Paying for green : a scoping review of alternative financing models for nature-based solutions

Abstract

Nature-based solutions (NBS) are widely regarded as cost-effective responses to climate change and environmental degradation that also provide numerous co-benefits. However, despite significant policy attention, NBS plans often fail to materialize due to public budget shortfalls. Alongside traditional public finance, the international debate increasingly urges the mobilization of private capital for NBS through alternative financing (AF) techniques. In this scoping review, we examine the literature on a) the AF models connected to NBS and b) the drivers and barriers associated with these AF models in terms of their financial technicity and their embeddedness in the political, economic, social, technological, legal/institutional, and environmental/spatial ("PESTLE") context. Although many models are discussed, the results indicate that none can be considered full substitutes for traditional public finance. Barriers and drivers converge around seven overarching tensions: new revenue and risk distribution vs. uncertainty, budgetary and legal pressure vs. political willingness and risk aversion, market demand vs. market failures, private sector engagement vs. social acceptance and risks, legal and institutional conduciveness vs. inertia, and upscaling potential vs. environmental risks and land use. Future research should focus on a) how to further integrate NBS monitoring, quantification, valuation, and monetization into AF models, b) systemic and empirical approaches to improve the understanding of the applicability and transferability of AF models, and c) an exploration of the potential qualities and social risks of AF models in NBS governance arrangements.

Keywords: nature-based solutions, green infrastructure, finance, funding, alternative finance

1. Introduction

Policy and academic circles are increasingly emphasizing the urgency of infrastructure renewal to cope with climate change. There is a strong EU policy agenda to promote natural solutions over "gray," or engineered, physical infrastructures. Hence, cities are implementing infrastructure policies based on natural resources and structures, commonly framed as nature-based solutions (NBS).

The European Commission defines NBS as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience […]" (European Commission, 2015). NBS comprise a broad catalog, ranging from large nature reserves and forestry to meso-level riparian buffers and urban parks to the more local green walls and roofs (Anderson & Gough, 2021; Dorst et al., 2019).

Although allegedly more cost effective and efficient than gray infrastructure, NBS implementation remains ostensibly slow (Deely et al., 2020). Prior studies have identified myriad barriers, including the lack of design standards, political unwillingness, sectoral approaches to NBS, path dependencies, technological uncertainty, the unavailability of funds, insufficient institutional capacities, and the lack of legal basis to enforce NBS policy (Dorst et al., 2022; Kabisch et al., 2016; Sarabi et al., 2019).

Among these barriers, in particular, the financial precarity of NBS has recently drawn scholarly attention. NBS projects generate widespread public benefits but do not produce immediate revenue streams to support the high sunk costs they often entail (Mayor et al., 2021). Given the low revenue potential and susceptibility to market failures such as freeriding, NBS typically rely on public financing. Continuous austerity policies, however, have spurred governments to restrict their budget allocation to investments related to legal obligations and political priorities, neither of which traditionally account for NBS (Kabisch et al., 2016; Mell, 2018b; Mell, 2020). In part, this public divestment derives from the inability of public accountancy praxis to account for the economic value of natural assets (Matsler, 2019).

To improve the economic case for NBS, scholars have approached NBS from a business model perspective, with the overarching aim of demonstrating how NBS create value and pinpointing which financial models can ultimately translate this value into tangible cash flows (Egusquiza et al., 2021; Kampelmann, 2021; Mayor et al., 2021; Ternell et al., 2020; Toxopeus & Polzin, 2017). The focus is increasingly shifting toward mechanisms that also unlock private resources for NBS, sourced from institutional investors, businesses, and citizens (European Commission, 2015; Polzin et al., 2017; Toxopeus & Polzin, 2021). In their recent review of NBS financing challenges and strategies, Toxopeus and Polzin (2021) briefly touch upon several potential models, including tax increment financing, land value capture, impact bonds, and crowdfunding. All of these can be described as forms of alternative financing (AF), that is, arrangements that draw on financial resources other than public budgets collected through general taxation.

While potentially fruitful for enhancing private capital flows to NBS, such models are unlikely to be simple "plug-and-play" solutions. Toxopeus and Polzin (2021) identify the barrier effect of (monetary) valuation techniques being ill equipped to account for the value of NBS, as well as the challenges of managing cooperative action between public actors and potential private financiers. In this scoping review article, we build upon their work in two ways. First, we further identify the alternative financing models currently under discussion for NBS projects. Second, we scrutinize the facets that potentially affect their use in practice, in terms of both their financial technicity (i.e., how they mobilize cash flows) and their broader societal embeddedness. We address two research questions:

a) What AF models are currently conceptualized or applied to NBS?
b) What drivers and barriers are associated with AF models?

The article proceeds as follows. In the next section, we describe the methods we used to conduct our scoping review. In the third section, we present the results; we describe the characteristics of the reviewed literature, provide an overview of financial models, and present recurring themes regarding

their associated drivers and barriers. In the fourth section, we discuss avenues that require further attention. Finally, we summarize the main findings and limitations of the review.

2. Methods

2.1 Protocol

Given the broad scope of the research questions and the heterogeneity of the literature under scrutiny, we have applied a scoping review method. A scoping review is methodologically similar to a systematic review but differs in its objectives, as it "seeks to present an overview of a potentially large and diverse body of literature pertaining to a broad topic" (Pham et al., 2014, p. 372). To capture the breadth of AF models currently discussed, we have consulted various study designs and sources. Tables 1 and 2 present the consulted databases, search queries, and eligibility criteria.

[insert Table 1]

[insert Table 2]

The concept of NBS, as defined above, resembles prior concepts such as "green infrastructure," "ecosystem-based adaptation," and "ecosystem services," all of which articulate similar ideas on the cost-effectiveness and multifunctionality of natural resources (Dorst et al., 2019; Escobedo et al., 2019; Pauleit et al., 2017). The keyword "nature-based solutions" was therefore supplemented with one of the most related concepts, namely "green infrastructure," as well as with more generic terms that generally refer to natural resources and surroundings, such as "green space" and "natural infrastructure." Concerning financial keywords, we used "funding" and "financing" and supplemented these with the versatile financial nomenclature that emerged from a preliminary screening of research articles and web pages. We used a longlist of keywords for WoS and Scopus and, for convenience, applied a shortlist to Google Scholar and Google Search. Despite its limitations regarding replicability, we deemed a Google Search query necessary, as reports from government agencies and gray literature resources are not universally indexed in academic databases.

After searching the databases, duplicates were removed, and titles and abstracts were screened against the eligibility criteria. In total, we screened 1,862 titles and abstracts. Based on the inclusion and exclusion criteria, we removed 1,654 search results in the first iteration. Predominant reasons for exclusion included a) not mentioning NBS or related concepts, b) not addressing NBS or financial models for NBS, or c) emphasizing the (monetary) valuation of NBS. Many publications did not explicitly focus on NBS finance but covered the financial dimension as part of a broader discussion on NBS management techniques. We also included these publications.

We withheld 208 reports for full-text screening, of which 34 were omitted due to inaccessibility. Many of the omitted reports were likely useful contributions from the North American Water

Environment Federation's Technical Exhibition and Conference (WEFTEC) conferences, to which our subscriptions, unfortunately, did not allow access. Parallel to academic databases, we identified 19 additional results through Google Search, which comprised scientific reports resulting from European research projects (e.g., Horizon 2020), as well as government reports. Following the eligibility criteria, we included 15 additional reports. We eventually included 121 publications for review. Fig. 1 presents an overview of the selection process.

[insert Figure 1]

2.2 Data charting, extraction, and analysis

As this review aims to a) identify alternative financial models for NBS and related conceptual domains and b) examine their associated drivers and barriers. We examined the literature for data items on the following topics (T):

- T1: Dataset characteristics
  - T1a: Conceptual domain (NBS, GI, ES…) and type/function of NBS
  - T1b: Location of (conceptual) application of AF model
  - T1c: Type of publication and subject area (if applicable)
  - T1d: Ex-ante/conceptual or ex-post/applied nature of the study
  - T1e: Research objective(s)
- T2: Discussed AF model(s)
- T3: Drivers and barriers associated with AF for NBS

[insert Figure 2]

In addressing T2, we introduced a matrix typology for financial models in which we differentiated between the financiers and funders of NBS projects (Fig. 2). Financing refers to the provision of resources needed to implement a project, whereas funding refers to the ultimate payment of the implementation, operation, and capital costs. In terms of "who" finances or funds a project, we distinguished broadly between public and private actors, the former referring to governments and government-affiliated entities such as state-owned enterprises, and the latter denoting any actor that does not directly associate with a government setting. This includes banks, institutional investors, enterprises, NGOs, non-profit organizations, and citizens.

Regarding T3, we analyzed the drivers and barriers of AF models according to their financial–technical traits and societal influences. With financial–technical traits, we refer to elements derived from the design of a model itself, such as the implied longevity of payment periods, monetization needs, interest rates, transaction sizes, types of transaction (payments, debt, equity, etc.), risk distributions, and transaction costs. We mapped external influences through the PESTLE framework, which reviews the

potential influences of politics, social factors, economics, technology, legal/institutional/regulatory frameworks, and environmental/spatial conditions on business cases. PESTLE, which is popular in mainstream business analyses, has been applied previously in scholarship considering drivers and barriers in sustainability matters (Lee & Jepson, 2020; Zalengera et al., 2014).

Given the heterogeneity of the dataset in terms of conceptual domains (NBS, ES, GI…) and financial models, we utilized a narrative synthesis approach and deductively coded the reviewed literature. When we identified a financial–technical or PESTLE element, we designated it as a driver or barrier, by assigning a tick or cross, and briefly described its content. We assigned an asterisk to a financial–technical or PESTLE element if it was not discussed. Since our aim was to identify all the drivers or barriers that authors associate with AF models, we did not systematically distinguish between assessments derived from peer-reviewed or gray literature sources and empirical or conceptual studies. We thus also included remarks not yet supported by empirical evidence. We considered the inclusion of conceptual publications (modeling of new financial models, research of possible models for specific locations) necessary to collect the most novel AF models currently under discussion. After analyzing the literature, we compared and summarized the barriers and drivers per AF model and finally compiled them into overarching themes. We organized our analysis using Microsoft Excel, the result of which can be viewed in the Supplementary Data section of the article.

3. Results

3.1 Dataset

Seventy percent of the reviewed literature conceptualized natural interventions as either NBS, GI, or ES. The remainder employed concepts such as “open space,” “natural area,” “water” and “marine infrastructure,” “sustainable development,” or “sustainable infrastructure.” More specific concepts included “large green infrastructure projects” (LGIP) and “low carbon climate resilient” (LCCR) infrastructure. Concerning concrete types and functions of NBS, most publications did not apply a specific scope but referred to the multifunctionality of NBS in general. Where type and function were detailed, topics mostly touched upon hydrological, recreational, or conservation scopes. The dataset covers 34 countries, with the US and UK particularly well represented, accounting for half of the reviewed literature.

The dataset exhibits a diverse literature base. Sixty-three percent of the literature comprises peer-reviewed journal articles, and 22% scientific or governmental reports. The remainder includes book chapters, conference proceedings, and opinions and responses to articles published in academic journals. Regarding the literature indexed by WoS and Scopus (n = 77), 64% relate to fields in the environmental sciences. Other fields include research on the built environment, such as geography, planning and development, and urban studies (17%). Somewhat surprisingly, literature on leisure and hospitality is also well represented in the dataset (12%). Less common subject areas include economics and

engineering (5% and 3%, respectively). The strikingly low proportion of economics is likely due to many financial or economic studies on NBS appearing in journals indexed primarily as environmental sciences.

[insert Figure 3]

Fifty-nine of the reviewed publications are predominantly conceptual or ex-ante in nature, with research objectives including explorations of potential AF models for specific ecological challenges or locations, simulations of the use of a model, or examinations of, for example, the local acceptability of AF model use. Fifty-four publications entail predominantly ex-post studies on AF models applied in practice. These aimed mostly to inform on the performance, reasons for adoption, and further potential of AF models. Eight publications included both ex-ante and ex-post assessments of AF models, to inform potential AF techniques based on existing cases.

Most publications drew findings from qualitative analyses of case studies, surveys, or interviews with stakeholders. Also common were qualitative review approaches to systematically synthesize knowledge on a specific AF model or, less systematically, to identify potential AF models. Quantitative approaches were applied a) when considering broader datasets (e.g., inter-municipal or regional surveys and census data), b) when modeling the viability of an AF technique, or c) when seeking relations between AF model adoption and (local) societal conditions. In several studies, the methodological approach was poorly defined or absent, which we attribute to the large number of gray literature sources included. Fig. 3 summarizes the study designs and evidence sources in the reviewed literature.

3.2 Alternative financial models for nature-based solutions

[insert Table 3]

3.2.1 Public financing, public funding

Table 3 provides an overview and brief description of the AF models found in the literature. In terms of traditional public finance, authors often suggest new iterations of classic funding models (taxes and grant programs). Rather than draw new revenue sources, more innovative models aim to use existing public resources more efficiently. For example, public authorities can strategically source funds from other government departments that equally benefit from NBS investments (co-financing) or can transfer public capital to more proficient private capital managers, who then use the income derived from investments with this capital to finance and manage projects (endowment funds).

3.2.2 Public financing, private funding

Various models aim to recover the costs of public investments in NBS by extracting revenues from either NBS users or beneficiaries. One financing option in this regard is to create a fund through which public capital is lent perpetually to those who implement NBS, with the capital returning to the fund over time through repayment formulas (state revolving loan funds). Other models are distinctly funding modalities that extract revenue by monetizing the added socio-cultural value of public green space (commercial exploitation), by addressing the windfall value gains of surrounding properties caused by NBS projects (land value capture tools), or by charging the users of, for example, water and sewer utilities for the benefits enjoyed through the enhanced quality produced by NBS projects (utility fees).

3.2.3 Private financing, public funding

Traditionally, governments turn to capital markets to finance large infrastructure projects. As for NBS specifically, new types of bonds have received attention as ways to accelerate and scale up public NBS investment. For example, green bonds, like regular bonds, are fixed-income securities with a relatively long maturity, but they earmark raised capital exclusively for sustainability purposes. More recent innovative bond types apply variable interest rates based on the performance of underlying NBS projects (environmental impact bonds) or seek to finance NBS measures that help prevent natural disasters by monetizing insurance premium savings and avoided capital costs manifested by the risk-reducing effect of NBS (resilience bonds). Also highlighted is the broader field of "impact investing," which refers to any type of investment that explicitly aims to generate a positive social or environmental impact.

3.2.4 Private financing, private funding

Various AF models rely entirely on the private sector to implement NBS, by either establishing bottom-up platforms or applying market mechanisms. Regarding the former, modes of crowdfunding and community currencies, for example, are used as platforms for (voluntary) financial contributions from citizens to, usually, finance neighborhood NBS projects. More formal bottom-up approaches include business improvement districts (BIDs) and their many variants, community asset transfers, and land trusts, all of which seek to (partially) transfer the public responsibilities of local public goods, such as parks, to self-financing private entities.

Market mechanisms apply mostly to efforts to internalize environmental costs in market environments, for example, by allowing owners of environmentally valuable land to sell their unused building rights to other landowners (TDR) or by allowing actors exerting pressure on ecosystems to offset their impacts (cap-and-trade and credit systems). Conversely, payment for ecosystems services (PES) markets emphasize NBS benefits and aim to incentivize private NBS measures by establishing fora for beneficiaries of NBS to pay the providers thereof.

3.2.5 Hybrid

Hybrid models for NBS draw simultaneously on private and public resources and can be classified in one of two categories: public–private partnerships (PPPs) and blended finance. PPPs aim to raise private capital for public investments and are vested solutions for public infrastructure projects such as schools, highways, airports, railroads and public parks. Blended finance refers to the use of public capital to stimulate private investment through techniques that alleviate the economic barriers associated with NBS, including high levels of risk, insufficient revenue capacities, and market failures. Common techniques include subsidies, tax or fee exemptions, flexible permits, and eco-certification schemes (Burszta-Adamiak & Fiałkiewicz, 2019; Chaplin-Kramer et al., 2019; Grant, 2018; Kohsaka, 2010; Liberalesso et al., 2020).

3.3 Drivers and barriers associated with alternative financial models for NBS

Despite the great number of AF models under scrutiny, the analysis of their financial technicity and PESTLE elements indicates that arguably none can be considered "one-size-fits-all" solutions. AF models are conceptualized and applied in different parts of the world and in highly localized contexts, making their barriers and drivers subject to three main concerns: place-based societal configurations, the types of NBS under scrutiny, and their specific financial profiles. However, as Fig. 4 demonstrates, we identified seven overarching tensions in terms of the financial–technical and PESTLE facets of AF models.

[insert Figure 4]

3.3.1 Financial–technical: new revenue and risk distribution vs. uncertainty

Key drivers for applying AF models are a) their potential to better redistribute risks and ameliorate the return on NBS investments and b) their ability to enable new cash flows, resulting either directly, from converting NBS benefits into cash flows, or indirectly, from the monetization of avoided costs or property value gains caused by NBS (Colgan et al., 2017; EIB, 2020; Ikeda et al., 2020; Mačiulytė et al., 2018; Marchal et al., 2019; Marsters et al., 2021; Toxopeus & Polzin, 2017; World Bank Group, 2020).

However, despite their innovative character, many AF models face financial uncertainties, expressed in cash flow instabilities, insufficiencies, or unpredictability. Exactly which uncertainty applies depends in part on the profiles and expectations of the actors implied by a specific AF model. For example, community initiatives result in relatively little revenue due to their voluntary nature and reliance on local participants (Brent & Lorah, 2019; Ikeda et al., 2020; Seyfang & Longhurst, 2013). On the other hand, bonds attract more capital-rich investors and thus sizable investments but require aggregation vehicles and strong fits within risk–return horizons and thus a relatively high cash flow stability and low revenue uncertainty, which NBS traditionally do not provide (Marsters et al., 2021; Pascal et al., 2021).

Also, part and parcel of financial uncertainty is the way AF models are designed and how costs and benefits are computed and forecast. Simulations of individual AF models indicate the varying financial effects they produce when using different AF model designs and baseline criteria (Borie et al., 2014; Fedorchak et al., 2017; Fu et al., 2019; Menghini et al., 2015; Xu et al., 2019). Concerning cost calculations, AF models are often informed by average cost calculations rather than actual costs incurred, rendering cost–benefit forecasts inaccurate (Merk et al., 2012; Sinha et al., 2014; Zhao et al., 2019). This issue was particularly evident in the case of DC Water's 2016 Environmental Impact Bond. Here, the cost of green infrastructure implementation was underestimated, which jeopardized the underlying financial arrangement and ultimately necessitated a shift in project strategy from solely green infrastructure to gray–green, or "hybrid," interventions (Christophers, 2018; World Bank Group, 2020). Furthermore, additional cost considerations, such as transaction costs, life-cycle costs, and pre-financing needs are presumably disregarded in practice, although their impact on risk–return balances can be significant (Bark, 2021; Richards & Thompson, 2019; Trémolet et al., 2021; Vanderklift et al., 2019).

In terms of revenues and benefits, authors note the dearth of (accessible) techniques to monetize and forecast the value of NBS. This applies firstly to models where private actors expect a strong evidence base for payments, such as utility fees and developer obligations (Buck, 2021; Trémolet et al., 2021). Similar concerns exist for models relying on a predictable and demonstrable return on investment, such as bonds (Coles et al., 2019; Tirumala & Tiwari, 2020; Valderrama & Levine, 2012), types of blended finance (Burszta-Adamiak & Fiałkiewicz, 2019; Kohsaka, 2010), PPPs (Koppenjan, 2015), and market systems (dos Santos et al., 2020; Vanderklift et al., 2019).

3.3.2 Technological: data deficits vs. cost-efficient monitoring

Related to adopting adequate valuation techniques, it is equally important to efficiently monitor the performance of NBS in support of AF models (Droste et al., 2017; Galecka-Drozda et al., 2021; Vanderklift et al., 2019). Particularly for models relying on conditional payments, cost-effective monitoring methods are essential to verify cash flows and limit transaction costs. Examples include impact investments (Herrera et al., 2019; Pascal et al., 2021), PES (Chaplin-Kramer et al., 2019; dos Santos et al., 2020; Ternell et al., 2020; Vanderklift et al., 2019; World Bank Group, 2020), blended finance (Tirumala & Tiwari, 2020), credit systems (Trémolet et al., 2021), and various types of incentive programs (Burszta-Adamiak & Fiałkiewicz, 2019). Suggested pathways to improve the cost efficiency and rigor of monitoring include remote sensing technology and Internet-of-Things applications (Ikeda et al., 2020).

3.3.3 Political: budgetary and legal pressure vs. political willingness and risk aversion

Key political drivers mostly point to factors beyond the direct control of local authorities, such as the pressure to conform to supra-municipal legislation (e.g., environmental obligations, restrictions on debt issuance) and austerity policies, both of which ultimately prompt a search for ways to render NBS

investments independent of local public budgets (Cousins & Hill, 2021; Mell, 2018b; Singla et al., 2019). Singla et al. (2019) found that in the US, AF models for infrastructure draw particular interest when the political climate is unsupportive of issuing new debts to finance municipal needs. In addition to financial considerations, several AF models are also seen as viable solutions for transferring risks and management tasks normally incumbent on the public sector to more proficient private actors (Koppenjan, 2015; Marsters et al., 2021). For community-driven AF models such as crowdfunding, authors further denote the potential in benchmarking NBS policy decisions and in improving citizen engagement in NBS decision-making (Georgi et al., 2017).

AF models nevertheless require significant policy changes and political guidance vis-à-vis a willingness to reorient municipal policies (Kim & Choi, 2022). Various studies indicate that AF models are acceptable when the local ideology is accommodating to privately financed NBS with a public goods character (Linkous et al., 2019; Pitas et al., 2019; Pitas et al., 2020). However, due to risk-averse political attitudes and dominant socio-economically oriented agendas, preference remains for existing financial instruments and proven technologies (Koppenjan, 2015; Singla et al., 2019; Toxopeus & Polzin, 2017). Hence, the willingness to design and deploy AF models for NBS may be hampered or insufficient to proactively "command-and-control" cash flows solely for NBS (Buck, 2021; Mačiulytė et al., 2018; Mandle, 2019; Mell, 2021; Trémolet et al., 2021; Tubridy, 2021).

In addition, stable policy environments are paramount. In particular, debt instruments require "project pipelines" anchored in cross-sectoral, long-term policies for capital to be mobilized effectively (Pascal et al., 2021; Tirumala & Tiwari, 2020). Given the dynamics of electoral cycles and the differing political views that emerge, authors denote the difficulties of maintaining sufficiently stable policies in political praxis (Mell, 2021; Vanderklift et al., 2019).

3.3.4 Economic: market demand vs. market failures

AF models provide new platforms that materialize the growing demand for "green finance." However, in view of general economic conditions, the demand for NBS-specific finance is quite low relative to the overall demand for sustainable investment (Marchal et al., 2019). In addition, AF models are not necessarily apt to overcome the market failures classically associated with NBS, such as freeriding (Marchal et al., 2019; Richards & Thompson, 2019). Finally, various models rely on economic cycles in their revenue capacities (Mačiulytė et al., 2018). The range of land value capture instruments, for example, ties in directly to the real estate market, rendering revenues dependent on the conditions of local development markets (Neal, 2013; Ternell et al., 2020).

Considering local economic conditions, authors reflect upon the lack of efficiency in market systems and blended finance techniques. Commonly noted impediments include the pricing of NBS, price volatilities, prohibitively high transaction and opportunity costs, local market failures, temporal barriers, and market opacity concerning demand and supply conditions (Bark, 2021; Dyca et al., 2020; Hein et al., 2013; Mandle, 2019; Silveira-Junior et al., 2020; Vanderklift et al., 2019). To improve market

efficiency, technological advances such as distributed ledgers (e.g., blockchains) and smart contracts are posited to increase the transparency of markets, while alleviating transaction costs and temporal barriers (OECD, 2019).

3.3.5 Social: private sector engagement vs. social acceptance and risks

Several studies in the UK and US demonstrate that citizen support for AF models for NBS diverges, with factors of influence including education rates, race, ideological convictions, income, individual attitudes toward environmental affairs, homeownership status, household composition, gender, and length of residence (Farmer et al., 2016; Hawkins & Yu, 2018; Nam & Dempsey, 2020; Pitas, Mowen, Taff, et al., 2018; Silveira-Junior et al., 2020). The study by Davies et al. (2018) is illustrative of corporate attitudes, noting that businesses in Southampton, UK, are most lenient toward payments for NBS if they are cost effective and publishable as a part of corporate social responsibility agendas.

As opposed to acceptance, several models provoke outright critique. For example, models that transfer public responsibilities to private hands instigate both academic and social opposition and raise questions about their democratic legitimacy (Drayson, 2014; Mell, 2018a, 2021; Smith, 2021). More generally, AF raises concerns about greenwashing, gentrification risks, and the equitable distribution of NBS (Castree & Christophers, 2015; Mačiulytė et al., 2018; Rigolon & Németh, 2018). Further criticism entails the utilitarianist and commodifying backdrop of AF models, the potential loss of public access to green space, and the resulting social inequality thereof (Mell, 2018a; Mell, 2018b; Nam & Dempsey, 2019; Smith, 2014, 2021; Thompson & Harris, 2021).

Authors also raise critical questions about who ultimately bears the costs and risks when using AF models for NBS and whether these burdens are justified. Washington DC's impact bond is illustrative, with Christophers (2018) arguing that its structure has failed to redistribute risks to private investors, as it alleged to achieve. Instead, he argues, it constituted coalescing financial and environmental risks ultimately borne by local communities. Other studies express similar concerns and argue that in pursuit of AF models for NBS, income extraction supersedes socio-spatial needs. This is alleged to fuel developments in high-risk areas, pressure real estate development at the cost of green space, or result in the adaptation and perhaps the abuse of AF models for purposes beyond their original intent (Chen & Hu, 2015; Cousins & Hill, 2021; Merk et al., 2012).

3.3.6 Legal/institutional: legal and institutional conduciveness vs. inertia

AF models show success when pre-existing governance, legal, and institutional frameworks are accommodating to them (Chaplin-Kramer et al., 2019; Mandle, 2019; Marsters et al., 2021). Most often, however, AF models imply radical shifts from business-as-usual and demand adapted regulatory and legal frameworks, along with foundations for fruitful partnerships between the various actors involved. (Thompson & Harris, 2021).

The numerous barriers cited indeed indicate the need for institutional shifts. Many relate to the general difficulties encountered in implementing NBS, such as lacking municipal competencies, knowledge deficits, path dependencies, procedural and organizational complexity, stakeholder heterogeneity, divergent stakeholder perceptions of NBS value, and the traditional, siloed government approach to NBS (Crabbé & Coppens, 2019; Droste et al., 2017; Kim & Choi, 2022; Kohsaka, 2010; Mell, 2021; Rigolon et al., 2018; Ternell et al., 2020; Tubridy, 2021; Vanderklift et al., 2019). To combat institutional inertia, some authors argue that the role of local "NBS champions" is pivotal in rendering the institutional field receptive to both NBS and AF (Buck, 2021; Coles et al., 2019; Coxon et al., 2021; Thompson & Harris, 2021).

Two facets stand out in particular: coordination and collaboration, and regulatory adequacy. Cooperation between the many private and public actors is often complex, opaque, and fraught with conflicts of interest (Coxon et al., 2021). Stakeholder heterogeneity particularly affects AF types that require recurrent partnerships and a shared understanding of NBS values and objectives in support of the AF and NBS at hand (Herrera et al., 2019). In terms of regulatory adequacy, authors refer to environmental or other cross-sectoral regulations that are either too strict, too flexible, unclear, absent, or subversive to the goals of the AF model at play (Crabbé & Coppens, 2019; Francis, 2012; Kohsaka, 2010; Marchal et al., 2019; Slavíková & Raška, 2019; Vanderklift et al., 2019). When AF models seek to implement NBS on privately owned land, authors denote barriers following incumbent property rights and, relatedly, senior rights to cash flows extracted from properties, such as taxation and mortgage payments (Campbell-Hunt, 2008; Godyn et al., 2020; Rodriguez-Loinaz et al., 2018; Ternell et al., 2020; Valderrama et al., 2013; Vanderklift et al., 2019).

In overcoming institutional challenges, pilot projects provide a powerful impetus for the adoption of regulatory changes (Coxon et al., 2021), while blockchain technologies may improve the traceability and transparency in AF arrangements (Kim & Choi, 2022). In Fremantle, Australia, for example, "smart city" trials have already applied to allow for the peer-to-peer trading of water rights (Ikeda et al., 2020).

3.3.7 Environmental/spatial: upscaling potential vs. land-use and environmental risks

Overall, AF models for NBS aim to incentivize capital flows to consolidate and scale up coherent ecological measures. However, several AF models risk not materializing as permanent solutions (Silveira-Junior et al., 2020; Thompson, 2021) or potentially resulting in "leakage," that is, the spatial displacement of environmentally harmful activity to other areas (dos Santos et al., 2020; Mandle, 2019). Furthermore, outright environmental damage may result from, the commercial exploitation of public green space through heavily attended, ticketed events, for example (Smith, 2014, 2018).

Notwithstanding the risks, spatial factors influencing the applicability of AF models relate to the geographies of stakeholders and land-use conditions (Brent & Lorah, 2019). The extensive geographic dispersion of stakeholders challenges cooperative action, which would need to transgress administrative jurisdictions (Cousins & Hill, 2021; Silveira-Junior et al., 2020). Richards and Thompson (2019) thus

suggest that urban settings are viable for PES systems, given the proximity of stakeholders, relative ease of monitoring, and potential for more direct exchanges.

Research also shows how land use is related to the level of public support for AF models for NBS. Hawkins and Yu (2018), for example, illustrate how voter support for an environmental bond in Rhode Island, US was linked to voting districts in high-density residential areas and publicly accessible open space, while support was lower in districts with a high percentage of natural land uses. Relatedly, from an economic perspective, land-use conditions affect the exploitation potential of land and thus highly influence the potential opportunity costs with which AF models must compete (Rescia et al., 2017).

4. Key lessons and future research avenues

While AF models have the potential to leverage private capital for NBS, our results indicate that both their financial technicity and societal embeddedness require further attention. In this section, we frame our results alongside the review by Toxopeus and Polzin (2021), which sought to identify overarching financing challenges and strategies for NBS. In reviewing the more specific financing modalities currently under discussion to foster private financing for NBS, we articulate several additions to their conclusions. We outline three future avenues of research.

4.1 Valuating, monitoring, and accounting for NBS values

In line with Toxopeus and Polzin (2021), our results indicate that quantifying, valuating, and monetizing the benefits of NBS measures is crucial to applying AF. However, relatedly, our results further suggest the importance of demonstrable data to support AF models, especially when a predictable return on investment is expected or when payments depend directly on the effectively delivered services of NBS. Linked to valuation techniques, AF models thus demand monitoring techniques, and notably cost-effective ones to limit transaction costs. We urge future research to consider how monitoring and valuation techniques can jointly be incorporated in AF to better inform cost–benefit analyses and, specifically, to better support the aggregation ("bundling") or juxtaposition ("stacking") of values derived from NBS (Bark, 2021; Hein et al., 2013; Vanderklift et al., 2019).

In addition to the technical side of valuation, future research should also further explore valuation processes. AF for NBS often involves broad stakeholder groups whose perceptions of NBS value and appropriate metrics can vary considerably. In addition to "objectifying" cost–benefit analyses, AF collaborations could benefit from more co-constructive valuation processes oriented toward mitigating potentially conflicting value perceptions. A rather pragmatic valuation process might present itself, for example, to monetize only those NBS values on which relative consensus exists. The field of participatory modeling provides comprehensive methodologies for mapping and prioritizing NBS values in collective settings and has previously been used to capture stakeholder perceptions regarding NBS (see e.g., Pagano et al., 2019).

In terms of public accounting, the results confirm a general lack of recognition of the economic value of natural resources, by which NBS remains politically underprioritized. Specific to AF models for NBS, we add that remarkably little attention has been paid to the equally crucial question of how AF models fit within the "on-balance" versus "off-balance" debate in public finance praxis and literature (Guter-Sandu & Murau, 2022).

In addition to austerity, governments often face (supra-)national legislation that restricts the uptake of new debts and expenses, to which they have increasingly sought "off-balance-sheet" financing techniques, that is, techniques that do not affect government balance sheets. In Europe, for example, public–private partnerships proliferated in the 2000s as strategies to remove public investments from the public account (van den Hurk, 2018). We find little notion of this issue in the reviewed literature and therefore strongly recommend future research on NBS finance to address how and in what legal structures AF models could qualify as "on-balance" or "off-balance" finance, especially given that the latter is politically prioritized.

4.2 Applicability, scalability, and transferability

Our results are also consistent with the general conclusion of Toxopeus and Polzin (2021) that fruitful cooperation between public and private actors is essential to enable private finance for NBS. However, the seven tensions uncovered further contribute to the debate by revealing the complexities and interdependencies between the institutional, legal, socio-political, technological, economic, and environmental factors underwriting the use of AF models for NBS. To improve collaboration through new financing vehicles, we identify several key societal facilitators: pre-existing legal frameworks, stable and integrated policy environments, institutional simplicity and receptivity to adapt regulations, local frontrunners and pilot projects, socio-political willingness and acceptance, public engagement, stable economic conditions, low opportunity costs, efficient/transparent (market) arrangements, and finally, socio-spatial environments and land-use conditions conducive to both the use of AF models and NBS. Each facilitating factor has a counterpart in the form of a barrier; these are not independent and thus require a parallel approach (Dorst et al., 2022; Frantzeskaki et al., 2020).

Since the myriad societal facets are bound to specific geographies, research could rely on more systemic and systematic, as well as empirical, analyses of local practices to improve the comparability and thus understanding of AF models' scalability, transferability, and local applicability. As the collected literature in this review was biased toward the Anglo-Saxon sphere and contains a high degree of conceptual work, we specifically underscore the need for empirically supported studies in contexts other than the UK and US. The PESTLE approach applied in this review offers one possible avenue, but the business model perspective introduced by prior studies also offers a promising qualitative method to guide future analyses. A quantitative approach could apply to rank and compare AF models in terms of the state of development and feasibility. A bespoke adaptation of maturity indices, such as the

technological, institutional, and organizational "readiness levels" applied in innovation studies, can prove useful in this respect (Bruno et al., 2020; Van Cauwenbergh et al., 2022; Yun & Lee, 2015).

4.3 Potential and risks of AF in NBS governance

Beyond solely considering the financial possibilities of AF, the reviewed literature notably mentions several ancillary qualities. Authors refer to the redistribution of public risks to private actors (e.g., PPPs and impact bonds), the potential of AF to foster the integration and institutionalization of the roles of (new) actors involved in NBS financing and decision-making (e.g., crowdfunding and BIDs), and the increased transparency and verifiability of transactions (e.g., blockchain-based finance). Such qualities of AF models can provide bases for new governance arrangements that support new fora for stakeholder participation, as well as more effective and efficient private-public collaborations in delivering NBS, and perhaps may ultimately enhance the democratic quality of privately financed NBS. Thus, we urge looking beyond merely the financial potential of AF, by examining how implied additional qualities, such as potentially increased transparency, verifiability, accountability, and risk-sharing modalities, may add to NBS governance arrangements.

However, beyond the financial and governance potentials, future research should also include assessments of the possible socio-ecological risks entailed by AF models. Much of the reviewed literature touches upon social issues, including gentrification, greenwashing, questions of legitimacy, inequitable cost and risk spreads, and inequitable socio-spatial distributions of NBS. As noted by the literature on the financialization of society, the proliferation of off-balance financing tactics and the further involvement of private capital in infrastructure projects holds a variety of risks and may obscure the societal goals infrastructure projects are expected to meet (Deruytter & Bassens, 2021; O'Brien & Pike, 2017). Previous studies indicate that nature is not necessarily exempt from this fate (Ouma et al., 2018; Sullivan, 2013). In outlining AF models and conjoined governance arrangements, future research should explore mitigation strategies to prevent the financial motive from taking the upper hand vis-à-vis social needs. In line with the proposed maturity indices for AF models, we suggest integrating societal risk indices as a measure of the potential social impact AF arrangements may generate.

5. Conclusion

In this article, we have built upon a prior review on financing challenges and strategies for NBS by reviewing the literature to further identify and examine the various alternative financing models that could enable private financing and funding for NBS. We have analyzed the drivers and barriers that authors associate with AF models for NBS by looking at their financial technicity and their broader political, economic, social, technological, legal, and environmental (PESTLE) embeddedness.

Despite the numerous types of AF models under scrutiny, we find little evidence to identify any model as a best practice for financing NBS, nor do we claim that AF models are full-fledged substitutes

for traditional public financing. Such models are developed or applied in various parts of the world and vary greatly in terms of their revenue capacity, reliability, and dependence on local societal factors. We nonetheless find that drivers and barriers converge around seven overarching tensions, in line with the financial–technical and PESTLE dimensions of AF models.

The most salient factors driving AF are the opportunities of generating new cash flows and, relatedly, making the return on private capital investment in NBS more attractive. More latently, several AF models also possess qualities that may improve the governance structures surrounding public–private collaborations in NBS projects.

Nevertheless, for AF to be effective in practice, the financial aspects and myriad societal facets surrounding AF models must be addressed in parallel. Financial uncertainties, reflected in revenue shortfalls, instability, and unpredictability, occur partly due to a lack of alignment with the broader societal context. Important factors conducive in this respect include pre-existing institutional and legal frameworks, a stable and unified policy environment, political willingness and institutional receptiveness to regulatory change, social acceptance, economic stability with low opportunity costs, and efficient and transparent arrangements of cooperation. On the other hand, barriers relate to the lack of adequate valuation, monetization and monitoring techniques, socio-political resistance and risks in transferring public goods to private actors, legal and institutional complexity, misaligned regulatory frameworks, market failures, market dependencies, and finally, displaced environmental impacts and insufficient alignment with existing land-use conditions.

To further substantiate the potential of AF models for NBS, we have proposed three lines of research. First, we have argued for investing in explorations of how stakeholder-oriented and cost-effective valuation and monitoring can take root to better inform AF models. In addition, we have considered how public accounting can be adapted to consider NBS values, as well as how it can facilitate AF models, with a specific focus on the debate over on- vs. off-balance financing. Second, we have urged the advancement of the applicability, transferability, and scalability of AF models for NBS via more systemic and systematic, as well as empirical, analyses. Finally, we have highlighted the need for research into the potential impacts of AF models beyond their financial potential, by examining both how AF could improve NBS governance structures and the potential social risks that may ensue. Regarding the latter, we have called for researchers to confront AF models with the dangers of "financialization" and consider how financial motives are perhaps best not considered as the sole or primary objective for using AF.

6. Limitations

We acknowledge several limitations to our review. First, the search strategy included a wide lexicon on financial arrangements, NBS, and related concepts that we screened before conducting our review. Nevertheless, other overlapping terms have not been considered in our queries. Thus, some AF models have likely escaped our scrutiny. Second, we did not systematically distinguish between drivers and

barriers derived from conceptual or empirical studies but included all appraisals of AF models. Future research could systematically review the barriers and drivers of AF models separately to develop a critical appraisal of sources of evidence more feasibly. Third, we did not distinguish between the types of NBS, as has been done by Toxopeus and Polzin (2021). Here, we also invite future reviews to address AF models for specific types or functions of NBS.

7. Acknowledgments

This work was supported by a research grant from the University of Antwerp [grant number 43947] and the Research Foundation Flanders (FWO) [grant number 11J4622N].

We thank Erin Cooper and Simon Demuynck for proofreading earlier versions of this article.

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