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Forum

Humanity for Habitat: Residential Yards as an Opportunity for Biodiversity Conservation

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Abstract

The primary threat to biodiversity is habitat loss and degradation. Private residential land (yards) encompass large proportions of urban, suburban, and rural spaces and is among the most rapidly expanding systems on Earth. Yards also represent a conservation opportunity to provide wildlife habitat, support biodiversity, restore ecosystem function and ecosystem services, and increase local opportunities for people to connect with nature. In the present article, we propose a humanity for habitat stewardship practice by synthesizing the evidence-based yard management actions that can advance the conservation value of yards, with a focus on benefits to biodiversity, climate resiliency, and people. The magnitude and extent of yard management might differ, depending on the region, specific management practices, the yard's size, and the yard's location along the urban to rural gradient. We detail opportunities, challenges, and strategies for encouraging stronger public participation in conservation through yard stewardship to facilitate biodiversity-friendly residential landscapes that benefit wildlife and people.

Keywords: gardens, climate resiliency, ecosystem services, ecological belonging, wildlife

An increasingly residential world

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment estimates that approximately 500,000 terrestrial species are on the brink of extinction. Habitat loss and degradation are the primary drivers of this unprecedented biodiversity decline, followed by overexploitation, climate change, pollution, and invasive species (IPBES 2019, Jaureguiberry et al. 2022). Furthermore, habitat degradation rates continue to accelerate with human population growth (Dirzo et al. 2014). Feedback loops likely exist among these drivers, compounding the magnitude of their overall negative impact on species persistence. Reversing this biodiversity crisis is one of humanity's most significant challenges, and has tremendous implications for the more than 8 billion humans who rely on and benefit from biodiversity, because biodiversity supports ecosystem function, ecosystem services, and climate resiliency (Cardinale et al. 2012). Biodiversity loss could also have the unexpected consequence of magnifying the detachment people have with the natural world, potentially reducing the likelihood of engaging in conservation (Soga and Gaston 2016). The hopeful news is that opportunities for household action where people live can have valuable and positive impacts on biodiversity. We propose a "humanity for habitat" environmental stewardship practice for private residential yard management and detail the evidence-based yard management activities that can stimulate the transformative action necessary to minimize biodiversity loss in the Anthropocene (Díaz et al. 2020). By encouraging and incentivizing more vigorous participation in conservation actions where people live, residential yard management can provide mutual benefits for wildlife and people.

Collectively, yards (also called *domestic gardens*, *home gardens*, *homesteads*) contribute to a large proportion of green spaces in urban, suburban, and rural lands (Goddard et al. 2017). For example, in the United Kingdom and other European countries that exhibit compact development patterns, yards constitute roughly 25% of the total urban land cover and as much as 50% of green spaces (Goddard et al. 2017). Although 87% of UK households have yards, scaling the extent of yards up to the country level, yards cover about 2% of the United Kingdom, whereas protected areas cover 19% (Davies et al. 2009). In the conterminous United States, single-unit detached housing and its associated private land use cover 30% of the country (figure 1; CIESIN 2017, McDonald et al. 2020), four times greater than the 7% classified as protected (e.g., national forests and national parks; Jenkins et al. 2015). Although urban and suburban areas house the majority of individual residential properties in the United States (85%), the residential development footprint in rural lands is almost three times greater and consists of 72% of land area classified as housing (box 1; CIESIN 2017). These differences in the percentage of land classified as yards between the United States and the United Kingdom likely reflect yard size, with mean size of 0.02 hectares (ha) in the United Kingdom and 0.48 ha in the United States for urban and suburban areas and a mean of 3.2 ha including urban, suburban, and rural (box 1; Davies et al. 2009). Regardless of the spatial extent of rural yards, most of the world's population lives in urban and suburban areas. But many conservation efforts focus on protected lands, parks, and other nonresidential greenspaces, limiting

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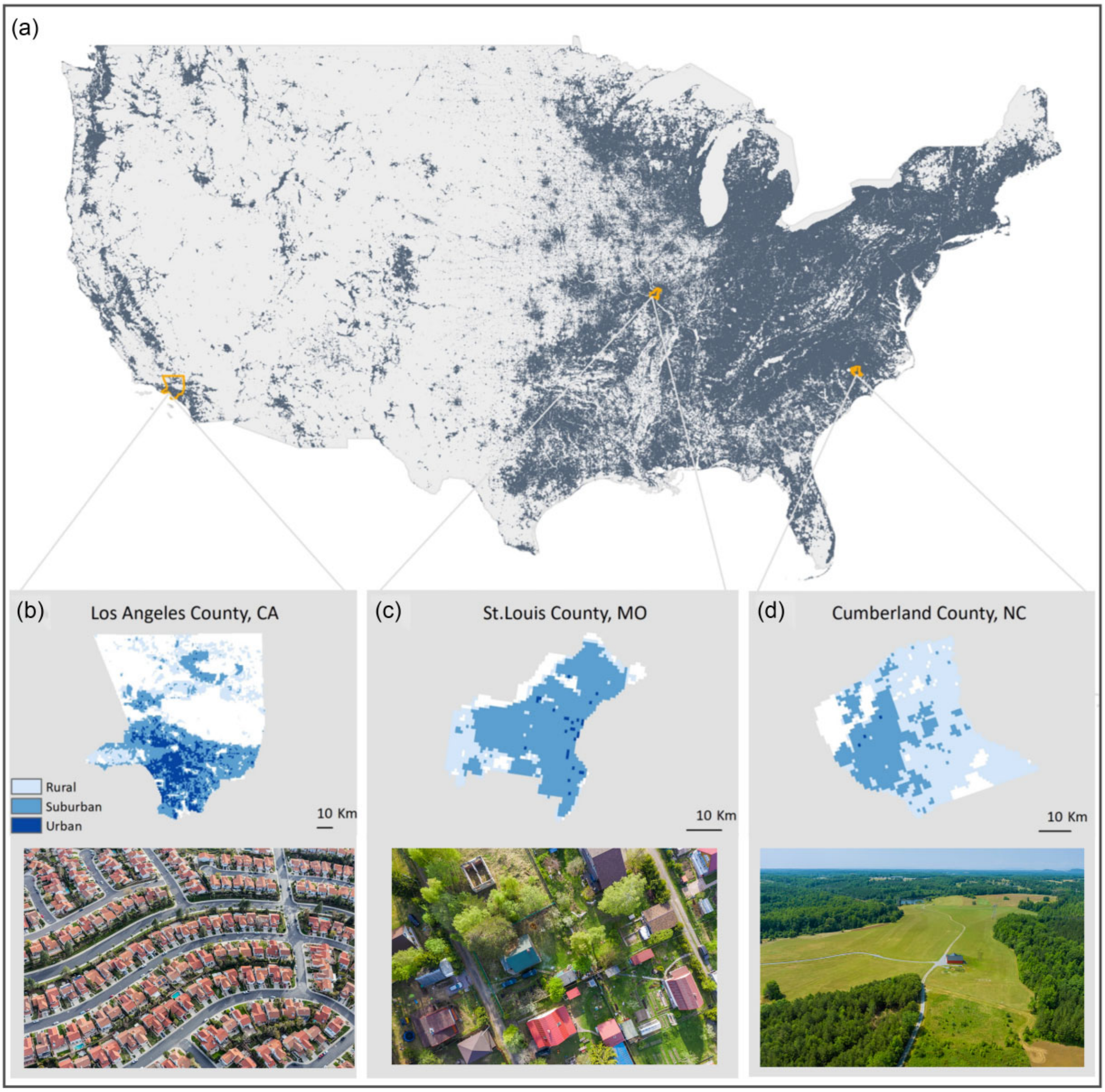

Figure 1. Residential lands are a significant proportion (estimated at 30%) of the conterminous US landscape. (a) The high-resolution map (1 square kilometer resolution) shows detached housing density and the extent of residential yards based on the 2010 US Census for the conterminous United States (CIESIN 2017). To demonstrate how this might vary along the urban to rural gradient, we present county-level housing density for urban Los Angeles County, California (b); suburban St. Louis County, Missouri (c); and rural Cumberland County, North Carolina (d), and associated neighborhood photos from each region to show how urban, suburban, and rural landscapes differ at the county and neighborhood scale. Photographs: Each photo was obtained from Adobe Stock Images and used with permission.

opportunities for the vast majority of residents to advance biodiversity conservation (McKinney 2002, Prévot et al. 2018, Elmqvist et al. 2019, Oke et al. 2021).

Although residential development represents a key driver of habitat loss and ecosystem degradation (Grimm et al. 2008) and likely contributed significantly to steep declines of North American birds (Rosenberg et al. 2019), insects, and other taxa (Dirzo et al. 2014), yards also support regional biodiversity (Aronson et al. 2014). Furthermore, features within yards and across neighborhoods interact and can provide critical habitat for imperiled species (Akinnifesi et al. 2010, Soanes and Lentini 2019). For example, species of conservation concern and endangered species, such as song thrush (*Turdus philomelos*) in the United Kingdom (Mason 2000) and the western ringtail possum (*Pseudocheirus occidentalis*) in Australia (Van Helden et al. 2020) have strongholds in yards, particularly when yards include the required vegetation composition and structure for these species. In the United States, householders played a critical role in the rebounding of the presumed extinct *Eumaeus atala* butterfly by increasing ornamental Zamia plantings that became popular in horticulture (Ramírez-Restrepo et al. 2017). Yards can harbor opportunities for scientific surprises, such as the discovery of 30 new species of *Megaselia* flies collected in Los Angeles, in the United States (Hartop et al. 2015). Furthermore, yards contribute to keeping common wildlife common, a particular concern for birds, whereby common species have declined at more rapid rates and, in some cases, more than rare species (Rosenberg et al. 2019). Yards cannot replace protected lands, nor do they support the same biodiversity assemblages (Padullés Cubino et al. 2020, Lerman et al. 2021). However, yards do contribute to conservation, with unique opportunities depending

Box 1. Estimating the extent of yards in the United States along an urban to rural gradient.

To further demonstrate how urban, suburban, and rural residential development within the conterminous United States varies spatially, we conducted an initial assessment of the extent of detached housing within each land use category. To get at these values, we used data from CIESIN (2017) and collated information on housing density per km^2. Using the raster file, we identified pixels with at least one housing unit present (each pixel is roughly 1 km^2) and classified each pixel as urban when more than 855 housing units per pixel, suburban when 28–854 housing units per pixel, and rural when 1–27 housing units per pixel. Using this method, we calculated a total of 14,390 pixels classified as urban, 549,310 pixels classified as suburban, and 4,367,254 pixels classified as rural. We then calculated the total number of yards by taking the sum of each pixel category, multiplying by the number of housing units (i.e., yards) per pixel, and adding together. For example, with 738,297 pixels with two houses per pixel, we estimated a total of 2*738,297 or 1,476,594 yards. We added this number to all the other categories for 1–27 houses per pixel to derive the total number of rural yards. We used the same process to calculate total number of suburban and urban yards. We estimated a total of 130,541,292 yards across the United States. We then used McDonald's yard size estimates (McDonald et al. 2019) to calculate total yard area in the United States for each land use category based on total number of yards as described above. With these data, we calculated the percentage of individual yards for each land use category, and the percentage of land area (km^2) as yard for each land use category.

The location of yards along the urban to rural gradient, yard size and landscape context all contribute to the type and amount of wildlife habitat potential. Given our estimates, collectively, yards occupy a much larger area than typically recognized (approximately 30% of the conterminous United States), revealing a more expansive potential to advance biodiversity conservation, climate resiliency, and human well-being. See table 1.

Table 1. Estimates of yard area in the conterminous United States. Although the majority of individual yards are located in urban and suburban land uses (85%), yards located in rural land use cover a much greater spatial footprint.

Land use category	Housing density (per km^2)	Total number of yards	Yard size (ha)	Total yard area (km^2)	Total number of yards (%)	Total yard area (%)
Urban	855+	21,311,342	0.33	70,327	16.33	3.03
Suburban	28–854	89,742,283	0.64	576,010	68.75	24.76
Rural	1–27	19,487,667	8.62	1,679,973	14.93	72.20

on their size, their location along the urban gradient, and their management.

In this Forum, we synthesize the emerging evidence that yards play a key role in biodiversity conservation (Zhou et al. 2021) with emphasis on quantitative studies that document how biodiversity relates to specific management practices. We also highlight how biodiversity conservation in residential settings can provide synergistic benefits to climate resiliency and human well-being. Inspired by Aldo Leopold's land ethic, which centers stewardship as humanity's responsibility in caring for the land (Leopold 1949), we advance a pragmatic approach to enhancing biodiversity in residential contexts by detailing the land management practices that have conserved biodiversity. Although we focus on ecological knowledge, we also underscore the importance of social–ecological approaches that consider household- to landscape-level opportunities and challenges to overcome. In doing so, our intent is not an exhaustive literature review. Rather, our aim is to inspire yard stewardship to enhance private parcels as habitat (Segar et al. 2022), to alleviate some of the negative pressures facing biodiversity, and to inform land management to benefit both wildlife and people.

Yards as habitat for biodiversity

At its core, a functioning habitat provides refuge and breeding areas for plants, animals, and other organisms, ultimately contributing to biological, functional, and genetic diversity (Dirzo et al. 2014). However, the ability for yards to support biodiversity, both individually and collectively, relies heavily on management practices (Goddard et al. 2010, Aronson et al. 2017), which are influenced at several spatial scales. Vegetation management is the primary way residents manipulate habitat availability and quality within their yard (Faeth et al. 2011). These management decisions drive community assembly and coexistence of the yard's biodiversity (Avolio et al. 2021). Vegetation management includes planting and maintaining trees, shrubs, succulents, and other woody and herbaceous plants and managing different yard zones such as meadows or lawn. Although lawns lack structural diversity, they cover a majority of a residential parcel, and low-management lawns have been shown to support high levels of plant diversity (Thompson et al. 2004, Lerman and Milam 2016, Wheeler et al. 2017). In the present article, we highlight and synthesize research that explicitly quantifies and or directly relates yard management practices, both active and passive to wildlife responses and biodiversity.

Because plants form the foundation for vast consumer food webs, yards that include a higher proportion and abundance of native plants support richer and more abundant native wildlife communities (Burghardt et al. 2009, Lerman and Warren 2011, Coetzee et al. 2018, Berthon et al. 2021). For animals with highly specialized biological and physical requirements, such as herbivorous insects and insectivorous birds, even small landscaping changes can have persistent positive population-level impacts. For example, Carolina chickadees (*Poecile carolinensis*) in the Washington, DC, metro region spent more time foraging in native plants within yards because native species support a higher abundance

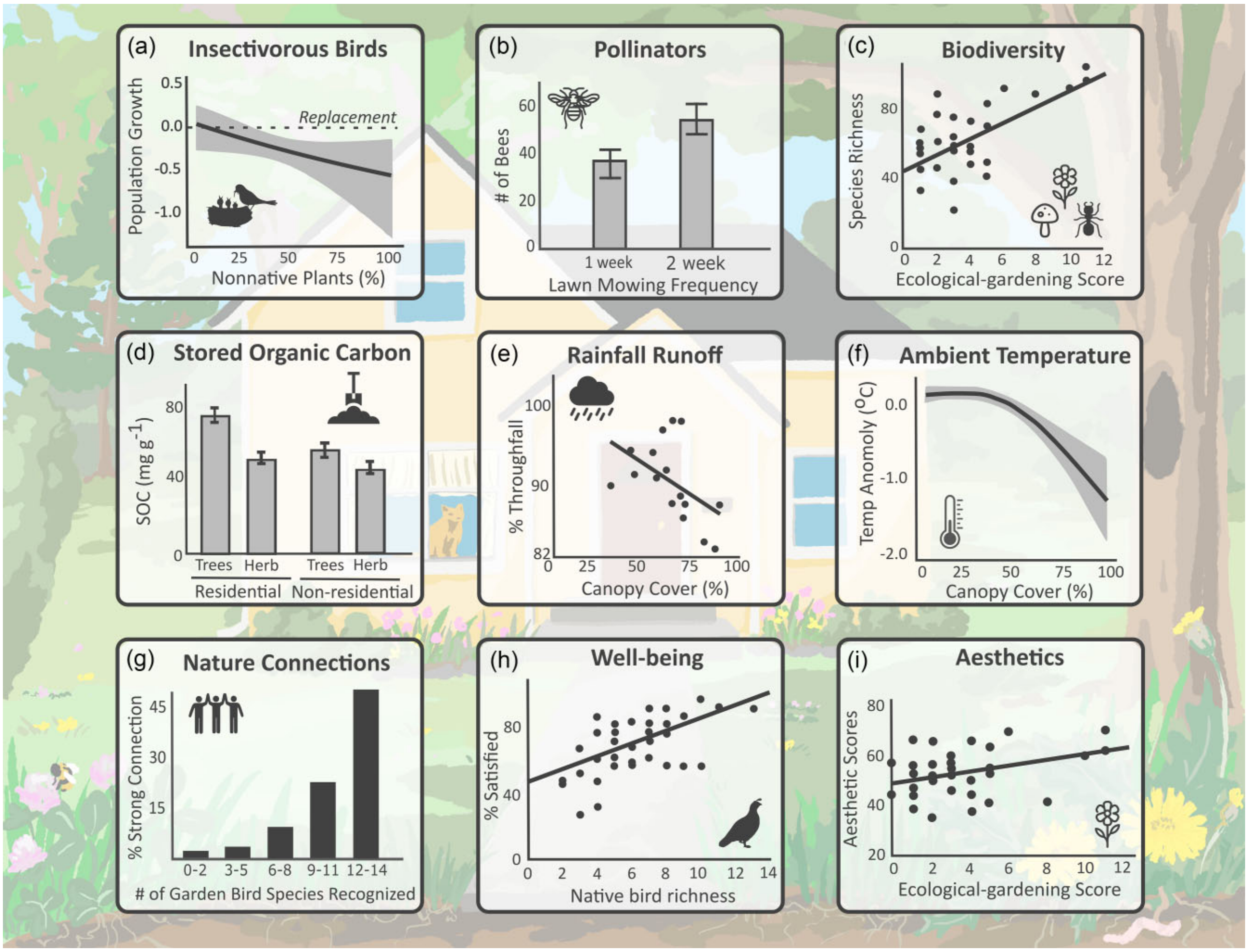

Figure 2. Quantifying achievements in yards to better inform management. These nine examples highlight studies that explicitly quantify relationships between a humanity for habitat yard stewardship practice and the profound ecological benefits for biodiversity, climate resiliency, and human well-being. Examples include (a) ensuring 70% of horticultural plants are native, which, in turn, provides sufficient densities of lepidopterans to support positive population growth for songbirds (Narango et al. 2018); (b) mowing lawns every 2 weeks rather than weekly to support more native bees because of the increased abundance of floral resources (Lerman et al. 2018); (c) increasing the number of ecologically friendly management practices and features to support higher species richness (Lindemann-Matthies and Marty 2013); (d) the importance of trees, compared with turf and other herbaceous ground cover, for storing carbon (Edmondson et al. 2014); (e) increasing canopy cover infiltrates more rainfall (Inkiläinen et al. 2013), and (f) increasing it to at least 40% cover reduces daytime air temperature 1 degree (Ziter et al. 2019); (g) increased species richness positively relates to a stronger connection with nature (Cox and Gaston 2015); (h) having habitat for native birds, which, in turn, relates to higher levels of satisfaction with neighborhood birds (Lerman and Warren 2011); and (i) increasing the number of ecologically friendly management practices and features positively correlates to a more aesthetically pleasing yard (Lindemann-Matthies and Marty 2013). Source: The figures were recreated from results derived from original publications. See the citations for additional details on individual study methods and context. Original artwork by Elsa Cousins.

and biomass of arthropods, a critical food resource during the breeding season (Narango et al. 2017, 2018). Furthermore, these landscaping choices had population-level implications in that chickadees nesting in yards dominated by native plants—in this case, at least 70% of the plant biomass—had higher reproductive success and were more likely to maintain sustainable populations (figure 2; Narango et al. 2018). These and other studies demonstrate the importance of native plants for supporting biodiversity in yards. However, in some cases, nonnative plants and increasing structural complexity within the yard can also provide habitat and support wildlife communities (Lerman et al. 2018, Baldock et al. 2019).

Increasing structural and compositional diversity, such as planting different sized trees and shrubs or planting flower gardens can benefit invertebrate communities. For example, across four UK cities, 54%–83% of all pollinating insects sampled within nine different types of urban land use were found in yards because of their high floral richness that included a mix of native and nonnative plants (Baldock et al. 2019). An individual parcel might include a vegetable plot, perennial flower and berry gardens, and lawn. These different zones and their associated plants can increase total plant diversity and can, in turn, support other trophic levels (e.g., earthworms and springtails; Tresch et al. 2019). Cultivating popular ornamental plant species and allowing weedy or spontaneous species to persist (which could be nonnative) in some cases may promote bird diversity and support pollinator networks by extending the availability and seasonality of floral resources (Salisbury et al. 2015, Gray and van Heezik 2016, Staab et al. 2020), at least for flower-visiting species (but see Pardee and Philpott 2014, Lowenstein et al. 2019). Reducing yard management activities can also benefit biodiversity. For example, when experimentally manipulating lawn mowing frequency in yards in Springfield, Massachusetts, in the United States, mowing lawns less frequently supported more floral resources such as dandelions and clover and, subsequently, higher bee abundance (figure 2; Lerman et al. 2018). And finally, yards in Bangalore, India, with less intensive weeding practices, higher plant diversity, and more bare soil than lawn had higher insect abundance and richness (Jaganmohan et al. 2013).

Managing yards for wildlife can also include nonvegetative features such as wildlife feeders, artificial houses for birds, bats, and bees, bird baths and ponds, and log and compost piles (Gaston et al. 2005, Goddard et al. 2013), and their inclusion can be extensive. For instance, Davies and colleagues (2009) modeled the extent of wildlife habitat resources in yards throughout the United Kingdom: 48% of UK residents had bird feeders with a ratio for bird feeders to feeder-using birds at one to nine. Yards housed 4.7 million nest boxes equating to roughly one box for every six pairs of cavity nesting birds (Davies et al. 2009). In the United States, residents provide roughly 500,000 tons of supplementary food per year, enough to feed 300 million chickadees (*Poecile* spp; Robb et al. 2008). Although introducing bird feeders might have negative ecological consequences (e.g., altering community structure and increasing disease transmission; Robb et al. 2008, Galbraith et al. 2015), feeding wildlife also provides opportunities for intimate connections between people and nature (Cox and Gaston 2018). Indeed, erecting a bird feeder often produces instant results and might explain the popularity of feeding wild birds (Davies et al. 2009). Applying mulches and keeping compost piles or bare ground can protect soils and provide additional resources, which has cascading effects on the plant, soil fauna communities, and bee nesting opportunities in yards (Osborne et al. 2007, Tresch et al. 2019).

Yards containing a greater number of wildlife supplemental features can support greater bird species richness and diversity, as has been documented in Leeds, in the United Kingdom, and Zurich, Switzerland (figure 2; Goddard et al. 2013, Lindemann-Matthies and Marty 2013). However, individual taxon responses vary, and the time scale for establishing wildlife features as part of the landscape and occupancy might not align with householder expectations (Gaston et al. 2005). For example, when experimentally placing logs in Sheffield yards, in the United Kingdom, researchers documented 15 different taxa, ranging from frogs, woodlice, beetles, and snails. But the rate of decay of the logs within the 2-year study was not suitable for fungi and saproxylic insects (i.e., species dependent on decaying wood). Furthermore, the artificial nest sites attracted solitary bees and wasps, but bumblebees did not respond to the introduced resources (Gaston et al. 2005). Research from Dunedin, New Zealand, further highlighted how aesthetics might interact with greater uptake of wildlife features whereby bee hotels were perceived more attractive than log piles, and residents already engaged in wildlife gardening were more likely to expand habitat features for lizards (van Heezik et al. 2020). These results suggest that somewhat immediate rewards might facilitate a positive feedback loop (while also acknowledging the importance of aesthetics) whereby a steward is motivated to increase the number of habitat features when they witness the fruits of their labor (Nassauer 2011).

Yard management can also impart significant negative impacts by driving the introduction and spread of nonnative and exotic plants and animals, especially invasive ones, which inevitably escape to adjacent natural areas (Reichard and White 2001, Jenerette et al. 2022) and ultimately increase management needs. For example, the United States spends $500 million per year to control exotic weeds in protected areas that have escaped from residential sources, with $45 million spent on eradicating purple loosestrife (*Lythrum salicaria*) that regularly escapes from yards (Pimentel et al. 2005). The proximity of yards to protected areas also influences the impact of nonnative and invasive plants. In Northland, New Zealand, for instance, the variation and density of exotic plants in forests significantly increased with housing density within 250 meters of these forests (Sullivan et al. 2005). In rural landscapes of Wisconsin, in the United States, housing density within a 1-kilometer buffer most significantly correlated with nonnative invasive plants in protected areas (Gavier-Pizarro et al. 2010). Increasing pesticide application to eradicate unwanted plants or "pest" insects has inadvertent effects on nontarget species such as butterflies, bees (Muratet and Fontaine 2015), and birds (Eng et al. 2017). Furthermore, purchasing ornamental plants bought from garden centers can unwittingly introduce pesticides to wildlife such as neonicotinoids (Lentola et al. 2017). Planting exotic species can also create ecological traps for native wildlife. For example, exotic fruiting trees cultivated in Sri Lankan yards attracted Indian flying foxes (*Pteropus giganteus*), which then came into close contact with and often got electrocuted by nearby power lines (Tella et al. 2020). Finally, nonnative and invasive mammals such as domestic cats (*Felis catus*), both owned and free roaming, and rats have a long history of negative impacts on native birds, reptiles, amphibians and mammals, and are one of the leading causes of global species endangerment (Loss and Marra 2017). Although the decision to keep cats indoors is not directly related to vegetation management, doing so has positive implications for the health and survival for wildlife in yards.

When yards include medicinal plants (i.e., medicinal gardens or health clinic gardens), they also contribute to biological diversity (Lubbe et al. 2010, Leakey 2017, Cilliers et al. 2018). Medicinal gardens may play a particularly critical role in the Global South, especially for Indigenous and rural communities, given their historical and cultural significance, as well as potential health benefits (Davoren et al. 2016, Cilliers et al. 2018, Caballero-Serrano et al. 2019). Although sometimes small (i.e., more similar to urban and suburban yards, 0.1–0.6 ha; Barbhuiya et al. 2016), medicinal gardens can serve as reservoirs for plant phylogenetic and taxonomic diversity. For example, research from 90 medicinal gardens in the Eastern Himalayans of Northeast India documented 333 plant species from 128 different families, with an average of 78 species per parcel. Species accumulation curves indicated the likelihood of additional species not documented in the 90 gardens studied (Barbhuiya et al. 2016). These and other studies highlight how yard management can maximize synergistic benefits, including the maintenance of historic and cultural practices, and how Indigenous knowledge, particularly the coproduction of knowledge from different stakeholders (Tengö et al. 2014), can guide yard management (Cilliers et al. 2018, Caballero-Serrano et al. 2019). But the transfer of knowledge about medicinal plants and their specific uses has declined (Caballero-Serrano et al. 2019), potentially reducing the biodiversity potential of these gardens.

Managing yards that include diverse plant communities with structural and resource complexity can support a variety of wildlife species. Many of these species perform critical ecosystem functions, such as dispersing seeds, pollinating plants, scavenging carrion, consuming insect pests, and contributing to nutrient cycling (Şekercioğlu et al. 2004, Luck et al. 2009, Cardinale et al. 2012). The scientific evidence for managing yards with wildlife in mind demonstrates how wildlife responds to and benefits from specific yard features and yard management.

Synergistic benefits of managing yards for biodiversity

Wildlife habitat management practices, in addition to supporting biodiversity, also align with several nature-based strategies. Specifically, these practices have the added benefit of advancing climate resiliency and human well-being (de Groot et al. 2002, Hobbie and Grimm 2020).

Advancing climate resiliency

The pervious parts of yards, including vegetation and soils, play important roles for regulating ecological processes such as carbon storage (Jo and McPherson 1995), nutrient inputs (Livesley et al. 2010), hydrological cycles (Groffman et al. 2017), and microclimates (Ziter et al. 2019). Therefore, yard management practices that include increasing and maintaining plant biomass (e.g., trees and shrubs) and reducing management intensity (e.g., lawn mowing and fertilizer application) support biodiversity and advance climate resiliency by reducing carbon dioxide emissions, mitigating stormwater management, and improving living conditions by reducing extreme temperatures (Lerman and Contosta 2019, Hobbie and Grimm 2020). Although many studies have documented the capacity of yards to store carbon (e.g., Davies et al. 2011, Raciti et al. 2014), and have reviewed how green infrastructure can mitigate stormwater management and climate change (e.g., Berland et al. 2017, Hobbie and Grimm 2020), in the present article, we highlight a few examples that connect yard vegetation features that benefit wildlife with benefits to climate resiliency.

Trees, shrubs, and other woody plants in yards store significant amounts of above ground carbon, with complex relationships between tree species, size and density, land use, and yard size (Jo and McPherson 1995, Golubiewski 2006, Davies et al. 2011, Edmondson et al. 2012). For example, calculating the carbon storage among different zones in the rural yards of southern Michigan, in the United States, Currie and colleagues (2016) demonstrated that the dense vegetation zone (trees and shrubs) stored the most carbon, although the carbon pools were 17% lower than mature forest elsewhere in the region because of their larger tree size compared to yards. However, the open grown trees in lawns had larger trees than the dense woody areas, accounting for relatively high carbon storage. And research from suburban yards in Orlando, Florida, in the United States, documented how native trees sequester nine times as much carbon as invasive and exotic trees and palms do (Horn et al. 2015) while also contributing more to biodiversity conservation.

Belowground, soils in yards can store at least twice as much carbon as trees and other vegetation (Jo and McPherson 1995, Golubiewski 2006, Edmondson et al. 2012), although the vegetation structure and composition aboveground influence the amounts. For example, in Leicester, in the United Kingdom, soil organic carbon stocks under trees and shrubs in yards were significantly higher than that under herbaceous vegetation, all vegetation in urban parks, and almost twice that from agricultural fields (figure 2; Edmondson et al. 2014). Yards, particularly when dominated by lawn, also exhibit higher rates of soil carbon dioxide flux as compared to other green spaces (Groffman et al. 2017). Warmer temperatures from increased solar radiation, moister soils from irrigation, or enhanced nitrogen availability from fertilizer application explain these relationships (Lilly et al. 2015).

Trees can mitigate stormwater management and their role becomes more important with increased frequency and intensity of storms resulting from climate change because their tree canopy cover and root system can efficiently intercept precipitation and remove water from saturated soils via transpiration (Berland et al. 2017, Hobbie and Grimm 2020). Several factors determine the effectiveness of rainfall interception by trees, including regional climate, storm intensity, season, soil permeability, and tree species. In Raleigh, North Carolina, in the United States; for instance, trees in yards in three neighborhoods with a mean canopy cover of 67% reduced throughfall up to 21%, with rainfall interception increasing significantly with canopy cover and coniferous tree cover (figure 2; Inkiläinen et al. 2013). The conversion of vegetated residential land (especially trees) to impervious or artificial surfaces is therefore a concerning trend, with estimates of increased conversion ranging from 11% to 56%, from humid western Europe to relatively arid portions of the United States (Warhurst et al. 2014, Strohbach et al. 2019, Laćan et al. 2020). The popularity of installing artificial lawns also exacerbates runoff and decreases water retention compared with living lawns (Simpson and Francis 2021), while also reducing available habitat for plants and animals.

Increasing tree abundance and canopy cover in yards and the neighborhood can significantly reduce temperatures through evapotranspirational cooling and shading (Hobbie and Grimm 2020). When comparing yards that lack trees, increasing tree cover in Sacramento, California, in the United States, by 10%, or the equivalent of an additional tree, can reduce peak summertime air temperature by 3.4 degrees Celsius (°C), whereas adding 2.5 trees can reduce temperatures by 4.5°C (Huang et al. 1987). Scaling up to the neighborhood, another study in Madison, Wisconsin, in the United States, showed that at least 40% canopy cover within a 90-meter radius of a particular location reduces daytime air temperatures; at 100% canopy cover, daytime temperatures were almost 1.5°C cooler than locations without tree canopies (figure 2; Ziter et al. 2019). These and other studies provide achievable tree planting goals for climate action plans and directly link to forest assessment tools that match habitat suitability with percentage canopy cover (Tirpak et al. 2009, Lerman et al. 2014). As we have described it so far, yard management can support biodiversity and climate resiliency, with additional benefits for the people managing and experiencing these yards as well.

Stewarding yards for human well-being

Research has shown that restoring the ecological functions and integrity in yards benefits people in numerous ways related to human well-being. Regardless of whether humanity notices wildlife and values wildlife habitat in their yards, the extinction of experience posits that as access to nature declines, fewer opportunities exist to observe and interact with vegetation and wildlife, leading to diminished well-being and a loss of curiosity about the natural world, potentially contributing to a disaffection for nature and conservation (Pyle 1978, Miller 2005, Soga and Gaston 2016). Several systematic reviews document the relationship between access to and experience with nature and human well-being including physical and mental health (e.g., Keniger et al. 2013, Houlden et al. 2018), with nature used as an inclusive term and not specific to biodiversity per se (except, see Fuller et al. 2007). In this next section, we highlight a few documented relationships between human interactions with biodiversity through yard management practices, and demonstrate how wildlife gardening, observing wildlife, and citizen science at home contribute both to residents' well-being and to environmental literacy.

The physical aspect of wildlife gardening can reduce stress, anxiety, depression, and obesity and can increase satisfaction and sense of community (Soga et al. 2017, de Bell et al. 2020). For instance, residents who managed certified biodiversity yards in Winnipeg, Canada, reported an increased connection to nature and natural history knowledge, stronger place attachment, and several other well-being measurements including satisfaction and attention restoration (Raymond et al. 2019). Additional benefits include a stronger sense of purpose in providing wildlife habitat and supporting biodiversity, gaining yard management skills, and being part of a community of gardeners (Goddard et al. 2013, Mumaw and Mata 2022). Although the possible angst associated with bucking the trend of a neat and tidy yard might diminish some of the well-being benefits for some people (Raymond et al. 2019), research shows positive relationships between the number of wildlife yard features and aesthetics (figure 2; Lindemann-Matthies and Marty 2013), addressing a key motivator for yard management (Larson et al. 2016).

Observing birds at feeders and in yards presents one of the more common ways residents interact with wildlife. For example, results from a survey in the United Kingdom, showed that interacting with birds in yards and neighborhood parks was correlated with higher well-being (among people with and without depression), with the benefits lasting beyond the initial encounter (Hammoud et al. 2022). Research has demonstrated, however, that responses to different species varies. For example, in southern England, songbirds such as robins (*Erithacus rubecula*), Eurasian blue tits (*Cyanistes caeruleus*), and European goldfinches (*Carduelis carduelis*) had higher likability scores than nonsongbirds (e.g., doves and corvid species), and a positive correlation was documented between residents' knowledge of birds and how connected residents felt when they observed birds (figure 2; Cox and Gaston 2015). Evidence from Phoenix, Arizona, in the United States, further suggests that distinctive aesthetics, such as bird song, size, and coloration influence perceptions with smaller and more colorful species such as hummingbirds (*Trochilidae*) and regionally unique species such as cactus wrens (*Campylorhynchus brunneicapillus*) eliciting positive attitudes, whereas nonnative and cosmopolitan species such as rock pigeons (*Columba livia*) eliciting negative perceptions (Andrade et al. 2022). Additional research from Phoenix showed that residents surveyed expressed higher satisfaction with the bird community in their neighborhood when native bird species richness was higher (figure 2; Lerman and Warren 2011). In this case, higher resident satisfaction correlated significantly with greater biodiversity in specific neighborhoods. These and other studies demonstrate how yard management practices not only influence habitat quality and therefore the species present (i.e., planting native plants for attracting native birds; Lerman and Warren 2011, Belaire et al. 2014, Narango et al. 2017) but also the cascading effects on human–wildlife interactions and well-being.

Although the above examples demonstrate positive relationships between biodiversity and well-being, it is important to note other research has shown that people often do not accurately assess biodiversity (e.g., Dallimer et al. 2012, Marselle et al. 2021), which could indicate a disconnect between actual biodiversity and reported well-being. In other words, research has shown positive correlations between perceived levels of species richness and well-being but not between actual levels of species richness. Although these mismatches complicate our understanding of whether relationships between well-being and species richness exist (Pett et al. 2016), subjective views of nature seem more paramount than knowledge (e.g., the ability to identify species or accurately assess biodiversity relative to diversity metrics) because people likely use different cues to assess biodiversity, such as tree cover or abundance of a particular taxonomic group (e.g., birds; Dallimer et al. 2012, Belaire et al. 2015, Marselle et al. 2021) or have different relationships and interests with the natural world (Larson et al. 2021). Nonetheless, because many people have their primary experiences with wildlife and biodiversity in yards and nearby parks (DeStefano and DeGraaf 2003, Hand et al. 2017), these spaces are ideal for implementing strategies to enhance biodiversity and human well-being through increased experiences with wildlife. Such connections may, in turn, also increase species identification skills and monitoring abilities (McKinney 2002), which can be amplified when participating in yard-based citizen science.

Yard-based citizen science programs can further increase the relevancy of biodiversity to the public through exposure to the various steps within the scientific process, an opportunity for residents to acquire new ecological knowledge, strengthen their sense of place, and increase environmental literacy and empathy for wildlife and biodiversity (Cooper et al. 2007, Dickinson et al. 2012). Internet-based projects such as the Royal Society for the Protection of Birds Big Garden Birdwatch (www.rspb.org.uk/get-involved/activities/birdwatch) task their participants with reporting the birds observed in their yards, provide tips on how to hone identification skills, and ultimately promote activities to increase local natural history knowledge. In the Smithsonian Institution's Neighborhood Nestwatch project on the population dynamics of backyard birds, 80% of the participants reported an increased awareness of their local environment and more than half of the participants made habitat improvements since joining the program (Evans et al. 2005). Overall, a potential feedback loop might emerge whereby residents gain intimate knowledge about and interactions with the flora and fauna in their yard, which, in turn, fosters a sense of connectedness to nature and inspires additional stewardship practices with mutual benefits for wildlife and people (e.g., van Heezik et al. 2012, Prévot et al. 2018).

Overcoming the tyranny of small decisions

So far, our Forum has primarily focused on the individual yard scale. However, yard management has an inherent scale-dependent tension whereby the unit of management (i.e., the yard) is often smaller than the management unit required for retaining viable wildlife populations (Goddard et al. 2010). Following the initial residential development phase, a multitude of different management decisions happen at individual property scales (Cook et al. 2012, Groffman et al. 2014). But the additive effects of numerous individual householder decisions on individual parcels of land across a neighborhood, town, or region might converge—for example, whereby all residents have a monoculture lawn. Alternatively, management might differ from yard to yard, leading to a heterogenous patchwork of habitat across the landscape (figure 3). This tyranny of small decisions (Odum 1982) results in millions of individual management actions, which collectively can lead to landscape-scale habitat heterogeneity and biodiversity enhancement.

The tyranny of small decisions can also present a challenge for conservation given inherent scale mismatches between species and ecological communities, whereby biological requirements often transcend parcel boundaries (Borgström et al. 2006). For example, when a yard that includes nest boxes and insect-supporting and berry-producing shrubs is directly adjacent to a yard with outdoor domestic cats, the benefits for breeding and feeding opportunities for birds may be negated by the additive mortality from the cats (Loss et al. 2013). Therefore, certain yard management decisions can lead to ecological sinks or traps (Schlaepfer et al.

Figure 3. Yards represent a heterogeneous patchwork of habitat across the landscape. Individual yards are part of a network of parcels. The variation in yard design, as was shown from examples from four different yards in Phoenix, Arizona, in the United States, all within around 10 kilometers of each other, includes different management decisions, with each having different implications for biodiversity conservation, climate resiliency, and human well-being. Photograph: The top left photo was obtained from Adobe Stock Images and used with permission.

2002), potentially constraining the ability of many wildlife species to maintain populations and affecting local to global biodiversity (Butchart et al. 2010, Shochat et al. 2010). Simultaneously addressing resources and anthropogenic threats, and managing yards collectively can potentially reconcile the scale mismatches while accounting for scales and hierarchical filters (Goddard et al. 2010, Belaire et al. 2014).

As we described above, most yard management practices occur within individual parcels, and translating those decisions to better manage yards at the neighborhood and regional scale will be essential to satisfy life history requirements for species with territories that span beyond parcel boundaries (e.g., highly mobile species such as birds and mammals). For example, native bird diversity increased with yard size in Brisbane, Australia, and Dunedin, New Zealand (Daniels and Kirkpatrick 2006, van Heezik et al. 2013), and when scaling up from an individual yard to the neighborhood, the species area relationship holds. In the case of Chicago, Illinois, in the United States, when multiple and adjacent yards (i.e., the neighborhood scale) included berry-producing shrubs, a higher ratio of coniferous to deciduous trees and fewer outdoor cats, researchers found that these yards, collectively, supported higher native bird diversity (Belaire et al. 2014). Furthermore, moth assemblages in Dublin, Ireland, correlated with shrub density, although at a scale, that extended beyond the individual yard (30-meter radius), amplifying the importance of managing yards collectively (Ellis and Wilkinson 2021). These and other studies suggest that rather than replicating habitat features within individual yards, the neighborhood and landscape scale have a broader spatial opportunity for habitat complexity. Therefore, managing multiple yards using a habitat zone concept, whereby individual yard management encourages a specific habitat type, such as a woodland or meadow, rather than all yards including several habitat features, can encourage a mosaic of habitat patches to promote heterogeneity throughout residential landscapes (Goddard et al. 2010).

An individual yard exists within hierarchies of scales, interacting with social, environmental, and spatial processes, and climatic conditions. These, in turn, influence management decisions and ultimately drive biodiversity patterns within nested spatial scales, both within and beyond the individual yard (Aronson et al. 2016, Andrade et al. 2021). For example, research from the United Kingdom and six cities in the United States showed that at the individual yard scale, aesthetics, cultural traditions, and ease of maintenance directly influenced specific yard features (e.g., native plants, vegetable garden, amount of lawn; Goddard et al. 2013, Larson et al. 2016). Scaling up to the neighborhood, variation in household socioeconomic status and social lifestyles, coupled with neighborhood rules and norms are potentially strong influences on adjacent yards as residents emphasize and enforce local priorities and governance mechanisms (Grove et al. 2006, Nassauer et al. 2009, Nassauer 2011, Visscher et al. 2014).

At the municipal scale, land use and land cover ordinances further guide and constrain some ecological features such as vegetation height within a parcel (Larson et al. 2020). At national scales, systemic racism (Schell et al. 2020) and economic factors, such as recessions could further structure and filter biodiversity in yards. During the Great Recession of 2008, for instance, housing foreclosures and abandonment increased, which led to the cessation of irrigation, fertilizer application, and plantings in the Phoenix, Arizona, metropolitan region, in the United States, and, consequentially, to changes in biodiversity patterns. Specifically, the lack of active management shifted the vegetation composition to an increased abundance in annual species after the recession (Ripplinger et al. 2017). Furthermore, the nursery industry and horticultural availability also plays a strong role in determining the vegetation palate in yards (Avolio et al. 2018, Cavender-Bares et al. 2020). The above examples represent just a few of the ways in which management interacts across scales to influence the habitat potential of yards, individually and collectively, for biodiversity. Given such place-based constraints at varying geographic levels, researchers and practitioners can consider how local-to-national and even broader scale forces affect flora and fauna across diverse urban-to-rural areas.

Yard research and conservation across the urban to rural gradient

Much of our understanding of the conservation value of yards for biodiversity stems from the urban ecology literature (e.g., Grimm et al. 2000, Edmondson et al. 2012, Lepczyk et al. 2017). But yards located across exurban and rural areas might have a disproportionate impact on biodiversity. For example, when low-density residential development in the outskirts of metropolitan regions abuts or falls within protected areas, yard management in these areas can inadvertently influence habitat quality and species of conservation concern more than yards in urban and suburban areas (Wood et al. 2014). In research from Colorado and upstate New York (near the Adirondack Park), in the United States, scholars identified a development footprint that extended beyond the house and managed lawn of individual properties. Specifically, bird communities within 200 meters of the home included more synanthropic and generalist species than more specialized species in protected areas (Odell and Knight 2001, Glennon and Kretser 2013). Although these studies did not specifically explore management within yards, research from US cities showed that when yards adopted wildlife-friendly management, the bird community turnover patterns from yard to yard more closely aligned with community patterns of protected parks than it did in more traditional yard (lawn) management (Lerman et al. 2021). Collectively, significant research demonstrates that managing yards for biodiversity potentially extends the benefits of protected lands beyond their borders. In more agricultural settings, yards can also enhance resources for pollinators, particularly when wild plants are limited (Samnegård et al. 2011). These and other studies underscore the importance of residential areas at urban–wildland interfaces, as well as more rural areas.

Rural yards have different management, largely because of their increased size (box 1). Often, a small proportion of the parcel is managed intensively like their urban and suburban counterparts (e.g., mowed lawns, ornamental plantings; i.e., a *zone of care* as per Nassauer et al. 2014), with much of the land passively or actively managed as forest, rangeland, desert, and other intact lands (Wood et al. 2014) and agricultural areas. In an extensive survey of rural landowners across the United States, primary management activities included improving wildlife habitat, cutting or removing trees for personal use or sale, and removing invasive plants (Butler et al. 2021). Residential development solutions, such as clustering rural housing into conservation development subdivisions, shows some promise for preserving biodiversity, both within the yards and the protected open space (Hostetler and Reed 2014, Farr et al. 2017). Nevertheless, because residential yards in rural areas may especially affect biodiversity, scientists beyond the field of urban ecology can inform how to manage landscapes most effectively at scales that have the greatest positive impacts. One way of thinking about how yards fit into the broader landscape is provided by the land sparing versus land sharing framework.

Land sparing and land sharing

A land sparing approach protects natural lands so they can support high levels of biodiversity and species of conservation concern, with human-dominated areas kept separately focused on human needs. Several studies have modeled different urban development scenarios, confirming that protecting and restoring natural lands by concentrating and clustering residential development in urban and suburban areas supports more native trees, birds, bats, invertebrates, and other wildlife (Sushinsky et al. 2013, Soga et al. 2014, Caryl et al. 2016, Collas et al. 2017).

Land sharing—that is, the management of yards as habitat—can also support birds, pollinators, small mammals, and other wildlife (Belaire et al. 2014, Grade et al. 2022, Jimenez et al. 2022). However, as was detailed above, several factors can influence the habitat quality of yards including the presence of native plants and wildlife-friendly landscaping and features (i.e., bird houses and feeders; Goddard et al. 2013, Narango et al. 2017, Larson et al. 2020, Berthon et al. 2021). Therefore, employing both a land sparing and land sharing approach has the potential to address the biodiversity crisis more effectively than either one by itself (Kremen 2015, Lerman et al. 2021, Valente et al. 2022). Land sharing can have the added benefit of increasing and maintaining human interactions with biodiversity (Sushinsky et al. 2017). Furthermore, land sharing can also increase the connectivity across the landscape via corridors to facilitate animal movement among yards, between neighborhoods, across metropolitan regions and to protected land.

When planning for a coupled land sharing or sparing approach, research on how best to enhance connectivity is crucial. Although features of the surrounding matrix can affect the habitat quality of protected land (Jenerette et al. 2022), we lack a complete understanding of how and whether habitat quality within yards can facilitate dispersal and habitat connectivity, and reduce adverse effects on protected and preserved land. These gaps in knowledge are not unique to residential landscapes, and Knapp and colleagues laid out a strong agenda for how urban biodiversity research can better address policy, management, and conservation needs (Knapp et al. 2021). Planning tools that identify corridors for increasing the connectivity across the landscape show promise (e.g., least-cost paths resistance-based modeling; Balbi et al. 2021). Identifying the relative importance of an individual yard versus landscape habitat features and their complex interactions throughout an individual animal's life cycle is critical (Lepczyk et al. 2017).

Advancing a humanity for habitat stewardship practice to benefit all

Our argument for biodiversity conservation programs focused on residential yards builds on a strong tradition of voluntary initiatives led by nongovernmental organizations. For example, existing programs include the National Wildlife Federation's Garden for Wildlife program (www.nwf.org/Garden-for-Wildlife), established in 1974; Wild Ones: Native Plants, Natural Landscapes (https://wildones.org), established in 1990; and the Royal Society for the Protection of Birds Give Nature a Home program (www.rspb.org.uk/get-involved/activities/give-nature-a-home-in-your-garden), established in 2013, to name a few. Research has now verified that these voluntary stewardship programs provide more native plant diversity (Padullés Cubino et al. 2020) and more heterogenous bird communities (Lerman et al. 2021), thereby providing a foundation for promoting yards as wildlife habitat. Scaling up, expanding wildlife yards, and managing multiple and adjacent yards—especially in connection with broader landscape features—can improve the ecological integrity of residential landscapes for wildlife populations, because many species require habitat patches that extend beyond an individual yard (Goddard et al. 2010, Lepczyk et al. 2017).

When advancing the humanity for habitat practice, considering the spatial distribution of biodiversity patterns is essential because they are not equitably distributed across residential landscapes. Specifically, people of color have less access to biodiversity because of a variety of factors, including those stemming from both historic and current systemic racism imposed by policies such as redlining and Apartheid (Schell et al. 2020, Shackleton and Gwedla 2021). For example, in Baltimore, Maryland, in the United States, neighborhoods that were redlined in 1937—through the policy of systematically denying minoritized people access to mortgages and other financial investments provided to predominantly White neighborhoods—still have lower alpha tree diversity, lower occupancy of large trees, and higher occupancy of young trees (Burghardt et al. 2023). Higher occupancy in young trees likely reflects recent tree planting efforts in redlined neighborhoods compared to others. Although the Apartheid regime in South Africa ended in 1994, inequities remain whereby the doubling of income in White neighborhoods equates to a significant increase in vegetation and tree cover compared to lower income neighborhoods of color (Venter et al. 2020).

The unequal distribution of vegetation can have cascading effects on wildlife, with socioeconomic status serving as a strong predictor of plant, bird, bat, lizard, and arthropod biodiversity patterns (Leong et al. 2018). This so-called "luxury effect", wherein communities with higher socioeconomic status experience higher biodiversity, has been documented in the United States, United Kingdom, Canada, China, South Africa, and Spain, among other countries, but these biodiversity and income relationships are not universal and the patterns complex (Hope et al. 2003, Chamberlain et al. 2019, Kuras et al. 2020). Nonetheless, these disparities highlight environmental injustices and the need for additional research and action aimed at remedying these concerns, ideally guided by the needs and desires of local communities (Schell et al. 2020), with the aim of enhancing biodiversity for all people. However, because urban greening efforts aim to serve residential communities that currently lack the benefits of biodiversity, exercising caution is essential to avoid green gentrification wherein increasing vegetation and habitat increase property values and lead to the displacement of lower income people or other marginalized groups. For more on green gentrification, see Wolch and colleagues (2014) and Gould and Lewis (2016).

Actionable solutions

Our Forum has highlighted how the trifecta of environmental conservation—biodiversity conservation, climate resiliency, and well-being—can be realized in yard management. However, several biological, social, economic, and policy barriers exist that might hinder widespread establishment of yards that achieve these benefits and other ecosystem services. Because yards and their management can also contribute to ecosystem disservices, managing yards as wildlife habitat requires anticipating and managing negative impacts on humans, whether perceived or actual (Larson et al. 2019). For example, a yard with high plant diversity and habitat quality may provide opportunities to appreciate wildlife visiting their yards for some residents. But for others, such yards might be perceived as weedy and messy, more allergen producing, attractive to nuisance and pest species (Gómez-Baggethun and Barton 2013, Brown et al. 2020), and introducing health risks because of increased exposure to wildlife such as mosquitoes (Brown et al. 2021). Therefore, the benefits of yards may be viewed differently by diverse people, and both perceived and real ecosystem disservices can negate or affect the services provided by yards. In this next section, we provide examples of barriers and opportunities for reducing ecosystem disservices and enhancing ecosystem services in residential yards (table 2). Although we acknowledge that numerous barriers exist, our intention is to highlight a few examples that specifically relate to biodiversity.

Biological barriers and opportunities

The challenges associated with a higher abundance of trees and other yard vegetation could dissuade widespread adoption of practices that benefit ecosystems. For example, more yard vegetation could attract nuisance species, such as the black-legged tick (*Ixodes scapularis*), and could increase transmission rates of zoonotic pathogens (e.g., *Lyme borreliosis*; Fischhoff et al. 2019, Halsey et al. 2022). Dead and dying trees that provide resources for cavity-nesting species can also pose a higher hazard for personal injury and property damage when not maintained properly or when planted in the wrong location (Kane et al. 2015). Composting yard (and food) waste for organic fertilizer may also increase pests (e.g., Norway rats *Rattus norvegicus*, raccoons *Procyon lotor*) or nuisances such as odors, even though compost heaps may provide wildlife habitat (Gaston et al. 2005). Therefore, balancing the needs of wildlife with public safety represents an important point of how biological outcomes of wildlife gardening may prevent stewardship practices or raise concerns to be addressed and managed. One potential opportunity includes working with extension, conservation, or horticultural programs on developing informal outreach activities for yard management and developing training material for arborists and landscape designers to address potential hazards when providing wildlife habitat. However, social and economic barriers likely have a stronger influence on implementation.

Social barriers and opportunities

Related to social norms and cultural traditions, aesthetic considerations are crucial for the social sustainability of residential yards, because the appearance of landscapes is a dominant

Table 2. Examples of biological, social, economic, and policy barriers and possible opportunities for implementing and advancing yard management that embraces a humanity for habitat stewardship practice.

Category	Barriers	Opportunities
Biological	Attract nuisance species Increased risk or injury to households	Create resources for extension programs Work with arborists (Kane et al. 2015)
Social	Less aesthetically pleasing landscapes Potential misalignment with social norms Disconnect with yards as part of nature	Integrate “cues to care” (Nassauer 1995) Empower “local champions” (Goddard et al. 2013) Convey the relevancy of yards and simple steps to enhance biodiversity benefits (figure 4) Partner with existing organizations and gardeners (Larson et al. 2022, Mumaw and Mata 2022)
Economic	Cost prohibitive to purchase new plants, redesign the yard, or repurpose part of the yard for habitat	Establish rebate programs with utility companies and natural resource agencies to plant more trees and other vegetation (e.g., NGO Cedar Falls TREES (www.cfu.net/save-energy/shade-tree-discounts), a program that provides households a $100 per year discount for purchasing a shade tree. The program includes various approved species with different ecological attributes (e.g., spread, height), including several native species that provide habitat for wildlife Tax incentives to reduce management intensity (e.g., excise tax on chemical application, outright pesticide bans in France; Lefebvre et al. 2022)
Policy	Promotion of traditional lawn aesthetic Local “weed laws” that limit height of vegetation Legacies of redlining, structural racism that reduce equitable access to biodiversity	Add to or amend existing regulations and policies (e.g., Biden administration Executive Order 14008 to protect 30% of US lands and waters by 2030 (30 × 30) can include yards as part of the strategy)

priority for many residents and therefore affects their willingness to adopt wildlife gardening practices (Nassauer et al. 2009, Larson et al. 2016, Li and Nassauer 2020). Specifically, managing for biodiversity typically increases the natural look of yards, which can appear messy and disorderly compared with traditional lawns that are heavily managed to a uniformly green, weed-free aesthetic. One solution is designing wildlife yards with cues to care, which include mown edges or other curvilinear features, signage and other cues that are recognizable as human intervention (for reviews, see Nassauer 1995, Li and Nassauer 2020). Such cues to care can reconcile wildlife habitat with aesthetics by communicating the intentionality of wildlife gardening while featuring design elements known to be widely attractive to residents. In addition to aesthetic cues, efforts to establish norms for naturalistic wildlife yards could rely on key influentials, such as individuals with high social status who may influence the views of others (Byerly et al. 2018) within neighborhoods or at broader scales. In short, communicating simple steps for residents to achieve yard priorities including aesthetic appreciation, easy to maintain yard designs, and engaging with local champions are essential for the widespread adoption of wildlife yards and their collective impacts at larger scales (figure 4; Goddard et al. 2013, Larson et al. 2022).

Economic barriers and opportunities

Purchasing new plants or redesigning and maintaining a yard can be cost prohibitive (Helfand et al. 2006, EPA 2016). For example, one estimate for the 5-year cost of installing and maintaining turf for a 1-acre parcel in Michigan, in the United States, amounts to approximately $7000, which although it is expensive, is less than a corollary estimate for a landscape with biodiversity benefits (e.g., half turf and half prairie approximately $11,000, 75% prairie approximately $9000 or 75% prairie and shrubs approximately $9300; Helfand et al. 2006). Ornamental native vegetation has also been shown to be more expensive than exotic vegetation, at least in the United States (Avolio et al. 2018). Tenancy can also pose a barrier to implementing yard management that supports biodiversity. For example, renters might be less inclined to spend time and or money on incorporating wildlife features to the yard (García-Antúnez et al. 2023). Rebate programs with specific goals for increasing wildlife habitat including incentives for yard conservation and plant giveaways can be used by municipalities, nonprofit organizations, and other entities to subsidize the costs of wildlife greening (Byerly et al. 2018). Designing wildlife yards to be low cost or implementing programs to help offset costs can help overcome economic barriers.

Policy barriers and opportunities

Policy barriers exist within a hierarchy of management scales encompassing local, regional, and national policies and programs (Nilon et al. 2017, Larson et al. 2020). For example, although research has shown that biodiversity conservation is often a stated goal in municipal codes (i.e., ordinances), at least in the United States (Nilon et al. 2017), local regulations and guidelines directly pertaining to yard management practices, such as weed-height limits, requirements to remove dead wood, and allowance and even the promotion of exotic plants, often contradict this goal (Larson et al. 2020). Neighborhood-level rules can also dictate or otherwise influence what residents can do with their yards, including through homeowners association covenant, codes, and restrictions that often reinforce norms of neatness and maintenance of property values over environmental goals (Turner and Stiller 2020). The National Spatial Planning and Land Use Management Act (SPLUMA, Act 16 of 2013) in South Africa demonstrates one example of how national policies can increase wildlife habitat in an equitable way. In particular, the SPLUMA prioritizes tree planting and increasing vegetation in areas historically neglected during the Apartheid regime (Venter et al. 2020). Many barriers are likely to occur at more local levels (i.e., neighborhoods and

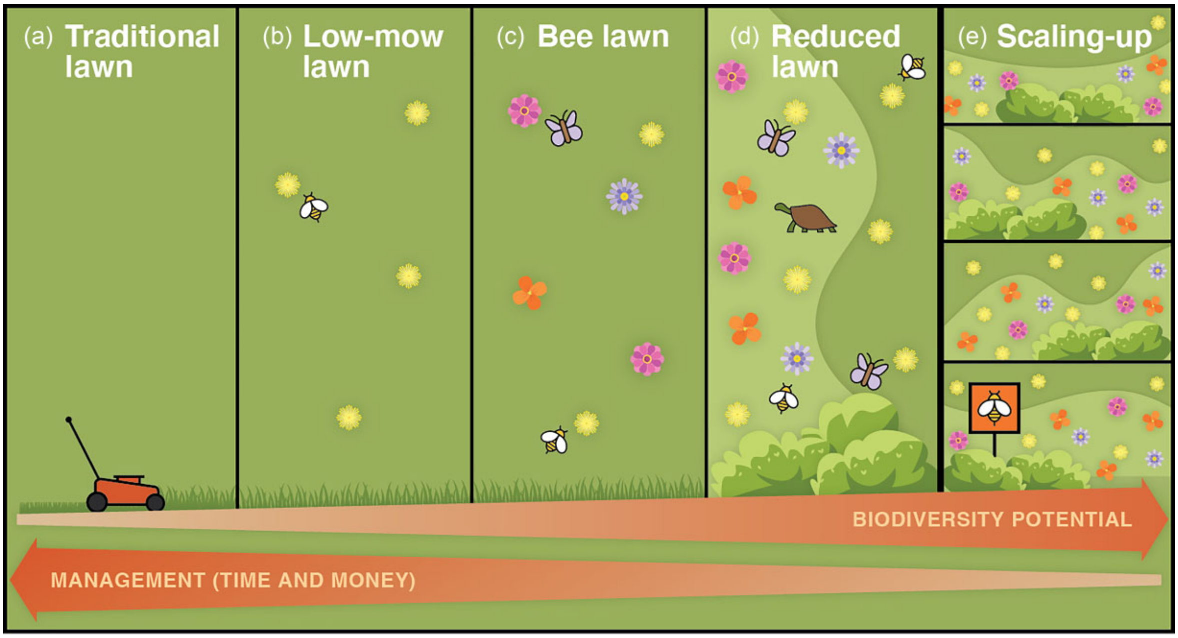

Figure 4. Simple solutions for transforming traditional lawns (a) can increase biodiversity. Altering the management by (b) mowing less frequently or (c) managing a bee lawn (i.e., turfgrass seeded with pollinator-friendly flowers) presents simple solutions that can have immediate benefits for biodiversity. (d) Reducing the amount of lawn and replacing it with native plants can further increase the biodiversity potential of an individual yard. (e) Sharing information about yard management activities with neighbors via signage or with promotional materials has the capacity to scale up individual efforts and can have population-level results. Image: Original artwork by Lisa Viviani.

municipalities), but state, federal, and broader scale policies and programs may also play important roles in promoting or constraining wildlife yards. Although these are only a few specific points derived from the literature, additional research, and consideration of the policy barriers to wildlife gardening, are essential when expanding the scale of yards that support biodiversity.

Bringing it all back home

Over the past decades, scholars and conservationists have increased calls for better land stewardship in response to the growing biodiversity and climate crises. In 2009, the Ecological Society of America launched the *Earth Stewardship* initiative, which integrated a social–ecological scientific approach for counteracting the human degradation of the Earth (Chapin et al. 2011). Pope Francis's groundbreaking 2015 encyclical, the *Laudato Si' of the Holy Father Francis on Care for our Common Home*, called for a new ethos of global land stewardship at the home (Francis 2015). And there is precedent for stewardship for the greater good in residential settings. During World War II, for instance, millions of households in the United States, Canada, the United Kingdom, and Australia planted Victory Gardens to address the food shortages due to high military enlistment of farmers. Governments and popular media outlets promoted this act of stewardship and praised the benefits of these gardens for both the war effort and nutritional value. More recently, First Lady Michelle Obama revitalized the spirit of victory gardens with the White House kitchen garden. Expanding the Biden administration's 30 × 30 Executive Order 14008, which lays out an ambitious goal to combat the climate crisis by protecting 30% of US land and waters by 2030 and includes private land (Executive Office of the President 2021), to yards, carries on the tradition of residential land contributing to the war effort, with the focus including biodiversity conservation (figure 5).

The Victory Garden model might more closely align with yard management in the Global South given the stronger reliance on local resources to address poverty and food security (du Toit et al. 2021). Although many of the examples and interpretations of yards for biodiversity stem from the Global North, additional research from the Global South can provide important context on developing universal theories, frameworks, research approaches and solutions for promoting a humanity for habitat practice on a global scale (Shackleton et al. 2021). Furthermore, the importance of a humanity for habitat yard management is relevant in the Global South because of higher levels of biodiversity, high population growth, and vulnerability to effects of climate change (du Toit et al. 2021). Additional studies that assess patterns and process of wildlife distribution, the legacy effects of how colonialism influenced the vegetation palate, how and whether these introduced plants outcompete native plants (Shackleton and Gwedla 2021), and the synergistic benefits of medicinal plants for wildlife and people can amplify the relevance of yards for supporting biodiversity (Leakey 2017, Caballero-Serrano et al. 2019). Overall, research and practice across the globe can inform planning aimed at conserving biodiversity within the residential matrix (du Toit et al. 2021, Shackleton et al. 2021).

Capitalizing on the potential of yards for biodiversity conservation rests on the understanding that residents have agency to create, manage, and protect nature in their yards through planting, retaining, and managing vegetation that fosters connectivity and complementarity with local-to-regional natural habitat. Furthermore, social, cultural, design and governance issues also influence the success of yards as habitats (e.g., Gobster et al. 2007, Roy Chowdhury et al. 2011, Cook et al. 2012, Li and Nassauer 2020, Zhou et al. 2021). Theoretical frameworks, combined with a rich history of empirical research from the social sciences, can further guide our understanding of the current and future role of yards in conservation and in addressing the biodiversity crisis.

Figure 5. Shared stewardship. Collectively managing yards for ecosystem services has a strong precedent, as is exemplified by the victory gardens promoted by governments in the United States, Canada, the United Kingdom, and Australia during WWII. Identifying effective campaigns will further contribute to the success of existing programs. Image: Original artwork by Elsa Cousins.

Additional social–ecological research in particular contexts will further our understanding of the opportunities and constraints within yard management for biodiversity conservation. Harnessing widespread support for policy-level changes might depend on positive interactions with wildlife and biodiversity in residential areas (Sushinsky et al. 2013). Therefore, creating a feedback loop wherein residential environmental stewardship benefits human well-being and biodiversity is crucial. Although images of nature and wildlife habitat might conjure dramatic landscapes, charismatic megafauna, and majestic protected areas rather than our own personal yards (Cardinale et al. 2012), expanding this paradigm to include yards as a fundamental part of the habitat matrix throughout human-dominated landscapes is an important first step (Tallamy 2020).

Biodiversity conservation has evolved as a crisis science; however, reframing a conservation narrative that contains optimism and clear examples of successful science-based management and policy can instill a sense of hope and help motivate stewardship action (McAfee et al. 2019). Planting and maintaining native plants, increasing wildlife resources, reducing management intensity, and minimizing anthropogenic threats, in addition to acknowledging the importance of aesthetics and addressing policy barriers, are key considerations for the pursuit of a humanity for habitat stewardship practice. Dennis Murphy wrote, “If we cannot act as responsible stewards in our own backyards, the long-term prospects for biological diversity in the rest of this planet are grim indeed" (Murphy 1988: 76). His prophetic statement emphasized the importance of individual yards to broader conservation goals, and identifies their tremendous potential for strengthening connections between people and nature. Our Forum has demonstrated how yards are key for marshalling broader respect for the environment and recognition of the role households' play in protecting our shared natural resources for the future.

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