Received: 28 June 2018 | Accepted: 22 February 2019

DOI: 10.1002/pan3.20

PERSPECTIVE

PEOPLE AND NATURE | BRITISH ECOLOGICAL SOCIETY

Urban ecosystems: A new frontier for payments for ecosystem services

Daniel R. Richards[1] | Benjamin S. Thompson[2]

[1]Singapore-ETH Centre, ETH Zurich, Singapore

[2]Department of Geography, National University of Singapore, Singapore

Correspondence
Daniel R. Richards, Singapore-ETH Centre, ETH Zurich, Singapore.
Email: richards@arch.ethz.ch

Abstract

1. Urban ecosystems provide many benefits to people, including regulation of environmental conditions, recreational opportunities, and positive health impacts. However, many urban ecosystems are under pressure from increasing urbanisation, because the economic benefits they provide are rarely captured by the people who own and manage them. Such ecosystems are seldom economically competitive compared to more profitable residential, commercial, and industrial land uses.
2. To develop more sustainable cities, we require new approaches for encouraging and enabling interventions that maintain, improve and create urban ecosystems. Payments for ecosystem services (PES) schemes are increasingly used to incentivise conservation and changes in environmental management in rural settings, but this approach has rarely been considered in cities. Here, we explain how payments for urban ecosystem services (PUES) could help protect, restore, and manage urban ecosystems.
3. To implement PUES, we must understand the differences between various public and private actors who could potentially provide or benefit from urban ecosystem services. For example, utilities companies could pay for reduced water treatment costs via deculverting streams, homeowners could pay for improved stormwater management via increasing permeable surface area, and business proprietors could pay for street tree installation and maintenance to provide shade and reduce air conditioning costs.
4. Urban densities, land values, and land tenure will impact the types of PUES projects that are most likely to be viable. To be successful, PUES will require an improved understanding of urban ecosystem service science—particularly how service provision changes under different land management practices.
5. Nevertheless, because of the high densities, co-location, and wide variety of stakeholders that live in cities, there is potential for PUES to become an innovative funding source to support future urban ecosystem management.

KEYWORDS

economic incentives, environmental services, sustainability, urban ecology, urban green space, urban planning

1 | INTRODUCTION

Urban ecosystems provide many services to city residents, such as reducing urban temperatures, regulating stormwater, and offering opportunities for recreation (Bolund & Hunhammar, 1999; Haase et al., 2014). However, many cities have relatively little green space, because protecting or creating urban ecosystems is not economically competitive compared to more profitable residential, commercial, and industrial land uses (Huang, Yang, Lu, Huang, & Yu, 2017). Economic incentives for conservation, including payments for ecosystem services (PES) schemes, have been used, predominantly in rural areas, to encourage land owners to apply new management practices in order to protect, create, and enhance service provision (Naeem et al., 2015; Wunder, 2015). Although between 70 (Wunder et al., 2018) and 550 (Salzman, Bennett, Carroll, Goldstein, & Jenkins, 2018) PES schemes are now operational worldwide, the feasibility of using PES to support ecosystem management in urban areas has rarely been considered (Cerra, 2017).

The economic benefits provided by urban ecosystems can be substantial (Elmqvist et al., 2015). However, the economic benefits of urban ecosystems are rarely captured by the people who own and manage urban green spaces, which generally exist because of legislative protection enforced by city governments. For example, large green spaces such as public parks are protected through land use zoning, while smaller patches of urban greenery are encouraged by planning rules and development guidelines (Haaland & van den Bosch, 2015; Wang, 2009). The low economic return from urban green spaces also impacts the way that they are managed, as city governments with limited budgets may not be able to afford maintenance that maximises the delivery of ecosystem services. For example, the shortage of funding for urban park management has impacted ecosystem service provision in Dhaka, Bangladesh, where poor maintenance reduces the recreational potential of public parks (Ahmed & Sohail, 2008).

Economic incentives could help to protect, create, and enhance the provision of urban ecosystem services. PES schemes are increasingly used in rural areas to enable those that benefit from ecosystem services (the beneficiaries) to compensate or reward those that supply them (the providers) through cash payments or in-kind incentives (Wunder, 2015). Although the ecosystem services paradigm has come under criticism for promoting the commodification of nature (Silvertown, 2015), PES does not necessarily require economic valuation or trade on an open market (Wunder, 2013). Schemes should however, adhere to the principles of additionality and conditionality; they must enable an environmental management action that would not otherwise have been taken, and the payment must be conditional on this action taking place (Wunder, 2015) (Table 1). While others have explored rural–urban PES (e.g. Caro-Borrero, Corbera, Neitzel, & Almeida-Leñero, 2015), we conceptualise PUES as 'intra-city' initiatives where the beneficiaries and providers are both situated within the urban zone. To evaluate the potential for PUES, we must identify groups of people who may be able to supply ecosystem services, and goals of ecosystem service management that could lead beneficiaries to invest

TABLE 1 Glossary of terms relevant to this article

Term	Definition	Source
Urban zone	Urban and rural systems are not dichotomous but form a continuous gradient. In this article we take a broad interpretation of "urban" that includes a range of forms; from densely built-up city cores to peri-urban regions that incorporate agricultural land within an urban matrix.	Tacoli (1998)
Urban ecosystem services	The benefits that city residents derive from urban ecosystems.	Adapted from Jack et al. (2008)
Ecosystem service supply	The total biophysical potential (or capacity) of an ecosystem to provide a service to people, irrespective of whether people actually benefit.	Karp et al. (2015)
Ecosystem service demand	The amount of a service required or desired by society.	Yahdjian et al. (2015)
Payments for urban ecosystem services (PUES)	Voluntary transactions between urban ecosystem service "users" (beneficiaries) and "providers" (providers) that are conditional on new and improved rules of natural resource management.	Adapted from Wunder (2015)
Additionality	The rationale that without financial compensation or reward, there would be no actions towards maintaining or enhancing the provision of ecosystem services.	Pattanyak et al. (2010)
Conditionality	Payments are conditional on the fulfilment of contract terms, which stipulate verifiable project outcomes (e.g. completion of project activities, or delivery of ecosystem services).	Wunder (2015)

in PUES (Yahdjian, Sala, & Havstad, 2015) (Table 1). Since cities hold high densities of people and wealth, there could be significant demand for PUES. In this article, we present (a) a typology of urban landowners who provide urban ecosystem services; and (b) a typology of beneficiary goals for ecosystem services that can partially explain motivations for investing in PUES. Finally, we discuss how PUES may be impacted by issues that have been raised in relation to other forms of PES, and how urban densities, land values, and land tenure could lead to PUES schemes that differ in size and structure from existing forms of rural PES.

2 | TYPOLOGY OF PROVIDERS OF URBAN ECOSYSTEM SERVICES

Cities differ from rural areas in their high densities of landowners, relatively smaller land parcels, and high diversity of motivations driving green space management (Figure 1). Since the feasibility and mechanisms of PUES will vary between different groups of landowners, it is important to differentiate these groups based on their dependence on, and motivations for managing, their land. We define three main groups of landowners:

Private commercial landowners: Landowners who manage urban ecosystems commercially. Such landowners include the owners of sports facilities, and commercial urban farmers.

Private non-commercial landowners: Landowners who manage urban ecosystems non-commercially. Such landowners include homeowners with private gardens.

Public landowners: Landowners who manage urban ecosystems for public benefit. Such landowners are typically city governments who are responsible for managing public parks and roadside vegetation.

These three groups are not unique to urban settings, and all have (to some extent) been involved as providers in rural PES schemes in the past. Private commercial landowners are most similar to the rural land managers that existing PES schemes usually target (Grima, Singh, Smetschka, & Ringhofer, 2016); for example, farmers in the Vittel™ PES scheme in France (Perrot-Maître, 2014) and Sloping Land Conversion Program in China (Pan, Xu, Yang, & Yu, 2017). Private non-commercial landowners also act as providers in rural PES schemes, such as property owners in Uganda that are paid not to cut trees for charcoal (Jayachandran et al., 2017), or communities with de facto land tenure in Thailand that construct check-dams to enhance water retention in catchments (Thompson, 2019). Few rural PES schemes involve public providers (Grima et al., 2016), although there are rare examples of State-led provision in Bolivia (Pereira, 2010) and Madagascar (Brimont et al., 2015).

2.1 | Private commercial landowners

Landowners whose livelihoods depend directly on their use of green spaces may be rare in developed cities, but economic activity such as urban agriculture is economically significant in the suburbs of many developing cities (Orsini, Kahane, Nono-Womdim, & Gianquinto, 2013). Land use decisions for private commercial landowners are to some degree motivated by the objective of profit maximisation, although these landowners may also have other priorities, and have the difficult task of making decisions based on imperfect information (Levine, Chan, &

FIGURE 1 The urban landscape of Singapore. Urban green spaces range from remnant natural habitat fragments, to heavily managed amenity vegetation, to green buildings. Different types of urban ecosystem provide different ecosystem services. Image provided by M. Jiang

Satterfield, 2015). Nonetheless, involvement in a PUES scheme is more likely to be feasible if the scheme results in no net loss in a landowners' income. Hence, the payment made to a private commercial landowner through a PUES scheme would ideally cover the direct costs of changes in management, and fully compensate any associated opportunity costs such as loss of revenue. In some cases, ecosystem service values may not be sufficient to fully offset opportunity costs (Kolinjivadi, Gamboa, Adamowski, & Kosoy, 2015; Thompson, Clubbe, Primavera, Curnick, & Koldewey, 2014), and therefore payment amounts may be negotiated based on a beneficiary's willingness-to-pay and provider's willingness-to-accept (Wunder, 2015). Additionally, in cases where opportunity costs are negligible, payments may be made simply to reward good environmental stewardship, such as compliance with environmental regulations when enforcement and sanctions are weak (Karsenty et al., 2017). PUES schemes for private commercial landowners could incentivise a switch to management practices that simultaneously provide other urban ecosystem services alongside their core business; for example, by using crops and practices that reduce mosquito occurrence in agriculture (Dongus et al., 2009). Alternatively, such PUES could incentivise complete conversion to a land use that provides a different suite of services, for example by converting agricultural or aesthetic green spaces into pollinator meadows that provide habitats for biodiversity and increase pollinator abundance (Aronson et al., 2017).

2.2 | Private non-commercial landowners

Private non-commercial landowners manage a substantial area of land in low-density cities; private gardens account for between 11% and 25% of the land area of five cities in the United Kingdom (Loram, Tratalos, Warren, & Gaston, 2007). Land use and management decisions for private non-commercial landowners are less strongly motivated by profit generation, because their livelihoods are less dependent on their land. Instead, landowners' motivation to participate in environmental management will be subjective based on their spending capacities and preferences for ecosystem service outcomes; some gardens are managed to reduce maintenance costs, while others are managed for physical and mental health benefits, aesthetics, recreation, biodiversity, or personal food production (Freeman, Dickinson, Porter, & Heezik, 2012). PUES schemes for private non-commercial landowners should aim to cover the direct costs of management changes and could provide some relatively small economic incentives to landowners, but would not usually need to cover any opportunity costs of management changes. In this sense, PUES for private non-commercial landowners will likely compensate the costs of activities that participating landowners engage in, rather than rewarding a change in management. Acceptance for PUES will vary significantly depending on the beliefs and preferences of the landowners (Freeman et al., 2012), leaving potential for a wide range of interventions. Large scale interventions such as pond creation may have limited acceptability, while relatively small and unobtrusive interventions such as the addition of nest boxes may be widely acceptable; indeed, over a quarter of private gardens in Sheffield, UK, were found to already have nest boxes (Gaston, Warren, Thompson, & Smith, 2005).

2.3 | Public landowners

In cities, public landowners are responsible for managing many of the largest contiguous urban green spaces, such as recreational parks and nature reserves. Public landowners are motivated to deliver basic public services and minimise the costs of maintenance, but less often have a remit to provide ecosystem services (Hansen et al., 2015). Due to funding constraints there can be variation in management practices within the same jurisdiction, leading to spatial and socio-economic disparities in the quantity and quality of urban green spaces (Joassart-Marcelli, 2010). PUES schemes for public landowners should cover the direct costs of management changes and could contribute to the general budget of the landowner, thus subsidising management of green space elsewhere in the city. PUES payments to public landowners would not need to cover opportunity costs, but changes in management must avoid conflict with the provision of public services such as sports facilities. The acceptability of PUES to public landowners will vary depending on the public service objectives of the landowner, who may prioritise reducing maintenance costs, maximising recreational value, or reducing habitat for disease vectors. However, many public landowners are already trying to incorporate biodiversity-friendly and pro-ecosystem service management (Tan, Wang, & Sia, 2013). PUES could therefore provide top-up funding to expand practices that are already targeted by these public landowners.

3 | TYPOLOGY OF BENEFICIARY GOALS FOR ECOSYSTEM SERVICES

Cities are home to a range of commercial, administrative, and non-governmental organisations that benefit from ecosystem services and may be motivated to invest in PUES schemes (Table 2). The precise ecosystem service that potential beneficiaries desire will vary, but their goals for providing ecosystem services can be broadly defined into four general types:

Maintenance of an ecosystem service that the beneficiary directly benefits from.

Improvement of an ecosystem service that the beneficiary directly benefits from.

Offsetting the disruption of an ecosystem service caused by a beneficiary's activities.

Philanthropic maintenance, improvement, or offsetting of ecosystem services that benefit broader society and may indirectly benefit the beneficiary.

3.1 | Maintenance PUES

"Maintenance PUES" schemes could provide a mechanism for beneficiaries to contribute to the upkeep costs of urban ecosystems that they benefit from, thus securing the provision of ecosystem services in the future. Many organisations currently benefit from ecosystem services; for example, restaurants that are located adjacent to or

TABLE 2 Rationales for PUES based on beneficiary–provider arrangements point out to reviewer 2

Provider (service provider)	Management action	Ecosystem service	Beneficiary (service user)	Return on investment (ROI)
Maintenance of an ecosystem service that the beneficiary directly benefits from				
City government agencies	Maintenance to preserve recreational amenities	Recreational services	Park users paying user fees	Maximised enjoyment of using high-quality green space
City government agencies	Green spaces adjacent to business premises are well maintained	Aesthetic services to attract patrons	Private companies with premises near to city green spaces (e.g. restaurants)	Increased customers which increases revenue
Improvement of an ecosystem service that the beneficiary directly benefits from				
City government agencies	New street trees are planted to increase building shade	Decreased ambient air temperature	Private companies with premises along roads and squares (e.g. restaurants, shops, offices)	Reduced energy costs from air conditioning
City government agencies	Deculverting "combined sewer outflow" (CSO) streams, and creating adjacent wetland habitats	Nutrient filtering services that reduce stream pollution and eutrophication	Water treatment companies	Reducing water treatment operating costs
Private property owners	Small-scale bio-infiltration projects in backyards	Stormwater regulation leading to reduced frequency and magnitude of flood damage	Insurance companies	Reduced pay-outs
Private property owners	Creating niche urban habitats by installing wildlife-friendly garden features	Increased urban biodiversity	City government agencies	Achievement of biodiversity targets and effective implementation of urban environmental plans
Offsetting the disruption of an ecosystem service caused by a beneficiary's activities				
Private property owners	Ecological restoration (e.g. tree planting)	Climate change mitigation services through carbon storage and sequestration	Private companies that emit CO_2	Avoiding fines associated with carbon emissions; 'carbon neutral' status
Philanthropic maintenance, improvement, or offsetting of ecosystem services that benefit broader society				
Private property owners	Increasing wildlife attractant features	Increase in quality and quantity of biodiversity habitat	City government agencies	Contribution to national and city biodiversity targets

within popular public parks can benefit from their attractant value (National Parks Board, 2017). In some cases, existing market mechanisms can indirectly support maintenance costs; for example, public landowners often lease properties within park areas to commercial businesses, and the attractant benefits of park locations will be reflected in rental prices. This rental income can contribute substantially to support organisations that maintain urban green spaces; the Singapore National Parks Board gained almost SGD 10 million, or a third of its external income, from property rental in 2016 (National Parks Board, 2017). In many cases, existing mechanisms do not provide financial support for the continued provision of services. For example, Rall, Kabisch, and Hansen (2015) describe the challenges in funding green storm water management and climate resilience projects in New York; while funding for the implementation of new projects is "readily available", long-term maintenance is 'chronically underfunded'. Although it is difficult to encourage people to voluntarily start paying for something that they are used to getting for free (Jack, Kousky, & Sims, 2008), maintenance PUES may be attractive to beneficiaries who would like more say over maintenance levels and practices, or who feel that that continued provision of ecosystem services is at risk.

3.2 | Improvement PUES

'Improvement PUES' could provide a mechanism for beneficiaries to gain from new ecosystem services, or an increased magnitude of ecosystem service delivery. The services to be increased through improvement PUES are not already accounted for through existing market mechanisms, thus providing a significant opportunity to incentivise urban greening. Opportunities for improvement

PUES schemes include street tree planting for shade (Vailshery, Jaganmohan, & Nagendra, 2013), deculverting streams to reduce water treatment costs (Wild, Bernet, Westling, & Lerner, 2011), and increasing the permeable surface area to improve stormwater management (Berland et al., 2017).

Increasing tree canopy cover increases shade and decreases ambient air temperatures; temperature reductions of 5.6°C have been seen between vegetated and non-vegetated city roads (Vailshery et al., 2013). Private companies with premises along city roads and squares (e.g. restaurants, shops, offices) may wish to improve these microclimate regulation services in order to lower their energy expenditure on air conditioning. For instance, energy savings of US$ 72–218 per month were calculated for tree-shaded buildings in Akure, Nigeria, based on an energy price of US$ 0.15 per kWh (Balogun, Morakinyo, & Adegun, 2014). Through PUES, companies could pay government agencies or NGOs to plant and maintain street trees proximal to their premises to provide shade (Figure 2).

In another form of improvement PUES, water treatment firms could pay to retrofit buried streams that have become part of the sewage system (Figure 3). Such 'deculverting' or 'daylighting' of buried streams can reduce sewage treatment costs by separating clean and waste water, thus reducing the volume that needs to be treated (Wild et al., 2011). Additional benefits to water treatment companies can accrue when wetland habitats are added to provide nutrient filtering services that reduce pollution and eutrophication in city streams. However, deculverting is seldom addressed in existing urban policies (Wild et al., 2011).

As a further example of potential improvement PUES interventions, investment in water-sensitive urban design features (e.g. bioswales) can reduce the pressure on urban drainage systems, reducing the risk of surface water flooding. An emerging approach in Baltimore, USA, encourages private property owners to undertake small-scale projects in their yards, like replacing impermeable patios with permeable vegetation (Hager et al., 2013). Such initiatives could be financed by insurance companies that cover property damage due to flooding, in a bid to decrease flood frequency and magnitude, and reduce pay-outs. Since flash flooding mostly occurs within intra-city watersheds (McPhearson, Hamstead, & Kremer, 2014), the scales of management action, service supply, and service demand are compatible with PUES.

3.3 | Offsetting PUES

'Offsetting PUES' schemes could provide a redemption mechanism for organisations that cause environmental harm through their normal activities. Carbon offsetting is a common focus for rural PES (Cacho, Lipper, & Moss, 2013), but urban forests also store carbon (Haase et al., 2014). Similarly, biodiversity offsetting policies already exist to allow developers to replace biodiversity-rich habitats lost during urban development (Dupont, 2017). The magnitude of offsetting that is possible in cities is limited by the relatively small area available, so it may often be more cost-effective for organisations to invest in offsetting some activities using rural PES. This is particularly true for carbon offsetting, where the benefits of planting trees accrue no matter where in the world they are planted. However, there are administrative advantages to reducing the distance between beneficiaries and providers in PES (Bagstad, Johnson, Voigt, & Villa, 2013), such as making it easier to check compliance. An embryonic example of offsetting PUES can be seen in the city of Sacramento, California, where a construction company has financed the planting of 580 trees in private gardens, to offset carbon emissions from its work vehicles

FIGURE 2 Street trees provide shade for tourists and locals along La Rambla, Barcelona. Street tree shade can enhance pedestrian thermal comfort and reduce air conditioning costs in neighbouring buildings. Image provided by B. Thompson

FIGURE 3 The deculverted Burrow Beck in Lancaster, United Kingdom. Deculverting rivers can reduce water treatment costs by separating clean river water from sewage, and provide a range of other ecological and social benefits. Image provided by A. Broadhead: www.facebook.com/DaylightingUrbanRivers

(Schadler & Danks, 2011). In this example, only in-kind support (i.e. the trees) were financed, with no separate or ongoing payments to homeowners. Offsetting PUES would be most feasible where schemes can leverage on existing legal mandates, such as in Vancouver, where all public-sector organisations are required to become carbon neutral through offset purchases (Peterson St-Laurent, Hagerman, & Hoberg, 2017).

Despite the attractiveness of offsetting schemes as a solution to the challenges of climate change and biodiversity loss, there have been a range of practical and ethical criticisms of this approach, that must be considered before implementing offsetting PUES (Hyams & Fawcett, 2013; Moreno-Mateos, Maris, Béchet, & Curran, 2015). For offsetting to work in practical terms, it must be supported by strong scientific evidence that the offsets are ecologically equivalent to the area that was converted or degraded elsewhere (Hyams & Fawcett, 2013; Moreno-Mateos et al., 2015). Furthermore, offsetting should be considered as an ethically undesirable option; it would be more desirable for actors to avoid causing environmental harm in the first place (Hyams & Fawcett, 2013).

3.4 | Philanthropic PUES

'Philanthropic PUES' could provide a mechanism for organisations that do not directly benefit from urban ecosystem services to finance their delivery for the greater benefit of society. For example, city agencies could pay private property owners to create niche urban habitats (e.g. install wildlife-accessible fencing) to enhance city biodiversity, which can help governments achieve their policy commitments to reduce biodiversity loss (Cerra, 2017). Financial incentives could help increase participation in existing initiatives; for instance, findings from Florida suggest that the National Wildlife Federation's Certified Wildlife Habitat™ program in USA could increase involvement though 'incentives or technical and cost-share assistance' (Widows & Drake, 2014). Philanthropic PUES is not necessarily selfless, as beneficiaries could benefit indirectly from positive publicity and improving stakeholder relations (Thompson, 2018). In this way, philanthropic PUES would be similar to sponsorship of public parks and nature reserves by major companies—but would enable companies to quantify their contributions to a range of ecosystem services (Thompson, 2018). Cities are ideal locations for philanthropic PUES that aims to generate publicity, due to their high densities of residents who would benefit from schemes, and thus form positive associations with the beneficiary organisation.

4 | KEY CONSIDERATIONS FOR PUES

There is a considerable body of work analysing the ecological and socio-economic conditions which make PES viable, and the ethical and practical issues which must be considered for PES schemes (Chan, Anderson, Chapman, Jespersen, & Olmsted, 2017; Pascual et al., 2014; Prager et al., 2016). Urban areas differ from rural landscapes due to relatively higher land prices, greater fragmentation of land ownership, and higher densities of people. This section discusses some challenges that the urban setting will pose to PES, before outlining some key critical issues that should be considered when designing and implementing PUES.

4.1 | Individual PUES interventions will be small in scope

The fragmentation of urban land tenure, and high land values in urban areas, will make it challenging for PUES schemes to create

large, uninterrupted areas of ecosystems. In contrast, PUES provides opportunities to fund relatively small interventions that, when scaled across large numbers of providers, could improve the ecological functioning and permeability of the urban landscape. Many of the opportunities for PUES come in retrofitting existing urban infrastructure; in the simplest cases through financing better maintenance and management of existing parks and private gardens. More ambitious PUES interventions could include the creation of new urban micro-ecosystems in the form of pocket parks, roadside trees, stormwater retention ponds, and adding green roofs. Such interventions would be suitable for integrating PUES into new developments. This could provide PUES beneficiaries with a way to reach a large number of private non-commercial providers within a concentrated neighbourhood, and could provide new property owners with a novel income stream.

4.2 | PUES will require alliances of both beneficiaries and providers

The fragmentation of land ownership in urban areas provides a challenge for beneficiaries looking to invest in PUES, because they must deal with large numbers of providers. This in turn can increase transaction costs associated with contract negotiations, payment distribution, and monitoring (Cacho et al., 2013; Jack et al., 2008). PES is most straightforward in cases where one beneficiary contracts one provider to supply desired services, but this situation is likely to be rare in cities. However, the close proximity of private landowners in cities presents an opportunity to establish 'provider alliances' that can encourage collective action and peer-monitoring of schemes through citizen science initiatives (Cacho et al., 2013; Cooper, Dickinson, Phillips, & Bonney, 2007). Existing informal institutions such as neighbourhood associations or horticultural societies could be targeted to form the core of PUES provider alliances.

At the other end of the spectrum, city authorities own many of the remaining contiguous urban ecosystems, such as parks and remnant forest patches. This could aid the governance and implementation of PUES in situations where government agencies act as providers, since beneficiaries would have only one central provider to target their negotiations and payments towards. However, the high density of actors in urban areas means that providers will often have to deal with numerous potential beneficiaries (e.g. neighbouring businesses). This can increase the risk of 'free-riding', where proximal beneficiaries that do not participate as PUES beneficiaries still receive the benefits (e.g. aesthetic upkeep of adjacent green space) because of those that do pay. To combat the risk of free-riding, 'beneficiary alliances' could be formed to centralise and enforce payments. Urban ecosystems provide multiple services, which "stack" together to provide a greater net benefit. A further advantage of beneficiary alliances is that they could enable stacking of payments for services; beneficiaries interested in different services could share the costs of PUES interventions, to reduce their individual costs and provide a greater budget for PUES investment (Robertson et al., 2014).

4.3 | PUES will benefit from the co-location of beneficiaries and providers in high densities

Payments for ecosystem services in rural areas is often hindered by spatial mismatches between providers and beneficiaries (Yahdjian et al., 2015). Increasing distances make it more complicated for beneficiaries and providers to meet and form transactions, and make it difficult for beneficiaries to verify that the required actions have been carried out and ecosystem services delivered. Some services may also suffer distance-decay, with either the quantity or measurement accuracy decreasing with increasing distance between provider and beneficiary (Bagstad et al., 2013). When beneficiaries and providers are located in close proximity to one another, service delivery is often more direct, traceable, and measurable (Bagstad et al., 2013), making issues of distance decay and spatial mismatch less likely in urban areas due to higher population densities, and the co-location of prospective beneficiaries and providers.

4.4 | PUES should not increase social inequity

After early interest in the environmental effectiveness and economic efficiency of PES (Engel, Pagiola & Wunder, 2008), socially equity considerations are now receiving equal attention (Pascual, Pagiola, & Wunder, , 2014). Equity has three inter-related dimensions: procedural equity which relates to an actor's ability to participate in a scheme, contextual equity which regards the surrounding social conditions (e.g., wealth and power disparities), and distributional equity which regards the ways in which payments are disbursed to providers (McDermott, Mahanty, & Schreckenberg, 2013). There is a risk that PES may optimise the provision of services desired by some stakeholders, at the detriment of services desired by others (Barnaud & Antona, 2014). Since levels of wealth, power, and education will be highly variable among urban residents, equity considerations will be just as important for PES development in urban settings, as in rural settings. For example, related initiatives such as land use planning for climate change adaptation have been found to exacerbate socio-spatial inequalities by displacing the urban poor, or protecting and prioritising urban elites (Anguelovski et al., 2016). Urban green space is inequitably distributed, and often concentrated in higher-wealth neighbourhoods (Wen, Zhang, Harris, Holt, & Croft, 2013). Hence, the uptake of PUES could be higher in these areas, since councils and homeowners will have more space to allocate to nature, rather than more practical uses. Therefore, it must be ensured that participation in PUES is not only made available to the wealthy; novel schemes in highly urbanised and low-wealth neighbourhoods must also be devised.

4.5 | PUES should not crowd out other motivations for nature conservation

Payments for ecosystem services scholars are giving increased attention to 'motivation crowding': how the provision of financial

incentives may strengthen (crowd-in) or weaken (crowd-out) intrinsic motivations to conserve nature (Ezzine-de-Blas, Corbera, & Lapeyre, 2019). There is mixed evidence on whether ecosystem service providers persist with project activities after payments cease (Dayer, Lutter, Sesser, Hickey, & Gardali, 2018). Indeed, such research is often hindered by a lack of appropriate baseline information about intrinsic motivations prior to PES implementation (Rode, Gómez-Baggethun, & Krause, 2015). Interestingly, although urban and rural residents experience the environment in very different ways, there is inconclusive evidence on whether one group harbours greater environmental knowledge and concern than the other (Gifford & Nilsson, 2014). To mitigate the risk of motivational crowding out, some authors have suggested that only a proportion of the opportunity costs could be covered (Kosoy, Martinez-Tuna, Muradian, & Martinez-Alier, 2007; Rode et al., 2015). Alternatively, coupling economic incentives with environmental education can crowd in intrinsic motivations to conserve nature (Andersson et al., 2018), and since the intensity of urbanisation around homes is negatively associated with homeowner's environmental knowledge (Coldwell & Evans, 2017), participant education may be a particularly important add-on to PUES.

4.6 | PUES should reflect a plurality of values

Ecosystem assessments can fail to reflect a plurality of values across different stakeholder groups within complex socio-ecological systems (Kolinjivadi et al., 2015). In urban planning, it is recommended to use formal decision-making tools to determine stakeholder preferences, to ensure that the values highlighted in a project reflect a broad range of stakeholders (Rall et al., 2015). As an exemplar method, multi-criteria decision analysis (MCDA) has been used to incorporate stakeholder knowledge and values into environmental decision making (Langemeyer, Palomo, Baraibar, & Gómez-Baggethun, 2018; Thompson & Friess, 2019). MCDA or similar participatory processes could be used to increase procedural equity and ensure that PUES schemes are designed to fulfil the needs and motivations of multiple city stakeholders. It is likely that the values associated with urban nature will fit somewhere between the 'purely instrumental' and 'purely intrinsic', and could be more accurately described as 'relational values' (Chan et al., 2016). These values are rooted in an obligation to fellow humans and non-humans, and are associated with traditional practices, intergenerational learning, and cultural identity (Bremmer et al., 2018). Relational values are not new to studies of urban nature; the concept of 'biophilia' outlines a set of relational values describing the innate connections that humans have with nature (Ross et al., 2018), and this concept has gained traction in urban planning over the past decade (Beatley, 2014; Beatley & Newman, 2013). Although successful examples of biophilic urban designs remain rare, the popularity of the concept amongst planners and architects in some cities (Newman, 2014) could provide a common language and opportunity to build PUES in as an inherent part of new urban designs.

4.7 | PUES must be sensitive to the differences between and within cities

The provision of ecosystem services, and public demand for them, varies in cities around the world, depending on the climatic conditions present, and the socio-economic characteristics of residents (Dobbs, Nitschke, & Kendal, 2014; Song, Richards, Edwards, & Tan, 2017). Even within individual cities, different members of society have different desires, and there will be spatial variation in provision (Baró et al., 2016). Such variation raises challenges for designing PES schemes, and impacts the feasibility of PUES, in urban areas around the world.

The demand for ecosystem services in a particular area will be impacted by the climate; for example, the cooling effect of vegetation may be prioritised in hotter and more humid cities, where heat-related mortality is a severe risk (Mora et al., 2017), and electricity consumption for air conditioning is higher (Akbari, Pomerantz, & Taha, 2001). Ecosystem service demand is also influenced by the characteristics of urban residents, particularly their economic characteristics (Casado-Arzuaga, Madariaga, & Onaindia, 2013). For example, urban food production can be important in supporting livelihoods among the poorest urban residents (Martinho da Silva, Oliveira Fernandes, Castiglione, & Costa, 2016; Zezza & Tasciotti, 2010), and the quantity of food produced in developing cities such as Vientiane in Laos can be substantial (Kethonga, Thadavong, & Moustier, 2004). Conversely, for wealthier residents in more economically developed cities, urban food production is generally an activity that is undertaken for recreation (Martinho da Silva et al., 2016). Therefore, PUES schemes around the world cannot all focus on the same suite of ecosystem services, but must be attuned to the most relevant services in the local context.

The viability of PUES, and the most appropriate form, will vary between cities due to considerable disparities in economics, education, and standards of living (Nagendra, Bai, Brondizio, & Lwasa, 2018). The economic benefits provided by urban ecosystems can be substantial, as reflected in the average economic value of US$30,000 per hectare per year found in a review of 25 studies (Elmqvist et al., 2015). However, this figure represents an average, and the economic value of urban ecosystem services is highly variable in different regions (Song, Tan, Edwards, & Richards, 2018). Similarly, the value of urban land is highly variable, ranging from over $100,000,000, to around $30,000 dollars per acre across the USA alone (Albouy, Ehrlich, & Shin, 2018). The relationship between the cost of land and the economic value of urban ecosystem services will impact the viability of PUES, particularly in cases where services are provided by private commercial landowners who are most dependent on land for their livelihoods. It may be more challenging to implement PUES in urban areas with high-value land, but feasibility may be enhanced in such cities when the potential benefits of urban ecosystem services have a high economic value. In addition to affecting the viability and focus of PUES, climatic and socio-economic variation in local context will impact practical and social considerations outlined above; including social equity, motivational crowding, and the size and organisational structure of the schemes.

4.8 | PUES must be grounded in science

In order for a beneficiary to invest in a PUES scheme, they must be able to predict the ecosystem service benefits that they will gain, and verify the success of the scheme as it progresses. PUES will therefore require a strong scientific grounding that quantifies the ecosystem services provided by different urban ecosystems under different management. There is a growing literature in mapping and valuing urban ecosystem services, although this work shows spatial biases towards China, Europe, and North America, and is predominantly conducted at the city-scale (Haase et al., 2014). To build capacity for PUES, more research should focus on under-studied regions, and on assessments of service quantity and value at the neighbourhood, street, or lot scale, in order to quantify the relationship between a new management activity and ecosystem service provision (sensu Naeem et al., 2015). Relatedly, determining the additionality of PUES schemes will require measuring environmental outcomes against both project and control sites, to determine what would have happened in the absence of the scheme (Pattanayak, Wunder, & Ferraro, 2010). However, there is a trade-off between analysing the potential for PUES at a local case study, and providing information that is generally applicable across multiple locations and cities. Due to the complexities inherent in PES, and the limited capacity of many stakeholders, it is not always feasible for providers or beneficiaries to conduct in-depth studies of PES potential (Naeem et al., 2015). To enable large-scale uptake of PUES, research must therefore aim to provide general rules that describe the benefits of different types of ecosystem, or management strategies. In some cases, PUES practitioners could build on existing bodies of research that have defined and synthesised the benefits of some management practices, such as green infrastructure for flood risk management (Lim & Lu, 2016), or the cooling effects of vegetation (Bowler, Buyung-Ali, Knight, & Pullin, 2010).

Verification and validation of PUES schemes will be challenging due to the limitations of remote sensing methods in heterogeneous urban areas. High-resolution satellite imagery could be used to monitor larger PUES schemes as they develop over time (Gibbs, Brown, Niles, & Foley, 2007), and could be supported by even higher-resolution remote sensing data, such as point cloud data derived from laser scanning, unmanned aerial vehicle photography, and ground-based photographic databases such as Google Street View (Richards & Edwards, 2017).

5 | CONCLUSIONS

Cities are short of space, and continue to grow rapidly and with little planning oversight in many parts of the world. This environmental change results in the loss of ecosystems and the vital services they provide to urban residents. Incentive-based conservation practices hold potential to improve livelihoods and support biodiversity conservation (Hein, Miller, & Groot, 2013; Ingram et al., 2014). Here, we have focused on the potential for PUES, discussing how urban settings already exhibit some widely reported enabling conditions for PES, such as: substantial benefits from ecosystems, threatened ecosystem service supply, clear land tenure, and a diverse array of prospective beneficiaries (Grima et al., 2016; Jack et al., 2008; Yahdjian et al., 2015). Hence, PUES offers an innovative approach that may help city authorities achieve their environmental policy goals, and also offers local citizens the incentive or opportunity to enhance environmental stewardship through bespoke, bottom-up initiatives. To implement PUES, we require a firm understanding of the relationship between urban ecosystems, their management, and the delivery of ecosystem services. Furthermore, PUES requires an interdisciplinary understanding of the motivations of potential beneficiaries and providers, the institutional setting, and the likely payment frameworks, for specific locations and types of interventions (sensu Acuto, Parnell, & Keto, 2018). With the right knowledge and active participation from governmental and non-governmental facilitators, we envisage that PES will expand from its current rural setting into urban areas.

CONFLICT OF INTEREST

Nothing to declare.

ACKNOWLEDGEMENTS

We thank the Editors and two anonymous reviewers for their reflections on PUES and helpful feedback which has improved this manuscript.

AUTHORS' CONTRIBUTIONS

D.R.R. and B.S.T. developed the concept behind this paper and wrote the manuscript. Both authors contributed critically to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

This article includes no data.

ORCID


Daniel R. Richards https://orcid.org/0000-0002-8196-8421

REFERENCES

Acuto, M., Parnell, S., & Keto, S. (2018). Building a global urban science. *Nature Sustainability*, *1*, 2–4. https://doi.org/10.1038/s41893-017-0013-9

Ahmed, K., & Sohail, K. (2008). Child's play and recreation in Dhaka City, Bangladesh. *Municipal Engineer: Proceedings of the Institute of Civil Engineers*, *161*, 263–270. https://doi.org/10.1680/muen.2008.161.4.263

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, *70*, 295–310. https://doi.org/10.1016/s0038-092x(00)00089-x

Albouy, D., Ehrlich, G., & Shin, M. (2018). Metropolitan land values. *The Review of Economics and Statistics*, *100*, 454–466. https://doi.org/10.1162/rest_a_00710

Andersson, K. P., Cook, N. J., Grillos, T., Lopez, M. C., Salk, C. F., Wright, G. D., & Mwangi, E. (2018). Experimental evidence on payments for forest commons conservation. *Nature Sustainability*, *1*, 128–135. https://doi.org/10.1038/s41893-018-0034-z

Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., … Teicher, H. (2016). Equity impacts of urban land use planning for climate adaptation: Critical perspectives from the global north and south. *Journal of Planning Education and Research*, *36*(3), 333–348. https://doi.org/10.1177/0739456X16645166

Aronson, M. F. J., Lepczyk, C. A., Evans, K. L., Goddard, M. A., Lerman, S. B., MacIvor, J. S., … Vargo, T. (2017). Biodiversity in the city: Key challenges for urban green space management. *Frontiers in Ecology and the Environment*, *15*, 189–196. https://doi.org/10.1002/fee.1480

Bagstad, K. J., Johnson, G. W., Voigt, B., & Villa, F. (2013). Spatial dynamics of ecosystem service flows: A comprehensive approach to quantifying actual services. *Ecosystem Services*, *4*, 117–125. https://doi.org/10.1016/j.ecoser.2012.07.012

Balogun, A. A., Morakinyo, T. E., & Adegun, O. B. (2014). Effect of tree-shading on energy demand of two similar buildings. *Energy and Buildings*, *81*, 305–315. https://doi.org/10.1016/j.enbuild.2014.05.046

Barnaud, C., & Antona, M. (2014). Deconstructing ecosystem services: Uncertainties and controversies around a socially constructed concept. *Geoforum*, *56*, 113–123. https://doi.org/10.1016/j.geoforum.2014.07.003

Baró, F., Palomo, I., Zulian, G., Vizcaino, P., Haase, D., & Gómez-Baggethun, E. (2016). Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy*, *57*, 405–417. https://doi.org/10.1016/j.landusepol.2016.06.006

Beatley, T. (2014). Imagining biophilic cities. In S. Lehmann (Ed.), *Low carbon cities* (pp. 123–134). London, UK: Routledge.

Beatley, T., & Newman, P. (2013). Biophilic cities are sustainable, resilient cities. *Sustainability*, *5*, 3328–3345. https://doi.org/10.3390/su5083328

Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. *Landscape and Urban Planning*, *162*, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics*, *29*(2), 293–301. https://doi.org/10.1016/S0921-8009(99)00013-0

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, *97*, 147–155. https://doi.org/10.1016/j.landurbplan.2010.05.006

Bremer, L. L., Brauman, K. A., Nelson, S., Prado, K. M., Wilburn, E., & Fiorini, A. C. O. (2018). Relational values in evaluations of upstream social outcomes of watershed Payment for Ecosystem Services: A review. *Current Opinion in Environmental Sustainability*, *35*, 116–123. https://doi.org/10.1016/j.cosust.2018.10.024

Brimont, L., Ezzine-de-Blas, D., Karsenty, A., Tambaza, F., Toulon, A., Rasolofonirina, G., & Razanamihanta, E. (2015). Achieving REDD+ objectives along with equity principles in Madagascar: A critical analysis of Makira project's development strategy. *Forests*, *2015*(6), 748–768.

Cacho, O. J., Lipper, L., & Moss, J. (2013). Transaction costs of carbon offset projects: A comparative study. *Ecological Economics*, *88*, 232–243. https://doi.org/10.1016/j.ecolecon.2012.12.008

Caro-Borrero, A., Corbera, E., Neitzel, K. C., & Almeida-Leñero, L. (2015). "We are the city lungs": Payments for ecosystem services in the outskirts of Mexico City. *Land Use Policy*, *43*, 138–148. https://doi.org/10.1016/j.landusepol.2014.11.008

Casado-Arzuaga, I., Madariaga, I., & Onaindia, M. (2013). Perception, demand and user contribution to ecosystem services in the Bilbao Metropolitan Greenbelt. *Journal of Environmental Management*, *129C*, 33–43. https://doi.org/10.1016/j.jenvman.2013.05.059

Cerra, J. F. (2017). Emerging strategies for voluntary urban ecological stewardship on private property. *Landscape and Urban Planning*, *157*, 586–597. https://doi.org/10.1016/j.landurbplan.2016.06.016

Chan, K. M. A., Anderson, E., Chapman, M., Jespersen, K., & Olmsted, P. (2017). Payments for ecosystem services: Rife with problems and potential—For transformation towards sustainability. *Ecological Economics*, *140*, 110–122. https://doi.org/10.1016/j.ecolecon.2017.04.029

Chan, K. M. A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., … Turner, N. (2016). Why protect nature? Rethinking values and the environment. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(6), 1462–1465. https://doi.org/10.1073/pnas.1525002113

Coldwell, D. F., & Evans, K. L. (2017). Contrasting effects of visiting urban green-space and the countryside on biodiversity knowledge and conservation support. *PLoS ONE*, *12*(3), e0174376. https://doi.org/10.1371/journal.pone.0174376

Cooper, C. B., Dickinson, J., Phillips, T., & Bonney, R. (2007). Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society*, *12*, 2. https://doi.org/10.5751/es-02197-120211

Dayer, A. A., Lutter, S. H., Sesser, K. A., Hickey, C. M., & Gardali, T. (2018). Private landowner conservation behavior following participation in voluntary incentive programs: Recommendations to facilitate behavioral persistence. *Conservation Letters*, *11*(2), 1–11. https://doi.org/10.1111/conl.12394

Dobbs, C., Nitschke, C. R., & Kendal, D. (2014). Global drivers and tradeoffs of three urban vegetation ecosystem services. *PLoS ONE*, *9*, e113000. https://doi.org/10.1371/journal.pone.0113000

Dongus, S., Nyika, D., Kannady, K., Mtasiwa, D., Mshinda, H., Gosoniu, L., … Castro, M. C. (2009). Urban agriculture and Anopheles habitats in Dar es Salaam, Tanzania. *Geospatial Health*, *3*, 189–210. https://doi.org/10.4081/gh.2009.220

Dupont, V. (2017). Biodiversity offsets in NSW Australia: The biobanking scheme versus negotiated offsets in Urban areas. *Journal of Environmental Law*, *29*, 75–100. https://doi.org/10.1093/jel/eqw031

Elmqvist, T., Setälä, H., Handel, S. N., van der Ploeg, S., Aronson, J., Blignaut, J. N., … de Groot, R. (2015). Benefits of restoring ecosystem services in urban areas. *Current Opinion in Environmental Sustainability*, *14*, 101–108. https://doi.org/10.1016/j.cosust.2015.05.001

Engel, S., Pagiola, S., & Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics*, *65*, 663–674.

Ezzine-de-blas, D., Corbera, E., & Lapeyre, R. (2019). Payments for environmental services and motivation crowding: Towards a conceptual framework. *Ecological Economics*, *156*, 434–443. https://doi.org/10.1016/j.ecolecon.2018.07.026

Freeman, C., Dickinson, K. J. M., Porter, S., & van Heezik, Y. (2012). "My garden is an expression of me": Exploring householders' relationships with their gardens. *Journal of Environmental Psychology*, *32*, 135–143. https://doi.org/10.1016/j.jenvp.2012.01.005

Gaston, K. J., Warren, P. H., Thompson, K., & Smith, R. M. (2005). Urban domestic gardens (IV): The extent of the resource and its associated features. *Biodiversity and Conservation*, *14*, 3327–3349. https://doi.org/10.1007/s10531-004-9513-9

Gibbs, H. K., Brown, S., Niles, J. O., & Foley, J. A. (2007). Monitoring and estimating tropical forest carbon stocks: Making REDD a reality. *Environmental Research Letters*, *2*, 45023. https://doi.org/10.1088/1748-9326/2/4/045023

Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review. *International Journal of Psychology*, *49*, 141–157. https://doi.org/10.1002/ijop.12034

Grima, N., Singh, S. J., Smetschka, B., & Ringhofer, L. (2016). Payment for Ecosystem Services (PES) in Latin America: Analysing the

performance of 40 case studies. *Ecosystem Services*, *17*, 24–32. https://doi.org/10.1016/j.ecoser.2015.11.010

Haaland, C., & van den Bosch, C. K. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry & Urban Greening*, *14*, 760–771. https://doi.org/10.1016/j.ufug.2015.07.009

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., … Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, *43*, 413–433. https://doi.org/10.1007/s13280-014-0504-0

Hager, G. W., Belt, K. T., Stack, W., Burgess, K., Grove, J. M., Caplan, B., … Groffman, P. M. (2013). Socioecological revitalization of an urban watershed. *Frontiers in Ecology and the Environment*, *11*, 28–36. https://doi.org/10.1890/120069

Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., … Pauleit, S. (2015). The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosystem Services*, *12*, 228–246. https://doi.org/10.1016/j.ecoser.2014.11.013

Hein, L., Miller, D. C., & de Groot, R. (2013). Payments for ecosystem services and the financing of global biodiversity conservation. *Current Opinion in Environmental Sustainability*, *5*, 87–93. https://doi.org/10.1016/j.cosust.2012.12.004

Huang, C., Yang, J., Lu, H., Huang, H., & Yu, L. (2017). Green spaces as an indicator of urban health: Evaluating its changes in 28 mega-cities. *Remote Sensing*, *9*, 1266. https://doi.org/10.3390/rs9121266

Hyams, K., & Fawcett, T. (2013). The ethics of carbon offsetting. *Wiley Interdisciplinary Reviews: Climate Change*, *4*, 91–98. https://doi.org/10.1002/wcc.207

Ingram, J. C., Wilkie, D., Clements, T., McNab, R. B., Nelson, F., Baur, E. H., … Foley, C. A. H. (2014). Evidence of Payments for Ecosystem Services as a mechanism for supporting biodiversity conservation and rural livelihoods. *Ecosystem Services*, *7*, 10–21. https://doi.org/10.1016/j.ecoser.2013.12.003

Jack, B. K., Kousky, C., & Sims, K. R. E. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 9465–9470. https://doi.org/10.1073/pnas.0705503104

Jayachandran, S., de Laat, J., Lambin, E. F., Stanton, C. Y., Audy, R., & Thomas, N. E. (2017). Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. *Science*, *357*, 267–273. https://doi.org/10.1126/science.aan0568

Joassart-Marcelli, P. (2010). Leveling the playing field? Urban disparities in funding for local parks and recreation in the Los Angeles region. *Environment and Planning A: Economy and Space*, *42*, 1174–1192. https://doi.org/10.1068/a42198

Karp, D. S., Tallis, H., Sachse, R., Halpern, B., Thonicke, K., Cramer, W., … Wolny, S. (2015). National indicators for observing ecosystem service change. *Global Environmental Change*, *35*, 12–21. https://doi.org/10.1016/j.gloenvcha.2015.07.014

Karsenty, A., Aubert, S., Brimont, L., Dutilly, C., Desbureaux, S., Ezzine de Blas, D., & Le Velly, G. (2017). The economic and legal sides of additionality in payments for environmental services. *Environmental Policy and Governance*, *27*(5), 422–435.

Kethonga, S., Thadavong, K., & Moustier, P. (2004). Vegetable marketing in Vientiane. FSP project 2000–56. Funded by the French Ministry of Foreign Affairs. Retrieved from https://agritrop.cirad.fr/544876/1/document_544876.pdf

Kolinjivadi, V., Gamboa, G., Adamowski, J., & Kosoy, N. (2015). Capabilities as justice: Analysing the acceptability of payments for ecosystem services (PES) through 'social multi-criteria evaluation'. *Ecological Economics*, *118*, 99–113.

Kosoy, N., Martinez-Tuna, M., Muradian, R., & Martinez-Alier, J. (2007). Payments for environmental services in watersheds: Insights from a comparative study of three cases in Central America. *Ecological Economics*, *61*(2), 446–455. https://doi.org/10.1016/j.ecolecon.2006.03.016

Langemeyer, J., Palomo, I., Baraibar, S., & Gómez-Baggethun, E. (2018). Participatory multi-criteria decision aid: Operationalizing an integrated assessment of ecosystem services. *Ecosystem Services*, *30*, 49–60. https://doi.org/10.1016/j.ecoser.2018.01.012

Levine, J., Chan, K. M. A., & Satterfield, T. (2015). From rational actor to efficient complexity manager: Exorcising the ghost of Homo economicus with a unified synthesis of cognition research. *Ecological Economics*, *114*, 22–32. https://doi.org/10.1016/j.ecolecon.2015.03.010

Lim, H. S., & Lu, X. X. (2016). Sustainable urban stormwater management in the tropics: An evaluation of Singapore's ABC Waters Program. *Journal of Hydrology*, *538*, 842–862. https://doi.org/10.1016/j.jhydrol.2016.04.063

Loram, A., Tratalos, J., Warren, P. H., & Gaston, K. J. (2007). Urban domestic gardens (X): The extent & structure of the resource in five major cities. *Landscape Ecology*, *22*, 601–615. https://doi.org/10.1007/s10980-006-9051-9

Martinho da Silva, I., Oliveira Fernandes, C., Castiglione, B., & Costa, L. (2016). Characteristics and motivations of potential users of urban allotment gardens: The case of Vila Nova de Gaia municipal network of urban allotment gardens. *Urban Forestry & Urban Greening*, *20*, 56–64. https://doi.org/10.1016/j.ufug.2016.07.014

McDermott, M., Mahanty, S., & Schreckenberg, K. (2013). Examining equity: A multidimensional framework for assessing equity in payments for ecosystem services. *Environmental Science & Policy*, *33*, 416–427. https://doi.org/10.1016/j.envsci.2012.10.006

McPhearson, T., Hamstead, Z. A., & Kremer, P. (2014). Urban ecosystem services for resilience planning and management in New York City. *Ambio*, *43*, 502–515. https://doi.org/10.1007/s13280-014-0509-8

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, C. R., … Trauernicht, C. (2017). Global risk of deadly heat. *Nature Climate Change*, *7*, 501–506. https://doi.org/10.1038/nclimate3322

Moreno-Mateos, D., Maris, V., Béchet, A., & Curran, M. (2015). The true loss caused by biodiversity offsets. *Biological Conservation*, *192*, 552–559. https://doi.org/10.1016/j.biocon.2015.08.016

Naeem, B. S., Ingram, J. C., Varga, A., Agardy, T., Barten, P., Bennett, G., … Wunder, S. (2015). Get the science right when paying for nature's services. *Science*, *347*, 1206–1207. https://doi.org/10.1126/science.aaa1403

Nagendra, H., Bai, X., Brondizio, E. S., & Lwasa, S. (2018). The urban south and the predicament of global sustainability. *Nature Sustainability*, *1*, 341–349. https://doi.org/10.1038/s41893-018-0101-5

National Parks Board. (2017). *Annual Report*. *National Parks Board of Singapore*. Retrieved from www.nparks.gov.sg/about-us/annual-reports/nparks-annual-report-archives

Newman, P. (2014). Biophilic urbanism: A case study on Singapore. *Australian Planner*, *51*, 47–65. https://doi.org/10.1080/07293682.2013.790832

Orsini, F., Kahane, R., Nono-Womdim, R., & Gianquinto, G. (2013). Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development*, *33*, 695–720. https://doi.org/10.1007/s13593-013-0143-z

Pan, X., Xu, L., Yang, Z., & Yu, B. (2017). Payments for ecosystem services in China: Policy, practice, and progress. *Journal of Cleaner Production*, *158*, 200–208. https://doi.org/10.1016/j.jclepro.2017.04.127

Pascual, U., Phelps, J., Garmendia, E., Brown, K., Corbera, E., Martin, A., … Muradian, R. (2014). Social equity matters in payments for ecosystem services. *BioScience*, *64*(11), 1027–1036. https://doi.org/10.1093/biosci/biu146

Pattanayak, S. K., Wunder, S., & Ferraro, P. J. (2010). Show me the money: Do payments supply environmental services in developing countries?

Review of Environmental Economics and Policy, *4*, 254–274. https://doi.org/10.1093/reep/req006

Pereira, S. (2010). Payment for ecosystem services in the Amazon Forest: How can conservation and development be reconciled? *The Journal of Environment & Development*, *19*(2), 171–190. https://doi.org/10.1177/1070496510368047

Perrot-Maître, D. (2014). The Vittel case: A public-private partnership in the mineral water industry. Case studies on Remuneration of Positive Externalities (RPE)/Payments for Environmental Services (PES), prepared for the Multi-stakeholder dialogue 12-13 September 2013, FAO, Rome (p. 8). Retrieved from http://www.fao.org/3/a-bl927e.pdf

Peterson St-Laurent, G., Hagerman, S., & Hoberg, G. (2017). Emergence and influence of a new policy regime: The case of forest carbon offsets in British Columbia. *Land Use Policy*, *60*, 169–180. https://doi.org/10.1016/j.landusepol.2016.10.025

Prager, C. M., Varga, A., Olmsted, P., Ingram, J. C., Cattau, M., Freund, C., … Naeem, S. (2016). An assessment of adherence to basic ecological principles by payments for ecosystem service projects. *Conservation Biology*, *30*, 836–845. https://doi.org/10.1111/cobi.12648

Rall, E. L., Kabisch, N., & Hansen, R. (2015). A comparative exploration of uptake and potential application of ecosystem services in urban planning. *Ecosystem Services*, *16*, 230–242. https://doi.org/10.1016/j.ecoser.2015.10.005

Richards, D. R., & Edwards, P. J. (2017). Quantifying street tree regulating ecosystem services using Google Street View. *Ecological Indicators*, *77*, 31–40. https://doi.org/10.1016/j.ecolind.2017.01.028

Robertson, M., BenDor, T. K., Lave, R., Riggsbee, A., Ruhl, J. B., & Doyle, M. (2014). Stacking ecosystem services. *Frontiers in Ecology and the Environment*, *12*, 186–193. https://doi.org/10.1890/110292

Rode, J., Gómez-Baggethun, E., & Krause, T. (2015). Motivation crowding by economic incentives in conservation policy: A review of the empirical evidence. *Ecological Economics*, *117*, 270–282. https://doi.org/10.1016/j.ecolecon.2014.11.019

Ross, H., Witt, K., & Jones, N. A. (2018). Stephen Kellert's development and contribution of relational values in social-ecological systems. *Current Opinion in Environmental Sustainability*, *35*, 46–53.

Salzman, J., Bennett, G., Carroll, N., Goldstein, A., & Jenkins, M. (2018). The global status and trends of Payments for Ecosystem Services. *Nature Sustainability*, *1*, 136–144. https://doi.org/10.1038/s41893-018-0033-0

Schadler, E., & Danks, C. (2011). Carbon offsetting through tree planting. The Sacramento Tree Foundation and Harbison-Mahony-Higgins Builders Inc., Retrieved from http://www.uvm.edu/%7Ecfcm/UCF/SacTree02022012.pdf

Silvertown, J. (2015). Have ecosystem services been oversold? *Trends in Ecology & Evolution*, *30*, 641–648. https://doi.org/10.1016/j.tree.2015.08.007

Song, X. P., Richards, D., Edwards, P. J., & Tan, P. Y. (2017). Benefits of trees in tropical cities. *Science*, *356*, 1241. https://doi.org/10.1126/science.aan6642

Song, X. P., Tan, P. Y., Edwards, P., & Richards, D. (2018). The economic benefits and costs of trees in urban forest stewardship: A systematic review. *Urban Forestry & Urban Greening*, *29*, 162–170. https://doi.org/10.1016/j.ufug.2017.11.017

Tacoli, C. (1998). Rural-urban interactions: A guide to the literature. *Environment and Urbanization*, *10*, 147–166. https://doi.org/10.1630/095624798101284356

Tan, P. Y., Wang, J., & Sia, A. (2013). Perspectives on five decades of the urban greening of Singapore. *Cities*, *32*, 24–32. https://doi.org/10.1016/j.cities.2013.02.001

Thompson, B. S. (2018). Institutional challenges for corporate participation in payments for ecosystem services (PES): Insights from Southeast Asia. *Sustainability Science*, *13*, 919–935. https://doi.org/10.1007/s11625-018-0569-y

Thompson, B. S. (2019). Payments for ecosystem services (PES) and corporate social responsibility (CSR): Perspectives on sustainable production, stakeholder relations, and philanthropy in Thailand. *Business Strategy and the Environment*, *28*, 497–511. https://doi.org/10.1002/bse.2260

Thompson, B. S., Clubbe, C. P., Primavera, J. H., Curnick, D., & Koldewey, H. J. (2014). Locally assessing the economic viability of blue carbon: A case study from Panay Island, the Philippines. *Ecosystem Services*, *8*, 128–140. https://doi.org/10.1016/j.ecoser.2014.03.004

Thompson, B. S., & Friess, D. A. (2019). Stakeholder preferences for payments for ecosystem services (PES) versus other environmental management approaches for mangrove forests. *Journal of Environmental Management*, *233*, 636–648. https://doi.org/10.1016/j.jenvman.2018.12.032

Vailshery, L. S., Jaganmohan, M., & Nagendra, H. (2013). Effect of street trees on microclimate and air pollution in a tropical city. *Urban Forestry & Urban Greening*, *12*, 408–415. https://doi.org/10.1016/j.ufug.2013.03.002

Wang, X.-J. (2009). Analysis of problems in urban green space system planning in China. *Journal of Forestry Research*, *20*, 79–82. https://doi.org/10.1007/s11676-009-0014-2

Wen, M., Zhang, X., Harris, C. D., Holt, J. B., & Croft, J. B. (2013). Spatial disparities in the distribution of parks and green spaces in the USA. *Annals of Behavioral Medicine*, *45*, 18–27. https://doi.org/10.1007/s12160-012-9426-x

Widows, S. A., & Drake, D. (2014). Evaluating the National Wildlife Federation's Certified Wildlife Habitat™ program. *Landscape and Urban Planning*, *129*, 32–43. https://doi.org/10.1016/j.landurbplan.2014.05.005

Wild, T. C., Bernet, J. F., Westling, E. L., & Lerner, D. N. (2011). Deculverting: Reviewing the evidence on the "daylighting" and restoration of culverted rivers. *Water and Environment Journal*, *25*, 412–421. https://doi.org/10.1111/j.1747-6593.2010.00236.x

Wunder, S. (2013). When payments for environmental services will work for conservation. *Conservation Letters*, *6*, 230–237.

Wunder, S. (2015). Revisiting the concept of payments for environmental services. *Ecological Economics*, *117*, 234–243. https://doi.org/10.1016/j.ecolecon.2014.08.016

Wunder, S., Brouwer, R., Engel, S., Ezzine-de-Blas, D., Muradian, R., Pascual, U., & Pinto, R. (2018). From principles to practice in paying for nature's services. *Nature Sustainability*, *1*, 145–150. https://doi.org/10.1038/s41893-018-0036-x

Yahdjian, L., Sala, O. E., & Havstad, K. M. (2015). Rangeland ecosystem services: Shifting focus from supply to reconciling supply and demand. *Frontiers in Ecology and the Environment*, *13*, 44–51. https://doi.org/10.1890/140156

Zezza, A., & Tasciotti, L. (2010). Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy*, *35*, 265–273. https://doi.org/10.1016/j.foodpol.2010.04.007

How to cite this article: Richards DR, Thompson BS. Urban ecosystems: A new frontier for payments for ecosystem services. *People Nat*. 2019;1:249–261. https://doi.org/10.1002/pan3.20