reversion to smaller, more resilient rural lifestyles which is a phenomenon formerly interpreted solely as political failure but now understood as a "Polycrisis" driven by the misalignment between an inflexible urban metabolism and a fluctuating environment (Lawrence et al., 2022; Roberts et al., 2011). At the same time, "collapse" is widely treated as multicausal rather than climate-deterministic; climate shocks can act as triggers or amplifiers inside coupled socio-ecological systems, not as a universal single cause (Butzer, 2012). Thus, the Bronze Age collapse serves as the first historical lesson on the limits of carrying capacity when mediated by complex social hierarchies.

3.4 Connectivity as an Ecological Vector: The Iron Age and Roman Legacy

While the Bronze Age is defined by the concentration of impact around specific urban nodes, the Iron Age and Roman periods can be defined by connectivity. The establishment of vast trade networks, colonial expansions, and imperial infrastructures transformed the Mediterranean into a unified socio-ecological zone. This connectivity acted as a powerful vector, facilitating not just the movement of goods and people, but the rapid dispersal of species, pollutants, and ecological pressures across the basin.

3.4.1 The Evolution of Connectivity: From Urban Nodes to Imperial Integration

The intense connectivity of the Mediterranean can be analyzed in two distinct phases. During the Iron Age (c. 1200–500 BCE), the collapse of Bronze Age palace economies gave way to a dynamic, multi-nodal maritime network. Driven by the expansion of Greek and Phoenician colonies and the rise of Carthage as a dominant maritime power, this era witnessed major advances in seafaring that facilitated the movement of goods and materials over unprecedented distances (Broodbank, 2013; Horden & Purcell, 2013). Island hubs like Sardinia, Cyprus, and Sicily acted as critical intermediaries, circulating commodities such as amphorae and basaltic millstones across diverse cultural spheres (Knapp et al., 2022; Renzulli et al., 2019). This archaeological picture of intensified trade is now strongly corroborated by ancient genomic studies, which reveal that this connectivity was not limited to goods. There was a significant and parallel increase in human mobility across the Mediterranean basin during this period (Antonio et al., 2024; Moots et al., 2023).

Crucially, Anatolia emerged as a pivotal hub within this fluid network since it became integrated deeply into Aegean networks (Gunter, 2022). A transformative innovation occurred here by the mid-seventh century BCE: the adoption of civic silver coinage by western Anatolian city-states (Konuk, 2015; Loy, 2024; Sherratt, 2022). This standardization replaced cumbersome barter systems, drastically lowering transaction costs and accelerating long-distance exchange with the Near East and the broader Mediterranean (Loy, 2024; Van De Mieroop, 2014). Thus, the Iron Age was characterized by localized adaptation and mobility, where connectivity was driven by independent city-states rather than a singular imperial center (Kostoglou, 2010).

The rise of the Roman Empire marked a fundamental shift toward a highly integrated, administratively regulated system. Rome effectively "closed the loop," connecting specialized production regions via a synchronized network of sea, river, and land routes (Scheidel, 2014). Goods were strictly documented, standardized, and taxed, creating a "centripetal" flow that drew resources from the periphery to the imperial core (Morley, 2010, p. 75). In the Anatolian Peninsula alone, a dense network of approximately 500 cities and many villages formed an interconnected economic web, shaped by local topography and agricultural potential (Willet, 2021). This network extended far beyond the Mediterranean basin through the Indian Ocean trade, funneling exotic organics and luxury goods through eastern Mediterranean ports (Fitzpatrick, 2011; Seland, 2014). This profound integration meant that an ecological disturbance in one region was directly linked to consumption patterns in another.

3.4.2 Ecological Consequences of Connectivity: From Fragmentation to Biotic Globalization

The infrastructure that bound this vast empire together also acted as a potent agent of ecological partition. The Roman road network (*viae publicae*), which is often celebrated as an engineering achievement (Laurence, 1999), was one of the earliest large-scale examples of human-induced habitat fragmentation. From an ecological perspective, roads simultaneously create "barriers" and "corridors" that reorganize flows of organisms, water, and materials across landscapes (Forman & Alexander, 1998; Marucci et al., 2019). In that sense, the Roman transport grid can be read as an early fragmentation mechanism whose effects scale with network density (van Strien & Grêt-Regamey, 2016). However, while these roads blocked some species, they accelerated others. The road verges and disturbed soils associated with construction created distinct ecological niches, functioning as "dispersal corridors" for synanthropic and invasive plant species. Archaeobotanical evidence suggests that the introduction of new weeds and cultivated plants was facilitated by these transport corridors, allowing them to penetrate deep into inland territories (Bosi et al., 2020; Orengo & Livarda, 2016). Thus, the Roman road network functioned as a selective filter, hindering specialists while promoting the spread of ecological generalists.

The ecological footprint of this connectivity extended significantly beyond the terrestrial sphere into the marine environment. The Roman Mediterranean Sea (*Mare Nostrum*) was not merely a passive medium of transport but a zone of intensive industrial extraction and contamination. Geochemical analyses of harbor sediments reveal that Roman ports were hotspots of heavy metal pollution. At many sites in the Empire, sharp increases in Lead (Pb), Copper (Cu), and Zinc (Zn) concentrations have been documented during the Roman period (Elmaleh et al., 2012; Irabien et al., 2020; Stock et al., 2016; Véron et al., 2018). These spikes are directly linked to human activities and the local metallurgy required for shipbuilding and coin production, leaving a toxic legacy that persists in coastal sediments today. In parallel, the scale of fish processing and commodified distribution (e.g., salted fish and sauces such as *garum/liquamen*) implies sustained extraction pressure (Roselló-Izquierdo & Morales-Muñiz, 2008), with plausible ecosystem-level effects. Indeed, the sheer volume of processing facilities along the coasts of Spain and North Africa suggests that Roman demand likely altered the trophic structure of local marine ecosystems (Marzano, 2013; Trakadas, 2006).

Perhaps the most enduring legacy of this era is the botanical transformation of the Mediterranean basin, a process of "Biotic Globalization" in which Anatolia played a central role. At the basin scale, Holocene syntheses combining pollen and archaeological proxies show that Mediterranean land cover was increasingly transformed by human land use, with especially strong, regionally coherent shifts over the last ~ 3–4 millennia (i.e., broadly overlapping with Iron Age to Roman intensification in many subregions) (Roberts et al., 2019; Woodbridge et al., 2018). In Anatolia

specifically, classic palynological–archaeological work links Late Holocene vegetation change to phases of intensive land use and arboriculture (the "Beyşehir Occupation Phase"), consistent with widespread woodland clearance and expansion of anthropogenic indicators (Eastwood et al., 1998). For the Sagalassos hinterland in Southwest Turkey, pollen-based reconstructions explicitly document a profound shift beginning around 2600 BP, coinciding with the Hellenistic-Roman flourishing. The data reveal a sharp decline in native arboreal pollen, indicating the clearance of evergreen oak woodlands, and a simultaneous surge in *Olea* (olive) and *Vitis* (grape) pollen (Vermoere et al., 2001). This shift represented not merely subsistence farming but surplus production driven by the integrated Roman economy. Archaeobotanical meta-analyses from Southwest Asia confirm that olive and grape cultivation, initially concentrated in the Levant, expanded significantly into Anatolia during the Roman period, correlating with high population densities and trade integration (Deckers et al., 2024). This replacement of diverse mixed forests with tree-crop monocultures reduced habitat heterogeneity, while crop choices were increasingly driven by imperial market demands and taxation rather than local environmental constraints (Marston, 2012, 2017; Marston & Castellano, 2025). For other long-lived "Roman signature" cultigens frequently discussed in connection with connectivity and managed landscapes (notably chestnut and walnut), the Roman legacy is explicitly treated as a driver of enduring arboricultural regimes in parts of Europe (Krebs et al., 2022). Conceptually, this is well captured by "human niche construction" perspectives: connectivity does not only move goods and people; it also reorders species distributions and accelerates long-term biotic mixing (Boivin et al., 2016). By monetizing trade, fragmenting terrestrial habitats with roads, polluting coastal waters with heavy metals, and replacing native forests with export-oriented orchards, this era finalized the transition of the Mediterranean from a primarily climate-structured biome to a human-nature hybrid mosaic, in which semi-natural systems persisted but were increasingly reorganized by land use.

3.5 Conclusion: The Long Anthropocene and the Mediterranean Paradox

The narrative arc traced in this chapter from the Pleistocene refugia to the integrated networks of the Roman Empire challenges the simplistic view of Mediterranean history as a linear descent into degradation. Instead, it reveals a layered process of co-evolution, where the boundaries between the "natural" and the "anthropogenic" have been progressively dissolved. The ecological identity of the Mediterranean Basin is not merely a product of its geography, climate, or natural wildfire regimes, but also a result of cumulative human interference that has operated with increasing intensity and complexity over the last 12,000 years.

Reviewing the stages of this transformation reveals a distinct shift in the geometry of anthropogenic pressure. The "First Rupture" during the Neolithic was

primarily extensive and biological; by functionally replacing wild megaherbivores with domestic herds and creating shadow ecosystems for synanthropes, early farmers homogenized the biotic community across vast areas, yet their structural footprint remained diffuse. In contrast, the "Second Rupture" of the Bronze Age shifted this geometry to an intensive and concentrated form. The rise of the "Urban Metabolism" drew resources from distant hinterlands into fortified nodes, creating localized zones of extreme degradation driven by elite demands for metal and prestige. Finally, the "Third Rupture" during the Iron Age and Roman periods rendered this impact networked and systemic. Through the infrastructure of roads, harbors, and standardized economies, connectivity itself became an ecological vector, making pollution mobile and radically standardizing vegetation through the arboricultural revolution.

It is important to acknowledge that the ecological history of the region does not conclude with the Classical Era. The subsequent fluctuations of the anthroposphere are evident, ranging from the partial "rewilding" of the landscapes following the period of demographic contraction that was experienced during the Late Antiquity, to more intense land-use regimes that were observed in the Medieval periods. This is followed by the modern era, in which the intensified land-use resulting from the utilisation of fossil fuels can be seen to represent a separate and equally transformative phase, known as the "Great Acceleration." While a detailed examination of these later periods falls outside the scope of this chapter, they built directly upon the structural foundations established during the millennia discussed here. The anthropogenic baseline set by the Roman era created the enduring stage upon which these later dramas of resilience, collapse, and regeneration would be enacted.

Crucially, this deep history demonstrates that increased complexity often correlates with increased fragility. The collapse of Early Bronze Age polities during the 4.2 ka event serves as a stark reminder that rigid, high-energy systems are vulnerable to climatic volatility. In contrast, the persistence of traditional agro-silvo-pastoral systems highlights that resilience lies in diversity and flexibility. These so-called "cultural landscapes," which are frequently misrepresented as degraded, in fact represent a successful equilibrium; they are the legacy of moderate disturbance, and they support a high level of biodiversity. Consequently, the challenges currently faced under the umbrella of what has come to be termed the "Polycrisis Era" (including biodiversity loss, soil exhaustion, and climatic instability) cannot be solely attributed to modern phenomena arising from the Industrial Revolution. It is an irrefutable fact that climate change has accelerated the rate of ecological change in the Mediterranean ecosystem. However, it should be noted that the mechanisms of change, such as habitat fragmentation, biological invasion, chemical contamination and trophic simplification, have existed in this ecosystem for millennia.

In conclusion, the Mediterranean region can be regarded as a "laboratory of the Anthropocene." The historical record demonstrates that human societies are inherently intertwined with their ecological context. This means that we do not merely manage this environment as an external entity, but rather we are integral components of its metabolic flows. In the context of a new era characterised by accelerated climatic shifts, the survival of Mediterranean civilisations will be contingent, as it was for the Natufians and the Bronze Age Anatolians, not on the capacity to dominate

nature, but on the ability to adapt social and economic systems to the inescapable constraints of the biosphere. The past is not just a prologue; it is the blueprint of our current ecological reality.

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