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Urban conservation gardening in the decade of restoration

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Global commitments and policy interventions for conservation have failed to halt widespread declines in plant biodiversity, highlighting an urgent need to engage novel approaches and actors. Here we propose that urban conservation gardening, namely the cultivation of declining native plant species in public and private green spaces, can be one such approach. We identify policy and complementary social mechanisms to promote conservation gardening and reform the existing horticultural market into an innovative nature-protection instrument. Conservation gardening can be an economically viable and participatory measure that complements traditional approaches to plant conservation.

Declines in native floral richness can lead to cascading effects across trophic levels and impair the functioning of key ecosystem services upon which humanity relies[1]. Despite species conservation being high on the political agenda, with national and global targets to halt biodiversity loss, species populations have continued to decline[2]. Similarly, the key global commitment to halt biodiversity loss by the end of this decade, the Post-2020 Global Biodiversity Framework, is anticipated to miss its species conservation target, in part because the current draft fails to explicitly state that population declines of native species must be halted[3]. To maintain unique ecosystem functions and services and global biodiversity, it is critical that nations find and implement measures to conserve their declining native species.

Conservation measures of threatened plant species have a strong focus on preserving habitat in protected areas[4,5]. While these efforts are integral to successful species conservation, they also face several long-term challenges. Maintaining adequate conservation conditions is resource intensive, with an estimated financial cost of meeting global conservation goals of US$76.1 billion annually[6], requiring sustained policy support. Conservation often relies heavily on non-market, poorly scalable funding mechanisms, leaving it under-funded or forced to meet an overwhelming number of diverse socio-economic objectives[5]. Consequently, conservation often competes with other political targets, potentially compelling landowners who are currently implementing conservation measures to opt for more economically attractive land uses. A stark example of this is biodiversity funding competing with subsidies such as the Common Agriculture Policy, representing 7.5% and 36% of the total European Union (EU) budget, respectively[7]. The cumulative pressures on traditional conservation approaches are exemplified in the continued declines of species, despite high-level efforts to increase the size and spread of protected areas[5].

Continued species declines, even in protected areas, highlight the need for reconciliation ecology. This means redesigning anthropogenic areas such as cities, suburbs, towns and villages (hereafter referred to as urban areas[8]) to be compatible for a broad array of species[9]. Urban ecosystems represent a rapidly increasing land surface area (projected to be 1.9 million km^2 by 2030 and 3.6 million km^2 by 2050[8]), where conservation can and should be implemented[8,10]. Urban ecosystems can have higher biodiversity than surrounding natural areas[11]. Although often dominated by human-tolerant, widespread species, urban areas also have the potential to harbour many threatened species[12,13]. Furthermore, conserving and restoring biodiversity in urban area can provide multiple co-benefits, such as unique socio-cultural services and health benefits to a substantial proportion of people[14,15]. Today, 55% of people live in urban areas, a value projected to rise to 92% by 2100[16]. This means that urban areas are and will be where most people experience nature regularly, making them key places to expand people's understanding of biodiversity, foster nature stewardship and strengthen societal commitment to biodiversity conservation[13,17]. Novel mechanisms that encourage and integrate the conservation of biodiversity and promote nature stewardship in an increasingly urban world are urgently needed.

We propose that the widespread implementation of conservation gardening in both private and public urban green spaces can act as a form of community-based conservation for the protection of native species. While the idea of native plant gardening is not novel (otherwise known as, for example, wildlife-friendly, native/indigenous, wildscape and pollinator-friendly plant gardening[18–22]), the potential for urban green spaces to contribute actively to the conservation of declining and threatened native species is rarely reported in the scientific literature. Demonstrated justifications for native plant gardening include enhancing biodiversity, particularly insect and bird conservation, and associated social, cultural and psychological benefits[14,21,23]. We argue that native plant species can and should be protected in their own right through conservation gardening and that this may advance the science and practice of sustainable landscaping in multiple useful ways. Here we use Germany as a case study to illustrate this potential, where comprehensive long-term biodiversity data are available, the political system is becoming more

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attuned to biodiversity concerns and the socio-economic dimensions are largely exemplary for higher-income countries[24,25]. We (1) provide ecological arguments for conservation gardening, (2) suggest economic and policy mechanisms for mainstreaming this approach via the horticultural market, (3) present a tiered system to select appropriate candidate species for planting and (4) propose community-led, participatory approaches to broadly implement conservation gardening. In addition to this initial Eurocentric focus, we suggest our proposals hold insights that can be useful in any region and include examples from outside Europe.

Ecological arguments

Drivers of plant species declines and gains. Globally, two out of five plant species are estimated to be at risk of extinction[26]. This negative trend is also reflected in the German Red List, whereby 27.5% of vascular plant species are currently classified as threatened[27]. Moreover, it has recently been estimated that 70% of plant species are in decline across Germany, and species richness at the landscape scale has decreased by an average of 1.9% per decade over the past 60 years[25]. Drivers of species decline can be grouped by (1) abiotic pressures caused by more intensive land use, atmospheric nitrogen deposition and climate change, and (2) biotic pressures from the arrival of novel competitors, including invasive species[2,27]. In contrast, species associated with nutrient-rich, often anthropogenic habitats are increasing their populations across a wide range of habitats[28,29]. With the advent of the Green Revolution, anthropogenic habitats were made increasingly productive[30]. These conditions have probably benefited nutrient-demanding species, creating (1) a greater availability of suitable habitat and (2) pathways for their dispersal, allowing them to colonize new sites as indicated by the increase of nutrient-demanding species in semi-natural habitats[29]. The success of nutrient-demanding species may be partially reflected in their relatively larger area of occupancy, a pattern that we also found across Germany (Fig. 1). Conservation efforts therefore need to address biotic and abiotic drivers of species decline while harnessing mechanisms of species increases.

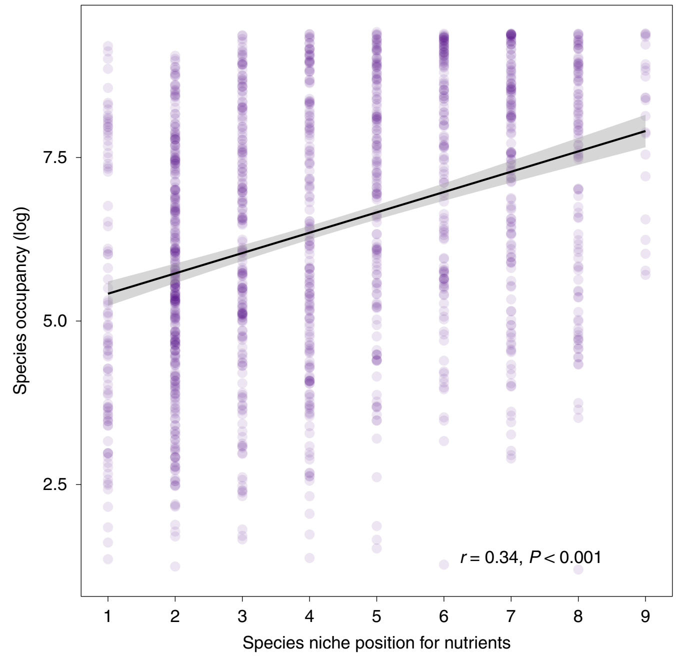

Fig. 1 | A species' niche position for nutrients is positively associated with its occupancy across Germany. Positive association between a species' grid-cell (5 × 5 km) frequency during the years 1960–1987 (data taken from ref. [25]) and Ellenberg indicator values for nutrients (data taken from sci.muni.cz/botany/juice/ELLENB.TXT). From ref. [25], 1,249 species also had *N* values. Larger *N* values indicate that a species is associated with more nutrient-rich habitats. The black line and grey ribbon indicate the fitted mean regression line and the ±95% confidence interval, respectively. Points are coloured semi-transparently, darker shades represent overlaps and higher point density.

Reversing population trends. Conservation gardening in urban green spaces may address the two main drivers of plant species decline. First, when building green infrastructure, humans can, in many cases, actively create adequate abiotic conditions that correspond to the habitat of threatened species (for example, nutrient-poor soils, low soil pH, sandy soils)[31]. Many threatened plant species have high light demands and occur on nutrient-poor soils[32]. Certain soil characteristics could be created by incorporating soil amendments, removing topsoil, and selecting specific soil substrates, with novel approaches such as constructed technosols having a high potential to provide multiple soil functions[33]. High light demands of threatened species could be met in open parks or on roof spaces, for example, with 80 million m^2 of rooftop area having been built in 2019 in Germany alone[34]. Second, humans can support slower-growing, declining native species by creating competition-free spaces through the regulation of biotic pressure (for example, removing faster-growing, competitive plants), where in urban green spaces, management effort per unit area can be particularly high. Thus, intentional gardening of declining native plant species may address both abiotic and biotic drivers of species decline.

Horticulture is well documented for its key role in the population trend of plant species. Historically, horticulture has had a problematic association with the spread of exotic, weedy and invasive species worldwide[35]. However, horticulture may similarly be leveraged to facilitate the spread of species with conservation value. For instance, the garden ornamental plant *Muscari botryoides*, classified as 'Vulnerable' on the German Red List, has increased its population by 65% in recent decades[25]. Accordingly, we find that the cultivation of native plant species is positively associated with their occupancy change over time (Fig. 2). The effect of cultivation could be overestimated, as cultivation is likely to be biased towards species that spread more easily. However, even for neophytes (species introduced after 1492) that show a strong overall positive population trend in Germany, cultivation still proves beneficial (Fig. 2). Adding declining native species to urban environments via conservation gardening may therefore promote secondary dispersal[28,36]. This could increase the chance of vulnerable species to find additional suitable wild habitat, where a larger area of occupancy may be associated with higher phenotypic plasticity and thus greater resilience to continued global environmental change[37].

As such, conservation gardening could create considerable additional area for conservation measures alongside protected areas (Fig. 3a,b; ref. [38]) and act to complement ex situ conservation areas, such as botanical gardens, which often fall short in providing sufficient space for—and hence have low intra-genetic diversity of—threatened species[39,40]. In Germany, public green spaces amount to 65,000 ha across the country's 50 major cities[41]. Although some of this area will be unavailable for conservation use due to competing societal needs, this estimate does not account for the other urban areas within these cities potentially available for conservation gardening (for example, allotments, private gardens, balconies, roofs and pavements) and green spaces in smaller cities, suburban and more rural settings, for which there are currently few data available. As a result, this is therefore probably a conservative estimate of the potential space available. For instance, the area of allotment gardens in Germany alone is an additional 44,000 ha (ref. [42]). Importantly, urban green spaces also have high spatial complementarity and can

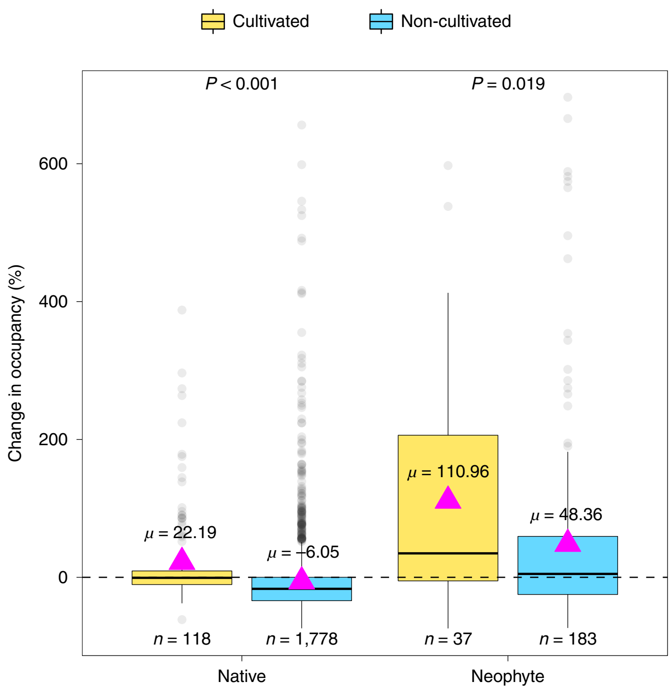

Fig. 2 | Cultivation has a positive impact on the occupancy trend of both native plants and neophytes. Boxplot for the percentage change in occupancy across Germany of cultivated (yellow) and non-cultivated (blue) plants for native plants and neophytes (species introduced to Germany after 1492). Changes in occupancy over the past six decades are taken from ref. [25]; plants with extreme trends according to ref. [25] are removed from this analysis. Supplementary Table 1 includes a list of plants that are commonly cultivated in Germany and used for this analysis. Displayed is the sample size (n), the estimated mean (μ, purple triangles) and the P value of a Mann–Whitney U test. The box bounds the interquartile range (IQR) divided by the median and whiskers extend up to a maximum of 1.5 × IQR beyond the box.

be well connected to current protected areas (Fig. 3c); this can minimize isolation and increase primary and anthropogenic dispersal from urban areas to protected habitats[38,43]. Conservation gardening can therefore not only create additional land for conservation but also be an approach to expand habitat networks.

Urban green spaces are increasingly recognized as important pieces of the conservation puzzle[12,13,44] that can support viable populations of threatened native species[13,40,44]. Of all threatened plant taxa assessed by the International Union for Conservation of Nature (IUCN), 17.4% were already found to occur in domestic garden collections[40], probably a conservative estimate of those actually present, as floristic inventory data of domestic gardens are far from complete, especially in biodiverse, lower-income countries[40,45]. Importantly, occurrences of declining native flora are not restricted to natural vegetation remnants or gardens but are found across diverse, heavily modified land-use types including roadsides, railways, golf courses and cemeteries[13,38,44]. Due to the documented potential for native species in urban areas, several initiatives have sprung up to implement their planting in anthropogenic ecosystems, despite this being rarely reported in the scientific literature[40]. In New Zealand, city councils promote threatened native plants in various urban environments[46]. On oceanic islands, where many native species are threatened, they are often used for landscaping as a mechanism for conservation[47], and in China, a case study suggests that cultivation of threatened plants in urban green spaces contributes towards their conservation[48]. These findings and initiatives highlight that while the protection of natural habitats for many species remains essential, conservation gardening, implemented in anthropogenic ecosystems, could complement the protection of declining native plant species.

Economic arguments

Market potential. The global horticulture market is currently estimated to be valued at US$109 billion and is projected to reach US$127 billion by 2024[49]. The German garden market is also a substantial source of economic revenue. Consumer spending on flowers and ornamental plants was €8.7 billion in 2018 alone (per capita spending ~€105), with Germans continuing to spend money on gardening in economic downturns[50]. In Germany, 12% of the active population (5 million people) own a small garden[42], reflecting a high consumer potential for conservation gardening. In parallel, strategies to improve the quality and availability of urban green spaces are also gaining momentum. For example, the EU Green City Accord mobilizes European cities to safeguard biodiversity, with several EU funding programmes and financial instruments available to support such measures (for example, European Agricultural Fund for Rural Development, LIFE and URBACT). Germany alone had €790 million available in 2017 to fund sustainable urban infrastructure (for example, federal spending programmes such as 'Zukunft Stadtgrün', 'Soziale Stadt' and 'Stadtumbau'). This funding landscape clearly provides a facilitating context for participatory conservation endeavours. With the proliferation of societal awareness and political will to tackle the biodiversity crisis, the green economy and the demand to actively participate in species conservation are both growing rapidly[51]. We therefore expect that garden businesses focusing on declining natives can be profitable in the future by tapping into green consumer spending.

An incomplete market. The formation of an ecologically meaningful market for conservation gardening is currently limited, however, by various factors, despite there being several declining natives already available for purchase online. We estimate through a random sample of 100 threatened species from the German Red List (~10%) that 35% of the species are readily available from various online retailers (Supplementary Table 2 provides search criteria). For example, *Iberis amara* is classified as extinct in Germany[27] but can be ordered for €3 per 100 seeds (Fig. 4 includes more examples). However, the majority of declining plant species are unavailable for purchase, and there is no comprehensive and accessible database for customers to find plant material that is available. This limited supply is probably due to the historical focus of the horticultural industry on 'winning' cultivars that are aesthetic and easy to establish and maintain with little concern for the origin or provenance of species[52]. This also means that there are generally (and not only in Germany) a lack of standards and quality certification for plants and seeds for use in conservation gardening[53]. Currently, it is not clear to consumers whether what they are buying is risk free and conservation oriented. One such risk is that seeds may come from spatially distant populations or they may be cultivars and selectively bred, potentially leading to reduced genetic diversity and outbreeding depression if they mix with wild populations[54]. Policy therefore needs to boost the supply of native plant material, while ensuring quality certification.

Policy mechanisms

Cross-sectoral integration. Integrating the emerging native seed sector into the mainstream horticulture market could greatly catalyse the multiplication of certified plant material for conservation gardening[52,55]. The native seed industry is projected to have substantial economic growth as ecological restoration activities and funding mechanisms gain momentum in the post-2020 policy environment[56] and could thus be a major source of native plant material for commercial enterprises. Moreover, the native seed sector already

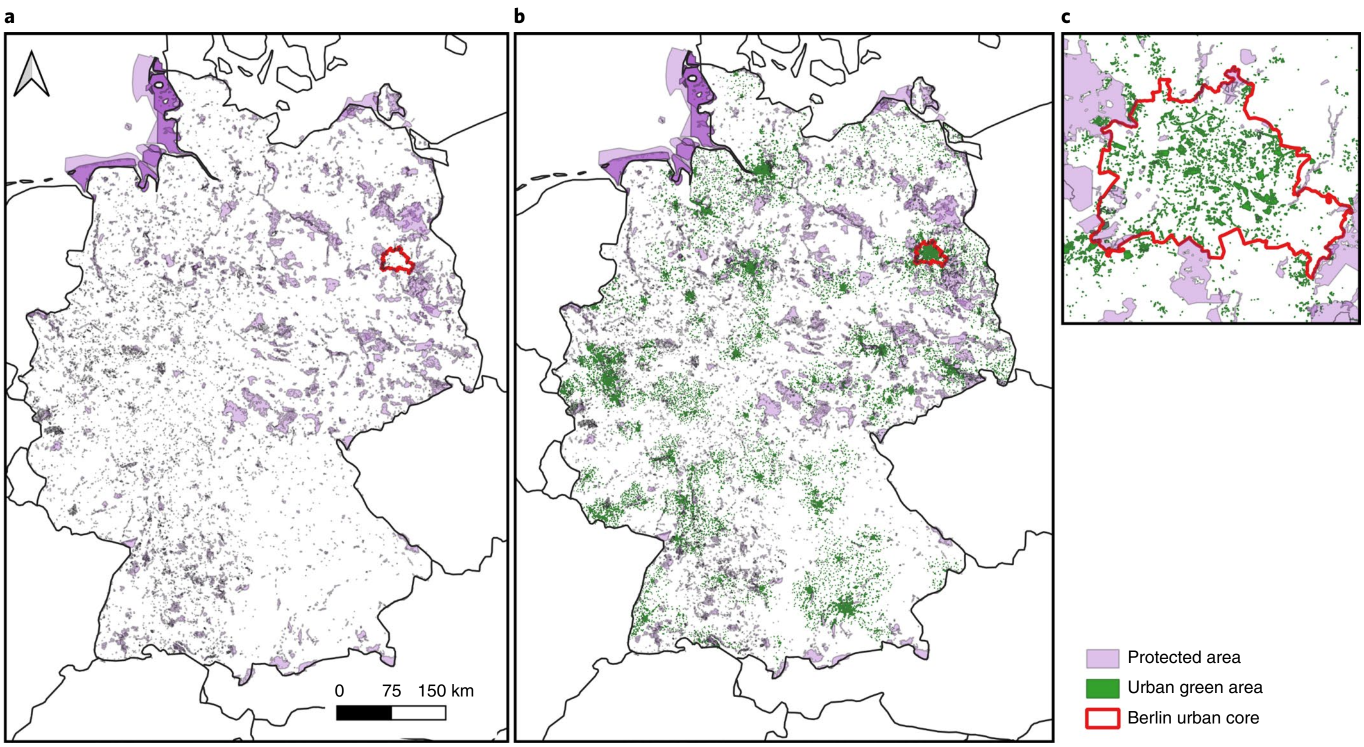

Fig. 3 | Urban green spaces can increase and better connect the area for conservation activities. a–c, A map of Germany displaying the spatial extent and distribution of protected areas only (available from protectedplanet.net; **a**), protected and urban green spaces for the largest 96 cities in Germany (available from Urban Atlas 2012, land.copernicus.eu/local/urban-atlas; **b**) and the urban core of Berlin (**c**), the most populous city in Germany, depicting both the spatial complementarity of the two networks and their connectedness. Note that while urban green spaces may not be classified as protected here, they can be weakly protected, for example, under Berlin's Green Spaces Law, and thus have comparable status to Landscape Protection Areas.

often has science-based standards for the production of native plant material[52,55]. These could therefore be adopted by the mainstream horticultural industry, using policies such as the 'International Standards for Native Seeds' to develop directives to ensure quality certification[55] with the potential to involve third party, publicly funded adjudicators to verify standards. To incentivize that certified producers are contracted by garden centres, financial support (for example, a lower value-added tax rate on native seeds) and national policy initiatives (for example, a requirement that city gardening projects use a certain percentage of native seeds) could be created. We further expect an increase in interest from the horticultural industry and government support for this cross-sector integration, as in many countries, species decline is accompanied by a growing awareness among owners of private gardens and the authorities responsible for the maintenance of public green spaces[51]. Structural support of the native seed sector will therefore allow native seeds to become more readily available for the horticulture market to meet increasing demand.

Currently, the native seed sector still faces several challenges, such as poorly scalable seed production techniques and lack of integration of applied knowledge. One of the biggest bottlenecks is that the industry often relies on wild stands for seed supply[53]. Funding needs to target initiatives that boost and stabilize the production capacity of native seeds, for example, through the creation of seed production areas and native seed farms. Rural regions in particular could share in these economic opportunities; in Europe, such funding provisions may come from the Common Agricultural Policy to support this[7]. In addition, Indigenous land, people and knowledge could be part of this native seed-farming enterprise, especially in lower-income countries, where initiatives such as the Tree Conservation Fund (treeconservationfund.org/) may help unlock private capital to support local communities for the production of native plant material. Moreover, botanical gardens could play a key role in giving access to the best science and practical advice and suitable native plant material for conservation gardening in commercial settings[57]. The world's botanical gardens grow at least one-third of all known plant species[58], can cultivate many threatened plants (even in mega-diverse countries such as China[39]) and comprise a community of >60,000 experts who can offer advice for plant collection, germination and propagation techniques[57]. A prominent example of such a cross-sectoral collaboration between botanical gardens and the native seed sector to boost seed supplies is Greening Australia[39]. Funding for the native seed and botanical garden communities (for example, through tax credits, grants, donations, fees for service) alongside better coordination of these sectors will be key to the uptake of garden-led plant conservation[57].

Conservation gardening label. In conjunction with cross-sectoral integration and certification, we posit that labelling schemes are needed to enable a shift of the demand curve towards 'conservation gardening' species. Appropriate and informative labelling on the trend and overall status of declining native species are typically lacking, hindering consumer choice between these and conventional species. Increasing awareness of biodiversity loss is frequently reported in surveys[51] and could therefore turn into a preference for buying conservation gardening-labelled species, potentially marketed at a premium. A conservation gardening label could therefore have the triple benefit of generating a price premium while ensuring quality certification and creating awareness of native plant diversity loss. Such a label could distinguish 'conservation gardening' species, guarantee that seeds are not taken from natural ecosystems at an unsustainable rate, and ensure that seeds have regional

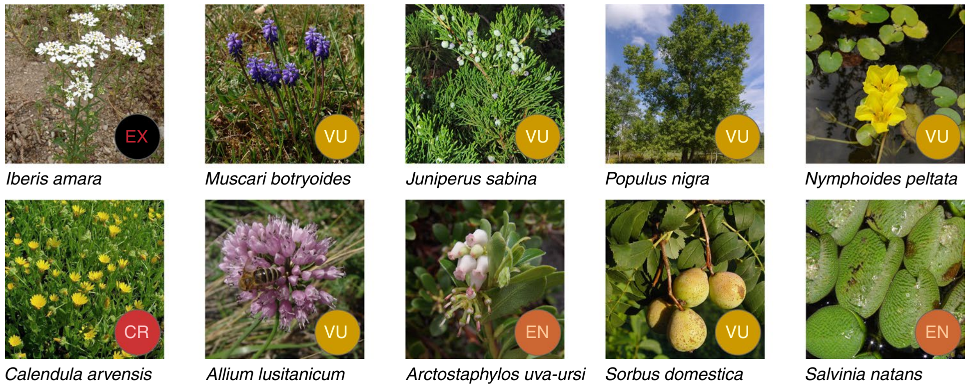

Fig. 4 | Many threatened native plant species are already available for purchase online. Examples of declining native plant species in Germany that can be bought from online retailers (Supplementary Table 2). Potential uses in urban settings (as specified by retailers) range from private balconies (for example, *Muscari botryoides*), green roofs (for example, *Juniperus sabina*), ponds (for example, *Nymphoides peltata*) and parks (for example, *Sorbus domestica*). German Red List criteria 0–3 were translated to IUCN Red List categories EX–VU, where EX is Extinct, EW is Extinct in the Wild, CR is Critically Endangered, EN is Endangered and VU is Vulnerable. Photographs © Michael Hassler (www.worldplants.de).

provenance or at least originate from spatially proximate populations[59]. A label should also include the following information: (1) the geographic area in which the plant is native, (2) whether the plant species is declining and/or listed as threatened on the national Red List and why, (3) the services it provides (for example, pollinator friendly, medicinal, ornamental) and (4) the habitats where the plant species occurs naturally. Finally, a conservation gardening label could advertise the investment of a percentage of profits into active conservation and restoration projects of habitats from which these species originate, thereby helping to redirect private consumer spending towards biodiversity conservation measures.

Candidate species

Conservation gardening targets the use of declining native species. For this, two fundamental concepts must be considered: the spatial scale of (1) species nativeness and (2) decline. Native status defined by political boundaries can be problematic in large countries where a species native to one state may be ecologically harmful in another (for example, *Sollya heterophylla* in Australia[60]). Considering nativeness at the scale of botanical countries[61] may help address this issue, with comprehensive data available at that scale (for example, Plants of the World Online, powo.science.kew.org). Yet, the concept of nativeness should also go beyond geographic origin, focusing on environmental outcomes such as potential for invasiveness[62]. Such assessments could in turn be guided by global databases on invasiveness (for example, GloNAF, glonaf.org). Finally, species population trends depend on spatial scale. Where fine-grained monitoring data are available, species declines may be considered at local scales, especially for emblematic species that are important for culture and heritage[63,64]. In the absence of fine-grained long-term monitoring data, regional and national Red Lists provide a basis for defining decline, where databases such as ThreatSearch (tools.bgci.org/threat_search.php) readily provide such information. The recent availability of these comprehensive global databases makes the definitions of nativeness and decline operational across applied contexts.

Accounting for these considerations, we propose a tiered approach to integrating appropriate declining natives with anthropogenic activities (Fig. 5). We also outline those species that will probably not be suitable. Declining species, which are specialized to habitats that do not occur in urban settings, are difficult to propagate or require specific and complex ecological mechanisms to survive (for example, specialized pollinators, fire and so on), need ongoing habitat-preservation efforts and professional ex situ conservation[65]. Similarly, declining endemics may have small populations or seed yields that are too low and variable for public use[66] or do not propagate with seeds and can so far only be reproduced effectively in vitro[67]. Many declining plants are, however, not endemic, having parts of their range in adjacent regions or countries where they are not listed as threatened[68], potentially providing sustained plant material sources. In many cases, 'near-local' provenances provide similarly for biodiversity as local populations[18]. Similarly, local provenance defined at larger spatial scales may justify the use of populations that occur in neighbouring areas with warmer or drier climates to prepare for species migrations with climate change[69]. Flexibility in the definition of the exact provenance must, however, go in tandem with ensuring that threatened species will not further be depressed by processes such as crossing and reduced genetic diversity[18,54].

Appropriate species for conservation gardening are those where a sufficient seed supply can be established (Fig. 5, middle and right). Species where germination and viability are strongly dependent on habitat management could be directed for use by trained gardeners and landscapers in appropriate urban habitats and be a basis for citizen-science projects. Species with a strong viability could be mainstreamed for use in private and public green spaces. Overall, conservation gardening can be considered as a socio-ecological restoration action at the anthropogenic end of the 'restoration continuum', providing an opportunity for urban and regional administrations—and the public—to become involved in participatory restoration and conservation activities[70]. Fostering integration of specialist plant knowledge on the amenability of species for urban gardening programmes, academic research on species provenance zones (for example, refs. [56,70,71]) and existing guidelines from the native seed industry[55] will be integral to putting this tiered approach into practice.

Promoting social uptake

For conservation gardening to become scalable, initiatives must be accepted and adopted at the individual-community level. Although surveys often report an increasing awareness of biodiversity loss (for example, ref. [51]) and signal a willingness for purchasing species for conservation gardening, a considerable barrier to widespread citizen participation is a continuing preference for tidy gardens. Additionally, many of the declining native plants may not have comparable aesthetic appeal to common garden ornamental plants. Social norms (for example, a duty to maintain neighbourhood standards[72]) and human perception of nature therefore have a strong influence on behaviours associated with maintaining urban green spaces. While research has shown that ecological aspects of

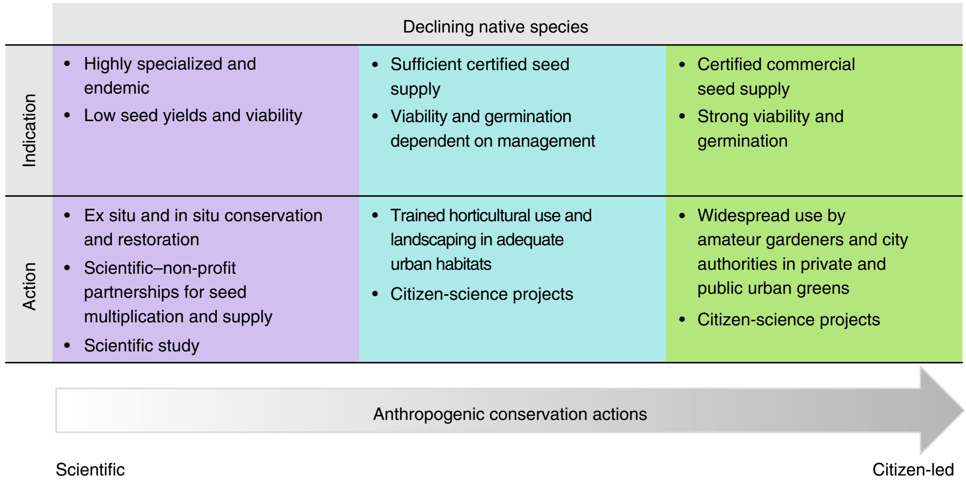

Fig. 5 | A tiered approach for selecting appropriate declining native species. We provide a tiered approach for determining which declining native species are appropriate to use in anthropogenic conservation and restoration activities. Boosting declining native species through conservation actions can gradually move from more scientific (purple) efforts to more citizen-led (green) ones. We highlight here both the indications for choosing which species should belong to each category (top), as well as the respective appropriate conservation actions for each category (bottom).

conservation gardening can strongly align with cultural conceptions of aesthetic beauty, the aforementioned barriers often prevent transitions to a more conservation-minded ethos[73].

Studies have shown that promoting connections to place and nature and disseminating practical information is key to overcoming these barriers[19,63,64,73]. Improving people's understanding of the importance of native biodiversity in their garden has been demonstrated to lead to a positive shift in people's attitudes, values and behaviours with regards to wildlife-friendly gardening[74]. Practical advice on which plants to remove and sow was found to be one of the most effective ways of encouraging previously non-engaged actors to participate in biodiversity-friendly gardening[75]. Encouraging influential actors such as government agencies and municipalities to disseminate this practical guidance can target a critical mass of residents[76]. The act of participating in conservation gardening, especially in a community setting, has further been shown to enhance people's commitment to nature stewardship, increase community linkages and create strong attachments to their sense of place and identity[15,63,64]. Therefore, there must be emphasis placed on bolstering information campaigns and nature connections to direct individual preferences and neighbourhood perceptions towards conservation gardening[75].

Specific mechanisms to enable this uptake should harness the use of social diffusion and neighbour mimicry[77]. Tested strategies include: (1) community outreach programmes that engage local residents (for example, using a block leader approach) and place emphasis on 'learning by doing'[64,75,78]; (2) social organizations (for example, homeowner and neighbourhood associations) that influence and allow the coordination of biodiversity-friendly management across gardens and provide ongoing advice and materials[79]; (3) collaborative networks (for example, UrBioNet, sites.rutgers.edu/urbionet/, and URBIO, urbionetwork.com) that engage diverse stakeholders in urban biodiversity management, design and planning and engage local residents to partake in scientific research regarding the ecological role of declining native plant species (for example, habitats for insects); (4) urban biodiversity stewardship networks that foster partnerships between local government and community member actors across both private and public land and place particular emphasis on nature and species of 'place'[63,76]; (5) citizen-science initiatives that further increase participant knowledge and skills, enhance conservation actions and inform future research priorities on the topic[78]; and (6) environmental community awards for conservation gardens (for examples, see review by ref. [72]) that encourage competition among neighbours and justify the perception of an unkempt garden[80]. Finally, botanical gardens can again play a key role here by advocating for and supporting these initiatives. Given the 500 million (predominantly urban) visitors to botanical gardens each year[58], they can provide a platform both for educational purposes, for example, courses for training (ncbg.unc.edu/learn/adult-programs/conservation-gardening/) and for contributing towards providing suitable plant material[81]. Through the promotion and support of community actions, powerful social mechanisms can be harnessed to implement and mainstream conservation gardening.

The time for conservation gardening

Species extinction rates are currently 10 to 100 times higher than background rates[2]. In response to these threats, the United Nations General Assembly declared 2021–2030 the UN Decade on Ecosystem Restoration to safeguard species and their habitats. Here we propose an opportunity for ecosystem restoration at the anthropogenic end of the 'restoration continuum' in the form of conservation gardening, whereby large-scale planting of declining native species in human-managed urban areas could not only result in additional land used for conservation but also help declining species find suitable wild habitat faster than they can naturally. Implementing conservation gardening at scale does not require wholesale changes to the existing architecture for conservation and can be cost-effective and self-sustainable while allowing for a more proactive, citizen-led approach to conservation. Furthermore, this effort could provide a platform to educate the public about the threats declining species face and thus promote awareness of the biodiversity crisis while providing positive, actionable steps to remedy it. By introducing such measures, conservation can become a tangible and integrated practice of urban living. We argue that integrating the native seed sector within the larger horticultural market, adding conservation gardening labels, and community dissemination of practical support will be key to scaling up and mainstreaming conservation gardening. While we recognize that this cannot be a panacea for native species conservation and that specific measures will always need to be adjusted for context, there is potential for conservation gardening to be implemented broadly and become ever more important in an increasingly urbanized world. Scaling up and mainstreaming conservation gardening can increase demographic rates of declining species, facilitate dispersal, promote human stewardship of nature, raise awareness of mostly unknown but disappearing species, be economically viable and sustainable, and potentially be used to co-fund other conservation initiatives.

Data availability

Data used for Figs. 1 and 2 are taken from ref. [25] and sci.muni.cz/botany/juice/ELLENB.TXT. Source data are provided with this paper.

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Author contributions

I.R.S. and J.S. devised the project and the main conceptual ideas with contributions from C.T.C., E.L., A.P., H.M.P. and J.N.M. J.S. and I.R.S. performed the analytical calculations. J.S., I.R.S. and E.L. produced figures. J.S. and I.R.S. wrote the manuscript with contributions from E.L., C.T.C., J.N.M., A.P. and H.M.P. I.R.S. supervised the project.

Competing interests

The authors declare no competing interests.

Additional information

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