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Reconceptualizing Urbanism: Insights From Maya Cosmology

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Sustainable practices in the present are typically designed to mitigate immediate concerns over decadal timespans. In the face of exponential population growth, overuse of resources, and global climate change, this time span is inadequate; longer, more resilient and sustainable options need to be implemented. Here, we tackle the intersection of human behavior and the urban environment by taking a holistic approach—that is, a non-anthropocentric approach critical to ensure the longevity, or even survival, of the planet. We thus approach urbanism as we would any ecosystem, with the broad understanding that the urban, the rural, humans, and non-humans are all interdependent. One cannot understand cities without an understanding of the surrounding rural or non-center areas, thus making critical an appreciation of urban-rural interdependence (URI). The holistic model is based on insights from the ancient Maya of Central America—a tropical society where farmers practiced widespread, sustainable agriculture for 4,000 years without denuding the landscape. The Classic Maya accomplished this feat in large part due to their sustainable URI and cosmocentric worldview (CWV)—that is, a cosmology of conservation, or merged existence, where people, animals, plants, rivers, stones, clouds, etc., each played a role in maintaining the world. Their CWV was also expressed in urban planning through manifestations of traditional knowledge, multi-purpose designs, and local resource networks. Insights from the Maya indicate that diversity is fundamental—across all scales; diverse strategies are flexible, spread risk, and are resilient in the face of change. As such, we present past lessons from Maya kings and farmers who built cities with reservoirs, causeways, monumental constructions and other urban features that integrated the built into the existing environment, ultimately resulting in green cities interspersed with farmsteads and managed biodiverse forests. In brief, our holistic model suggests possibilities for the re-integration of nature and culture, with the goal of a resilient URI.

Keywords: insights, urban-rural interdependence, Classic Maya, cosmocentric worldview, holistic approach, urban-rural resilience

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INTRODUCTION

Study the past if you would divine the future—Confucius (551–479 BCE)

History, especially since the Renaissance, demonstrates that humans have been attempting to tame, control, or reconfigure "nature." This approach is not sustainable in the long-term due to several factors including exponential population growth, overuse of resources, and global climate change. Instead, people need to change and adapt, including how we conceptualize sustainable cities, the focus of this paper. Current sustainability practices are typically designed to mitigate immediate concerns over decadal timespans. In today's world, this time span is inadequate; longer and more resilient and sustainable options need to be implemented. The past provides options on how to avoid repeating mistakes because it "offers a pool of experience of challenges, strategies, practices, successes and failures from which to draw" (Isendahl et al., 2018, p. 19). Archaeology, specifically, contributes: (1) evidence for climate instability, flooding, extreme weather events, etc.; and (2) how people responded and/or changed their behavior (e.g., Fiske et al., 2015).

The high interconnectivity of the modern world signifies that a call for urban resilience is a call for planetary resilience—expanding the spatial component of sustainability along with the temporal. Exceedingly vital is the necessity to think beyond humans since the survival of *Homo sapiens* is dependent on the endurance of the non-human world; if the environment and its resources, forests, water bodies and creatures are irrevocably damaged, humans cannot flourish. Thus, we opt for a non-anthropocentric approach for planning future cities; we broach changing the relationship between human behavior and the urban environment by taking a holistic, interspecies view of urban and non-urban spaces in the tropics.

We approach urbanism as we would any ecosystem, and approach humans as any other organism, acknowledging that everything is reciprocally connected. Ecosystems demonstrate that diversity is fundamental across all scales; diverse strategies are flexible, spread risk, and are resilient in the face of change. We set the stage for this holistic model by discussing the Classic Maya (c. 250–900 CE) of Central America—a tropical society where farmers practiced widespread, sustainable agriculture for 4,000 years without destroying their ecosystem. The Maya accomplished this feat in large part due to their cosmocentric worldview (CWV)—that is, a cosmology of conservation where people, animals, plants, rivers, stones, clouds, etc., each played a role in maintaining the world (Lucero, 2018a). Their non-anthropocentric worldview was also expressed in their Urban-Rural Interdependence (URI), where Maya kings and subject farmers built cities with reservoirs, causeways and monumental constructions integrated into the existing environment, resulting in green cities interspersed with farmsteads and managed biodiverse forests.

We present strategies gleaned from the tropical past that provide architypes for urban planning today (e.g., open and green spaces, natural cemeteries, constructed wetland biospheres, recycling organic waste, etc.). In brief, our holistic model re-integrates nature and culture. As archaeologists, we approach sustainable urbanism theoretically rather than empirically (Brenner and Schmid, 2015), and holistically as an ecosystem rather than an isolated unit of study. We begin with a brief discussion of urban-rural interdependency in tropical regions and elsewhere, followed by an introduction to the Classic Maya and their CWV. We then present a holistic approach for a future URI based on insights from the Maya.

THE TROPICS, URBAN-RURAL INTERDEPENDENCE, AND SUSTAINABILITY

Urban areas around the world have become a large rallying point in politics and policy, as well as sustainability initiatives, including tropical regions where over 40% of the world's population resides (Mora et al., 2013). The large population should come as no surprise given that people have been living in tropical regions for tens of thousands of years (Roberts et al., 2017). The tropics lie between 23.5° north and south of the equator; consequently, they have a high level of solar radiation throughout the year as well as some of the most diverse and complex ecosystems (Hutterer, 1985). Even though there is high forest biodiversity, resources are dispersed; species of flora and fauna are not concentrated in any given area. Healthy forests are critical for flora, fauna, and humans; forest cover also promotes precipitation and decreases evaporation and erosion (Lawrence and Vandecar, 2015). At present, the urban-rural divide looms increasingly prevalent as cities expand due to growing populations, which exerts pressure on rural communities and agricultural fields (Lichter and Brown, 2014; Barthel et al., 2019). This fact is even more significant given the expected expansion of the tropical belt beyond the ±23.5° latitude from the equator due to global climate change. Tropical features presumably also will spread, both good and bad, including wet and dry seasons, rainfall-dependency, hurricanes and tropical storms, changing biodiversity, diseases (e.g., Zika, malaria, dengue, etc.), and so on.

Throughout history, rainfall-dependent tropical societies lived sustainability for millennia, relying on a combination of local, small-scale subsistence technologies and large-scale water management systems, brought together in a low-density agrarian urban system that integrated water and agricultural systems, political centers, dispersed farmsteads and communities, exchange networks, and resources (Fletcher, 2009). Low-density agrarian urban systems embodied an efficient URI and covered a wide range of scales, from the hundreds of Classic Maya kingdoms of Central America between the first century BCE and the tenth century CE, and the Sinhalese Buddhist capital of Anuradhapura between the fourth century BCE and eleventh century CE in Sri Lanka, to the Khmer capital of Angkor in Cambodia between the ninth and sixteenth centuries CE (Lucero et al., 2015). While their scale varies (e.g., Angkor and its immediate area integrated c. 750,000 people, whereas the largest Maya capitals up to c. 80,000), they had key features in common: their rainfall-dependency and the URI that emerged as a means to address it and other tropical conditions. There was a fine balance between the centripetal pull of cities (reservoirs, markets, large-scale public ceremonies and other events, etc.) and the centrifugal forces of scattered resources and subjects in non-urban or rural areas (**Table 1**). **Table 1** represents a fluid system between the left and right columns; the amount of flow is largely dependent on seasonal variation because each has specific activities that relate to the dry season (agricultural downtime) and the wet season (agricultural intensive period).

Different tropical societies, though varying in size, had similar paths, signifying that future trajectories will likely be similar. Thus, it is crucial to be aware of the key factors that worked and did not work in the long term. As in the past, cities are heavily entangled with rural areas (Schaeffer et al., 2014). Rural communities provide food, recreation, energy, and other domesticates and natural resources to cities. The reliance of cities on rural populations bolsters an URI, a state in which the urban can only exist amidst a symbiotic relationship with the rural—in essence, they form an ecosystem of their own (**Figure 1**).

The word ecology stems from the Greek word *oikos* for home. Hence, from an ecological perspective, to look at the urban is to grasp its relationship with other living things and their environment or homes—encompassing not only the rural, but also non-human entities. What are the foundations of a home for humans and non-humans? The environment, a social milieu, and production and consumption are the three underpinnings of every society and ecosystem (**Table 2**). Regardless of species, a home is a physical place (habitation) containing a social unit (individual/family). In human societies, families or households interact on a daily basis within communities or neighborhoods, which typically serve as the basis of identity (Smith, 2010) in a wider, integrated system. For example, traditional Maya wear woven clothing with designs (social unit) specific to each village (environment) (Dywer, 2005). Each community or town contains public features, or services, such as sanitation and water systems, administrative buildings, recreation facilities, courthouses, and others.

TABLE 1 | Low-density agrarian societies: URI (adapted from Lucero, 2018b, Table 1).

Urban	Rural
Centripetal	Centrifugal (diverse, dispersed resources)
Hierarchy	Self-organizing
Political & religious elite, merchants	Farmers, craft producers
Temples, palaces, large public areas	Managed forests & dispersed fields, livestock*
Information nexus, exchange	Information collection
Markets, production nodes	Small-scale markets/household production & exchange
Provides services (protection, potable water)	Provides tribute (labor, goods)

**Livestock was rare in the Americas until Europeans introduced horses, cattle, and the like beginning in the 1500s.*

Current sustainable planning privileges humans, focusing on short-term solutions, which in turn leads to an imbalance caused by an over-reliance on technology, increased automation—and unintended consequences, the bane of human existence (e.g., Stokstad, 2019). For example, "influenza viruses coevolved with birds, pigs, and humans since the threshold of domestication, and the Industrial Revolution disrupted this ecosystem and amplified lethal viral mutations. The emergence of pandemic influenza viruses was…an unintended effect of the livestock revolution" (Keck, 2019, p. 1). Even green technology has unintended consequences; for instance, wind turbines, while producing stores of green energy, are killing swaths of migratory bats, already endangered by white nose syndrome (Frick et al., 2017). Bats provide many eco-services such as pollination, seed dispersal,

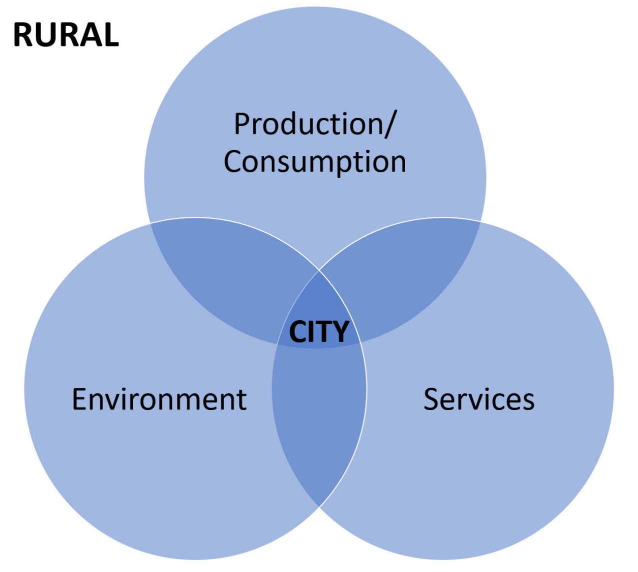

FIGURE 1 | Schematic showing intersection of urban and rural sectors. Generated by J. Gonzalez Cruz.

TABLE 2 | Fundamentals of urban-rural interdependence.

URI fundamentals	Characteristics	Examples
Production/Consumption	Food	Mono-cropping
	Energy	Electricity, fossil fuels
	Waste	Sewage
	Markets	Capitalism
Environment	Un/Built space & landscape	Place of worship
	Residence	Home
	Work/labor	Automation
Services	Administrative/government	State
	Public/social events	U.S. 4th of July celebrations
	Information exchange	Social media

fertilization, and insect control (Wilson, 1997). Dwindling bat species has major repercussions and elevates the need for human input to fill the increasing gap in their ecological niche. Similar critical repercussions occur with other taxa, such as the escalation of microplastic entanglements and ingestion by marine life, which ultimately affects various human food sources and environmental eco-services (Li et al., 2018).

This is not to say that modernization should be delayed, or that a return to pre-modern ways is necessary, or even possible for that matter, but rather that a more-than-human, more holistic approach needs to be considered in urban sustainability discourse. What would a highly populated urban ecosystem look like with a more-than-human worldview? Tropical societies like the Classic Maya provide insights for a sustainable URI.

THE CLASSIC MAYA

The Classic Maya (c. 250–900 CE) of the southern lowlands of present-day Belize, northern Guatemala and southeastern Mexico lived in urban centers or cities ruled by kings, or in dispersed rural farmsteads in a forested karstic landscape with high but dispersed biodiversity (Lucero, 2006, 2017) (**Figure 2**). There is also relatively limited surface water due to rainfall percolating through the permeable limestone bedrock. Water was vital in this rainfall-dependent society due to annual rainy and dry seasons; even most wetlands (c. 40% of the lowlands) became desiccated in the dry season (Dunning et al., 2006). The Maya area did not have metals or beasts of burden, and the Maya did not build extensive irrigation or extensive road systems. Instead they relied on labor, human ingenuity, stone tools, and working with the environment and its myriad of non-human entities. Organizing a dispersed subject populace required different administrative tools for efficient urban-rural interactions that encompassed diverse resource management strategies and long-term sustainable agriculture (Lucero, 2017, 2018b). Diversity in URI—in scale of water and subsistence technologies, resource types and locations, crops planted, forest management strategies, and other practices were key.

The diverse but scattered resources, including fertile agricultural soils, resulted in farmers living dispersed throughout the landscape; larger plots of fertile land supported more people and larger cities (Fedick and Ford, 1990). The Maya relied not only on diverse crops, but also diverse locations where they planted them—*milpas* (fields), house gardens, and managed forests. By planting in areas with fertile soils, the Maya not only fed more people by planting more crops per year, but they did not have the need to clear as much land (Ford and Clarke, 2016). An additional supply of food likely came from urban areas, where the Maya likely made use of the open, presumably green, spaces (Graham and Isendahl, 2018). Urban agriculture would have enhanced food security and resilience. **Figure 3**, an artist's rendition of Tikal, Guatemala, shows open areas between buildings, causeways, and reservoirs that could have supported urban gardens or even fields and forest stands. The Maya either walked through the jungle on well-established trails or canoed on navigable rivers. Thus, the lack of extensive road or transportation systems was not an issue because Maya relied on nearby resources and produce (Scarborough and Lucero, 2010).

Most of the 100's of urban centers had their own king, though some were more powerful than others, namely Tikal in Guatemala and Calakmul in Mexico, largely due to their location in areas with large amounts of fertile soils. These areas, however, lacked permanent surface water such as lakes and rivers because of the porous bedrock. Small- and large-scale water containment and conservation systems were thus vital for survival during the 5-month dry season. Rural farmers depended on city reservoirs for clean water during the dry season, which was the agricultural downtime. Urban planning and layout increasingly became interlinked with reservoir systems, creating anthropogenic landscapes that are still visible today (Scarborough, 1998; Scarborough et al., 2012). Urban features included multi-purpose ones; for example, while the causeways connected different political and ceremonial complexes, some also served as dams and walkways during the rainy season. In addition, cities exerted a centripetal pull on rural Maya through markets and access to goods, public ceremonies, and other large-scale public events. In turn, cities depended on the rural populace to fund the political economy in the form of labor, services (craft specialists, hunters, etc.), agricultural produce (e.g., maize, beans, manioc, squash, pineapple, tobacco, tomatoes, cacao, etc.), and forest resources (wood, fuel, construction materials, medicinal plants, chert, game, berries, twine, fruit, etc.).

The Maya began building water systems by c. 100 BCE (e.g., El Mirador, Guatemala) (Scarborough, 2000). Growing population resulted in increasingly larger and more sophisticated artificial reservoirs with dams, channels and sand filtration systems, a trend that continued through the Late Classic (c. 600–800 CE), the period with the highest population size (Scarborough and Gallopin, 1991; Scarborough, 1993, 2003, p. 50–51, Scarborough, 2007). Maintaining water quality would have been crucial to curtail the presence of water borne parasites and diseases such as hepatic schistosomiasis, and the build-up of noxious elements such as nitrogen (Burton et al., 1979). The Maya kept water clean by mimicking wetland biospheres through the use of certain surface and subsurface plants and aquatic life (Lucero et al., 2011). Reservoirs, that is, constructed wetland biospheres, "also had other uses; fish eat insects and their feces and other bottom debris can be used as fertilizer…Fish, as well as snails and shellfish, are excellent sources of protein…Edible and medicinal plants grow in aquatic environments and the Maya perhaps used reeds that grew at reservoir edges for baskets and mats" (Lucero, 2017, p. 170–171). A major concern would have been dealing with human waste due to the porous limestone, especially since latrines have not been found in the archaeological record; perhaps the Maya used night soil as fertilizer, as traditional Chinese and other farmers have done.

The URI developed out of the need to manage land and water in a tropical climate, which expanded and served people's needs until a series of prolonged droughts struck between c. 800 and 930 CE (Medina-Elizalde et al., 2010; Kennett et al., 2012; Douglas et al., 2015). Because kings relied on reservoirs to

FIGURE 2 | The Maya area with major sites noted. Generated by L. J. Lucero.

attract subjects and their services and labor, these droughts not only impacted reservoirs, but the foundation of royal power. As reservoirs dried up, water quality worsened and water plants died, along with Maya kingship. An urban diaspora ensued, resulting in c. 90% (Turner and Sabloff, 2012) of farming families leaving the interior southern lowlands for coastal areas and areas near major rivers and lakes (e.g., Belize River, Lake Petén Iztá) where smaller market towns emerged and trade thrived (Sabloff, 2007; Graham, 2011; Masson and Freidel, 2012). Maya families that remained lived near the relatively few perennial lakes and rivers (e.g., Belize River, Cara Blanca pools) in smaller communities with a different socio-political organization. Abandoned urban centers were never re-occupied. Maya families had to make hard, difficult and even radical decisions. They left their homes, fields,

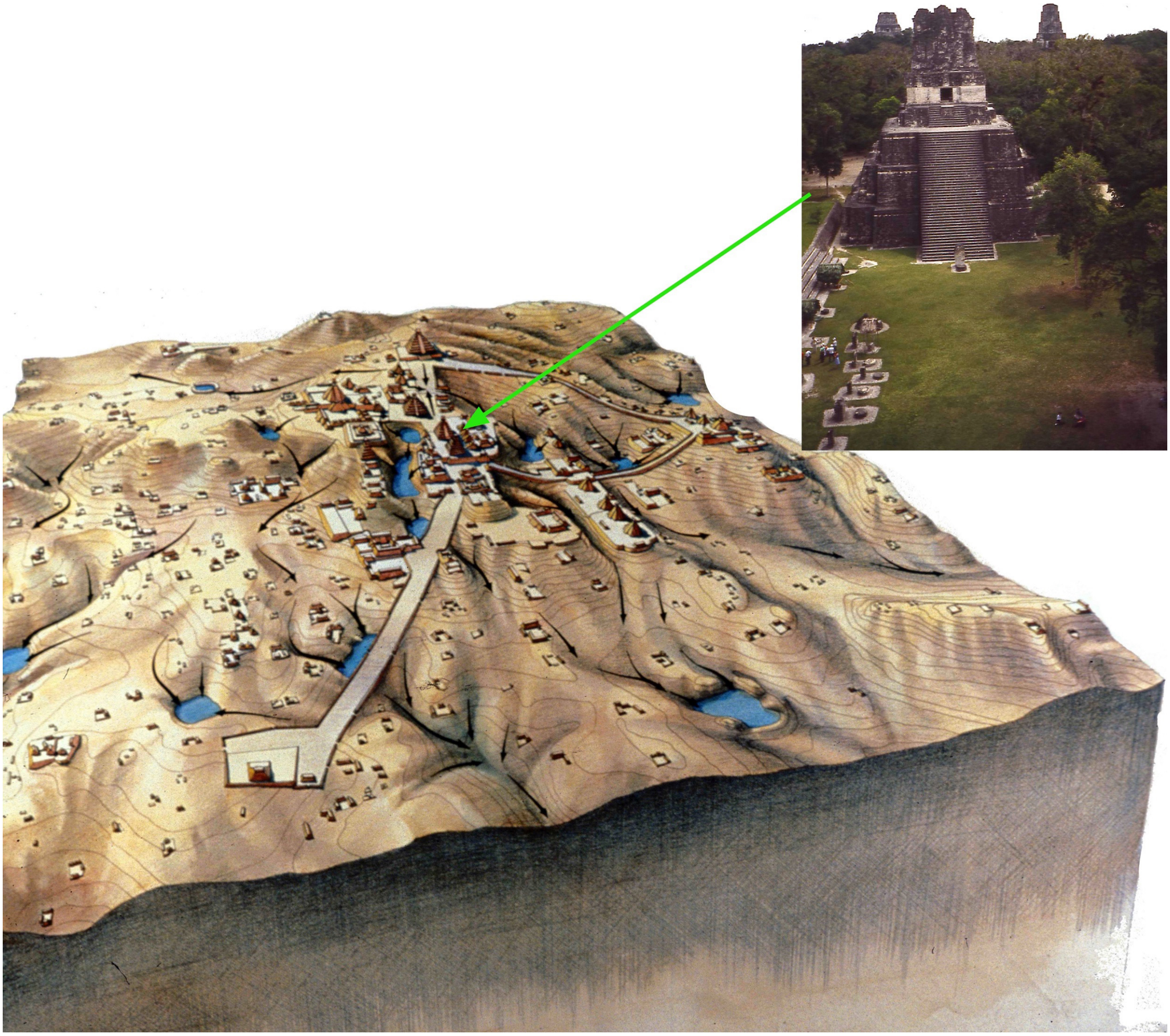

FIGURE 3 | Artist's rendition of Tikal, Guatemala (courtesy of Vernon Scarborough) showing open areas, urban core and dispersed settlement, and reservoirs. Photo of Temple II by L. J. Lucero.

and communities. But they did so to save their families. While this response was drastic, it was an adaptive strategy—one that worked as evidenced by the over seven million Maya currently living in Central America and beyond (McAnany and Gallareta Negrón, 2009).

Maya cities lasted as long as kings—water managers—provided clean water during the long dry season. By not diversifying their political economy, the kings became path dependent, which is in stark contrast to diverse and flexible strategies. "Path dependence connotes a sense of becoming increasingly stuck in a particular way of doing things, an inability to change even when change would be advantageous" (Nelson et al., 2014, p. 172; e.g., Hegmon et al., 2008). That said, cities in the southern lowlands prospered for over a thousand years. They lasted because of a fine-tuned URI that was dependent on predictable wet and dry seasons, which changed when the ninth century droughts struck. While Maya cities were not unsustainable *per se*, being path dependent was. Kings disappeared and cities remained empty; families and traditional knowledge endured.

How did Maya farmers live for thousands of years without destroying their environment? How did their cities persist for over a thousand years? We posit through a non-anthropocentric worldview that guided daily existence and engagement with the non-human world in such a way that promoted a more equal relationship (Lucero, 2018a; see Tsing et al., 2019).

THE MAYA COSMOLOGY OF CONSERVATION

> *The forest belongs to the Maya and they belong to it*—Hanks (1990, p. 389)

The current anthropocentric worldview as expressed in our Cartesian, dichotomous view of the world stands in stark contrast to a CWV found in many pre-modern or non-industrial societies (e.g., Weber, 2013; Lucero, 2017). A CWV is the opposite of anthropocentrism; it situates objects, humans, animals, land, water and everything on the same plane, with the goal of maintaining themselves and the world (Lucero, 2018a). The Maya thus were one with world, a concept illustrated in how they perceive the soul (*ch'ulel*). Every entity has a soul; every soul is connected and communicates with other souls (Houston et al., 2006, p. 142–143; Vogt, 1969, p. 369–371). Human souls are recycled; "Children and grandchildren were called *kexol*, "replacements" of their ancestors…" (Schele and Miller, 1986, p. 266). This CWV is embodied in languages as well; for example, "Native Americans often refer to the sun, mountains, clouds, rain, and so forth in kin terms" (Astor-Aguilera, 2010, p. 211). The Maya, and other societies with CWVs, saw more than we do—or at least acknowledged the vibrant forces of others and the fact that everything is connected and played their part to maintain the world, a concept illustrated in the ergative nature of Mayan languages and their "plurality of subjects" (England, 2017). Among the Tojolab'al Maya of Chiapas, Mexico, for instance, they emphasize "we" instead of "I" (Lenkersdorf, 2006); "we" includes clouds, plants, rivers, mountains, animals, and other entities.

The Maya, as one with world, were closely connected and intermingled with the world around them. This point is illustrated in how the Maya perceive *wits,* a term that signifies lineage mountains *and* pyramid temples (Stuart, 1987, 1997; Stuart and Houston, 1994, p. 82). Temples are not replicas of ancestral mountains, they *are* ancestral mountains (see Brady and Ashmore, 1999; Harrison–Buck, 2012). It is in mountains were ancestors reside and watch over their descendants; they also serve as a means of communication through the many caves or *ch'e'n*. Such openings in the earth, especially caves and water bodies, are portals to the otherworld, where the Maya communicated with ancestors and gods (e.g., the Rain God Chahk). The Maya engaged with urban center *wits* (temples) as animated entities via ceremonies and summit performances (Reese-Taylor, 2002), as well as rural *wits* (mountains) via pilgrimage journeys and ceremonies (Lucero, 2018a). And even though artificial reservoirs provided clean drinking water, they, too, were considered portals and treated accordingly.

There are no Mayan terms for "religion" or "nature" (Pharo, 2007), reflecting a merged existence that the Maya underscored through engaging with other entities via ceremonies in the home, gardens, *milpas*, cities and throughout the landscape (caves, water bodies, etc.). For example, Cara Blanca in central Belize served as a pilgrimage destination, especially during the ninth century droughts. This landscape includes fertile agricultural soils and 25 pools, some of which are deep watery portals or *cenotes* (steep-sided sinkholes filled by groundwater). *Cenotes* contain water throughout the year, including during the 5-month dry season. However, we only find minimal settlement near the *cenotes*, all ceremonial in nature (Lucero and Kinkella, 2015; Lucero et al., 2016). The Maya neither built houses nor planted fields near *cenotes*. They left these areas relatively untouched, despite the plentiful resources, likely because it held some significant cultural meaning. As a result, the lack of houses and fields near Cara Blanca *cenotes* allowed local flora and fauna to flourish, which in turn promoted biodiversity, and thus, conservation (Lucero, 2018a).

Maya engagement of such "sacred" places was a type of sustainable management. Diversifying what they planted in their house gardens and *milpas*, in addition to this type of forest management, became an integral part in maintaining the landscape (Ford and Nigh, 2015, p. 13). There are other types of forest management strategies as well. A mosaic of built, managed and untouched areas sustained the Maya for millennia (Ford and Clarke, 2016).

THE MAYA COSMOCENTRIC WORLDVIEW AND RESOURCE MANAGEMENT

The Maya left a sustainable imprint on the forested landscape. In fact, there is growing evidence that the "primary" forest we see today actually signifies a descendant forest reflecting ancient resource management (e.g., Gómez-Pompa et al., 1987; Lindsay, 2011, 2014; Ross, 2011). Forest management strategies included culling, promoting some species over others, land clearing, resource extraction, and intentional and accidental fires for uses including gathering wood for fuel and hunting (Ford and Nigh, 2009). Even at the height of population size in the Late Classic (c. 600–800 CE), the Maya managed and relied on forest products as evidenced in the flora and faunal remains in the archaeological record, as well as the current forest composition. For example, in a study of over 300 botanical specimens collected from areas with Maya sites in central Belize, a Mopan Maya foremen was able to identify approximately 95% of the specimens, most of which have uses today (e.g., spices, fruit, nuts, medicinal, construction materials, etc.) (Lindsay, 2011; Lucero et al., 2014). This knowledge reflects thousands of years of engaging responsibly with the living forest. Presently, the Maya make use of over 500 indigenous food plant species and a plethora of fauna, exotics, tools, ceramics, textiles, and aquatic foods (Fedick, 2010). In fact, current Maya house gardens and *milpas* typically mimic forest diversity (Lentz et al., 2015).

Maya farmers likely planted non-contiguous plots to prevent the spread of pests, and used diverse small-scale extensive and intensive subsistence technologies that were environmentally unobtrusive; they included low terraces and dams, short and shallow canals and localized "raised fields that were used to grow the staples of maize, beans and squash in house gardens, short-fallow infields, long-fallow outfields and combinations of these techniques" (Lucero, 2017, p. 166). Present Maya communities still cultivate and maintain home gardens that are species rich (Thompson et al., 2015).

Even with all of the history that has passed, including the Spanish conquest beginning in the 1520's, Spanish and English colonial rule, forced conversion to Christianity, massive population loss and displacement due to conflict and epidemic diseases and so on, the Maya and their knowledge of the environment prevail (e.g., Nations and Nigh, 1980; Argivo, 1994; Ford and Nigh, 2015) with broad implications for us all. The Maya and the tropical environment co-existed without either over-taxing the other. Low-density urbanism and URI, diverse crops and *milpas* and forest management are key components in tropical areas and play a key role in how we can implement sustainability goals. We propose a holistic approach for a sustainable URI that is inspired by insights from the Classic Maya.

RECONCEPTUALIZING URI AS ECOSYSTEM: A HOLISTIC APPROACH

Human encroachment in the natural world is undeniable, but how we proceed in the near future may mean the difference between hard choices and long-term survival vs. short-term solutions and disaster. **Figure 4** illustrates the worldview of the Anthropocene; while it may not be possible to completely revert to the other side of the spectrum, we must at least break down the hierarchical, anthropocentric view of the world—which would thus impact how we move forward to a sustainable URI.

At the outset, we first want to situate this model regarding the major challenges any urban model faces: (1) exponential population growth and concomitant expanding urban sprawl that endangers food security (Barthel et al., 2019); (2) overuse of resources; and (3) the need to factor in a global changing climate. Classic Maya society provides six relevant insights on how we can move toward sustainable cities with these challenges in mind, summarized here: (1) a CWV that places humans and non-humans on the same plane; (2) the importance of flexible and diverse practices and relations; (3) traditional knowledge; 4) multi-purpose designs like Maya reservoirs and causeways; (5) local resource networks; and (6) the family as the basic unit of society—and action. In brief, the Maya lived as part of the ecosystem, not divorced from it. In the remainder of this paper, we present alternative long-term strategies that are inspired from the Maya and approach the city with an integrated ecosystem lens.

A More Merged Existence

The Earth does not need humans to survive; it will continue to rotate beyond the existence of our species. As long as we are here, however, we need the Earth to support us. Environmental justice scholar David Schlosberg posits that it is necessary to put the non-human world at the forefront of planning, policy and the future more generally, coining the phrases ecological reflexivity and reflexive modernization (Schlosberg, 2007, p. 187–193). Reflexive modernization entails "citizen-directed policy informed by broad inclusion, ecological reflection, and social learning…in both the political and public spheres" (Schlosberg, 2007, p. 187), while ecological reflexivity demands paying close attention to nature's perspective (p. 189). Classic Maya society embodied these concepts, working with the environment, enculturating youth to respect the landscape, and abandoning cities and emigrating out of the interior when necessary for survival.

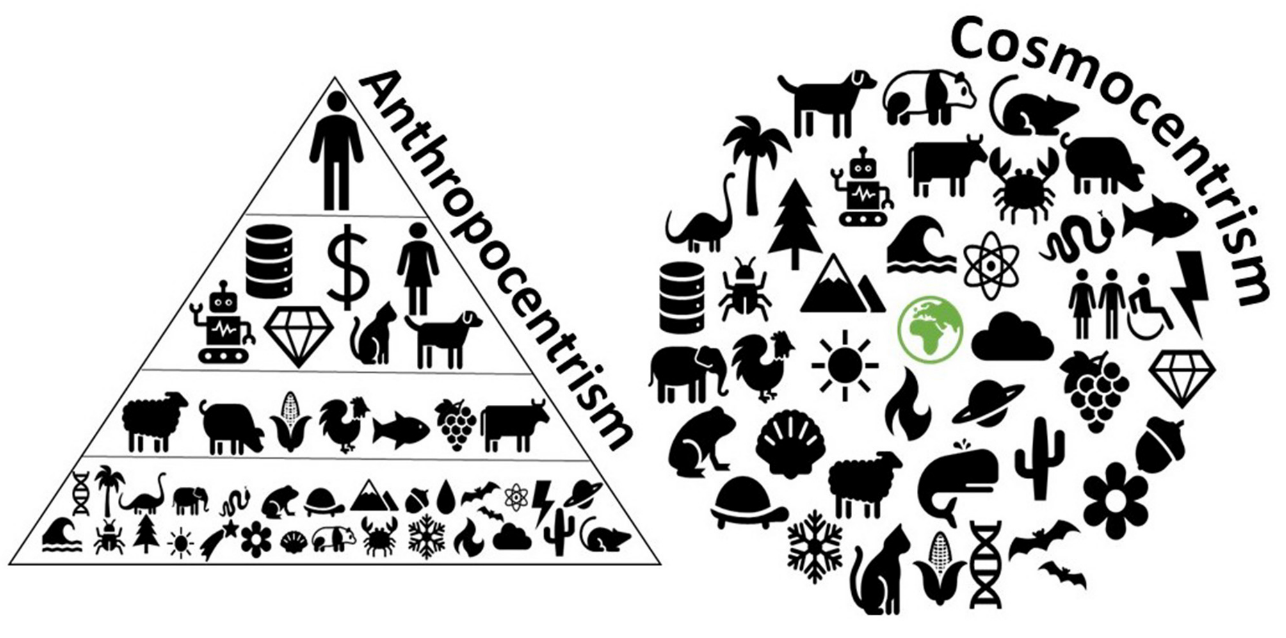

FIGURE 4 | Ego vs. Eco: the former resulted in the Anthropocene, the latter in sustainable practices. Generated by J. Gonzalez Cruz and L. J. Lucero.

Unlike the Maya case, migration is less of a long-term solution at present because of territorial and political issues, as well as the repercussions of exponential population growth, overuse of resources, and global climate change. Today, global climate change has been exacerbated by human activities due largely to a surge in greenhouse gases trapping in heat resulting from our reliance on fossil fuels and meat as a major source of food (methane gases from livestock) (Intergovernmental Panel on Climate Change (IPCC), 2019). The resulting fluctuations in precipitation patterns leading to droughts or floods, changes in animal habitats, colder winters and hotter summers have been quite noticeable, and are clear signs of environmental change. Cities, however, can develop infrastructure to educate and mobilize the public in environmental vigilance across urban and rural spaces, introducing a culture of ecological reflexivity. Residents who acknowledge the vital importance of nature may feel more inclined to advocate for nature and their non-human neighbors.

The growth in the number of environmental advocates suggests that ecological reflexivity will make its way into production and consumption habits, including urban design and services (Portney and Berry, 2016). For example, the incorporation of biomimicry (e.g., constructed wetland biosphere) into planning and construction for wildlife and human habitation can increase human and non-human contact and shrink habitat fragmentation, and in so doing, boost wildlife biodiversity and health. Similarly, encouragement of vertical construction with innovative materials (e.g., various kinds of wood from sustainably grown trees) can limit urban sprawl into rural communities and help combat contributors to global climate change, such as the asphalt albedo effect (Cornwall, 2016). Planning for interspecies urbanism increases green spaces within cities and in rural areas, thereby boosting land availability for rewilding efforts or the designation of sacred/natural spaces outside of institutional structures such as National Forest Preserves (Johnson and Munshi-South, 2017; Bastin et al., 2019). As with the merged existence of the Maya, when the focus is on the interspecies collective rather than individuals, efforts become proactive and sustainable rather than reactive and short-term.

Flexible and Diverse Strategies

Maya URI was expressed in a mosaic of urban areas and dispersed rural settlement, intermingled with managed forested landscapes resulting in a sustainable, green urban-rural ecosystem. Today, green practices involve converting to renewable energy, banning straws, going paperless, ride-sharing, etc. All of these practices are great movements, but are rigid in nature—this is green, that is not. For a successful URI, flexibility and diversity are key. A prime example of a rigid and inflexible strategy is the Green Revolution, where large-scale extensive mono-cropping and use of chemical fertilizers and pesticides reign supreme. "The success of the Green Revolution cast doubt on the idea of human "carrying capacity" (i.e., the maximal population of a species that an environment can support without being degraded)... It encouraged the belief to prevail that human numbers are not constrained by environmental parameters but can defy limits through technological and agronomic innovations" (Crist et al., 2017, p. 261). The Green Revolution, however, does not always succeed. For instance, in the 1970's when the government of Bali implemented modern agricultural strategies as part of the Green Revolution, it turned out to be a dismal failure; the government then proceeded to ask anthropologists and religious leaders how to revert back to sustainable, traditional, and diverse agricultural strategies that were scheduled via temple districts and ritual calendars (Lansing, 1991). Unfortunately, and despite these lessons, mono-cropping has become widespread. As cities attract more and more people, the question then becomes: Can rural areas and populations fulfill urban demands for sustenance? Possibly, if flexible and diverse strategies are implemented.

The IPCC summary report recently released (Aug., 2019) included a global call to consume less meat because of the land requirements (grazing resulting in massive deforestation) and atmospheric repercussions (methane contributing to CO_2 emissions) of meat production. To feed more people, scientists and farmers throughout the world are experimenting with novel techniques, even more critical given that urban sprawl contributes to soil loss and degradation (Barthel et al., 2019). For instance, sustainable intensification (SI) focuses on redesigning current land use via both ecological (e.g., diversification, non-chemical pest management) and technological means, without cultivating more land and further damaging the environment (Pretty, 2018; but see Crist et al., 2017). SI methods were assessed in 286 projects in 57 countries (study 1) and 40 projects in 20 African countries (study 2). "In both, several million farmers on tens of megahectares had adopted practices that had led to yield increases of 79% (study 1) and 113% (study 2)" (Pretty, 2018, p. 2) over a period of 3–10 years. In these instances, farmers voluntarily adopted strategies; top-down laws will not work on their own without people agreeing in principal that changes need to be made. Further, while the bottom line can be used to convince farmers to change their ways to a more sustainable existence, we still need to promote the key role non-humans play in maintaining our world.

There are also strategies that lessen technology-intensive agriculture and highlight traditional knowledge and diverse management strategies to promote sustainable food production and increase yields (e.g., agroforestry, forest management, silvopasture, diversified farming). One such means is through "working lands conservation" (Kremen and Merenlender, 2018); for instance, "[c]orn and soy grown in more complex rotations exhibited greater yields and more stability during hot and dry periods in the USA…and water infiltration that reduced drought effects was markedly improved in complex organic rotations compared to conventional monocultures" (Kremen and Merenlender, 2018, Table S2). SI and working lands conservation also benefit the environment (e.g., maintain biodiversity, pollinators, wildlife corridors, etc.). Incorporating traditional knowledge can help determine which practices are most suitable for any given region.

Flexible and diverse strategies are also necessary to overcome difficult, entrenched or stigmatized ideas, including, for example, the repurposing of organic waste in urban and rural areas, which not only serves to remove unhealthy materials, but also serves to give back—as fertilizer. "Food production hinges largely upon access to phosphorus (P) fertilizer. Most fertilizer P used in the global agricultural system comes from mining of non-renewable phosphate rock deposits located within few countries. However, P contained in livestock manure or urban wastes represents a recyclable source of P" (Powers et al., 2019, p. 1). The economic value of organic waste lies in the recoverable resources that can feed back into the urban metabolism while enhancing local ecosystem services, natural or bio-engineered (Trimmer et al., 2019, p. 1, **Figures 1–4**). "Urban organic waste is returned as fertilizers for food production, environmental impacts are relatively low because of reduced transport requirements, and energy is used more efficiently when fresh produce is consumed in the direct vicinity of the production site…" (Barthel et al., 2019, p. 16). As mentioned, the Classic Maya may have used human waste as fertilizer, based on the lack of latrines in the archaeological record; "it is conceivable that the sheer amount of human and food waste alone, if managed, would have allowed for more intensive agriculture in the city than in the rural zone" (Graham and Isendahl, 2018, p. 170). Such repurposing would limit the production of waste sites (biological and artificial waste) and innovate forms of waste recovery and reuse. Waste management can also take place at the household or community level—for example, using night soil for residential and community gardens. Diverse and flexible strategies are critical for more than just agriculture and sanitation to spread risk and minimize the impact of widespread disasters.

A major issue in the coming years will be adequate supplies of clean water. The Classic Maya engineered constructed wetland biospheres. We can, too. Civil engineers at the University of California at Berkeley, for example, have been developing non-chemical means to clean water (e.g., Jasper et al., 2014; Radjenovic and Sedlak, 2015). Water supply and quality can be managed via cooperative social groups or neighborhoods (e.g., Scarborough and Lucero, 2010). Communities can be responsible for maintaining clean water supplies and gray water use for house and community gardens, for sewage purposes, and other uses. Another option is to repurpose swimming pools, transforming them into wetland biospheres; in the U.S. alone, there are hundreds of thousands of public swimming pools and over 10 million residential swimming pools[1]. Not only would they provide clean water, but also food (fish, edible shellfish, etc.), as they did for the Classic Maya. In fact, Coggins et al. (2019) recommend the expanded use of such ponds to address current and future water and wastewater treatment needs. Multi-scalar and flexible management at multiple and diverse sites minimize environmental shocks while tending to urban and rural human and non-human needs.

Traditional Knowledge

As demonstrated in our discussion of flexible and diverse strategies illustrated with the Classic Maya, traditional knowledge is fundamental to a healthy URI. Thus, it is no surprise that the Classic Maya utilized their intimate knowledge of the tropical environment to emulate the wetland biosphere for their centralized reservoirs that provided clean drinking water, as well as reeds, fish, fertilizer, and edible snails (see Lucero et al., 2011). In discussing Maya history, it is evident how vital it is to include the wisdom of elders and other knowledgeable people (e.g., multi-generation farmers, indigenous groups, etc.) in sustainable urban design, and give them their due credit. Traditional knowledge is grounded in intergenerational experience and community. Today, Maya sons continue to learn from their fathers how to cull what they need from the jungle, as well as farm their *milpas*, and maintain gardens. Maya girls learn from their mothers how to cook, weave cotton, maintain the house, and take care of children. Imbued in all of these teachings is the CWV and traditional knowledge, passed down generation after generation for thousands of years.

While the sharing of traditional knowledge is at the discretion of each group, education in schools can foster sustainable behaviors that reflect a non-anthropocentric respect for the environment by re-introducing pre-industrial or traditional practices such as woodworking (using repurposed or extra wood), textiles (knitting, quilting, crocheting, sewing by hand, etc.), gardening, and others (e.g., Knudtson and Suzuki, 2006; Kimmerer, 2013, p. 385). Tangible practices such as gardening connect children with seeds, dirt and water, thus contextualizing the human and non-human efforts, raw materials, variables, and knowledge necessary for food production. Research suggests that involving children in urban improvement can be co-generative for both scholars and students (Horelli, 1997). Thus, education about traditional knowledge can help promote sustainable urbanism and environmental values. Community cohesion and reform, created by a shared knowledge base, is a relatively inexpensive means to promote a resilient URI. Similarly, traditional knowledge can inspire multi-purpose designs and engender ideas that promote intersections of the URI with other sectors such as the economy, which fall outside of the scope of this paper.

Multi-Purpose Design

We consider multi-purpose design as the antithesis to recycling. In fact, critics of recycling argue that it is not as sustainable as the public perceives (Lave et al., 1999; Hopewell et al., 2009). For example, "most of the recyclables that we so carefully triage are actually relatively inert (like glass and paper) and that the melting down of plastics into new shapes consumes a considerable amount of water" (Smith, 2019, p. 180). Because recycling requires an intermediary for reuse, resources such as water, capital and energy necessary for transportation and treatment, it lowers the sustainable effect of recycling substantially. As such, recycling should not be the apex of sustainable action; reuse and repurposing should.

The first notable and perhaps most obvious principle of multi-purpose design is that an object should have more than one use. As mentioned, Classic Maya causeways often also served as dams and flood walkways. Whether for people, trade or information, today's roads primarily serve as a means of transportation; most roads are not sustainable because they serve a single-purpose and require continual maintenance (e.g., asphalt and annual potholes). This single-purpose use stands

[1] https://www.apsp.org/Portals/0/2016%20Website%20Changes/2015%20Industry%20Stats/2015%20Industry%20Stats.pdf.

in stark contrast to ancient Roman roads, some of which are still used −2,000 years later (Dalgaard et al., 2018). Since cities rely on rural areas and people, roads will always be a part of URI. However, as climate change continues to disrupt weather patterns, water levels will rise and increased flood risks will render roads in coastal cities useless. Multi-purpose roads that double as flood barriers would ameliorate the dangers of entrenched roads; further, raised roads would provide shade underneath, as well as areas for walkways, bike paths, and small commercial enterprises.

The Maya were experts in reuse and repurposing, the second element of multi-purpose design. They utilized broken objects and transformed them, such as a broken chert biface being reworked from a hoe into a hammerstone. Hence, if an object's initial shelf-life has expired, the object should be designed such that it can be repurposed and begin its next shelf-life, cyclically until the object is null. What cannot be reused needs to be compostable. Multi-purpose design ensures that manufactured objects do not unnecessarily infringe on non-human lives and health, while also maintaining urban-rural connections that foster a sustainable resource network.

Resource Network

In line with multi-purpose design is the resource network, one that emphasizes local resources. The Maya participated in long-distance exchange primarily for exotic goods rather than staple foods; for these, as mentioned, they relied on local networks. Their reliance on local networks was based on a strong labor force and specialized occupations rather than on technology *per se*. The resource networks we rely on today are technologically sophisticated, vast and expedient—so much so that in this globally-interconnected world, packages can be shipped from every corner of the Earth to individual recipients within days. For cities to become more sustainable, they need to shrink their resource network and rely less on technology and more on labor, which entails collapsing the network range to focus on local URI. A smaller resource network means that food production and other resources are mobilized within cities and nearby rural areas. As such, the locally sourced food movement can expand beyond boutique restaurants to every household—and include non-food resources as well.

Technological responses alone to address energy and other needs are inadequate since they not only require finite resources to produce and energy to run, but also can put land and water supplies at risk (Intergovernmental Panel on Climate Change (IPCC), 2019; Stokstad, 2019). In the interspecies URI model presented here, labor is a form of green energy that is renewable, transportable, and currently available. We can decrease our reliance on automation and increase our reliance on a specialized labor force in the greening and urban self-sufficiency movement in a similar manner to the Classic Maya. We thus need innovations in both labor and technology (see Scarborough and Burnside, 2010); and unlike technology, we have an endless supply of ethically sourced labor. Relying on labor-intensive projects also ties in our need for more local resource networks. To truly construct a sustainable URI and address long-term issues, as we have attempted to show via the Classic Maya, we need a tool box that includes a revised worldview, traditional knowledge and bottom-up changes, each that begins at the family level.

Scale for Action

Healthier populations mean longer lifespans, and hence larger numbers of living people at any given time and place. With growing numbers of people living in cities, discussions of family planning in the before-life and afterlife become increasingly urgent. The before-life consists of all stages prior to birth and includes preventative contraceptives and minimally intrusive procedures upon informed consent. While innovative ideas exist to increase food supply, for some, this is not enough; we also need to focus on voluntary family planning, especially through increasing global access to education about family planning, particularly in the Global South (Crist et al., 2017).

The afterlife deserves similar attention. There are no cemeteries in the Maya archaeological record. The Maya interred some family members in house floors. Chase and Chase (2011) suggest a figure of c. 10%, based on their analysis of nearly 300 burials from elite houses in the Maya city of Caracol, Belize. Using the hieroglyphic record and radiocarbon dates, they further posit that a key factor in determining interment was not who, but when; specifically, whoever happened to die closest to either two *katuns* (c. 40 years) or the 52-year calendar round (when the ritual and solar calendars conjoined). The question is, what did the Maya do with the c. 90% not buried in house floors? Perhaps, since souls themselves are recycled, the corporeal remains were used as fertilizer, or returned to the ancestors in the forest. Either way, such practices would have been part of world maintenance. Lineage forests can contribute to this world maintenance by minimizing the space afforded to the non-living, establishing new modes of remembrance.

We need to encourage as part of future city planning natural cemeteries. In his book on the funeral industry, Harris (2007) begins in the preface by asking, what happened to "dust to dust"? This is an apt question that requires consideration. Natural cemeteries have no monuments, markers, plots *per se*, embalming, vaults, and metal caskets or fittings. Only biodegradable caskets are used, even though caskets are not required by law (Harris, 2007, p. 1–2, 155–163). The use of burial pods is another natural option (Rashmi et al., 2015). Other options to bury loved ones, though not as green as natural burials, include, in increasingly greener ways, cremation, burials at sea, memorial reefs, home funerals (where the body is prepared at home), use of locally made plain wood caskets, and backyard burials (in rural areas). By implementing natural burial practices, the interruption of the [food]chain of life through use of embalming chemicals ceases (not to mention loss of land for cemeteries). This movement is growing; for example, the company Ecocoffins makes caskets out of bamboo and banana leaf[2]. Natural cemeteries and burials are examples of some of the hard choices we will have to make in the near future if cities are to survive.

[2]http://www.ecocoffin.com/.

How We Move Forward

Ultimately, the basic unit of society, action, and change is the family. It was at the family level that the Maya responded to the several ninth century prolonged droughts; top-down strategies ultimately failed—that is, Maya kingship. Maya families persevered and still do. Similarly, policies such as the United States National Environmental Policy Act, though well-intended, ultimately fail to achieve widespread change because they attempt to impose value through a top-down approach (Caldwell, 1998, p. 21). A bottom-up approach understands that households are the foundation of society (White, 1959, p. 96, 247); together they constitute neighborhoods and communities. And it is at this level where cooperation can turn into collective action, that is, grassroots organization. After all, "It is ordinary people…who make cities what they are" (Smith, 2019, p. 4, 116–117).

We take a page from former President Barack Obama's first presidential campaign to suggest one idea of how we can move forward: "By taking to heart the mantra of the field campaign, "respect, empower, include," a small group of paid and unpaid organizers went out into the streets and the suburbs and started a movement powerful enough to overcome…attack ads, robocalls, and smear tactics" (Kennedy-Shaffer, 2009, p. 61). This was a grassroots effort that blossomed into the first elected African-American U.S. President. Social media makes this task even easier—neighborhood Facebook and Instagram pages are excellent places to start, even with concomitant challenges (e.g., fake news). In the Obama campaign, a key factor was recruiting young people (Kennedy-Shaffer, 2009, p. 88); this particularly resonates given that it is our youth that will have to deal with the repercussions of the Anthropocene—exponential population growth, overuse of resources, and global climate change. Another lesson is that people need specifics; "Obama fell short in some states where voters cared deeply about the specific challenges facing them and cared little for the generic rhetoric of hope" (p. 118). At the end of Kennedy-Shafer's book on the Obama campaign, he poses this question—and answer: "What turned the tide? A generation of believers, committed to creating a new kind of politics in America, started walking [door to door]" (p. 149).

The holistic model we have presented does not try to take us back into the past through some romantic notion; this is not possible. What is possible is to rethink how we perceive and engage the world in which we live. This call to arms is not a political one; it is a cosmological one that involves the entire planet, city and rural, and human and non-human alike—as the Classic Maya case demonstrates.

CONCLUDING REMARKS

In 2015, 193 Member States adopted the United Nations 17 Sustainable Development Goals (United Nations, 2015). Goal 11 is of particular significance—to make cities and human settlements inclusive, safe, resilient and sustainable—as is Target 11.4 to strengthen efforts to protect and safeguard the world's cultural and natural heritage. To attain this goal, we need to address increasingly extreme weather events, such as what happened relatively recently in Houston, Texas and Puerto Rico. Cities rarely collapse; they are resilient (Smith, 2019, p. 253–255); rural areas even more so. That said, can Houston take another major hurricane? Can New Orleans withstand another massive flooding event? We can ask the same questions for most cities, whose foundation of existence is changing due to climate change.

The model presented here has applications beyond tropical societies—especially since URI exists wherever cities do. As we have demonstrated from Classic Maya insights, URI must be the focal point for sustainability efforts. Cities do not stand alone; they are dependent on goods and produce from the rural area and populace. In turn, rural areas and people rely on cities for infrastructure, goods (e.g., machinery from factories), and cultural and political services. Focusing only on cities ignores the interrelations with rural communities and non-human entities, decreasing the overall impact of sustainability efforts.

We also need to keep in mind the omnipresent unintended consequences, especially with regard to technology and our assumption—or even belief—that it will save the day as it has done several times in the past. A hypothetical example of the impact of climate change and technology comes in the form of another Dust Bowl and its impact on solar panels—dust clouds and blocked sunlight means less or no solar power. The resources and energy required to build and maintain solar panels are other issues entirely, not to mention the space they require.

In cities, leaders come and go, with relatively little impact on their inhabitants (Smith, 2019, p. 239). Top-down mitigation in and of itself will not work without the support and action of the majority. Merging top-down and bottom-up approaches are the only alternative. And it begins at the foundation of any society—the family or household; it is and will be the basis for activism and action, including making some hard, life-altering decisions (e.g., using our own organic waste as fertilizer, natural cemeteries, etc.).

The Classic Maya and other non-anthropocentric societies can teach us much, if we are willing to learn. In so doing, we will be able to reconceptualize sustainable urban planning in the future in a more holistic manner that considers non-human survival as well. Instead of "live and learn," we need to learn and live.

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LL and JG contributed to the research design and holistic approach. LL wrote most of the Classic Maya material.

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