Planning support systems for strategic implementation of nature-based solutions in the global south: Current role and future potential in Indonesia

Martijn Kuller a, f, *, Megan Farrelly b, Dwinanti Rika Marthanty c, Ana Deletic d, f, Peter M. Bach a, e, f

a Swiss Federal Institute of Aquatic Science & Technology (Eawag), Überlandstrasse 133, 8600 Dübendorf, Switzerland
b School of Social Sciences, Human Geography, Monash University, Clayton 3800, VIC, Australia
c Civil Engineering Department, Gedung Teknik Sipil, Fakultas Teknik, Universitas Indonesia, Kampus Depok, Kota Depok, Jawa Barat 16424, Indonesia
d School of Civil and Environmental Engineering, Faculty of Engineering, Queensland University of Technology, 2434, Brisbane, Queensland 4001, Australia
e Institute of Environmental Engineering, ETH Zürich, 8093 Zürich, Switzerland
f Department of Civil Engineering, Monash University, Clayton 3800, VIC, Australia

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ABSTRACT
Nature Based Solutions (NBS) are increasingly used for improving water quality, reducing urban flooding and providing ecological and amenity benefits. Although predominantly developed and implemented in industrialised countries, NBS are gaining traction in the Global South. Strategic planning is required to deliver the anticipated benefits and ensure successful integration into urban landscapes. Spatial software and planning support systems (PSS), can inform such decision-making. We seek to understand the efficacy of utilising PSS for advancing NBS practices within Indonesian urban settings. Through workshops and in-depth interviews with urban planning practitioners, we examined (i) the current NBS planning context, (ii) tacit experiences with planning support systems (PSS), and (iii) potential utility of PSS to address identified challenges with NBS planning. While strategic planning processes were perceived as improving over past decades, significant challenges remain including inadequate collaboration between actors, insufficient capacity and resources of local governments and limited access to high-quality spatial data. Although strategic planners employ contemporary PSS, further embedding those into decision-making processes requires rethinking the socio-institutional and political context within which they operate. Results revealed keen interest to adopt innovative PSS. However, without access to high-quality spatial information, strategic planning will continue to be compromised, potentially leading to ill-sited NBS interventions.

1. Introduction

Around the world, largely in western contexts, nature-based solutions (e.g., rain gardens, constructed wetlands and bioswales) have been adopted to address urban water management challenges including waterway health and flooding impacts associated with urbanisation and increased runoff from impervious areas (Fletcher et al., 2014). Looking beyond Europe, North America and Australia, there has been growing scholarly and practical attention in relation to the benefits of adopting nature-based solutions within different socio-ecological and political contexts. Examples include Africa (Fischborn and Herr, 2015; Kalantari et al., 2018; Mguni et al., 2016), and Asia (Kooy et al., 2018), such as in China (Jia et al., 2017; Xia et al., 2017), Singapore (PUB, 2018), Malaysia (e.g., Liew et al., 2014; Quan et al., 2014) and Indonesia (Padawangi and Douglass, 2015).

Regardless of context, delivering the range of benefits associated with nature-based solutions requires a strategic approach to planning and implementation. Despite more than two decades of experience with planning NBS in industrialised countries, a persisting absence of strategic approaches is resulting in ad-hoc placement of infrastructure (see e.g., Eckart et al., 2017; Kuller et al., 2018a; Meierow and Newell, 2017). Inappropriately locating NBS can result in failed systems due to e.g., unsuitable biophysical conditions of their location; thus, planning support systems (PSS) can serve as mechanisms for improving their long-term feasibility by identifying the most suitable locations to deliver maximum benefits. However, despite academic promotion of the need...
for PSS (e.g., Geertman and Stillwell, 2012; Klosterman, 1997; te Brömmelstroet, 2013), their application in urban planning practice remains limited—a phenomenon referred to as the implementation gap (Gibson et al., 2017; Klosterman et al., 2018b; te Brömmelstroet, 2013).

PSS are not new, and were explicitly developed to assist urban planners with improving their decision-making process and outcomes (Klosterman, 1997). This has led to the development of a variety of PSS and other decision support systems (DSS) and models (Kuller et al., 2017; Leter et al., 2015). They range from high-level visioning (e.g., the societal transitions workshops: De Haan et al., 2011) to spatial planning and simulation tools (e.g., Kuller et al., 2019, Bach et al., 2020, Meerow and Newell, 2017) to detailed NBS design tools (e.g., MUSIC: eWater, 2011). Ferrans et al. (2022) provide a contemporary review of decision support tools for NBS planning, where they conclude that the vast majority of available PSS focus on the “what” question: what measures or infrastructure to implement? However, as the capacity of computer-aided geo-information systems (GIS) grows, PSS increasingly address the “where” question (Malczewski and Jankowski, 2020). At present, the majority of PSS used to site ‘where’ are rooted in hydrological and/or water balance modelling (Ferrans et al., 2022). However, this overlooks the associated co-benefits of NBS that go far beyond stormwater management and harvesting, and include aspects such as local climate control (e.g., Gill et al., 2007), recreation (e.g., Liu and Jensen, 2018) and biodiversity (e.g., Bolliger and Silbernagel, 2020). Thus, effectively deriving the multiple benefits arising from strategically placed NBS within urban form requires adopting spatially explicit tools (Kuller et al., 2017). GIS-based multi-criteria decision analysis (GIS-MCDA) is well positioned to support such spatially explicit multi-faceted siting problems (Malczewski and Rinner, 2015). Indeed, spatial (e.g., Viavattene et al., 2008) and non-spatial (e.g., Ellis and Viavattene, 2014) MCDA have been applied in industrialised countries to aid NBS planning. Although wider application of GIS-MCDA is needed, this approach remains time and resource intensive. To facilitate a wider application of GIS-MCDA for NBS planning, SSANTO was developed (Kuller et al., 2019).

Within the academic scholarship, NBS policies, implementation and PSS for NBS planning has primarily focussed on experiences of the Global North, with comparatively less research conducted on these topics within the Global South context (see e.g., Kooy et al., 2020; Pappalardo and La Rosa, 2020). This is problematic, as environments in the Global South are regarded as promising for adopting alternative infrastructures and technologies given the limited development of existing urban infrastructures (Barron et al., 2017; McClymont et al., 2020; UN-HABITAT, 2016). Indeed, scholars suggest the absence of widespread urban infrastructure within current and emerging Global South cities opens up the potential to ‘leapfrog’ towards more sustainable practices, including the adoption of NBS (e.g., Barron et al., 2017; Binz et al., 2012; Poustie et al., 2016). Thus, to assist with advancing the application of NBS, understanding how contemporary planning practitioners engage with PSS and NBS is of interest. We found only one study focussed on the application of PSS for sustainable urban water management in the Global South, using the existing SUSTAIN model in Jakarta, Indonesia (Kesuma Warganda and Sutijiningih, 2017). One further study presents a tool called GTIBOLA, which is used to support spatial planning considering NBS efficacy for flood mitigation in East Jakarta, Indonesia (Wiyati et al., 2020) and is developed as an add-on for different GIS software (Marthanly et al., 2019). The review by Wu et al. (2020) suggests that several surface of considerations related to tool selection for the implementation of NBS in a developing context. Furthermore, a limited body of literature exists on the use of planning support for different applications, such as siting of solar energy plants in Indonesia (Ruiz et al., 2020). Needs and practices of urban planners in the Global South differ from those of their counterparts in industrialised countries in a number of aspects, including: processes; social structures; institutional capacity; data availability and quality; and, human and financial resources (Armitage, 2011; Fisher-Jeffes et al., 2012; Mguni et al., 2016). It is thus critical to assess the transferability of PSS for NBS planning in the Global South.

Against this background, this paper seeks to redress the paucity of academic insights regarding NBS planning and PSS uptake within the Global South. Through examining the tacit experiences of urban planning professionals from Indonesia, this paper (i) explores urban planning practices and associated strengths and weaknesses, (ii) characterises the contemporary uses of existing PSS and their potential to strengthen planning practices, and (iii) assesses practical implications of PSS adoption into everyday decision-making processes. By understanding the utility of, and challenges associated with adopting PSS, this knowledge could assist with the ambition of leapfrogging towards more sustainable practices by promoting more strategic adoption of NBS in urban areas in the Global South. The remainder of this paper is structured as follows. The second section describes the research approach and context. The third section presents an assessment of current planning and urban water management practices. The fourth section describes the current role of PSS and their potential to overcome some of the important limitations of planning practices, as well as presenting considerations regarding practical implementation and transferability of a PSS. The final section concludes.

2. Research approach

2.1. Data collection

We adopted a qualitative social science approach, working directly with practitioners and experts in the field of urban planning in our study context of Indonesia. We primarily undertook our research activities in Bogor, a densely urbanised area of the West Java Province. Acknowledging the spatial, economic and cultural diversity of Indonesia, we supplemented the Bogor data with data from Surabaya, Indonesia’s second largest urban centre, located in East Java. We selected these locations given the current levels of public disturbance arising from urban floods (e.g., Ramdhana et al., 2018) and deteriorating water quality (Padawangi and Douglass, 2015), which have fuelled an academic and government ambition for higher levels of urban green space and the implementation of NBS (e.g., Putra and Ridwan, 2016; Ramdhana et al., 2018).

We collected data through two core research methods (Table 1). We conducted semi-structured interviews with 14 practitioners directly involved in urban planning and management to elicit their tacit experiences and generate a deeper understanding of contemporary planning practices. Interviewees included representatives from government officials, planning consultants and academics. We offered them choice of conducting the interview in English (provided in the supplementary materials; SI-1) or with a simultaneous translator in Bahasa Indonesia. We focused on the interviewee’s experiences within the current planning system, and then broadened to current PSS utilisation or consideration for future use. Furthermore, we addressed key challenges and opportunities to advance PSS uptake. We transcribed all Indonesian interview recordings and translated them to English, using an independent professional service.

To uncover potential limitations of transferring novel PSS, we designed participatory workshops to capture information regarding the utility of a specific PSS tool called SSANTO (see section 2.3) to assist with everyday urban planning decision-making, using the insights gained from the interviews. The workshops started with showcasing this tool as an example of a PSS. A step-by-step live demonstration of the software was provided, followed by a short questionnaire for participants (provided in the supplementary materials; SI-2) to provide feedback on the presented tool itself, and potential opportunities or constraints associated with adopting such a tool in their everyday planning practices. Workshop participants included (i) current planning experts and (ii) tertiary students studying urban planning and water management, who are considered future planning experts. The decision
to include student participants was shaped by the expectation they could provide additional novel perspectives on the utility of PSS planning in comparison to contemporary planning experts who have engaged in conventional decision-making for urban planning. This afforded the research team the opportunity to capture diverse insights into how PSS work and how this could shape future PSS aimed at facilitating NBS.

We asked all participants to reflect on aspects including user friendliness, rigour, flexibility and novelty of the PSS, as well as the likelihood and frequency of its potential use in their organisation. We provided the questionnaire in Bahasa Indonesia, translated responses and analysed to identify common themes that either aligned or contested the earlier interview data. Depending on the respondent’s role (practitioner or student) and previous answers, we asked them to fill out specific parts of the survey. To establish an overview of the current planning system relevant to NBS implementation in Indonesia, infor-

mation from the interviews and workshops were supplemented with a review of important secondary data (e.g., policy documents and national laws on urban planning and water management) which play an important role in Indonesian planning according to interview participants. This review took place after the interviews and workshops.

Analysis of interview data involved coding into emerging themes following an iterative process, focusing on: (i) everyday experiences, (ii) challenges associated with strategic planning and (iii) perceived utility of PSS tools. We inferred an overview of the local planning system from interview results, and checked for consistency with help of an expert in urban planning and water management in Indonesia. We categorised data on the challenges and opportunities for PSS adoption in emerging themes. After interview analysis, we once again presented these emerging issues to interviewees, who we asked to rank them from most important (1) to least important (7). Six sets of rankings were returned, which we analysed to identify an overall ranking of the issues with the Friedman test and post-hoc analysis (Conover, 1998), using the R package “agricolae” (de Mendiburu and de Mendiburu, 2019).

We analysed survey answers using a spreadsheet. We aggregated the answers to closed questions, while we aggregated the answers from open questions after coding of emerging issues, which partly aligned with the general PSS performance issues identified and ranked during the interviews. After this aggregation, we further analysed four questions related to the efficacy of the presented tool on these issues to calculate a “net performance”. We determined this by tallying together all positive and negative statements (equally weighted, e.g., five positive and two negative states yield a net performance of +3).

Finally, we explored the transferability of the PSS by comparing our research outputs to similar research undertaken for the same PSS in the context of Australia (Kuller et al., 2018b). For this, we focused on the issues raised by planning participants in the Australian context and compared those to the ones raised by the participants from this research.

2.2. Primary study location

Bogor is one of five urban centres in the greater Jakarta urban agglomeration known as Jabodetabek, and is located 50 km from Jakarta city centre in West Java, Indonesia (Fig. 1). The 2010 national census identified Bogor’s population at just under 1 million (BPS, 2010). Situated in the tropical rainforest climate zone, Bogor experiences very high rainfall up to 5000 mm/year (Pravitasari et al., 2014). Two main rivers, Cisadane and Ciliwung, flow through Bogor on either side of the city centre. Both rivers pass through greater Jakarta before entering the ocean. The entire Jabodetabek area is facing some of the most challenging circumstances related to integrated water management globally, including frequent flooding, increasing pollution and deteriorating water supply (Costa et al., 2016). Less than 40% of Bogor is undeveloped (e.g., open space, green areas, farms), a number that is projected to rapidly decrease in the near future (BPS, 2018a, 2018b). We included

<table>
<thead>
<tr>
<th>Stage</th>
<th>Who?</th>
<th>How many (total)</th>
<th>Research topics</th>
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<tbody>
<tr>
<td>Stage 1: Interviews (n = 14)</td>
<td>Government officials, academics and planning consultants</td>
<td>Bogor – 12 Surabaya – 2</td>
<td>Current planning practices, strengths and weaknesses, role of PSS.</td>
</tr>
<tr>
<td>Stage 2: Workshops (n = 2)</td>
<td>Government officials, academics, planning consultants and master students</td>
<td>28 practitioners and students from 2 workshops (Bogor). 16 questionnaires returned (10 practitioners, 6 students)</td>
<td>Demonstration of tool and discussion of the potential of such tool, specific aspects of the tool and potential barriers for uptake of novel PSS in Indonesian context. Review of grey literature (particularly planning laws) to check findings of stage 1 and 2.</td>
</tr>
<tr>
<td>Robustness check</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
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Table 1
Summary of qualitative research design, stages of research, stakeholder involvement and key research topics.

Surabaya as a secondary case study location (Fig. 1). It is the second largest Indonesia city, located in East Java. Surabaya has a long history of undertaking spatial planning with regularly updated spatial master plans (Surabaya City Government, 2016) and significant involvement of local academics (Novalia et al., 2020; Silas, 2006).

2.3. A planning support tool for NBS implementation

We used SSANTO, a PSS designed to support strategic NBS site-selection (Kuller et al., 2019), as a practical example for demonstration during the workshops. SSANTO was specifically developed for application across diverse contexts, demonstrated by e.g., its application on local (Kuller et al., 2021) and regional scale (Webber and Kuller, 2021). It allows for rigorous, spatially explicit analyses of opportunities for and needs associated with implementing NBS in a selected area of interest. The tool aims to mimic the in-depth, multi-faceted and multi-criteria decision-making process for the identification of suitable locations for NBS implementation. Using Geo-Information Systems (GIS) based Multi-Criteria Decision Analysis (MCDA), a process that normally requires significant investment of time and expertise; SSANTO follows a 4-step process (Fig. 2a):

1. Compiling geodatabase: gathering and pre-processing all relevant spatial data;
2. Masking: removing all areas from the analysis where NBS implementation is constrained;
3. Value scaling: translating raw data into suitability values for each criterion; and
4. Combining: overlaying all datasets based on user-defined criteria.

For each step, the user is asked for inputs, including user-defined weighting of criteria (step 4). Until now, the applicability and

Fig. 2. (a) Workflow of SSANTO with user inputs for each of four steps, adapted from (Kuller et al., 2019). (b) User interface of SSANTO in the ArcMap environment showing the output of the opportunities assessment for Melbourne City Council. Red lining: SSANTO’s toolbar and results dropdown menu. Black lining: pop-up window for criteria weighting. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
capacity of SSANTO was only studied within an industrialised context (e.g., Australia: Kuller et al., 2019, 2021 Canada: Lacroix et al., 2021, UK: Webber and Kuller, 2021). SSANTO’s simple interface is integrated in the widely used ArcMap software, for use by experts and lay people (Fig. 2b).

3. Urban planning and water management practices

This section presents and discusses the results from the analysis of the interviews. These results were organised into three parts: (i) general insights in the organisation of urban planning in Indonesia, (ii) urban water management in Bogor, and (iii) barriers to successful urban planning and water management.

3.1. Organisation of urban planning in Indonesia

A formal structure for urban planning is a recent phenomenon in Indonesia, with the first national planning laws coming into effect in 1992 (Rukmana, 2015). The most recent planning law (i.e., Law of the Republic of Indonesia Number 26 year, 2007) was introduced in 2007, and sets requirements for land use zoning (Law of the Republic of Indonesia Number 26 year, 2007). Nevertheless, many cities have long utilised master plans to guide their development. For example, Surabaya has master plans dating back to the 1970s (e.g., Surabaya City Government, 2016).

Fig. 3 presents an overview of the main components of urban planning as inferred from interview data. At the national level, Badan Perencanaan Pembangunan Nasional (BAPPENAS - Ministry of National Development Planning) is broadly responsible for urban planning and policy making across Indonesia. Following broader decentralisation of government decision-making (Hadiz, 2004; Rukmana, 2015), municipal authorities were conferred with planning authority (i.e., Badan Perencanaan Pembangunan Daerah - BAPPEDA). BAPPEDA is responsible for the implementation of Law 26/2007 and other relevant national laws, through the production of short-, medium- and long-term (master) plans. The development of these planning documents is typically conducted by domestic planning consultants, guided by and pending approval from BAPPEDA, as well as the municipal senate in the case of master plans. These municipal plans are critical, for they underpin how developers and other private actors can shape the urban footprint. Of note, while there are clear roles for the national and municipal authorities, interviewees identified no formal role for the provincial government.

Instrumental to the promotion of NBS, Law 26/2007 prescribes the provision of urban green space, known as the 30–20–10 rule, detailing that municipalities provide their inhabitants with 30% green open space, of which 20% is located in public, and 10% in private areas (Rukmana, 2015). Further relevant regulations for developments that influence local waterways are stipulated in the new and partially still active old laws on Water Resources Management Law 17/2019 (Undang-Undang Republik Indonesia Nomor i7 Tahun, 2019) and Law 7/2004 (Law no. 7/2004 on Water Resources, 2004), as well as in Law 24/1992 on Land Use (Undang-Undang Republik Indonesia Nomor24 Tahun1992 TentangPemanfaatanRuang, 1992). They include regulations on maximum impervious space, peak runoff and water quality. Of note it is also a requirement in the new Law 26/2007 and Law 17/2019 that public participation occurs during all phases of the planning process, which, according to interviewees, is generally implemented through ‘focus group discussions’.

Fig. 3. Overview of the organisation of spatial planning in Indonesia as derived from interview data.
3.2. Urban water management

Costa et al. (2016) conducted an in-depth study of the complex interplay between the human system of the megacity of Jakarta and the Ciliwung river system, arguing that integrated knowledge should support the management of these complex systems, where urbanisation hugely affects water quality, water quantity and the available safe water supply. Integrated water resources management remains challenging in Indonesia. BAPPENAS reformed the water resources and irrigation management policy in 2000, to improve the national institutional framework for water resources development and management (Fulazzaky, 2014). However, the law was revoked by the Indonesia Constitutional Court in 2015, arguing its rulings conflicted with a constitution article assigning exclusive water extraction rights to the government (The Constitutional Court Decree number 85/PUU-X/2013 on 18 February 2015).

In light of the absence of a statutory basis for water management after the revoked Water Resources Law, connecting integrated water management to local land-use planning carries great importance (e.g., Brears, 2018; Mitchell, 2005; Serrasou-Neumann et al., 2017). In recent years, efforts have been made by the all levels of government to integrate spatial and development plans across spatial scales (Mungkasa, 2015), from the presidential decree of Spatial Plans, through National Middle-Term Development Plans, to local regulations. At the local scale, regulations are applied to four management levels (Susetyo, 2017): (1) administrative, (2) physical, (3) zoning, and (4) activity.

There have been some recent attempts to integrate NBS planning at the lowest level of urban planning in cities like Bogor, particularly for new urban developments (e.g., BAPPEDA Cibinong, 2016; Faradilla, 2017). Similarly, plans are being developed on a strategic level, to promote sustainable urban water management into the future (Brodnik et al., 2018; Urban Water Cluster, 2018). Although application of NBS for urban water management remains a novel phenomenon within Bogor, its potential for supporting flood management has been recognised (see e.g., Putra and Ridwan, 2016).

3.3. Barriers to successful planning

Fig. 3 shows an apparent absence of involvement on a regional level, namely the ‘provincial scale’. This may lead to problems with strategic alignment of planning between municipalities, which is critical for catchment-scale water management. Despite this caveat, an increasing formalisation and regulation of urban planning is apparent from the national planning laws, which are generally perceived as an improvement. Of note, some interviewees regarded having a single organisation (BAPPEDA) responsible for the entire process as a strength to ensure coordination and collaboration between relevant stakeholders. This was illustrated by the following quote from a planning consultant:

“What is good is the coordination between stakeholders. Local government has full authority in their municipality to decide. So, if the central government says: ‘build the road here’, if the local government doesn’t want it, it goes as they want. So coordination between stakeholders is quite good.”

The need for central coordination, alignment between governing levels and strategic integration into planning systems is widely recognised in literature from around the world (Ahern, 2007; Brown et al., 2011; Gill et al., 2007; Kambites and Owen, 2006; Lennon, 2015; Mell, 2014) However, a lot of criticism was expressed by interviewees as well. Despite clear targets for on-site stormwater retention and green open space being established in Law 26, these are often not met. For example, interviewed experts estimated that Bogor only has 13% green open space, while Surabaya was estimated to score slightly better at 22%. Jakarta is reported to score even worse with just over 9% of land being covered with green space (Rukmana, 2015). Interviewees suggested that, although the formalised collaboration between developers, civil society, local government and planning consultancies was deemed positive, the practice of the participatory process through focus group discussions (FGDs) leaves room for improvement. Particularly, several interviewees noted that the variety of stakeholders involved was limited, with the FGDs typically centred around government actors with little to no local community representation. This was particularly notable with regards to private developments, where public consultation was largely regarded as absent. These findings resonate with a study by Hadiz (2004), who explored the effect that decentralisation had on public decision-making in Sumatra, concluding that public participation has largely failed due to its politicisation in practice.

To advance urban water management, scholars and practitioners have long pointed to the need for a holistic vision and coordinated approach to urban water systems (Pahl-Wostl, 2007; Van de Meene et al., 2011). Indeed, a lack of coordination is a real threat to strategic NBS planning, which is interdisciplinarily by nature. Interviewees within Bogor spoke of persistent challenges, including the need to address budgetary issues, political will and knowledge sharing. This was evidenced by interviewee’s comments:

“[…] it’s [urban planning] egocentric, agencies have their own ego. It is hard to combine. We’re talking about the budget, that is planned by national and local level. It is all about money and political will.”

(Academic respondent)

“For example, you have data from different sources, they tend to have constraints sharing it all in one database. Because of bureaucracy, mentality.”

(Urban planning professional)

Private organisations play a crucial role in the integration of urban planning, since national regulation prescribe planning documents to be drafted by non-governmental parties, to reduce corruption and promote objectivity. As a result, local governments rely on consultants and developers to deliver urban planning, including integrated and sustainable urban water management. Thus, these external actors are engaged with organising and facilitation focus group discussions, a key forum in bringing actors together. This regulation is, in part, due to the perception of limited skills, capacity and resources availability within government departments to deliver such processes. However, both academic and government respondents identified that this situation continues to perpetuate organisational capacity deficits within local government. Thus, interviewees perceived this regulation as costly and not in the public interest. A number of government interviewees expressed interest in upskilling in this domain:

“[…] if we need training, they [higher management in government organisations] think we don’t need to. Even if by doing so it would push us in the right direction. […] When the regulation budget proposal comes out, there’s nothing left for us to get training”

(Government official)

Integration of NBS elements in developments is typically associated with financial barriers for public and private developments (Ershad Sarabi et al., 2019). Indeed, as one academic respondent highlighted:

“Economy always wins over ecology. But in my opinion that is not good. In Bogor, there are many shopping malls, CBD [central business district] always gets bigger and bigger. But it comes at the cost of degrading farmland and degrading green space.”

Across all respondents (interviewees and workshop participants), the most frequently identified barrier to advancing strategic urban planning was limited access to good quality spatial data, which was regarded as a “weakness in our process. Data driven policymaking is very weak” (Planning Consultant). Several underlying causes were identified including: (1) dispersed sources of data and limited sharing between stakeholders; (2)
the absence of a centrally coordinated shared data platform; and (3) a lack of resources (skills and finances) for data collection. However, respondents noted that data availability varies between cities. For example, significant spatial data was available for Surabaya, part of which is publicly accessible through an online platform (BAPPEDA Surabaya, 2018). Contrasting, respondents from Bogor emphasised spatial data was very limited and that a similar online platform would be valuable. The lack of good quality spatial data typically resulted in lengthened process duration caused by e.g., the need for additional local data collection to inform the drafting of urban plans. This was highlighted by a planning consultant, who noted:

“That’s what makes one year an insufficient amount of time, [...] data should already be provided [...] for example the map of geology data should be at the geology office.”

Finally, illegal development arising from both formal (developers) and informal (slums) sectors generates discrepancies between well-defined urban plans and the physical, on-ground reality. Interviews revealed that informal settlements, as well as high-end urban developments, regularly take place within riparian zones, where urban development is officially prohibited. Such developments jeopardise appropriate urban water management and put residents in constant danger of floods, both in Indonesia (e.g., Vollmer and GRET-Regamey, 2013) and other countries in the Global South (e.g., Kondzewicz and Schellnhuber, 2004; Tanner et al., 2009). Collectively, these challenges reinforce the need for an accessible and user-friendly planning support system to support the strategic integration of NBS into contemporary planning processes.

4. Role and potential of PSS to aid NBS planning

PSS are well positioned to address certain challenges related to NBS planning in industrialised countries, but focus should be on transferability, technical support and implementation rather than development of new PSS (Giupponi and Sgobbi, 2013). This section describes the role PSS currently play in the context of Bogor, and their potential to address some of the challenges mentioned in section 3.

4.1. Current role of PSS in Indonesian planning practice

Interviews revealed that PSS application is typically limited to academic research and urban planning consulting. In the absence of in-house capacity, the local planning agency (BAPPEDA) typically relies on a commissioned consultancy (e.g., local engineering or planning consultants) to incorporate specific model outputs (e.g., maps, CAD drawings) as part of an urban planning task in planning reports. The production of such outputs is prescribed by national policy (Republic of Indonesia, 2018), and results in hard-copy reports delivered to local government officials. These officials can interpret the outputs, but are unable to ‘play around’ with the data to verify them independently of the organisation producing the report. Stronger involvement of academia with planning practice could partially overcome this implementation deficit within local government. However, such engagement requires careful navigation of national anti-corruption policies, which stipulate executive master plan development to be done by non-publicly funded organisations, such as consultancies (academic respondent). Further collaboration is thus often hampered.

Interviewees from academia and consultancies reported a widespread familiarity and application of spatial and design software including: ArcMap (Esri, 2018), AutoCAD (Autodesk, 2018), and also open-source counterparts such as QGIS (QGIS, 2018) and SketchUp (Trimble, 2018). Furthermore, respondents revealed that statistical tools such as SPSS are widely applied, but noted that economic tools such as Cost-Benefit Analysis were used far less. Advanced urban planning tools and methodologies such as SUSTAIN-EPA (Lee et al., 2012) and manual suitability analysis using GIS-MCDA were only applied by respondents from academia and do not appear to be applied in real-world planning practice. Similarly for urban water management, the use of hydrological and hydraulic tools such as SWMM (Rosman, 2010) remains limited to academia.

When asked for the most important considerations in adopting tools and models to support decision-making, interviewees and workshop participants emphasised data requirements and flexibility in applying the tools for their specific purposes (Table 2). In addition, user-friendliness and the type and quality of output were important factors.

Table 2: Practitioners’ considerations that inform the uptake of tools and models for planning support systems, inferred from interview and workshop questionnaire data on the application of SSANTO. First seven issues are ordered by their rank sum in descending order of importance (low rank means high importance). The rank order from Friedman post-hoc analysis is significant (p-value $\mu^2 = 0.02$).

<table>
<thead>
<tr>
<th>Issue</th>
<th>Descending order of interviewees’ perceived importance (rank sum, n = 6) $^a$</th>
<th>Perceived performance of SSANTO from workshop questionnaire $^b$</th>
</tr>
</thead>
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<tr>
<td>Data needs</td>
<td>16</td>
<td>☺ +9 (9)</td>
</tr>
<tr>
<td>Fit-for-purpose</td>
<td>16</td>
<td>☕ +8 (12)</td>
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<tr>
<td>User friendliness</td>
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<td>Output type and quality</td>
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<td>Transparency</td>
<td>23</td>
<td>N/A 0 (0)</td>
</tr>
<tr>
<td>Cost (how likely to use on 7-point Likert scale?)</td>
<td>32</td>
<td>☜ if free: very likely ($\mu = 6.7$)</td>
</tr>
<tr>
<td>Wide uptake in industry</td>
<td>39</td>
<td>☜ if cheap: somewhat likely ($\mu = 5.0$)</td>
</tr>
<tr>
<td>SSANTO's core functionality</td>
<td>Not assessed</td>
<td>☜ if expensive: somewhat unlikely ($\mu = 2.7$)</td>
</tr>
<tr>
<td>Level of complexity</td>
<td>Not assessed</td>
<td>N/A 0 (0)</td>
</tr>
<tr>
<td>Open source environment</td>
<td>Not assessed</td>
<td>☜ +16 (16)</td>
</tr>
<tr>
<td>SSANTO's weight assignment</td>
<td>Not assessed</td>
<td>☜ +1 (9)</td>
</tr>
<tr>
<td>Innovative</td>
<td>Not assessed</td>
<td>☜ +3 (3)</td>
</tr>
</tbody>
</table>

$^a$ Rank-sum represents the sum of the rankings of all respondents (n = 6) for an issue (total of seven issues). This means the best possible score is 6 * 7 = 42 if all respondents rank the issue first. The worst possible score is 6 * 1 = 6, and is achieved when all respondents rank the issue first. The worst possible score is 6 * 7 = 42 if all respondents rank the issue last.

$^b$ First column of numbers represent the net positive comments by questionnaire respondents (number of positive comments minus number of negative comments). The total number of comments is given in the second column, between brackets, giving an indication of the importance. Smileys are a qualitative interpretation of aforementioned information.

Unlike other issues, the performance of SSANTO on costs was measured using a 7-point Likert scale measuring the willingness to use SSANTO, ranging from very unlikely (1) to very likely (7).
Spatial outputs, in the form of maps, were considered critical to helping the planning process. Transparency of tool architecture and usage costs appeared to be less of a decisive factor in tool application. However, whether or not tools were commonly used in industry did not seem relevant to the interviewees’ and workshop participants’ decision-making around tool adaptation. Instead, they expressed a desire to try novel and innovative methodologies that are not (yet) commonly used around the world.

In short, we identified sufficient awareness of the capabilities from PSS to aid the planning process among Indonesian planning practitioners, but limited capacity to employ these capabilities, particularly among governmental stakeholders. Although standard spatial tools are used by planning consultancies, more advanced tools aimed at the integration of planning and water management are exclusively used by academic researchers. The next section further explores how integrated planning tools could address some of the planning challenges identified.

4.2. Potential of novel PSS in Bogor’s urban planning

To illustrate transferability and potential of novel, integrated PSS into the planning process of Bogor, the applicability of a GIS-MCDA tool (SSANTO) was evaluated with workshop participants (see Table 1). Overall, workshop participants were optimistic about the usability of the tool, indicating the steps to produce SSANTO’s outputs were intuitive. Furthermore, its integration in the ArcMap environment, which nearly all participants were familiar with, and its built-in support was considered clear and helpful. Regarding the interface, the most important limitation was the absence of an option to choose a local language, as mentioned by two workshop participants.

Both the interviews and workshop results revealed high receptivity among practitioners to novel tools and methodologies, particularly when available at no cost. The majority of all questionnaire respondents (13/16) indicated that they would use this tool if available to them. One government official wrote: “Yes, because it [SSANTO] increases knowledge and provides ease to the planning from a spatial angle.” Of the ten participants who were practitioners, seven indicated that they already apply manual GIS-MCDA techniques in practice, either by simply overlaying maps, or using more sophisticated methodologies including analytical hierarchy process: “Similar [process], but very manual. By overlaying all the data needed using simple GIS tools” (planning consultant). These respondents reflected that a tool like the one shown could significantly improve this process in terms of time invested, rigour and output quality: “Yes, it [suitability analysis] can be easier with this tool. Because the [SSANTO’s] design and operational processes are simpler” (government official).

Workshop participants indicated they would use tools, such as SSANTO, anywhere between two to ten times per year. Workshop results pointed to BAPPEDA as the greatest potential beneficiary and user. This appears counter intuitive considering the bulk of executive planning tasks are currently conducted by external consultancies. However, simple but rigorous analysis provided by PSS could strengthen Indonesia’s local government capacity to involve in the execution of urban planning, a sentiment that bears strong similarities to stakeholder perceptions in Australia (Kuller et al., 2019;2021). Hence, PSS could help accommodate the wish of local government practitioners (section 3.5) to upskill their organisation.

Workshop participants were asked to reflect on what they perceived to be strengths and weaknesses of the presented tool. In Table 2, these answers are compared to the considerations for tool adoption arising from the interviews. Overall, the tool was regarded as useful for the planning process, scoring very high on the issues fit-for-purpose and core functionality. User-friendliness, another priority for interviewees, also resulted in a high score, as well as output type and quality (Table 2). One workshop participant noted: “[it is] easy to operate, makes work easier.” SSANTO was considered innovative, and the map-based outputs were regarded to support planning: “[SSANTO] displays maps that are easy to understand” (government official). Most respondents acknowledged that the reliability of the outputs depend on input data quality.

Data availability is a critical barrier to the uptake of data intensive PSS in Indonesia, considering the high importance assigned by interviewees combined with low performance of the presented tool, common to many planning tools (Table 2). Particularly in Bogor, challenges associated with the availability and quality of spatial and other data are persistent. One consultant noted that SSANTO was “very data-dependent, and since the availability of detailed secondary data in Indonesia is very limited, this is likely to influence its success.”. This kind of PSS may have a higher utility in contexts with a higher level of available spatial data (e.g., Surabaya). Data-scarce environments, such as Bogor, can benefit from harnessing open source data platforms for essential spatial data (including some of the data required by SSANTO). Examples include the national government (https://tanahair.indonesia.go.id/portal-web), OpenStreetMap (www.openstreetmap.org), Google Earth Engine (www.google.com/earth), Worldbank data (https://datacatalog.worldbank.org), ESRI (https://esriindonesia.co.id/gis-data) as well as proprietary satellite data such as those from LANDSAT, available through the U.S. Geological Survey (https://earthexplorer.usgs.gov).

While data availability can limit the usefulness of PSS, their perceived utility can also serve as an incentive for better data collection and sharing, as apparent from some of the interviewees’ comments. We consider better contextual knowledge, derived from better data, to benefit the planning process. As such, PSS could serve as a catalyst to promote data collection.

Of note, the planning professionals engaged in the workshop were highly uncomfortable with performing weight assignment (Table 2). For example, as one government official mentioned: In the weighting I think it won’t be accurate, because each person has different opinions. Although participants were specifically selected as professionals in urban planning, most workshop participants with a professional background felt that they were not in the position to make this judgement. This apparent lack of confidence in their own expertise may be a product of the highly hierarchical nature of organisations and work-relations in Indonesia (e.g., Clarimenta et al., 2013). An inherent purpose of any MCDA exercise based on multi attribute value theory (Keeney and Raiffa, 1976) as used in SSANTO, is to incorporate subjective judgement in the form of preferences through weight elicitation (Eisenführ et al., 2010), in order to evaluate the performance of different decision alternatives (in our case: locations for NBS implementation). As we are dealing with preferences for objectives, these subjective judgements can come from any stakeholder in the decision-making process, and do not require specific expertise on the technical topic of the decision task (i.e., it does not consider expert judgement). The strength of MCDA is thus to uncover differences between stakeholder preferences and make explicit the consequences of trade-offs between objectives (Eisenführ et al., 2010). As MCDA and GIS-MCDA have been developed and primarily applied in industrialised countries (with some exceptions, e.g., Lienert et al., 2021), not much is known concerning the appropriateness of the method in the Global South. We therefore emphasise the importance of clear communication regarding PSS purpose and function (e.g., scenario exploration, data visualisation, option generation), and stakeholder selection in relation to the consequences for elicited weights. Further research should focus on the aptitude of MCDA-based methods within different socio-political contexts.

The importance of costs in practitioners’ decision to use PSS varies from one result to another. When workshop participants were asked to indicate their willingness to use SSANTO based on price (free, cheap or expensive), answers show a clear reduction in willingness with increased cost. Furthermore, open source software was preferred over licences software by most workshop respondents. On the other hand, there is a moderate level of importance attached to costs inferred from the interviews. These findings may reflect the diversity in preferences across the total pool of respondents, or stem from a difference in preference representation when the same objective (importance of low costs) is elicited using
different question framing.

The core functionality of the tested PSS, as well as its user-friendliness and it being fit-for-purpose received the highest perceived performance by workshop participants (Table 2). As they considered the latter two aspects as the most important issues for tool uptake, together with data needs, there is an apparent potential for spatial tools such as the tested one to be adopted by planning practice. Government interviewees pointed to the potential of such tools to strengthen their own capacity and agency in the planning process, one of the main barriers identified in section 3.3. Finally, PSS can address the identified barrier of lacking strategic involvement of all relevant stakeholders, as the core functionality of PSS such as SSANTO have a proven capacity to foster the collaborative planning processes and facilitate discussion between, and inclusion of all relevant stakeholders in the planning process (Geertman, 2002).

4.3. Transferability

In the 21st century, almost 90% of urban growth will be concentrated in the Africa and Asia (United Nations, 2019). Thus, the greatest needs and opportunities for sustainable development are also found there. However, the majority of research on sustainable urban planning and planning support tools are focussed the context of Europe, North America and Australia (Datta and Shaban, 2016; Nagendra et al., 2018). We attempted to address this gap by specifically testing the applicability of a novel PSS in the Indonesian context. The insights from practitioners across the two case studies highlight the unique challenges associated with each case study location, but also the influence of national planning laws alongside the climatological and socioeconomic similarities. Contrasting the outcomes with research from Australia revealed many commonalities both regarding issues with planning of sustainable urban water management as well as the use of PSS to assist this process, while some important differences also exist (Kuller et al., 2018b).

Firstly, for issues regarding planning (see Table 2: Kuller et al., 2018b) most important similarities were the perceived need and identified limitations in the collaboration of all relevant stakeholders. Both in Australia and Indonesia, the level of strategic collaboration varied, and its presence was regarded essential for successful planning of NBS. Furthermore, the presence of clear legislation around urban planning, which is regarded instrumental in Indonesia by interviewees, was also identified by planning practitioners in Australia (Kuller et al., 2018b; Morison and Brown, 2011) and other parts of the world (Brears, 2018; Kambites and Owen, 2006; Lennon, 2015; Mell, 2014). The limitations of local government capacity that were not identified in Australia, which has no laws preventing local government from executing planning tasks. However, in both countries the need for development and adoption of planning tools by government agencies was regarded important. Financial barriers to NBS implementation identified by certain interviewees were also mentioned in Australia, where the difficulty of “building a business case” (i.e., Kuller et al., 2018b) was regularly mentioned by planning practitioners. Finally, the problems with illegal developments were only identified in Indonesia.

Secondly, regarding PSS use and issues with PSS uptake our research indicates similarities, but also important differences with the Australian context. Similar to our respondents, spatial tools were among the most widely applied tools in Australia (see Fig. 3: Kuller et al., 2018b). Many comparable issues promoting and inhibiting PSS adoption arose in both cases including user-friendliness, output type and quality, flexibility, transparency and a trade-off between complexity and usability. Also similar were the ambiguous outcomes regarding the costs of a PSS. Most notable difference with responses from Australian practitioners regarded the low importance assigned by Indonesian interviewees to a wider uptake of a tool in industry. This finding was confirmed by the importance assigned to innovativeness by Indonesian workshop participants and interviewees, an aspect that did not emerge from the study in Australia. Furthermore, the biggest identified barrier for uptake of PSS in Indonesia was the availability and access to relevant data. While this issue was also mentioned for the Australian practice, it was assigned lower relative importance, a finding that may be explained by the high availability of data in the Australian case study. The presence of informal developments and settlements in Indonesia represents an additional difference with Australia concerning data availability. Future planning tools should explicitly address this issue, for example by incorporating tacit stakeholder knowledge and experiences. Finally, weight assignment to decision criteria was only identified as a barrier by Indonesian workshop respondents. This could indicate a mismatch between our framing of elicitation questions and the Indonesian professional culture. More insights into the transferability of participatory methodologies developed in industrialised countries should be the topic of further investigation. Instrumental for such exploration is an argument for public participation referred to by Fiorino (1990) as the “substantial rationale” and by Webler and Renn (1995) as the “functional” argument: conveying to participants that we do not demand from them a decision, but rather seek their contextualised knowledge as a valuable addition to the project.

5. Conclusion

While planning support systems are available and useful to aid NBS implementation, development and testing of these tools is limited to industrialised countries. The Global South accounts for the majority of current-day urban expansion, and have much to gain from the benefits provided by NBS. This research sought to understand the urban planning system relevant to NBS, and the current use of PSS and their potential to address identified challenges in the context of Bogor and Surabaya, Indonesia.

Despite comprehensive national planning laws with clear targets for green urban development, our interviewees and workshop participants indicated lagging implementation. Specifically, failure to include all relevant stakeholders in participatory planning, lacking capacity with local government and persistent problems with illegal developments inhibit successful NBS planning. While PSS are being recognised as vehicles for improvement, their current application is confined to the realms of academia and, to a lesser extent, private consultants working on government projects. Thus, effectiveness of PSS is restrained in this context.

Yet, we uncovered a broad willingness to adopt novel planning tools among all types of planning practitioners, including government officials, planning consultants and academics. Considerations for PSS uptake were found mostly similar to those in industrialised countries, including user-friendliness, being fit-for-purpose and clear and useable outputs. However, data availability and regulations preventing government agencies to execute technical planning tasks, causing capability limitations, contributed to their limited uptake.

Nevertheless, there are clear signals pointing to the potential of PSS to address some of the challenges identified, and to progress NBS implementation. The apparent appetite for innovative tools can serve as a catalyst for endeavours to improve data quantity, quality and availability across actors. Integrated planning tools can simplify otherwise complex modelling tasks, enabling capacity-constraint government officials to involve more closely in planning tasks and foster participatory planning including a broader variety of stakeholders. However, PSS should not be considered a panacea, and challenges related to policy constraints, political will and (planning) law enforcement preventing illegal development remain paramount for successful NBS planning.

Urban planning throughout Indonesia is governed by national planning laws. Therefore, many of the findings are expected to be valid for many cities across the country. Local differences always exist, but although our research mainly focussed on Bogor, and Surabaya to a lesser extent, many of its outcomes are expected to apply to Indonesia as a whole. Thus, our paper gives a valuable and rare insight into NBS planning, PSS use and potential in a country of the Global South. To gain
further understanding of these topics, future research should focus on verifying these findings for different contexts within Indonesia and throughout the Global South.

CRediT authorship contribution statement

Martijn Kuller: Conceptualization, Methodology, Formal analysis, Validation, Investigation, Data curation, Writing – original draft, Visualization, Project administration. Megan Farrelly: Conceptualization, Methodology, Writing – review & editing, Supervision. Dwinantti Rika Marthanthy: Investigation, Validation, Writing – review & editing. Ana Deletic: Conceptualization, Writing – review & editing, Supervision, Funding acquisition. Peter M. Bach: Conceptualization, Methodology, Writing – review & editing, Visualization, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Kanter, E., & Ruang Terbuka Biru di Sentul City, Bogor


