npj | urban sustainability

Article

Published in partnership with RMIT University

https://doi.org/10.1038/s42949-025-00252-6

Schoolyards greening for connecting people and nature: an example of nature-based solutions?

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In response to climate change, cities are increasingly implementing nature-based solutions (NbS) like schoolyard greening. This study investigates the Parisian OASIS program—a large-scale initiative to renature schoolyards—through arthropod biodiversity surveys and interviews with 21 stakeholders. Findings reveal that green schoolyards host diverse arthropod communities, comparable to those in urban green spaces, contributing to ecological connectivity and multispecies justice. However, realizing their full potential requires significant shifts in urban governance, long-term management, and inclusive social appropriation. Justice is key: ensuring all school communities—especially marginalized one—benefit equally from green infrastructure. The success of these NbS depend on biodiversity-informed practices and sustained engagement from educators, students, families, and city officials. By integrating justice into design and implementation, green schoolyards can become transformative spaces for more equitable and inclusive NbS in urban environments.

The growing challenges posed by climate change, frequent heatwaves, and increasing pollution have spurred global efforts to 'green' cities and improve their resilience[1,2]. Among these strategies, Nature-based Solutions (NbS) have emerged as a key framework to address urban environmental challenges by leveraging natural systems[3–5].NbS are currently defined as "*actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits*[6]" (p. 7). Urban areas are increasingly recognized as critical sites for implementing Nature-based Solutions (NbS), which provide essential ecosystem services through enhanced biodiversity and ecological connectivity, but also generate disservices[7,8]. These green spaces significantly contribute to public health by promoting physical activity, improving psychological well-being, and enhancing overall quality of life. Furthermore, NbS are valued for their potential to reshape the relationship between urban residents and nature[9,10]. Beyond managing local ecosystems, NbS can foster community engagement in decision-making processes and promote a more equitable distribution of environmental benefits[11]. Effective governance of NbS must therefore operate across multiple scales—from individual sites to neighborhoods and cities—while integrating social, economic, and ecological dimensions[12]. However, research consistently shows that such spaces are often unevenly distributed, with more affluent communities disproportionately benefiting[13]. A more comprehensive understanding of justice includes not only distributive outcomes, but also procedural justice (participation, recognition) and empowerment during NbS implementation[14]. Crucially, NbS should be developed through inclusive and participatory planning processes that actively involve local stakeholders, especially marginalized communities. Nevertheless, participatory processes are not immune to power imbalances and frequently fall short of their promises[15]. One of the key critiques of NbS is their often overly solutions-oriented framing, which can obscure deeper issues related to values, symbolic meanings, and governance processes. When applied narrowly, NbS risk reinforcing a separation between humans and nature, rather than fostering more integrated, just, and transformative relationships[16].

The greening of schoolyards has emerged as a flagship initiative for experimenting with NbS, in part due to the complex roles these spaces play—educational, recreational, and environmental[17,18]. In addition to addressing multiple socio-environmental challenges, including climate change, schoolyard NbS incorporate various dimensions of justice. These include implementation across diverse school environments, participatory design processes, recognition of children's diverse needs, and a strong emphasis on education. Traditionally designed for play and learning, schoolyards are now being reimagined as urban spaces for climate resilience, equitable

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access to nature and environmental education[19]. In this context, the co-production of NbS in schoolyards—through the engagement of teachers, children, parents, and local communities—holds promise for fostering inclusive approaches to urban sustainability, with potential benefits for both people and ecosystems[20].

Upscaling schoolyards greening is not just a matter of multiplying a number of green facilities. Upscaling[21] refers to the ways in which NbS can be deployed more widely and generate genuinely transformative change at different scales of time and space, engaging stakeholders of different status and professional sectors[22]. Different authors[23] promote NbSs, and their scaling up, as drivers of climate change adaptation. This is all the more difficult as the implementation of NbS requires considerable consideration of the context, both environmental and social. In schoolyards greening, scaling up is a major challenge, not only to extend this strategy to all schools, but above all to participate in transforming the administrative and educational cultures of these areas. In other terms, transforming the teachers' pedagogical program and habits as well the appropriation of schoolyards and surroundings could contribute to widen the stakeholder's participation.

Consequently, the evaluation of NbS, including schoolyards, may involve equity and justice issues, civic participation, well-being and health. And yet, even today, most evaluation relate to biodiversity and ecosystem services[3–5]. This underscores the need for a broader evaluation that avoid technomanagerial biases by enabling communities to shape how NbS can offer equitable and resilient responses to climate change. Developing such assessments necessitate an interdisciplinary and transdisciplinary approach, involving stakeholders from civil society (such as naturalist collectives but also social stakeholders) and ensuring co-production with end-users[12,24–26].

In this paper, we examine how the greening of schoolyards—originally introduced to mitigate urban heat islands and enhance climate adaptation—also advances broader NbS goals, such as promoting urban biodiversity, transforming social-ecological systems, and strengthening human-nature relationships underlining the challenge of conjointly addressing them[27]. We hypothesize that scaling up NbS requires a dynamic interaction between physical changes (like biodiversity-friendly landscaping) and shifts in social practices and perceptions, particularly among key stakeholders such as administrators and educators. We assumed that the presence of spontaneous biodiversity, not originally anticipated, plays a crucial role in informing policy-making decisions, to influence stakeholders and highlight opportunities for expanding NbS. This creates a positive feedback loop between policy discourse, intentions, and biodiversity outcomes. As biodiversity metrics as well as city-dwellers well-being inform urban policies, subsequent greening initiatives reinforce nature's role in urban planning, driving further policy adaptations and fostering the development of governance approaches that integrate nature for more sustainable and resilient cities.

We explore three main research questions and their associated hypotheses:

1. **How does the socio-technical production of nature in schoolyards occur?** We hypothesize that the complexity of school environments, which involve multiple actors (children, teachers, administrators, parents, etc.), poses challenges for the collaborative management and scaling of NbS. The success of NbS in these contexts depends on the ability of these diverse actors to adapt their routines, coordinate their efforts, and align their sometimes-competing values. However, we expect that stakeholder groups have interests or values that may not be aligned, or may even conflict[28].
2. **What is the ecological contribution of renaturing schoolyards?** We hypothesize that, although biodiversity might not be the primary objective of these initiatives, schoolyards can serve as small habitats that contribute to urban biodiversity, supporting species diversity, and potentially acting as stepping-stones between larger green spaces. In this perspective, schools are expected to have relatively similar levels of abundance and richness to green spaces, and the communities in both types of space to be similar (i.e., suggesting that connections and flows of non-human animals and vegetation are possible).
3. **How do schoolyards function as privileged places for human–nature interactions?** We hypothesize that the implementation of NbS in schools reshapes the use of these spaces, promoting a diverse range of activities—from free play to creative and environmental education—that fosters a stronger connection between children and nature[29]. This in turn may influence broader societal perceptions of nature and drive the scaling up of NbS beyond school settings, serving as models for larger urban NbS implementations.

Therefore, the socio-ecological transformation of schoolyards—driven by their redesign—entails addressing a wide range of changes that affect children, teachers, administrative staff, and parents alike. This transformation engages with critical issues related to both individual and collective well-being, spatial justice in access to green infrastructure across urban neighborhoods, and the equitable redistribution of schoolyard spaces to inclusively serve all children through participatory design and empowerment[30]. Socio-ecological transformation is understood as being place-based and ecologically grounded, while also involving institutional change and cultural evolution.

To address these research questions and hypotheses, we adopt an interdisciplinary methodological approach that integrates ecological assessments with social science perspectives. This approach allows us to examine both the biodiversity present in schoolyards and the representations, practices, and interactions of the various stakeholders involved in these spaces. By combining species inventories with semi-structured interviews, we aim to connect the quantitative and qualitative dimensions of NbS. Specifically, we explore the diversity and abundance of biodiversity, the practices used to design, manage, and maintain this biodiversity, and the stakeholders' perceptions and uses of these green spaces.

The interdisciplinary nature of this approach is crucial for several reasons. First, it enables us to capture the complex ecological processes involved in renaturing schoolyards, while simultaneously analyzing how social and administrative practices influence these processes. Second, it allows us to examine the socio-technical production of nature from both ecological and stakeholder perspectives, revealing how different actors contribute to or hinder the success of NbS. Finally, this comprehensive approach provides a deeper understanding of how schoolyards function as experimental spaces for human–nature interactions, highlighting the ways in which ecological and social dimensions interact to shape the success and scalability of NbS. Our case study, focused on the greening of schoolyards in Paris, France through the OASIS program (Fig. 1), provides an ideal setting to explore these interdisciplinary dynamics.

Results

Modalities of the socio-technical production of nature in school grounds

The Paris schoolyard greening project spans several years, engaging a broad range of stakeholders throughout its implementation. The Paris City Council primarily relies on its central (e.g. DEVE) and local (e.g. SEJ) services to design, implement, and manage the project. Each of these three main stages involves a diverse range of stakeholders and services (Fig. 2). Initially, the district council and the school and early childhood affairs division (CASPE) select schoolyards for the project based on two criteria: the level of dilapidation of the schoolyard and, less frequently, existing proposals from the city's participatory budget. Once a schoolyard and the budget are approved for inclusion, the project moves into a co-design phase involving children, teachers, school staff and various experts, including the Council for Architecture, Urban Planning, and Environment (CAUE), landscape architects from the Public buildings and architecture department (DCPA) and section (SLA) and council services (school affairs, early childhood, cultural affairs, green spaces, youth and sport, etc.).

The CAUE de Paris is offering each school concerned an opportunity to co-design the future playground, the first stage of co-design being with the school's children. The aim of the workshops with the children is to come up



Fig. 1 | Example of three OASIS schoolyards 1. École Merlin 11th arrondissement 2. Collège Courteline 12th arrondissement 3. Collège Guillaume Budé 19th arrondissement. Source: Recca Maccia.

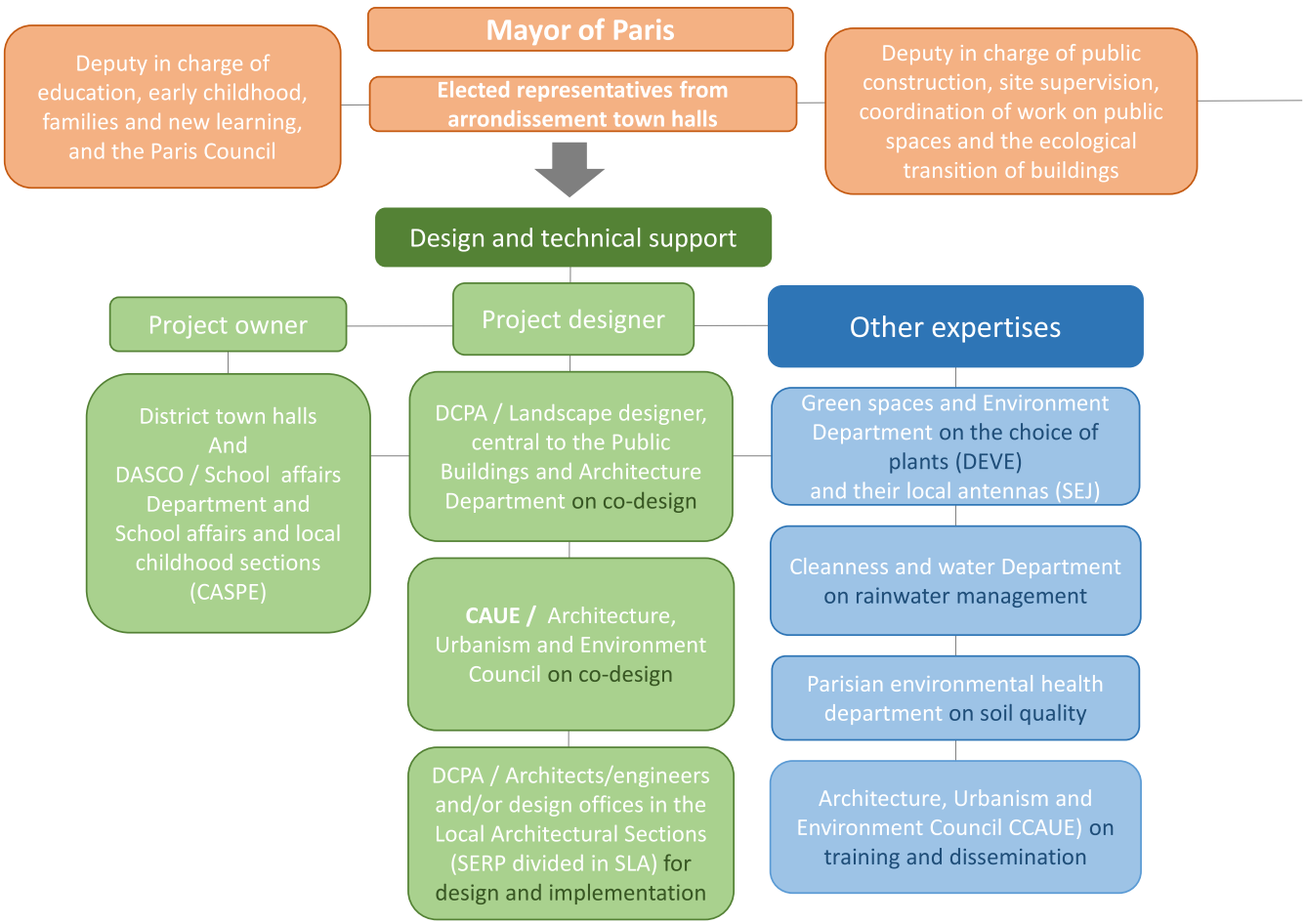


Fig. 2 | Diagram of the services involved in the Oasis project in Paris. Source: Cedissia About, 2023.

with design recommendations using a project-based approach. Raising awareness of the challenges of climate change and providing references help them to materialise their intuitions and understand the main challenges of a playground. The workshops are then used to establish a diagnosis of the uses of the playground, based on observations and surveys carried out by the children, and to draw up proposals for future developments using scale models.

Then consultation workshops bring together the head of the school, the teachers, the City of Paris, the education officer and the after-school care staff, as well as, if possible, the maintenance staff, the parents, the school doctor and psychologist, the caretakers. These workshops are devoted to report back on the children's work and make proposals for development scenarios arising from the workshops, to take account of the technical constraints formulated and to finalise, with SLA, the technical layout. In

parallel with the consultation workshops, a series of return visits are made to the operational departments of the City of Paris (SLA and CASPE). Recommendations are formulated by the CAUE based on the initial ideas put forward by the children. This collaboration is critical, as around January each year, a two-day project review occurs to discuss the 25 projects slated for the upcoming summer, focusing on technical challenges and assessing the ecological adequacy of the designs.

Despite this collaborative framework, communication can be challenging due to the diversity of involved services, and some stakeholders, such as maintenance staff, teachers, and local community members, often feel overlooked. The DCPA, along with its decentralized services, has been designated by the City Council to coordinate the greening efforts, leveraging its expertise in asset maintenance. However, the green spaces and environment Department (DEVE) faces staffing shortages that limit its capacity to oversee these projects effectively, as the demand for management of public green spaces continues to grow. Consequently, the decision to have the DCPA oversee the Oasis schoolyards necessitates the development of naturalist knowledge and expertise among all involved services.

The management of Oasis schoolyards varies across different schools. Typically, the CASPE assumes responsibility for cleaning and maintenance, serving as the primary contact for schools in case of issues. In some instances, teaching staff actively engage pupils in the daily cleaning of the playground. The DEVE may intervene through its decentralized services when necessary. Effective management requires a broad range of expertise, necessitating collaboration between both central and decentralized services, such as CASPE and SLA. However, challenges arise due to insufficient communication and staffing constraints, which hinder the coherence of the project.

Historically, management issues have been overlooked, though the School Affairs Department (DASCO) is now making efforts to involve DEVE in the management of some schools. Nevertheless, two thirds of the sampled schools remain unclear about whom to contact for support. Additionally, the management of vegetation has not been adequately planned, as school visits indicate that the responsibility for planting cannot fall solely on administrative and teaching staff, who often lack the necessary expertise and face increased workloads. This highlights the critical need to clarify the governance structure for managing Oasis schoolyards, particularly during the operational phase.

Initially, the Oasis school grounds project did not prioritize extensive greening efforts. However, a significant shift occurred after Parisian teams visited their counterparts in Brussels, where the focus was on "bringing nature back into the city" and reconnecting children with their natural environment (as explained by SERP Public-access facilities department). The Paris team including civil servants from the city hall as well as the CAUE was inspired by the extensive transformations in Brussels that emphasized vegetation while still achieving the goal of creating cool areas. They observed that replacing tarmac with permeable materials not only improved the environment but also proved to be more cost-effective: "if you take away the tarmac and replace it, as we had done, with light, draining ground, it improves things. And if you replace it with earth and vegetation, it works even better. And incidentally, it's cheaper than the materials." (SERP). As a result, from 2020 onwards, the project specifications have been revised to give priority to more vegetation than in previous years, placing greater emphasis on biodiversity than originally intended, even if, according to the SERP, this is not necessarily easy. NbS are interesting as long as they are related to anthropocentric considerations. In fact, children's well-being is a key argument used by the City Council to gain support for the transformations from both departments and school staff. As one Oasis project manager from the CAUE explained: 'It shouldn't just be an environmental response […] To a certain extent, we did meet the challenges. […] I think that by talking so broadly about children's well-being, it was, I don't know if it was marginal, but in any case, it was a clear-sighted move. And it's also what enabled us to get the schools on board in a big way. Because, if you like, at the beginning a lot of schools will say: "Yes, but it's a political project". And we tell them: "No, in fact, it's also for the pupils, it's also for the children, it's also for the citizens of tomorrow".

Despite this progress, challenges remain due to the limited size of Parisian schoolyards, high pupil density, and the need for space for recreational activities. Following the Brussels visit, the DEVE updated the project guidelines to emphasize landscape design and increase vegetation. However, the greening approach often remains largely ornamental, with plant selection primarily focusing on esthetic preferences, such as flower colors and year-round foliage. Additionally, plant choices are restricted to local, non-toxic species sourced from the city's nursery, which further limits biodiversity potential.

Comparison of biodiversity in schoolyards and nearby green spaces

Although vegetation was initially given low priority in the transformation of schoolyards, arthropods inventories reveal these areas support diverse communities, although often at lower levels than neighboring green spaces.

A total of 7929 individuals (3681 in schoolyards and 4248 in green spaces), attributed to 442 different morphospecies (280 in schoolyards and 345 in green spaces) and representing 16 orders, were collected and identified. Most individuals belonged to the Hemiptera, including aphids, mealybugs and bedbugs, followed by the Diptera, which encompasses flies, midges, and mosquitoes.

Variability in arthropod abundance was observed across different schoolyards (Fig. 3), with Merlin and Olivier Métra nursery schools hosting the highest numbers of individuals, followed by La Brèche aux Loups primary schools and Guillaume Budé and Courteline secondary schools. The average total arthropod abundance found in schoolyards (230 ± 104 individuals) was statistically no different (Chi², χ^2= 0.85, $p = 0.36$) from that of green spaces (265 ± 138), except for Diptera, whose abundance was significantly higher in green spaces (test post hoc, z.ratio ∞ = –6.74, $p < 0.0001$).

Arthropod morphospecies richness varied among schoolyards, with a range of 66 species at Charles Hermite and 29 at Quatre Fils (Fig. 4). Four schoolyards stand out with the highest levels of morphospecies richness: Charles Hermite landscaped in 2018 (first generation of green schoolyards), (Olivier Métra), Budé (second generation, respectively 2021 and 2023) and Courteline (Oasis candidate initiated by the local staff and helped by the City Council).

On average, schoolyards hosted 44 ± 12 morphospecies, which is significantly lower than the 58 ± 10 morphospecies found in nearby green spaces (Chi², $\chi^2 = 14.07$, $p < 0.001$). The disparity in morphospecies richness was particularly pronounced in Diptera, with an average of 25 morphospecies identified in green spaces compared to just 8 in schoolyards (test post hoc), z.ratio ∞ = –8.66, $p < 0.0001$. At the stratum level, only the herbaceous layer of green spaces shows greater species richness than that of schoolyards (Chi², $\chi^2 = 17.13$, $p < 0.001$).

Morphospecies richness positively correlated (Chi², $\chi^2 = 20.99$, $p < 0.0001$) with the area of vegetation within the schoolyards, indicating that larger vegetated areas support greater biodiversity. Additionally, richness was associated with the proportion of vegetation surrounding the schoolyards (Chi², $\chi^2 = 4.5112$, $p < 0.034$), while the distance from a green space showed no significant impact (Chi², $\chi^2 = 1.0721$, $p < 0.300$).

Community composition varies greatly between school grounds and green spaces, and within each category of site. The arthropod communities present in schools and green spaces differ in their composition by more than 70% (ANOSIM, R = 0.25, $p = 0.001$), mainly because of hemipterans of the Aphididae family, leafhoppers of the Eupteryx genus and ants of the Lasius genus, all of which are more common in schoolyards (in planters or on tarmac) and Chironomidae (a family of Diptera), which are more commonly found in the lawn areas of green spaces.

NbS to reinforce human–nature interactions

Our interviews with teachers and school principals highlighted both a strengthening of the interactions between children and nature, as well as the gradual formation of a broader community interested in biodiversity issues.

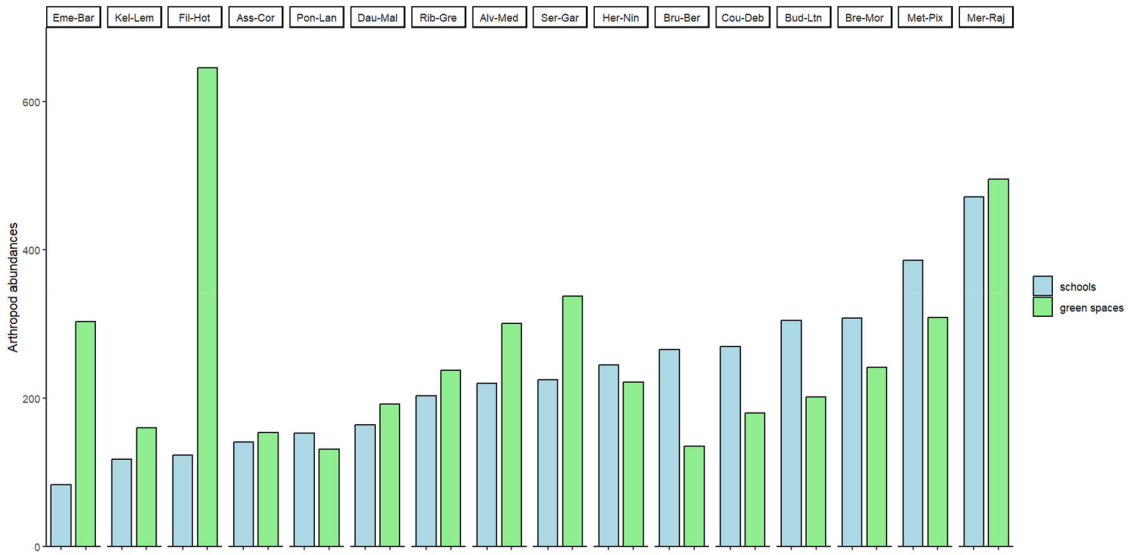


Fig. 3 | Abundance of arthropods collected in schools and the nearest green spaces. Name pairs are made up of the first three letters of the school's name followed by the first three letters of the name of the nearest green space. Data are ordered by increasing abundance in schools. Source: Mélanie Gippet.

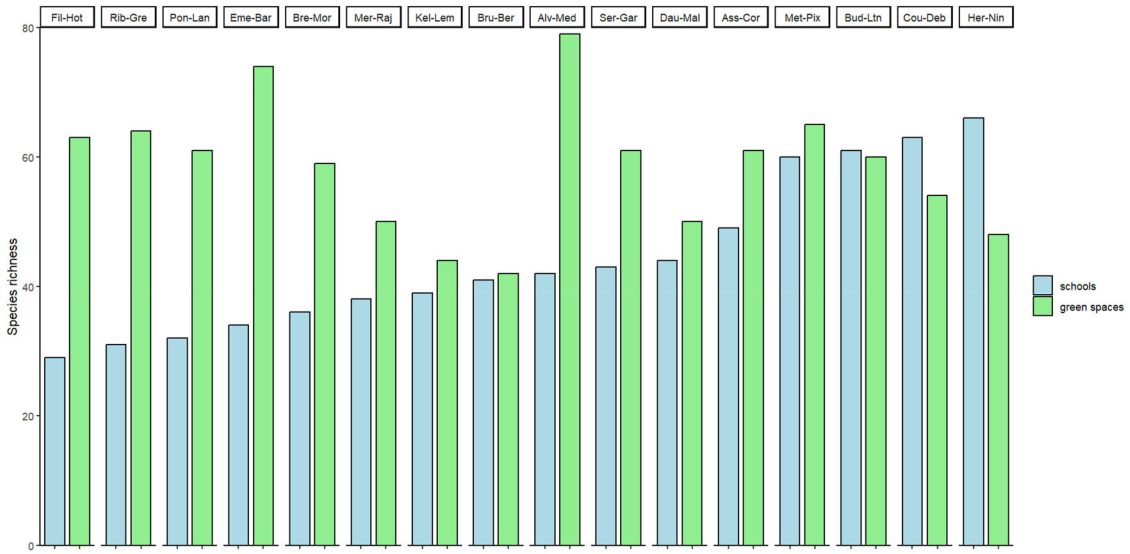


Fig. 4 | Number of arthropod morphospecies collected in schoolyards and the nearest green spaces. Name pairs are made up of the first three letters of the school's name followed by the first three letters of the name of the nearest green space. Data are ordered by increasing number of arthropods in schools. Source: Mélanie Gippet.

The biodiversity dynamic goes hand in hand with landscaping based on NbS. According to some of the school principals and teachers who have observed the project, this approach profoundly transforms schoolyard spaces and the social interactions within them. The diversity of the landscape and ecology of these redesigned schoolyards promote more prosocial and cooperative play by challenging traditional power dynamics. The schoolyards are widely recognized by our interviewees for reducing conflicts as the fragmented nature of the schoolyards encourages less competition from children for a single space. Children disperse into groups with different activities. Previously, the boys occupied most of the space for ball games, while the girls were often confined to the margins. Creating different areas in the playground helps to reduce gender inequalities in the use of space. On another hand, they also create areas that are less visible to supervisors, making it more difficult to observe and manage conflicts in vegetated areas.

In addition, the variety of NbS in schoolyards reinforces the diversity of games and behaviors related to nature. Some of our interviews show that creatures, particularly ants and other insects, play a significant role in children's games. As one school principal observed: 'children are often fascinated by ants. I've already seen children playing with ant houses in the orchard. Yes, they love it. They're quite respectful. They don't crush them or harry them. On the contrary, they make houses and paths !' These interactions and this wonderment for fauna also apply to plant species, as explained by the school principal in the 11th arrondissement of Paris who described the amazement of children when they dig up potatoes, comparing them to "gold bars."

Some members of these communities show a long-term commitment, as the school principal in the 11th arrondissement explained: 'I've been involved in this project for about 10 years now. I've got my notebook with the vegetable garden plan every year, where I write down what we're going to sow and plant, and then I write down the names of the classes with the children and what they come to do.' In some schools, parents contribute to the project, for example by donating plants or making a one-time financial

contribution. The sustainability of these initiatives and the growth of planted areas heavily rely on the commitment and personal motivation of the adults involved, whose sensitivity to nature and biodiversity issues varies. Some of them even dedicate their free time to maintain the schoolyards, often with significant help from the maintenance staff, who have had to adapt their work routines and for whom the development of these new schoolyards is a big and physically demanding job. As one maintenance worker remarked, 'this ground is shit, it doesn't soak up water and it's difficult to clean'. However, the motivation to maintain the schoolyards is essential, and unites a diverse group of individuals. For some, this motivation stems from their childhood experiences in natural environments, where they became familiar with nature, through gardening for example. For others, the motivation is linked to their professional background, like the parent we met at Collège Pierre Alviset, who now runs the school's gardening workshop. Additionally, many are motivated by seeing the deterioration and neglect of the schoolyard and feel a sense of responsibility to restore it. They feel it is both necessary and their responsibility to teach the importance of protecting nature and the environment, particularly in the current context.

However, this contribution is inconsistent, as it relies entirely on the goodwill of parents, as explained by a school principal in the 11th arrondissement, whose school has not received support from either the ERDF or the CAUE: 'Parents participate indirectly, because we have what are called school cooperatives in the schools […]. And it works with donations from parents, totally voluntary donations from parents, and with that money we can go on outings, for example, and a small part of that money is used to really keep the vegetable garden going, i.e., to buy potting soil, buy seedlings, seeds, that sort of thing.'

Discussion

How are nature-based solutions (NbS) implemented in schoolyards, and what are their limitations? The implementation of NbS represents an opportunity for the socio-ecological transformation of 73 hectares in a dense and highly mineralized city. However, Oasis schoolyards were initially designed not as natural spaces but as climate shelters aimed at mitigating urban heat island effects through landscaping projects. Biodiversity was considered secondary to this primary objective. The main argument then, as it is now, was children's well-being rather than environmental concerns. But these two don't need to be exclusive, as part of the child's agency is linked to the variety of environments children are able to experience, developing resourcefulness and autonomy, but also the richness of their lived space[31]. Above all chidren's well-being is closely related to their contact with nature in cities[32]. For teachers, NbS in schoolyards challenge traditional pedagogies and boost creativity, changing paradigms and roles.

After a visit by Paris City officials to Brussels, the design of Oasis schoolyards evolved to incorporate more nature and ensure a better distribution of NbS within schoolyards. Ultimately, departments responsible for green spaces expanded their role, and services such as CASPE now listen to schools' requests regarding courtyard management. Today, most schoolyards are planted with local species, using vegetation as a tool for temperature regulation. However, fauna has largely been overlooked by the designers of these Parisian schoolyards (including CAUE and other contractors operating within the framework agreement).

Thus, a better integration of NbS in schoolyards requires greater awareness of ecological processes and nature-related challenges. Not only do city officials lack knowledge and imagination regarding NbS as a cultural development tool, but so do teachers and students. They also lack insight into how such development could foster more child-friendly cities, improving children's life opportunities (rights in the city) and promoting their active involvement in urban development (rights to the city)[33]. The co-design and maintenance phases must be reinforced by involving school staff, pupils, and parents, which also requires better coordination among the city's decentralized services. As a landscape architect from the Paris Council explained, the more the school community is involved, the better the outcomes. Engaging children also means fostering discussions among pupils and encouraging collaboration among teachers, creating a ripple effect of participation.

Finally, the public use of schoolyards needs to be reconsidered so that these green, cool spaces can serve as refuges for Parisians during heatwaves. At the same time, they could become learning spaces for fostering human-nature relationships.

What is the ecological contribution of renaturing schoolyards? Biodiversity levels vary significantly between sites due to several factors. Since schoolyards often consist of small, fragmented planters or perennials beds, the richness of herbaceous species in school grounds is statistically lower than in larger green spaces. This difference may be attributed to the quality of the herbaceous layer: green spaces typically contain large extensive patches of flowering plants and extensive grass areas, sometimes left to rest. In contrast, grassy areas in schoolyards are often unprotected and subject to trampling, which puts pressure on colonizing species and may contribute to the observed lower species richness.

Despite the limited resources available in schoolyards, the comparable arthropod abundance levels between schools and green spaces confirms the ecological habitat function of schoolyards. Arthropod abundance in schoolyards could be explained by the absence or scarcity of predators[34]. The lower species richness observed in schoolyards compared to green spaces is expected, given that green spaces generally have larger, older, and more diverse plant populations. Since vegetation takes time to grow, it is reasonable to assume that biodiversity in schoolyards will increase over time.

The differentiation between arthropod communities in schools and green spaces raises further questions, and continued monitoring will be necessary in the coming years. This differentiation may be due to species turnover, a common phenomenon in urban environments[35]. This suggests that the differences in species composition between schoolyards and green spaces result from species substitution, rather than species loss, meaning that schoolyards do not simply contain a subset of the species found in green spaces, but rather different species altogether. Consequently, the hypothesis that schoolyards function as relay habitats (stepping-stones) between green spaces cannot be confirmed, as the arthropod communities in schoolyards do not appear to be subsets of those in green spaces.

These differences in community composition may be due to variations in plant composition between schools and green spaces[36]. Parisian green spaces often feature non-native exogenous ornamental species, except in cemeteries and the Bois de Boulogne and Bois de Vincennes, whereas schoolyards are primarily planted with local species. This leads to differences in the arthropod species they attract. As explained by the manager of the DEVE, one of the major goals of Paris's 2018–2024 Biodiversity Plan (which will be extended in the upcoming 2024–2030 plan) is to plant or allow to grow 50% regional plant species in all new green space projects. The creation of Oasis schoolyards aligns with this Paris Council initiative.

Species abundance and richness are influenced to multiple factors, including the size of the vegetated area in the school grounds, the plant species, the design and planting of the vegetation, and the care provided by both the asset management team and the teachers and children. In short, enhancing biodiversity requires a broader focus on the production of urban spaces, especially the creation of natural areas within cities.

How do schoolyards function as privileged places for human–nature interactions? Our results indicate that in some schools, a community actively engaged with the planted schoolyards. This interest in NbS depends on the sensitivities and education of staff members, as well as on their willingness to adapt their professional practices - whether they are school janitors, teachers or technical staff. The presence of nature in schoolyards could thus play an increasingly significant role in children's education and shaping their environmental attitudes[37,38]. New teaching and vocational practices, such as outdoor classes, should be widely deployed rather than the exception[39]. Additionally, more tools should be developed to enhance the connection with nature in schoolyards for all members of the school community. Observing interactions between children and insects, among other factors, highlights the importance of research focused on children's relationships with living organisms now present in school grounds due to



Fig. 5 | Schoolyards converted in 2019 (Amiral Roussin nursery school, 15th arrondissement) and 2020 (Küss nursery school, 13th arrondissement). Source: Thaïs Andro.

renaturing efforts. This approach is supported by the work of the Common Worlds collective and multispecies ethnographic approaches[40–42]. These are the elements that children, teachers, and parents are invited to engage with.

However, after 150 years of asphalt, managing natural soil is a challenge, according to the landscape designer of the city hall. Nevertheless, the envisioned transformation of teaching practices integrates pupils' engagement with nature as a tool for learning and fostering responsibility toward the environment. The aim is to develop pedagogical practices that move beyond a purely utilitarian view of the schoolyard and see the maintenance of schoolyard nature as part of cultivating a shared living environment[43]. This approach promotes education that is not only based on a rational understanding of nature but also on experiential learning as a situated practice[41]. The goal of developing such a practice is also to give more space for children's agentivity[42]. To encourage commitment and help stakeholders take ownership of the greened schoolyards, associations are involved in sharing naturalist knowledge and assisting staff members and pupils in making these spaces their own. This learning and appropriation process is long and resource-intensive, requiring both time and personnel. It also heavily depends on the involvement of school principals, who guide their teams in this direction. The leadership style has a strong and significant role in adopting change[44].

However, several factors limit this community's investment in embracing biodiversity areas. Within schools, staff members (both teachers and extracurricular staff) assess the potential risks associated with creating Oasis schoolyards. They are concerned that children might get pricked or scratched by vegetation or fall on uneven ground. Additionally, the division of the grounds into different compartments with various play areas and plants raises concerns about children hiding or being out of sight. Any risk must be eliminated from the school premises while the child is under the responsibility of school staff. In our view, such behavior prevents the very learning of risk.

Furthermore, the broader community's engagement with Oasis schoolyards is hindered by the closed nature of schools. While the Oasis program does allow certain schoolyards to be opened to local residents—particularly during heatwaves to address the shortage of green spaces—this openness is often seen as a safety risk, with concerns about letting unsuitable individuals into the school premises. As a result, in some neighborhoods, the idea of opening schoolyards to the public as part of the renaturing project is seen as unrealistic even if it's out of schooltime.

Moreover, changing established routines, both professional and personal, poses challenges at many levels, amongst them, technical and individual[44]. Promoting free play requires offering elements that do not have obvious play functions, encouraging children to use their imagination. Vegetation should be seen as a resource that helps define zones, create different spaces, and guide movement, rather than simply taking up space in the schoolyard. However, these goals can sometimes conflict with teachers' safety concerns. For instance, how much contact with planted areas should children be allowed? How can shelters be created while ensuring proper supervision of pupils? To conclude while building committed communities in the maintenance of NbS is important, there is currently no socio-economic or political framework to fully support their development. The role of committed citizen or responsible resident needs further exploration, even though it can be difficult to engage communities of parents or local residents, particularly in working-class neighborhoods[45]. However, parents often express a strong interest in getting involved, suggesting that successful collaborations can emerge when school staff remain flexible and open to various constraints[46]. Scaling up Nature-based Solutions (NbS) requires the active commitment of various community stakeholders—not just the public sector. Therefore, it is essential to strengthen support for collective engagement programs through funding and sustained commitment. To ensure justice in schoolyard NbS, it is important to examine governance structures and power dynamics in participatory design and long-term management. This also involves evaluating the benefits these solutions bring to children and school staff. Interdisciplinary and transdisciplinary research is necessary to better understand how different aspects of NbS contribute to inclusive and equitable schoolyard design.

Methods

Study areas

In 2018, the City of Paris initiated an ambitious project aimed at desealing and greening the grounds of all 650 schools by 2050, covering approximately 73 hectares, or 0.7% of the city's surface (https://www.paris.fr/pages/les-cours-oasis-7389). The goal is to transform the schoolyards of Parisian nursery, primary, and secondary schools into 'oases,' creating local 'cool islands' to help mitigate urban heat. This initiative is a key component of the city's Resilience Strategy, which is based on the international network of Resilient Cities (established by the Rockefeller Foundation), of which Paris has been a member since 2015.

Although the project was initiated by the City of Paris, the support available to schools varies. Some schools have received financial aid from European funds (European Regional Development Fund, ERDF) and/or guidance from the local Paris City Council services, including the Architecture, Urbanism and Environment Council (CAUE). This support has supposedly enabled the organization of co-design and co-construct workshops with school staff and pupils prior to the transformations, involving classroom visits to gather input and ideas about redesigning the schoolyards. In contrast, other schools have not benefited from such financial or technical assistance.

Regardless of the level of support, the nature of schoolyard transformations has evolved since the project's inception. Initially, the focus was primarily on replacing impermeable asphalt with permeable surfaces (Fig. 5, left).

Vegetation was minimal, often limited to fenced-off areas at the edges of the playground. However, from 2020 onward, the approach became more holistic, incorporating natural materials like wood, sand, and wood chips,

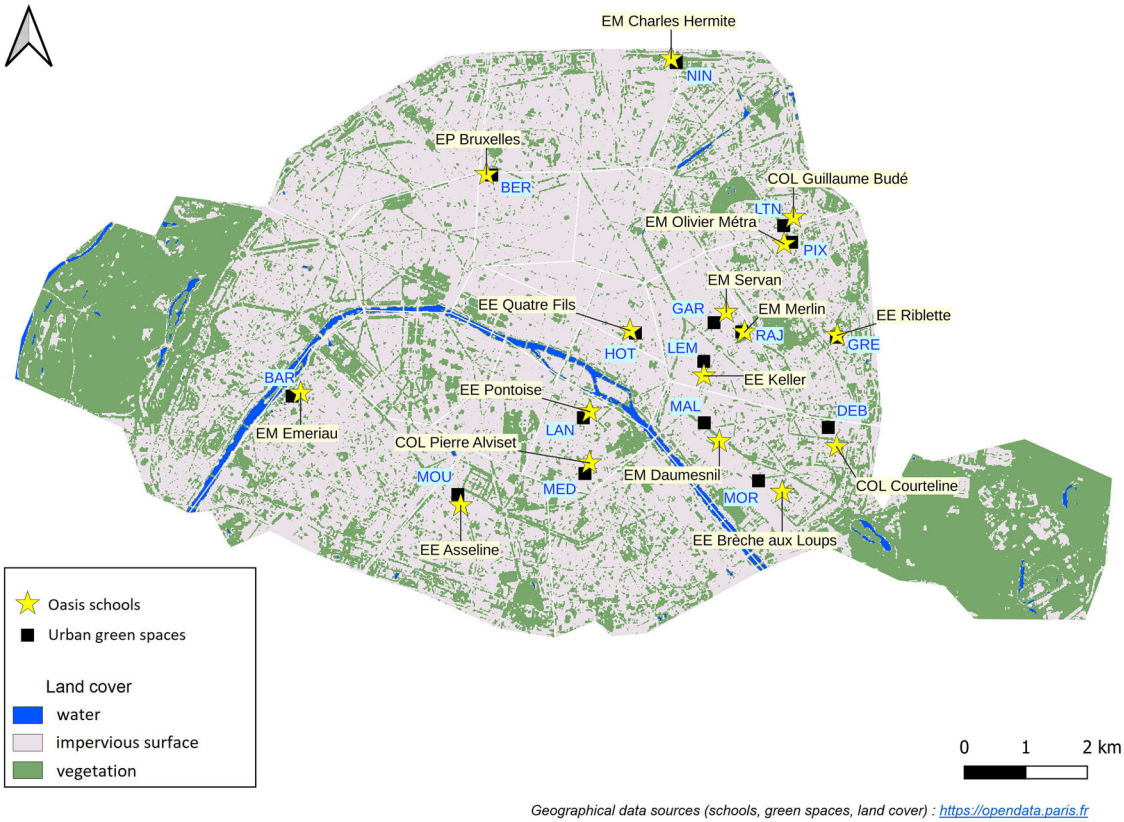


Fig. 6 | Location of the 16 schools studied and their nearest public green space in Paris, France. EM nursery school, EE junior school, EP primary school, COL secondary school. Source: Mélanie Gippet.

introducing diverse landscaping features, and integrating vegetation directly into play areas, making it accessible to pupils (Fig. 5, right).

As part of this research, we selected 16 schoolyards (Fig. 6) using several criteria to ensure a diverse range of profiles: type of support received (ERDF + CAUE, CAUE only, or none), neighborhood income levels (high/medium/low), proximity to public green spaces, and the year of the schoolyard conversion.

Qualitative methods

To investigate the Oasis school project, we conducted 21 private semi-structured interviews with key stakeholders. These included 16 project coordinators at the city or neighborhood level, and 5 local school staff members (teachers, headmasters, and maintenance personnel). This qualitative research was supplemented by a review of institutional documents related to schoolyard design by the CAUE, the history of the Oasis project, and municipal governance frameworks such as the Climate Plan, Biodiversity Plan, Circular Economy Plan, and Resilience Strategy, particularly in terms of their integration of the Oasis initiative. In addition, we held two group discussions with the interviewees (one with ten persons in 2023 and another one involving four workshops with 24 attendees from the various departments in 2024) to explore their perspectives on the changes brought about by the Oasis project, relatively to two main questions: how to develop the pedagogical use of schoolyards? What kind of maintenance and management should be adopted? The synthesis of the discussion was presented to the administrative heads of Paris, and discussed with school staff in order to better the engagement. We also conducted on site observations in schoolyards alongside headteachers and teachers to examine usages of the schoolyards by the children.

The goal was to not only capture the views of institutional actors but also incorporate the experiences of end users involved in the co-design process, such as school staff and children. The aim here is to understand the place and role of these stakeholders in the greening project, the network of stakeholders they work with, and their position on the place of biodiversity in greening. The interview guide was structured around five key analytical points:

- Professional background and role in the Oasis project: Questions explored interviewees' professional backgrounds, the nature of their daily tasks and their specific roles within the Oasis project. This aimed to contextualize their involvement, identify their contributions to the Oasis project, and outlining their tasks, objectives, challenges encountered, and solutions implemented.
- Project management and network of stakeholders: This theme focused on how the project was managed and coordinated across various teams and stakeholders. We explored how information flowed between partners, and the nature of collaboration with contractors and schools. Key questions examined the processes for managing schoolyard transformations, including follow-up actions and monitoring systems.
- Funding and decision-making processes: This section explored how the transformation projects were selected and funded, examining the role of participatory budgeting or other funding mechanisms. Questions also covered criteria for selecting schoolyards, tracking the success of interventions, and how funding was managed for unforeseen revisions or additional work.
- Environmental impact and educational integration: This theme examined the environmental and social aspects of the Oasis project, focusing on its contribution to urban resilience and ecological transitions. It addressed the selection and management of vegetation, including the criteria for choosing plant species based on factors such as resilience, maintenance, and environmental impact. Interviewees reflected on the integration of the project into educational programs and how the newly created green spaces have changed the usage of schoolyards.

– Integration into resilience strategy: This final theme examined the project's alignment with broader urban strategies, and its contribution to the city's resilience objectives.

All interviews were conducted in French, recorded and fully transcribed. A content analysis was carried out, using an analysis grid to divide the interviews into sections reflecting our main questions. As a research method, qualitative content analysis represents a systematic and objective means of describing and quantifying phenomena. The trustworthiness of our results is based on the fact that the inquiry's findings are "worth paying attention to". It's also based on *credibility* (e.g. the accuracy of interviewees description), *dependability* (e.g. the stability of data), *conformability* (e.g. the congruence between the interviewees), and transferability (e.g. the potential for extrapolation)[47]. Our results were discussed with the interviewees themselves and presented in front of city's services, headmasters, teachers and maintenance staff. Focus group were organized in order to work on sensitive matters, such as the role of different stakeholders in the management of green schoolyards. The interviews' excerpts used in the quotations have been translated into English for this paper after consent forms have been signed.

Arthropods as indicators of urban biodiversity

To assess biodiversity in schoolyards, we focus on arthropods, which are widely recognized as effective indicators of habitat quality, pollution levels, and land-use practices[48–50]. Their short generation times make their populations particularly responsive to environmental changes, allowing for rapid detection of ecological shifts[51]. Furthermore, engaging with arthropods in educational settings fosters pupils' understanding of ecological interconnections. By observing behaviors like bees pollinating or small mammals dispersing seeds, children can develop a direct appreciation for the ecological services these species provide, fostering empathy and respect for all living organisms[32,52,53].

Arthropod inventories and analysis

To investigate the role of vegetated schoolyards as habitats and stepping-stones for arthropod communities, we conducted inventories in 16 schools and their nearest green spaces (Fig. 6). We compared arthropod abundance and richness between these sites, assessing each vegetation stratum (herbaceous, shrub, tree) individually and in combination. Environmental parameters, such as the surface area and plant diversity, the area of tree canopy within 100, 200, and 1000 meters, and the distance from the nearest green space, were quantified for each site using field observations and GIS data (Open Paris Data). Buffers of 100 m and 1000 m were chosen based on evidence that arthropod communities respond to habitat features at these scales[54], and 200 meters corresponds to the average distance between schools and their nearby green spaces in our study.

Data collection occurred once per site from mid-May to mid-June 2023, under favorable weather conditions (temperature above 10°C, no rain, low wind). Where possible, paired sites (school and green space) were sampled on the same day to minimize variability. The non-invasive sampling protocol targeted three vegetation strata, with three replicates per stratum. Sampling locations were selected to ensure representativeness based on access to vegetation and foliage density. For the herbaceous stratum, a sweep net was used, while a beating tray was employed for the shrub and tree strata. After collection, each arthropod was photographed, taxonomically identified to the order level, and released on site. Photographs were then analysed to assign each individual to a morpho-species, based on key morphological traits like size, color, and body patterns[55]. This photographic approach is a common method in invertebrate biodiversity research[56] and is used in the French national protocol for monitoring pollinators[57].

Arthropod diversity was analysed at both alpha (within-site) and beta (between-site) scales using the *vegan*[58] and the *betapart* package[59] from R software (version 4.1.2 R Core Team 2021). The threshold of statistical significance was considered to be $\alpha = 0.05$. Beta diversity was calculated with Sorensen's index of dissimilarity applied to species occurrence matrices[60]. To test the influence of environmental factors on arthropod diversity, generalized linear models (GLMs) with negative binomial distributions were applied. The variation in community composition between schools and green spaces was visualised using non-metric multidimensional positioning (NMDS, *vegan* package). A similarity analysis (ANOSIM) was then used to statistically compare the species composition of school and green-space communities. Finally, a SIMPER analysis was carried out to calculate the average dissimilarity of communities between schools and green spaces, but above all to identify the species that weigh most in this dissimilarity. The values of the Sorensen index and its components (beta diversity) were compared with a Chi^2 test.

Data availability

The data that support the findings of this study are not publicly available due to privacy or ethical restrictions but are available from the corresponding author on reasonable request.

Received: 18 March 2025; Accepted: 18 July 2025;
Published online: 08 August 2025

References

1. IPCC, 2023: Climate Change 2023: Synthesis Report. IPCC, 184 p., Review of *IPCC, 2023: Climate Change 2023: Synthesis Report. IPCC, 184 p.*, *Population and Development Review*, **50**, 577–580. Blackwell Publishing Ltd., https://doi.org/10.59327/IPCC/AR6-9789291691647.
2. Ramyar, R., Ackerman, A & Johnston, D. M. Adapting cities for climate change through urban green infrastructure planning, *Cities*, **117**, https://doi.org/10.1016/j.cities.2021.103316 (2021).
3. Cohen-Shacham, E. et al. Core principles for successfully implementing and upscaling Nature-based Solutions. *Environ. Sci. Policy* **98**, 20–29 (2019).
4. Jessup, K. et al. Planting stormwater solutions: A methodology for siting nature-based solutions for pollution capture, habitat enhancement, and multiple health benefits. *Urban Forestry Urban Green.* **64**, 127300. https://doi.org/10.1016/j.ufug.2021.127300 (2021).
5. Seddon, N. Harnessing the potential of nature-based solutions for mitigating and adapting to climate change. *Science (N. Y.)* **376**, 1410–1416 (2022).
6. UNEP *Nature-based Solutions: Opportunities and Challenges for Scaling Up*. United Nations Environment Programme (UNEP). https://www.unep.org/resources/report/nature-based-solutions-opportunities-and-challenges-scaling (2022).
7. Felson, A. et al. Mapping the design process for urban ecology researchers. *BioScience* **63**, 854–865 (2013).
8. Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E. & Pauleit, S. Planning multifunctional green infrastructure for compact cities: What is the state of practice?. *Ecol. Indic.* **96**, 99–110 (2019).
9. Andersson, E. et al. What are the traits of a social-ecological system: towards a framework in support of urban sustainability. *Npj Urban Sustainability*, *1*. https://doi.org/10.1038/s42949-020-00008-4 (2021).
10. Pineda-Pinto, M., Frantzeskaki, N. & Nygaard, C. A. The potential of nature-based solutions to deliver ecologically just cities: Lessons for research and urban planning from a systematic literature review. *Ambio* **51**, 167–182 (2022).
11. Tozer, L., Hörschelmann, K., Anguelovski, I., Bulkeley, H. & Lazova, Y. Whose city? Whose nature? Towards inclusive nature-based solution governance. *Cities* **107**, 102892. https://doi.org/10.1016/j.cities.2020.102892 (2020).
12. Kabisch, N., Frantzeskaki, N. & Hansen, R. Principles for urban nature-based solutions. *Ambio* **51**, 1388–1401 (2022).

13. Anguelovski, I. & Corbera, E. Integrating justice in Nature-Based Solutions to avoid nature-enabled dispossession. *Ambio* **52**, 45–53 (2023).
14. Cousins, J. J. Justice in nature-based solutions: Research and pathways. *Ecol. Econ.* **180**, 106874. https://doi.org/10.1016/j.ecolecon.2020.106874 (2021).
15. Hafferty, C., Tomude, E. S., Wagner, A., McDermott, C. & Hirons, M. Unpacking the politics of Nature-based Solutions governance: Making space for transformative change. Environmental Science & Policy, 163, Article 103979. https://doi.org/10.1016/j.envsci.2024.103979 (2025).
16. Welden, E. A., Chausson, A. & Melanidis, M. S. Leveraging Nature-based Solutions for transformation: Reconnecting people and nature. *People Nat.* **3**, 966–977 (2021).
17. Baró *a*, F., Camacho, D. A., Pérez Del Pulgar, C., Triguero-Mas, M., & Anguelovski, I. School greening: Right or privilege? Examining urban nature within and around primary schools through an equity lens. *Landscape and Urban Planning*, **208**. https://doi.org/10.1016/j.landurbplan.2020.104019 (2021).
18. Gallez, E., Fraile Mujica, C. P., Gadeyne, S., Canters, F. & Baró, F. Nature-based school environments for all children? comparing exposure to school-related green and blue infrastructure in four European cities. *Ecol. Indic.* **166**, 112374. https://doi.org/10.1016/j.ecolind.2024.112374 (2024).
19. Flax, L., Altes, R. K., Kupers, R., & Mons, B. Greening schoolyards. An urban resilience perspective. *Cities*, **106**. https://doi.org/10.1016/j.cities.2020.102890 (2020).
20. Ruiz-Mallén, I. et al. Nature-based solutions for climate adaptation in school environments: An interdisciplinary assessment framework. In: Allam, Z. (ed.) *Sustainable Urban Transitions. Urban Sustainability*. Springer, Singapore. https://doi.org/10.1007/978-981-99-2695-4_ (2023).
21. Giezen, M. & Pellerey, V. Renaturing the city: Factors contributing to upscaling green schoolyards in Amsterdam and The Hague. *Urban Forestry Urban Green.* **63**, 127190. https://doi.org/10.1016/j.ufug.2021.127190 (2021).
22. Arlati, A. Navigating urban futures: Exploring NbS upscaling discourses, practices, and relations in reimagining human-nature relationships. *Futures: J. Policy, Plan. Futures Stud.* **161**, 103403. https://doi.org/10.1016/j.futures.2024.103403 (2024).
23. Mahmoud, I. H. et al. Towards a Co-Governance Approach For Nature-based Solutions. In I. Ferreira, G. Lupp, & I. H. [Israa Hanafi] Mahmoud (Eds.), *Guidelines for Co-creation and Co-governance of Nature-Based Solutions: Insights from EU-funded projects* (pp. 44–54). Publications Office of the European Union. https://data.europa.eu/doi/10.2777/157060 (2023).
24. Adams, C., Frantzeskaki, N. & Moglia, M. Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. *Land Use Policy* **130**, 106661. https://doi.org/10.1016/j.landusepol.2023.106661 (2023).
25. Fastenrath, S., Bush, J. & Coenen, L. Scaling-up nature-based solutions. Lessons from the Living Melbourne strategy. *Geoforum* **116**, 63–72 (2020).
26. Kiss, B. et al. Citizen participation in the governance of nature-based solutions. *Environ. Policy Gov.* **32**, 247–272 (2022).
27. Dunlop, T. et al. The evolution and future of research on Nature-based Solutions to address societal challenges. *Commun. Earth Environ.* **5**, 132 (2024).
28. Seddon, N. et al. Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philos. Trans. R. Soc. B* **375**, 20190120 (2020).
29. Beery, T. et al. Disconnection from nature: Expanding our understanding of human–nature relations. *People Nat.* **5**, 470–488 (2023).
30. Dominiak-Szymańska, P., Mackiewicz, E. & Jakub Kronenberg, J. Children's participation in green space planning: a pathway to environmental justice. *Child.'s. Geogr* **22**, 944–964 (2024).
31. Porter, L., Spark, C. & de Kleyn, L. Navigating the neighbourhood: gender, place and agency in children's mobility. *Child.'s. Geogr***19**, 339–350 (2021).
32. Chawla, L., Keena, K., Pevec, I. & Stanley, E. The benefits of children's engagement with nature: A systematic literature review. *Child., Youth Environ.* **24**, 10–34 (2014).
33. van Vliet, W. & Karsten, L. 'Child-Friendly Cities in a Globalizing World: Different Approaches and a Typology of Children's Roles'. *Child., Youth Environ.* **25**, 1–15 (2015).
34. Sorace, A. High density of bird and pest species in urban habitats and the role of predator abundance. *Ornis Fenn.* **69**, 76–93 (2002).
35. De Albuquerque Correa, C. M., Da Silva, P. G., Lara, M. A. & Puker, A. Spatiotemporal patterns of β-diversity of flower chafer beetles in urban park and natural reserve sites in Brazilian Cerrado. *Int J. Trop. Insect Sci.* **41**, 681–691 (2021).
36. Uno, S., Cotton, J. & Philpott, S. M. Diversity, abundance, and species composition of ants in urban green spaces. *Urban Ecosyst.* **13**, 425–441 (2010).
37. Barthes, A. Science de la durabilité et éducation. In Dangles & Fréour, *Science de la Durabilité. Comprendre, Co-construire, Transformer*. Editions IRD, Marseille (2023).
38. Gough, A., Chi-Kin Lee, J. & Po Keung Tsang, E. (Eds) *Green Schools* Globally. Stories of Impact on Education for Sustainable Development. Springer International Publishing (2020).
39. Lindgren, S. et al. Practical research: Outdoor teaching and learning in natural spaces and outdoor classrooms. *Sci. Scope* **46**, 72–77 (2023).
40. Affrica, T. & Pacini-Ketchabaw, V. Learning with children, ants, and worms in the Anthropocene: towards a common world pedagogy of multispecies vulnerability. *Pedagog. Cult. Soc.* **23**, 507–529 (2015).
41. Smith, T. A., & Pitt, H. Noticing Nature on the Waterways. Children's Geographies. https://doi.org/10.1080/14733285.2023.2279994 (2024).
42. Taylor, A. & Pacini-Ketchabaw, V. Learning with children, ants, and worms in the Anthropocene: towards a common world pedagogy of multispecies vulnerability. *Pedagog., Cult. Soc.* **23**, 1–21 (2015).
43. Pasek, M. et al. Environmental Knowledge of Participants' Outdoor and Indoor Physical Education Lessons as an Example of Implementing Sustainable Development Strategies. *Sustainability* **14**, 544 (2022).
44. Khaw, K. W. et al. Reactions towards organizational change: a systematic literature review. *Curr. Psychol.* **42**, 19137–19160 (2022).
45. Sekulova, F. & Ruiz-Mallen, I. The governance configurations of green schoolyards. *Env. Sci. & Pol.* **156**. https://doi.org/10.1016/j.envsci.2024.103752 (2024).
46. van Dijk-Wesselius, J. E., Hovinga, D., de Koning, M., Maas, J. & van den Berg, A. E. Parental perspectives on green schoolyards: advantages outweigh disadvantages, but willingness to help is limited. *Child.'s. Geogr.* **19**, 145–157 (2021).
47. Elo, S. et al. Qualitative content analysis: A focus on trustworthiness. *Sage Open*, **4**. https://doi-org.ezproxy.u-paris.fr/10.1177/2158244014522633 (2014).
48. McKinney, M. L. Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosyst.* **11**, 161–176 (2008).
49. Niemelä, J. et al. Carabid beetle assemblages (Coleoptera, Carabidae) across urban-rural gradients: an international comparison. *Landsc. Ecol.* **17**, 387–401 (2002).
50. Samways, M. J. Insect conservation in urban landscapes. *Insect Conservation and* Urban Environments, 303-315. Springer. (2015).
51. McIntyre, N. E. Ecology of urban arthropods: A review and a call to action. *Ann. Entomol. Soc. Am.* **93**, 825–835 (2000).

52. Kahn, P. H., Jr. & Kellert, S. R. *Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations*. MIT Press. https://doi.org/10.7551/mitpress/1807.001.0001 (2002).
53. Lerstrup, I., Chawla, L. & Heft, H. Affordances of small animals for young children: A path to environmental values of care. Int. J. Early Child. Environ. Educ. 9, 58–76 https://api.semanticscholar.org/CorpusID:271163382 (2021).
54. Philpott, S. M. et al. Local and landscape drivers of arthropod abundance, richness, and trophic composition in urban habitats. *Urban Ecosyst.* **17**, 513–532 (2014).
55. Oliver, I. & Beattie, A. J. Invertebrate Morphospecies as Surrogates for Species: A Case Study. *Conserv Biol.* **10**, 99–109 (1996).
56. SPIPOLL. Clé d'identification en ligne, http://spipoll.identificationkey.fr/mkey-spipoll.html (2008).
57. Ward, D. F. & Stanley, M. C. The value of RTUs and parataxonomy versus taxonomic species. *N. Z. Entomol.* **27**, 3–9 (2004).
58. Oksanen, Jari & Blanchet, F. Guillaume & Friendly, Michael & Kindt, Roeland & Legendre, Pierre & McGlinn, Daniel & Minchin, Peter & O'Hara, RB & Simpson, Gavin & Solymos, Peter & Stevens, MHH & Szöcs, Eduard & Wagner, Helene. Vegan: community ecology package version 2.5-7. (2020).
59. Baselga, A. & Orme, C. D. L. Betapart: an R package for the study of beta diversity: Betapart package. *Methods Ecol. Evol.* **3**, 808–812 (2012).
60. Baselga, A. Partitioning the turnover and nestedness components of beta diversity: Partitioning beta diversity. *Glob. Ecol. Biogeogr.* **19**, 134–143 (2010).

Acknowledgements

This work builds on the COOLSCHOOLS project (www.coolschools.eu) and has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 101003758, the Spanish Research Agency (AEI), Innoviris (Brussels Capital Region), the Dutch Research Council (NWO), The Research Foundation—Flanders (FWO), and France's Agence Nationale de la Recherche (ANR). The authors would like to thank Romain Nattier for his advice on the methodological protocol for the inventories, as well as Etienne Grésillon, François Bouteau, Patrick Laurenti and Joanne Clavel for their support and Christopher Sufcliffe for English proofreading. We would also like to extend our warmest thanks to all the schools that welcomed us, and to the school and city council staff who answered our questions.

Author contributions

N.B. and C.C. conceptualized, designed and realized the study, supervised the research process, contributed to data interpretation, and wrote the manuscript. A.L.R. and M. G. collected and analyzed data. C.A. brought their expertise in the field and in aspects of governance within the City of Paris. S.B. contributed to the study by participating in discussions and providing valuable comments to refine and improve the manuscript. All authors participated in drafting, revising, and approving the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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