A new participatory conservation framework built on the rise of native plant gardening

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Abstract: Global biodiversity strategies are ambitious on paper but fall short in practice. It is not strategy we lack, but the capacity to translate these plans into action on the ground. Akin to the community scientists that revolutionised biodiversity monitoring, we posit that community stewards, emerging from the rapidly growing native plant gardening movement, could scale up science-informed plant conservation. We present evidence that willingness to engage in conservation efforts is high amongst this community. We suggest a novel framework connecting these community stewards with the complementary strengths of existing institutions: the scientific expertise of botanical gardens, the legal mandates of conservation programs, the horticultural capacity of native plant producers, and the social infrastructure of gardening networks. Three case studies show how our framework could be operationalised. Activating the native plant gardening movement to bolster on-the-ground conservation may offer a promising way to close the doing gap in conservation.

Keywords: Participatory conservation, native plant gardening, ex-situ and in-situ conservation, botanical gardens, native plant producers, implementation gap

Main text

The "doing gap" in biodiversity policy

Global biodiversity targets are becoming more ambitious, including targets such as protecting 30% of land by 2030, yet the link between policy goals and ecological outcomes remains weak, particularly for plants (Sharrock 2020, Corlett 2023). For example, we still know little about how effective protected areas are at conserving plant species (Heywood 2019). A recent global synthesis of protected area impact studies did not include a single assessment focused on plants (Langhammer et al. 2024). Even in countries like Germany, where more than 30% of the land is already under protection, plant diversity continues to decline, and many protected areas are in poor ecological condition (Wirth et al. 2024, Ellerbrok et al. 2025). The lesson is not new: species do not persist simply because an area is designated as protected. They persist or perish depending on what happens on the ground. Without mitigating the direct drivers of population decline and without active management, many plant species will continue to decline.

This disconnect between conservation targets and ecological outcomes reflects a broader structural imbalance. Large investments go into planning, such as Red List assessments, species recovery plans, and global policy frameworks, while comparatively little supports the on-the-ground work these plans require (Heywood 2019). Even when resources are available, many programs become mired in prolonged preparatory steps that further delay implementation (Wirth et al. 2024). This imbalance typifies the "knowing–doing gap" (Knight et al. 2008): conservation science often identifies effective actions, yet the capacity to apply them remains limited. Long-term trends in the field reinforce this divide, with research increasingly favouring desk-based modelling and synthesis over field studies with practical application (Arlettaz et al. 2010, Ríos-Saldaña et al. 2018). The result is a growing misalignment between the production of strategies and knowledge, and the ability to implement them. But for conservation to work, it also takes people who do the work on the ground.

Community stewards: A new frontier for conservation

Where can on-the-ground conservation capacity come from? Increasing numbers of motivated non-professionals are turning to conservation on land they manage. We refer to these individuals as **"community stewards,"** analogous to community scientists (cf. Ellwood et al. 2023), but with an emphasis on action rather than data collection. Native plant gardening has become a highly visible and rapidly expanding expression of such stewardship (Fig.1 and 2). Because native plant gardeners often combine hands-on horticultural skills with solid botanical knowledge, they represent an especially promising group of potential community stewards, well positioned to spark and expand wider participatory conservation efforts.

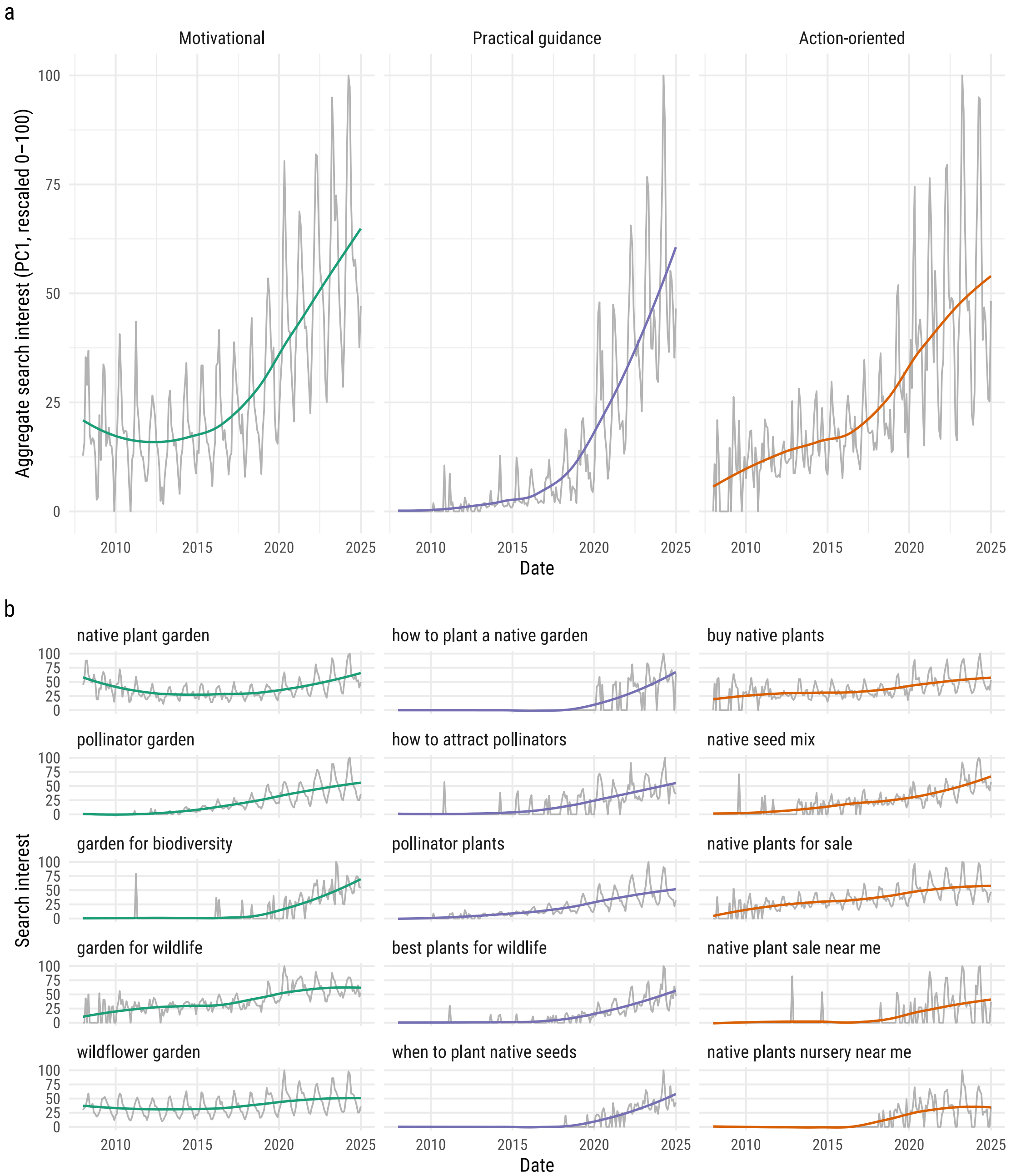

Fig. 1: **Rising public interest in native plant gardening, based on Google Trends data.** (a) For each engagement level (motivational, practical guidance, and action-oriented), a trend index was calculated by applying

principal component analysis (PCA) to five related search terms [e.g., "buy native plants" for action-oriented; see Methods S1 and (b)]. The first principal component (PC1) was min–max scaled to 0–100, representing relative aggregated search interest over time. Grey lines show monthly PC1 scores. (b) Search interest over time for individual native plant gardening terms. These terms form the basis for the PCA in (a). Each panel shows normalized monthly search volume (0–100 scale) for one term, with grey lines indicating raw values. Coloured lines in (a) and (b) show LOESS-smoothed trends. Data are based on global English-language web searches, using the "All categories" filter in Google Trends, from 2008 to 2025. For more details see Methods S1-S2.

Google Trends data show rising interest in native plant gardening across English-speaking countries. Since 2018, three indicators representing different stages of engagement (motivation, practical guidance, and action-oriented interest) have markedly increased (Fig. 1, Methods S1). In Germany, these trend patterns are also evident (Methods S1), with the nationwide initiative "Tausende Gärten – Tausende Arten" (https://www.tausende-gaerten.de/) supporting the movement by providing native plant material, practical guidance, mapping tools, and opportunities for community engagement among individuals and municipalities. Market signals reinforce the same trend. In Germany, a leading native plant nursery (Gartenbau Strickler; pers. comm.) saw steady revenue growth from the 1990s to 2016, followed by a 25% surge after the widely publicized Krefeld insect decline study in 2017 (Hallmann et al. 2017). From 2017 to 2024, annual growth averaged 14–18%, with demand consistently outpacing supply. Individual nurseries still report steady annual growth, despite growing competition from new producers entering the market post-2020. Native plant gardening appears to be moving from niche to mainstream.

Native plant gardening has been shown to foster a strong connection to nature and enhance environmental awareness (Lin et al. 2018, Beckwith et al. 2022, Hamlin and Richardson 2022, Soga and Gaston 2024). It may therefore offer a gateway to wider conservation efforts. In Germany, over 70% of native plant species are in decline, and about one-third are endangered (Eichenberg et al. 2021). As a result, many native plant gardeners—often unknowingly—cultivate declining and endangered species in their gardens (Munschek et al. 2023), gaining direct experience with their ecological needs, functions, and interactions. Native plant gardening thus not only promotes ecological literacy but already acts, in many cases, as a form of participatory *ex-situ* conservation (Segar et al. 2022, Bucher et al. 2025). In some instances, these efforts have even extended into *in-situ* conservation, as illustrated in Case Studies 1–3. Yet, to our knowledge, no study has examined whether, beyond such grassroots efforts, native plant gardening serves as a good proxy for willingness to volunteer in *in-situ* conservation.

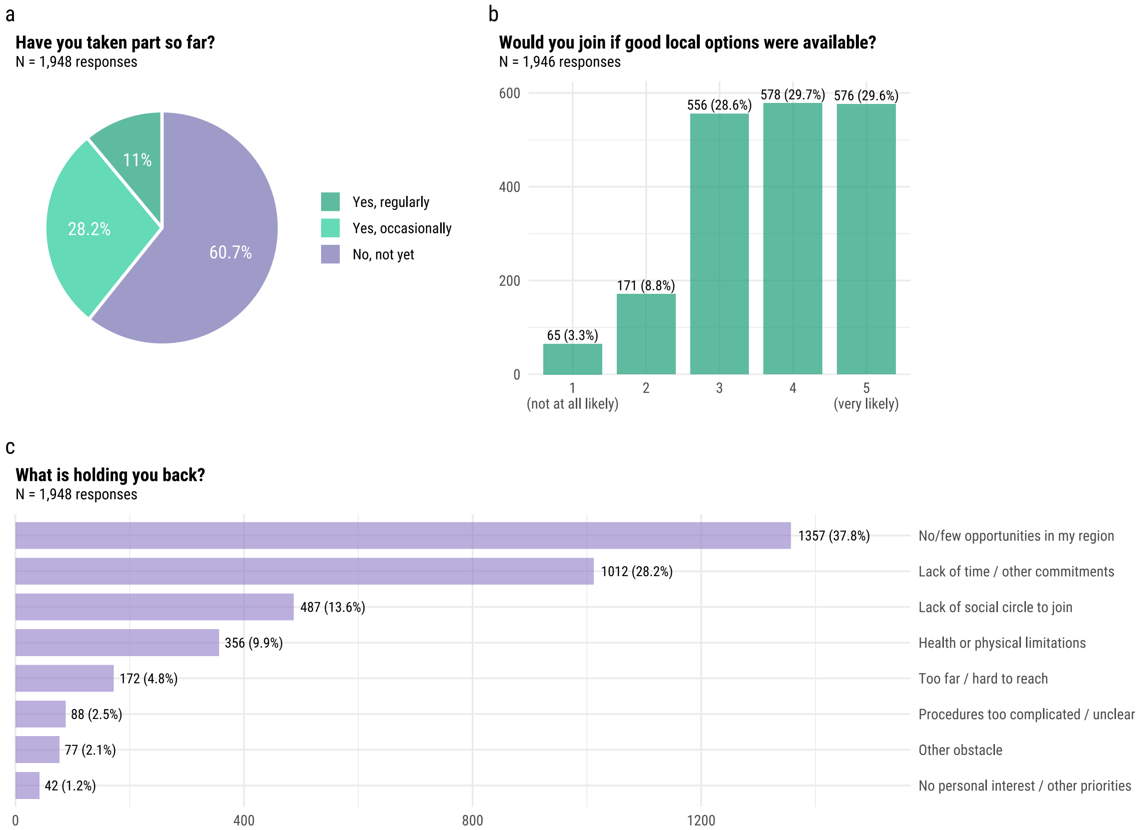

Fig. 2: **Native plant gardeners and willingness to participate in *in situ* plant conservation: potential and barriers**. Results from a questionnaire distributed via the newsletter of NaturaDB, a German native plant gardening platform, with 1,948 respondents. (a) Past participation in *in-situ* conservation activities. (b) Likelihood of joining in the next 12 months, assuming well-organized, supervised opportunities in the respondent's region (Likert scale 1–5). (c) Main barriers to (greater) participation in *in-situ* activities. For panels (a) and (b), respondents could select one option; for panel (c), up to three. Further details are provided in Methods S3.

We used a weekly newsletter from a major native-plant gardening platform in Germany, NaturaDB (https://www.naturadb.de/), which currently has around 38,000 subscribers, to distribute a short questionnaire gauging interest in plant conservation volunteering (Methods S3; Fig. S1-3). Responses from 1,948 native plant gardeners indicate that while engagement in *in-situ* activities remains modest so far (Fig. 2a), there is a strong willingness (c. 60% of native-plant gardeners) to participate if opportunities were more broadly available (Fig. 2b and c). Although some botanical gardens do offer plant conservation volunteering, these efforts are often restricted in scope, geographically scattered, and not widely publicized. Clearly, opportunities are insufficient, and volunteering in plant conservation is still far from being a normal part of everyday routines or community life (Sextus et al. 2024). The rise of native-plant gardening, together with the large share of gardeners interested in "bringing boots on the ground" (well distributed in this case across Germany; Fig. S1), points to a substantial but as yet untapped potential to scale up hands-on participation in conservation.

To facilitate participation at scale, a coordinating structure is needed that offers clear, accessible ways for people to get involved while also enabling decentralized, locally rooted conservation efforts across regions. Another challenge is establishing the requisite trust needed between conservation professionals and community stewards (Dietsch et al. 2021). Conservation professionals, especially in botanical conservation, are often cautious about involving non-professionals. Tasks like propagation, habitat management, and species reintroduction are complex (Godefroid et al. 2011), and mistakes can waste scarce resources or even harm already declining species. Scaling up participatory conservation will require both tangible, accessible opportunities and a system that builds competence and trust on all sides. Community scientists have already transformed global biodiversity monitoring (Chandler et al. 2017); in the same way, a new frontier of community stewards could expand on-the-ground capacity for both *ex-situ* and *in-situ* plant conservation if we build the right framework.

A framework for citizen-institutional collaboration

Here, we propose a framework that connects community stewards with the complementary strengths of existing institutions: (i) the scientific expertise and *ex-situ* collections of botanical gardens; (ii) the legal tools and coordination structures of species conservation programs; (iii) the horticultural capacity and distribution networks of native plant nurseries and seed producers; and (iv) the outreach power and social infrastructure of native plant gardening associations. To minimize risks, we emphasize training and certification of community stewards before they work with rare and endangered species. By aligning these sectors and building shared protocols, trust, and support systems, we can lay the groundwork for a participatory conservation framework that narrows the doing gap while ensuring that actions are both responsible and effective (Fig. 3). We draw from examples in Germany, where the institutional elements are already present but not yet systematically connected. Finally, we present a series of case studies showing that this vision is not merely aspirational.

Fig. 3: **Conceptual framework for scaling up plant conservation through community stewards.** The diagram illustrates the central role of community stewards in bridging institutional knowledge and local action. Each partner contributes complementary resources such as training, certification, legal mandates, or plant material. In return, community stewards can support conservation efforts through *ex-situ* and *in-situ* efforts, and place-based knowledge, creating a mutually reinforcing system that expands competency for plant conservation.

Botanical gardens: Centralized network hubs

Botanical gardens are well positioned to act as central hubs connecting institutional expertise and community stewards (Linsky et al. 2024). They maintain living collections of endangered plants, hold permits to collect native seeds, and employ staff with extensive propagation knowledge (Mounce et al. 2017). In some regions, this infrastructure already supports both *ex-situ* and *in-situ* conservation. In Germany, for example, a national network of five botanical gardens (the WIPs-De II project) conserves around 120 species for which Germany bears special responsibility (Wöhrmann et al. 2020). The project generates valuable knowledge: from species distributions to practical protocols for seed collection, cultivation, and reintroduction, while also building partnerships with local authorities and landowners. A public app even allows community scientists to report species occurrences to guide seed collection. Initiatives like this mark important progress in plant conservation.

Yet, given the scope of the biodiversity crisis, with hundreds of endangered species and many regional or local extinctions occurring long before species appear on a Red List, such lighthouse projects, while essential, still represent a relatively limited response. This is especially true for *in-situ* conservation, where each additional site requires sustained management, and human resources need to grow along with the number of sites (Westwood et al. 2021). Reintroduction sites, in particular, demand continuous post-planting management to ensure long-term success (Godefroid et al. 2011). Even in *ex-situ* conservation, constraints remain: botanical gardens have limited space in their living collections to maintain genetic diversity, nursery space is limited, and seed banks suspend evolutionary processes (Ismail et al. 2021). Recent studies suggest that private gardens and community participation could complement and expand these traditionally expert-led and centralized efforts (Ismail et al. 2021, Segar et al. 2022, Munschek et al. 2023, Staude 2024, Bucher et al. 2025).

Botanical gardens possess essential know-how for practical conservation efforts and already serve as critical starting points. But to drive species recovery at scale, they must be supported in taking a greater role in disseminating this knowledge, providing training, and helping decentralize conservation through strategic partnerships (Westwood et al. 2021). While outreach funding exists, it often supports general environmental education rather than the practical skills required for species conservation (Ardoin et al. 2020). This is a missed opportunity. Botanical gardens are well positioned to serve as species conservation competency centres, offering centralized training for community stewards in seed collection, propagation, *ex-situ* cultivation, and *in-situ* measures, while also providing the expertise to preserve and maximize genetic diversity in these processes. These training programs should involve additional key partners and include certification for community stewards, qualifying them to work with certain species (outlined below).

Species conservation programs: Legal mandates and regional coordination

Governmental species conservation programs represent additional key partners, as they coordinate *in-situ* action. In Germany, they operate at the state level and focus on regional priority species, documenting their occurrences and management needs. Their legal mandate enables direct coordination with landowners and local authorities, providing access to sites for monitoring, management, and reintroduction. Yet their capacity is extremely limited: reports suggest in some federal states a single officer may be responsible for around 1,150 locations and typically checks about 400 populations per year (Anja Görger, pers. comm.). Much of this expertise rests with individuals who have dedicated decades to the task, raising serious concerns about continuity as they retire. Implementation is further hampered by conflicts with land managers, who may perceive conservation measures as restrictions, and by conservation officers being frequently diverted to politically more salient issues (e.g., wolf management). Unless new collaborative models emerge, the system will likely remain overwhelmed by the scale of conservation needs.

This is where community stewards can make a difference. Acting as local experts, they provide continuity and embeddedness that institutions often lack: building trust with farmers and landowners, noticing changes in local populations, and carrying out routine monitoring or management in ways that fit into everyday life. They can also bridge divides with land managers: while large-scale farmers may resist conservation measures given limited financial compensation, part-time farmers or private landowners often take pride in supporting rare species (de Snoo et al. 2013). By partnering with conservation programs, such engagement can be channelled into legitimate, science-informed action. The programs' legal mandate allows them to carry out activities, such as seed collection or reintroductions, whilst ensuring that these are properly documented. This both lowers bureaucratic barriers for trained and certified stewards, who could act under official supervision rather than navigating regulatory procedures alone, and ensures that participatory conservation activities maintain scientific standards.

Navigating the transition toward broader community-supported coordination requires change on several levels. First, a cultural shift is needed: volunteer contributions must be valued as essential capacity rather than written off as amateur (Berkes 2004, Ganzevoort and van den Born 2023). Second, institutional reforms are required: conservation programs must evolve from overstretched individual offices into coordination hubs that broker relationships among stewards, botanical gardens, nurseries, and land managers, while delegating supervised tasks to trained stewards. Third, these shifts depend on political funding that sustains *in-situ* training, provides supervision, and covers the practical costs of participation. Finally, conservation practice must adapt by standardizing protocols that allow stewards to contribute observations, monitoring, and management in line with scientific standards. These transitions can reorient plant conservation from an overwhelmed system toward a distributed, community-supported network that brings local knowledge and daily, routine activities into conservation practice.

Native plant producers: Scaling up propagation and distribution

Native plant nurseries and seed producers are vastly underutilized partners in plant conservation. They possess expertise in propagating native species and have the capacity to produce seeds and young plants at relatively low cost. This makes them well suited to support both *ex-situ* conservation and broader ecological restoration. Yet, systemic barriers limit their contribution. Most native plant producers lack official permits to collect seeds from local wild populations of rare or endangered plants. As a result, the provenance of their seed stock is often unclear, which undermines their ability to reinforce regional gene pools. Although they play a key role in native plant production and are the primary source of material for native plant gardeners, nurseries and seed producers remain side-lined in formal conservation efforts. This is a missed opportunity. An expanded seed supply would not only support community-led conservation but also benefit restoration efforts more broadly.

Many commercial producers are eager to change this lack of integration (pers. comm. Friedhelm Strickler). Native plant producers are increasingly interested in working with botanical gardens and species conservation programs to access local provenance seed material, align with conservation standards, and meet the rising demand for regional plant material (Mainz and Wieden 2019). In turn, they could scale up the production of limited local-provenance seeds. Native plant producers could also take an active role in training community stewards by sharing propagation expertise, demonstrating techniques, and distributing seeds or young plants to participants. This would enable community stewards to practice *ex-situ* cultivation at home and develop familiarity with endangered species through direct experience (Segar et al. 2022). It would also help relieve the space constraints of botanical gardens, both in their living collections and in their nursery facilities, while at the same time enhancing genetic diversity by producing larger numbers of individuals from a wider range of seed sources (Ismail et al. 2021).

To make this vision more concrete, conservation programs and botanical gardens initiate the system by providing conditional permits, standard operating procedures, and a shared registry. Botanical gardens then supply small, provenance-verified starter lots (small initial batches of seeds or plant material) along with genetic guidance; native plant producers scale under the agreed standards and distribute to conservation program projects and certified stewards, maintaining lot-level traceability. Conservation programs coordinate land access and timing, while stewards handle planting under supervision and contribute routine monitoring. Periodic wild-source refreshes by producers and stewards under program permits prevent genetic drift (Basey et al. 2015), with all steps recorded in the registry. Costs are shared in kind: producers provide space and propagation capacity, botanical gardens contribute starter seed and oversight, and conservation programs manage permits and data. This makes producers integral to conservation supply chains while keeping governance light and auditable.

Native plant gardening networks: Activating community stewards

Native plant gardening networks provide a key initial step toward recruiting community stewards, as their members already combine enthusiasm with solid plant knowledge. Regional working groups within such networks bring place-based knowledge (e.g., contacts with landowners, awareness of potential introduction sites, or the ability to monitor populations during routine activities), foster peer-to-peer learning, enable shared stewardship, and create opportunities for social activities. In this way, they can serve as decentralized clusters that channel local knowledge directly into conservation. Germany's NaturGarten e.V. illustrates this potential. Over the past three decades, it has grown into a community of around 4,500 members, including both professionals (horticulturists, landscape architects) and private native plant gardeners. Its public Facebook group, "Naturgartenforum," now has more than 88,000 participants, and several working groups are already in place. Together, such networks hold extensive botanical knowledge and a strong commitment to species conservation (Fig. S3).

Of course, there are other potential sources of community stewards. Volunteer programs offered by botanical gardens, where they exist, can also activate stewards. Non-governmental organizations with a broad volunteer base, for example in Germany the "Naturschutzbund Deutschland (NABU)", are likewise valuable networks to tap, although participants here often do not specifically have a botanical background. More broadly, gardening is widespread in the general population. In Germany, around five million people from all segments of society cultivate allotment gardens, which are organized through associations up to the national level and can therefore be reached with regular communication (Staude et al. 2024). If conservation opportunities were to become more widespread and integrated into everyday routines, much like joining a sports club for social activity, the social diffusion that takes place through "block leaders" (Segar et al. 2022) in native plant gardening networks could extend into these broader groups interested in ecology and plants, though this remains a distant prospect.

To support such diffusion, structured incentives will be important, for example certification and a community platform where participants interact in a forum-like setting with different roles or levels of recognition. Since many native plant gardeners already seek acknowledgment through certification of their gardens, this idea could be extended to the people themselves. Unlike garden labels, which signal site-level qualities, a "Community Steward" certification would recognize individual expertise and readiness to participate in conservation (outlined below), thereby providing both motivation and recognition. As certified stewards share their experiences within these networks, peer exchange strengthens collective knowledge, and conservation literacy is likely to grow and spread across different networks. Ultimately, the aim would be to build a platform that both fosters community and serves as the central place to access organized conservation opportunities organized by regions, ranging from entry-level volunteering to certified stewardship roles.

Training, certification and safeguards

Scaling up science-informed participatory conservation requires not only willingness but also competence and safeguards. We propose a two-tier system organized through a central community platform for participatory conservation. This platform serves as an entry point where interested people can find and join organized volunteer opportunities. At the entry level, basic stewards might engage in low-risk activities such as planting common native plants, maintaining habitats (e.g., weeding, mowing), helping with logistics and event organization, monitoring common species, or supporting outreach. These activities require only a brief orientation and are carried out under the oversight of conservation programs or certified stewards. A smaller group of stewards would progress to full certification, which authorizes them to handle sensitive material such as rare species (see below) and to coordinate regional volunteer efforts. To reach this level, stewards must complete training that ensures they can work responsibly with rare and endangered species.

Training would draw on the strengths of the different sectors to equip stewards with core competencies. Botanical gardens could act as central training hubs, offering instruction in seed collection, propagation, *ex-situ* cultivation, and conservation etiquette, with a focus on preserving genetic diversity. Conservation programs would provide species-specific knowledge and practical management skills, combined with site visits and field work. Native plant producers could supply plant material and cultivation expertise, enabling stewards to gain experience with target species in their own gardens. Training would also cover monitoring and documentation using agreed standards and digital tools, alongside modules on data ethics and information sensitivity to prevent misuse of occurrence data (Soroye et al. 2022). Elements of such curricula already exist: the Center for Plant Conservation offers its Rare Plant Academy (https://saveplants.org/cpc-rare-plant-academy/), which provides online resources on a wide range of plant conservation practices and could be built upon.

After completing training, participants would undergo an assessment leading to certification. This process could follow audit-based models, beginning with a guided self-assessment and culminating in an evaluation by an accredited body, including both a written exam and practical demonstrations in the field. As part of certification, stewards would sign a code of conduct specifying their responsibilities in handling rare species and sensitive occurrence data. Certification would authorize specific responsibilities: (i) access to sensitive occurrence information on rare and endangered species, (ii) assist with propagation and *ex-situ* cultivation, including in their own gardens, (iii) participate in habitat management for specific species, (iv) contribute cultivated material for reintroduction trials in coordination with conservation programs, and (v) document all activities, including where wild-provenance material is planted *in-situ* or *ex-situ*, in a secure system accessible to authorized partners. In this way, competence, accountability, and safeguards are embedded into the system.

Emerging roles of community stewards: evidence from three case studies

In the framework we propose, collaboration follows a clear agenda: (i) systematic monitoring of endangered species to establish baselines, with stewards contributing local observations; (ii) propagation and *ex-situ* testing, with nurseries scaling up plant material, botanical gardens ensuring genetic diversity and running controlled trials to guide best practices, and stewards gaining hands-on experience through cultivation in their gardens; and (iii) reintroduction into local habitats, coordinated with landowners and conservation programs, with stewards supporting planting, management, and monitoring. While not yet organized at scale, elements of this pathway are already visible. In Germany's Black Forest, three case studies show how native plant gardeners have begun to act as community stewards: monitoring species, maintaining *ex-situ* populations in private gardens, collaborating with nurseries on propagation, and working with conservation programs on reintroductions and management (pers. comm. Ralf Engel).

Fig. 4: **Case studies illustrating how community stewards already contribute to *in-situ* (and *ex-situ*) conservation.** a–d: Silver thistle (*Carlina acaulis* ssp. *caulescens*). A relict population persists where mowing is difficult (a, b). Seeds were harvested, propagated by nursery (c), and reintroduced (d). e–i: Tufted loosestrife (*Lysimachia thyrsiflora*). Plants were successfully introduced to a suitable wetland (f-h) from an *ex-situ* private garden population (i). j–m: Bog pimpernel *(Anagallis tenella*). One of the last known occurrences is hand-managed with a scythe (j). The species is easily outcompeted and depends on moist, nutrient-poor sites (k), which are rare. It was introduced to new suitable sites (l) and also thrives in private *ex-situ* cultivation (m), representing a potential conservation reservoir.

Case 1: Silver thistle (*Carlina acaulis* ssp. *caulescens*; Fig. 4a-d) is a dry-grassland species that disappears quickly when sites are left unmanaged or converted to meadows, persisting only under a single late-season cut. Near where a community steward lives, a range-edge population is considered locally endangered. Today it persists in just two small meadow populations totalling 78 individuals, located mainly along field edges. While these populations were assumed to be stable in the short-term, consistent monitoring by the steward revealed an ongoing decline, information that would otherwise have been missed without regular on-the-ground presence. An initial steward-led propagation attempt, coordinated with the regional conservation program, failed due to premature seed collection. With guidance from a nearby native plant nursery familiar with the species' reproductive biology, the process was repeated correctly the following year. Seeds were collected from multiple individuals across the population to capture available genetic variation, propagated in the nursery, and sown in autumn, yielding 43 healthy seedlings that were reintroduced to the meadow. Only one survived. A third attempt, using older seedlings with more developed root systems, markedly improved survival in the field. This case illustrates several components of our framework. First, it shows how steward-led, routine monitoring can detect declines that would otherwise go unnoticed. Second, it highlights that successful reintroductions require horticultural expertise: nursery involvement was key, and early guidance from a botanical garden could have helped avoid missteps. Third, it underscores a component not fulfilled here—genetic assessment and management—typically coordinated by botanical gardens. Although seed was collected across the population, the small source size means a genetic bottleneck remains a risk. Genetic studies would help assess this risk, and, where permitted, supplementation with seed from other nearby Black Forest populations (coordinated by botanical gardens and propagated at scale by native-plant producers) could maximize genetic diversity and improve long-term population viability.

Case 2: Tufted loosestrife (*Lysimachia thyrsiflora*; Fig. 4e-i) had not previously been recorded in the Black Forest region until a community steward unexpectedly discovered and rescued a small population. They noticed an unusual, exotic-looking plant in a wet meadow and collected a small vegetative stem fragment with roots for identification. Rather than discarding it, they placed it in their garden pond, where it survived and eventually thrived. Meanwhile, the wild population from which it originated disappeared, leaving the garden population as the only remaining material in the region. Later, with permission from the regional conservation program, individuals from the garden population were successfully introduced into a suitable wet meadow. The steward identified the site, a former golf course, in consultation with the conservation program and secured landowner permission. On the one hand, the steward's initiative prevented the regional loss of an otherwise undocumented population, with a private garden serving as an *ex-situ* refuge that later enabled reintroduction under the oversight of a conservation program. Local knowledge was essential both for identifying a suitable site and for securing landowner permission. On the other hand, the entire stock derives from a single clone, creating an extreme genetic bottleneck. Moreover, although the effort was documented by the steward, it is not registered in a centralized repository, leaving the information scattered and its long-term availability uncertain. This case illustrates why two elements embedded in our framework are necessary: (i) establishing protocols and repositories so that information on ad hoc rescues is systematically captured and available for future decisions; and (ii) addressing genetic diversity in the training and certification of stewards. It also shows why coordination among stewards, botanical gardens, conservation programs, and native-plant producers would strengthen participatory efforts. Stewards contribute local site knowledge, regular on-site presence, landowner relationships, and hands-on cultivation capacity, and can act quickly to prevent loss, even when genetic limitations remain. These near-term actions buy time for more robust strategies in which institutional partners assess, preserve, and, where possible, maximize genetic diversity, helping to ensure long-term success.

Case 3: Bog pimpernel (*Anagallis tenella*; Fig. 4j-m) is on the brink of extinction in Germany. At one of only three known remaining sites, a community steward partnered with the regional conservation program to manage a wet meadow. During mowing, excised shoot fragments were redistributed across similar microhabitats (meadow swales), leading to two new stable populations over five years, both maintained through biannual management and documented in location. Supervised by a conservation program officer, the steward also experimented with small-scale soil disturbance, which appears to benefit the species. This optimized management is now planned for implementation in one of the remaining sites. The steward also maintains an *ex-situ* garden population, established under permit from wild-provenance material. This case illustrates multiple components of our framework. First, it highlights the value of oversight: conservation programs can expand their capacity by guiding and legitimizing steward-led habitat management. Second, it shows how such collaborations can generate new ecological knowledge, here about disturbance regimes that improve persistence. Third, the *ex-situ* garden population represents a potential conservation reservoir, even though genetic options remain constrained given the few remaining wild populations in Germany. Within our framework, botanical gardens could strengthen such efforts by verifying and recording such decentralized *ex-situ* populations, assessing their genetic value, and linking them to *ex-situ* conservation databases. In this way, steward-maintained populations would not remain isolated efforts but become part of coordinated species recovery planning. Nurseries could further contribute by multiplying these *ex-situ* stocks, and because *A. tenella* is relatively easy to cultivate *ex situ*, garden populations, if expanded, could provide a steady supply of plant material to secure the species' future.

Way forward

The case studies highlight that native plant gardening communities hold community stewards with the skills, commitment, and local knowledge to contribute meaningfully to conservation. The challenge now is to transform this scattered engagement into a coordinated network that structurally supports plant conservation. We argue that this requires treating stewardship not as a side activity but as societal infrastructure. Just as the Global Biodiversity Information Facility has become the backbone for community-science infrastructure and global biodiversity data, a European Stewardship Network could provide the backbone for community-based conservation, for people instead of data. Each country could host stewardship centres, anchored in botanical gardens, that provide training, certification, and support. These centres would build skills and connect stewards to national conservation priorities, from Red List species and habitat restoration to reintroduction programs. In this way, every hour a steward invests becomes part of a measurable, policy-relevant contribution.

For such a system to succeed, continuity is essential. Stewardship centres cannot depend on short-term projects but need structural funding. Conservation ministries and EU biodiversity strategies could earmark funding for participatory conservation as a complement to protected areas. In practice, this could mirror long-standing advisory systems in agriculture, for example, in Europe through the farm advisory systems embedded in the Common Agricultural Policy's Agricultural Knowledge and Innovation Systems. These provide farmers with permanent, publicly funded support services that ensure that scientific knowledge is translated into on-the-ground practice. In the same way, stewardship centres could serve biodiversity by convening networks, turning science into practical guidance, and ensuring accountability through standardized training and reporting. By integrating stewardship into policy and funding frameworks, plant conservation could become a normal and accessible societal activity, where knowledge expands, rather than remaining a centralized preserve of experts.

Botanical gardens would anchor the system by coordinating genetic and horticultural expertise, developing cultivation protocols, and providing training. Conservation programs would ensure oversight and alignment with policy priorities. Native plant producers, working closely with botanical gardens, would expand *ex-situ* capacity and scale up plant material for restoration and reintroductions. And gardeners, as stewards, would supply the on-the-ground continuity and local knowledge that no institution can match. Together, these actors would form a distributed network that builds science-informed conservation capacity at scale.

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Supplementary Material for

A new participatory conservation framework built on the rise of native plant gardening

Contents

Methods:

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Methods S1: Google Trends data

We used Google Trends as a proxy for public engagement with native plant gardening, asking: if someone wanted to make their garden more biodiversity-friendly, what would they type into Google? Google Trends tracks search activity as an indicator of public curiosity, attention, and topic, providing monthly data since 2004 (Phillips et al. 2022, Hölzl et al. 2025). The 'interest over time' index measures relative search volume on a scale from 0 to 100, where 100 represents peak search interest and all other values are calculated as (search volume at time t / maximum search volume) × 100.

We conducted searches across "All categories" and worldwide. All keywords were in English, and we did not use Google's "Topics" feature, as the method by which Google aggregates search terms into topics, and whether this method has changed over time, is not publicly documented. We obtained trend data from Google Trends between March and April 2025. Although Google Trends data are available from 2004 onward, we restricted our analysis to the period from 2008-01-01 to 2025-01-01. In 2008, Google introduced the auto-complete feature, which suggests query completions based in part on the searches of other users (Hölzl et al. 2025). This feature introduced potential search externalities, making individual search behavior partly dependent on collective patterns (Lazer et al. 2014). As a result, some recommended queries may have experienced substantial increases in search volume, complicating direct comparisons between search trends before and after 2008.

We aimed to select keywords reflecting three levels of engagement with native plant gardening: motivation, practical guidance, and action-oriented behavior. Motivation terms introduce the broader topic, practical guidance terms offer "how-to" information, and action-oriented terms relate to acquiring relevant (native plant) material. We began by compiling a list of potential search terms using Google's autocomplete and "related searches" suggestions (conducted in Incognito mode with English language settings) as well as drawing on personal expertise. Each candidate term was evaluated for relevance to the theoretical construct, specificity, ambiguity, and search volume. Terms that were too broad (e.g., "sustainable gardening"), too technical or niche (e.g., "ecological horticulture"), ambiguous (e.g., "garden insects"), or regionally biased (e.g., "xeriscape") were excluded. To minimize the risk of polysemy and unrelated search noise, we reviewed the "related queries" provided by Google Trends for each keyword; if unrelated, off-topic results appeared, the term was discarded in favor of clearer alternatives. We generally used straightforward terms that reflect typical user behavior, avoiding advanced search operators (e.g., plus and minus signs) to modify queries.

We ultimately selected 15 keywords, with five representing each engagement level: motivation ("native plant garden", "garden for biodiversity", "garden for wildlife", "wildflower garden", "pollinator garden"), practical guidance ("how to plant a native garden", "how to attract pollinators", "when to plant native seeds", "best plants for wildlife", "pollinator plants"), and action-oriented behavior ("buy native plants", "native seed mix", "native plants for sale", "native plant sale near me", "native plants nursery near me"). Note that our selection of search terms is not comprehensive. We focused on English-language terms with expected or observed search volume, excluding conceptually relevant terms that lacked meaningful search activity.

Any selection of keywords is inherently selective and not exhaustive. Nevertheless, the terms we selected each capture important aspects of public engagement with the native-plant gardening movement and can be used to infer broader patterns of interest. It is also noteworthy that terms in other languages, such as the German "Naturgarten," which describes the native-plant gardening movement in Germany, can similarly indicate positive trends[1].

[1] https://trends.google.com/trends/explore?date=2008-01-01%202025-01-01&geo=DE&q=naturgarten

Methods S2: Aggregating search terms by engagement category

To summarize temporal trends in public interest across related search terms, we used principal component analysis (PCA) to construct a single, aggregate index for each of three engagement levels: motivational, practical guidance, and action-oriented (see Methods S1 for terms). PCA was applied separately to the time series of search volume for each engagement level, using the *prcomp()* function in base R. Although Google Trends data are normalized to a 0–100 scale per term, we applied centering and scaling prior to PCA to ensure that differences in mean and variance across terms did not bias the resulting components. The first principal component (PC1) was extracted in each case and interpreted as the dominant shared trend in public interest across all five terms within that engagement level. PCA was chosen over simple averaging to ensure that the index reflects shared temporal dynamics rather than dominance by any single keyword. PC1 scores were then linearly rescaled to a 0–100 range using the formula $(x - \min(x)) / (\max(x) - \min(x)) \times 100$.

Methods S3: NaturaDB survey

NaturaDB is a German native-plant gardening platform that provides resources on several thousand species, including cultivation guidelines and information on associated insects. The platform has a weekly newsletter with ~38,000 subscribers. On 24 August 2025, we launched an online questionnaire via Google Forms (in German; available at: link). Responses were collected until 26 August 2025 (12:00 CEST). In total, 1,948 people responded. The full dataset is available via Google Sheets (link), and the R code used for data visualization and analysis is available on GitHub (link).

The survey was conducted anonymously. To assess both the potential and barriers to participation in *in-situ* plant conservation, we asked the following three main questions (original German wording and English translations provided):

1. Past participation: *Hast du dich bisher schon an Maßnahmen zum Schutz von Wildpflanzen in der Natur beteiligt?* ("Have you previously taken part in activities to protect wild plants in nature?")
2. Conditional willingness: *Angenommen, es gäbe in deiner Region gut organisierte und betreute Mitmach-Möglichkeiten – wie wahrscheinlich wäre es dann, dass du in den nächsten 12 Monaten mitmachst?* ("If there were well-organized and supervised opportunities in your region, how likely would you be to participate within the next 12 months?")
3. Barriers: *Welche Gründe halten dich aktuell davon ab, dich (stärker) direkt in der Natur für Wildpflanzen zu engagieren?* ("Which factors currently hold you back from getting involved (more) in in-situ conservation for wild plants?")

For Questions 1 and 2, respondents could select a single option; for Question 3, up to three options could be selected (Fig. 2).

Additionally, respondents were invited to optionally provide their postal code (for mapping responses across Germany, Fig. S1), indicate whether they would be open to training, specify how much time they could commit, report their age (Fig. S2), and answer self-assessment questions on their identity as native-plant gardeners and their concern for native-species conservation (Fig. S3).

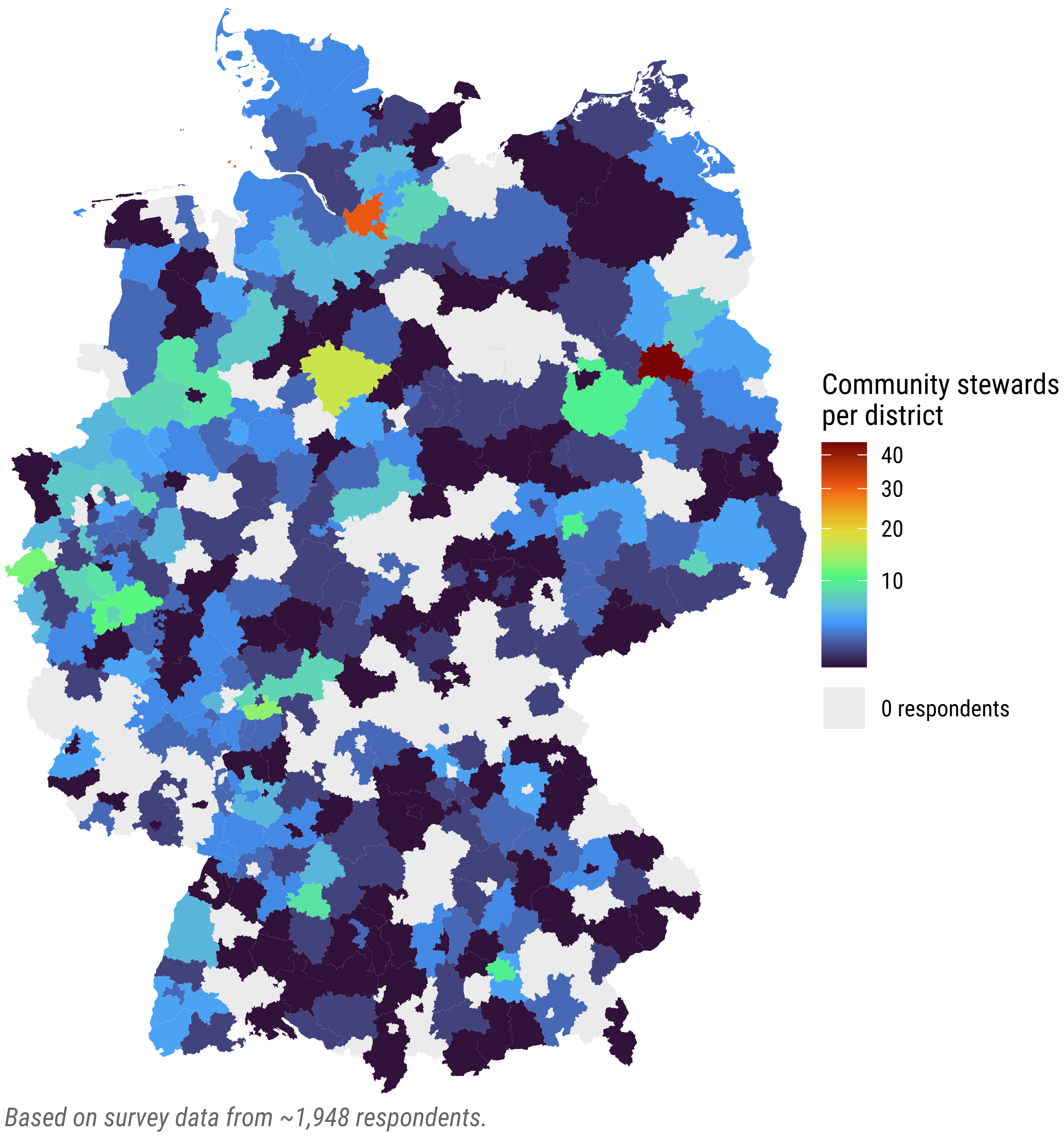

Fig. S1: **Distribution of potential community stewards across Germany based on a survey with 1,948 respondents.** The map shows, at the district level (German: Landkreise), the number of participants who indicated conditional willingness to engage in plant conservation (Methods S3), responding with 4 ("likely") or 5 ("very likely") on a Likert scale from "not at all likely" to "very likely." Respondents provided 5-digit postal codes, which were aggregated to the Landkreis level. Grey districts indicate areas without survey responses or with no reported willingness to engage.

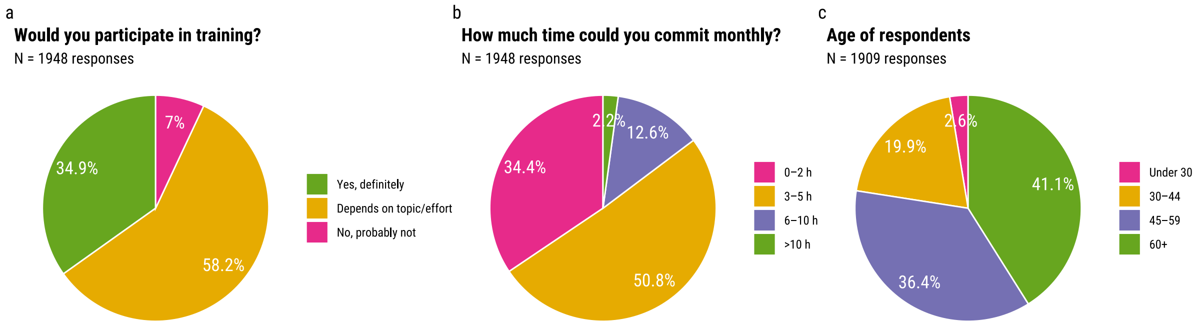

Fig. S2: **Willingness to participate in training, time respondents could commit per month, and age distribution among native-plant gardeners.** (a) Question in German: *"Wärst du grundsätzlich interessiert, an einem Training teilzunehmen, um beim Schutz von Wildpflanzen in ihren Lebensräumen mitzumachen?"* (English: "Would you, in principle, be interested in taking part in training to help protect wild plants in their habitats?") (b) German: *"Wie viel Zeit könntest du dir im Durchschnitt pro Monat für Mitmach-Aktivitäten vorstellen?"* (English: "On average, how much time per month could you commit to hands-on conservation activities?"), and (c) Age of respondents; this item was optional (non-mandatory).

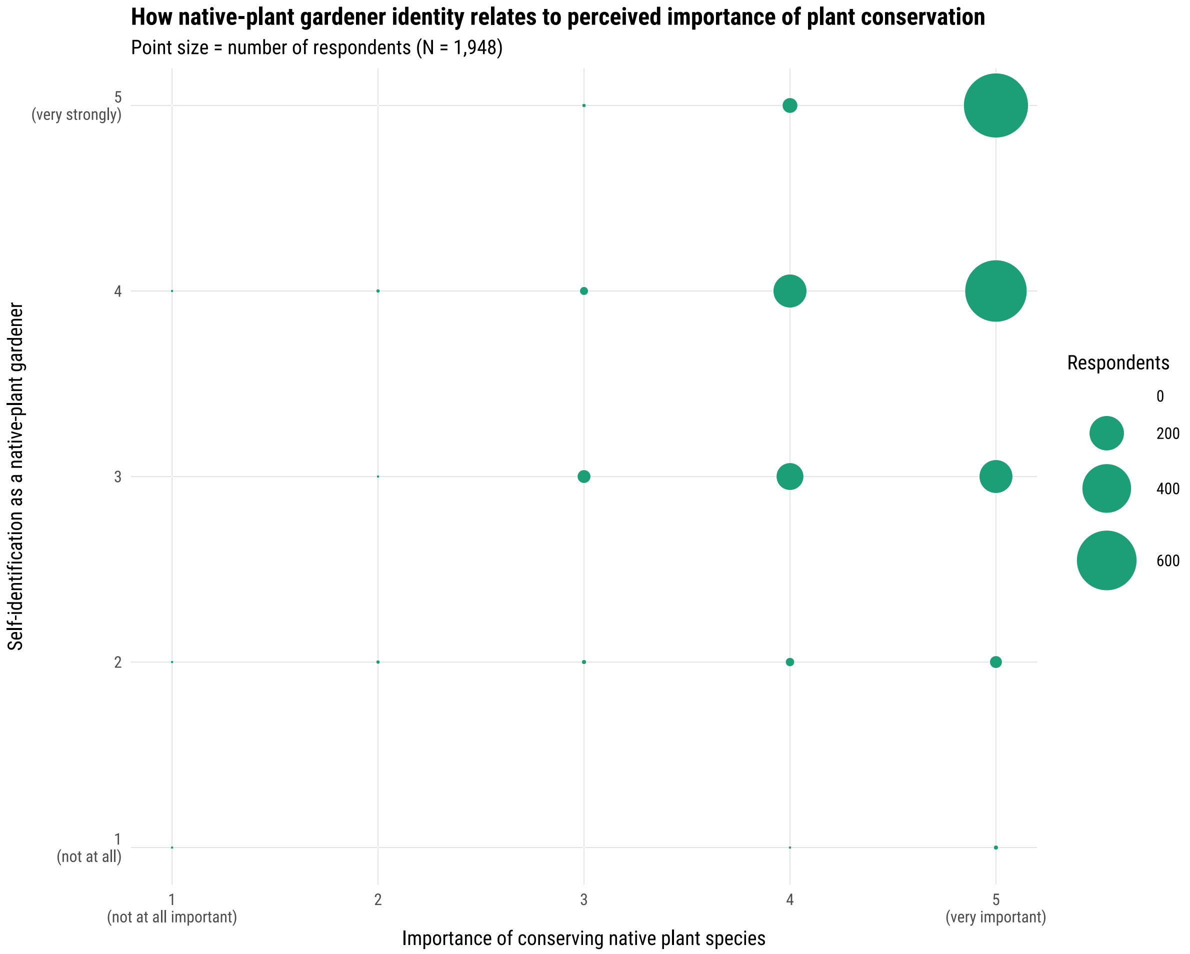

Fig. S3: **Relationship between self-identification as a native-plant gardener and the perceived importance of conserving native plant species.** Each point represents one combination of the two Likert ratings (1–5); point size is proportional to the number of respondents selecting that combination (N = 1,948 complete responses). X-axis: importance of plant conservation, 1 = not at all important, 5 = very important. Y-axis: identity as a native-plant gardener, 1 = not at all, 5 = very strongly. Empty cells indicate zero respondents.

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