Does diversity of water sensitive urban design match the diversity of the urban context?

La diversité des techniques alternatives pour la gestion des eaux pluviales répond-elle à la diversité du contexte urbain ?

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RÉSUMÉ

L'adéquation du paysage urbain pour la mise en oeuvre d'une des techniques alternatives pour la gestion des eaux de ruissellement urbain (Water Sensitive Urban Design - WSUD) change en fonction de l'espace et des différents types de WSUD. On observe de nos jours une volonté croissante de compléter le système de drainage urbain traditionnel avec la WSUD. Cependant, peu d'information est disponible sur son potentiel dans les différents contextes urbains. S'appuyant sur une étude de cas réalisée à Melbourne, en Australie, ce travail a pour objectif de déterminer si une l'utilisation de sept types de WSUD différents garantit l'exécution au sein d'un milieu urbain. L'analyse a été réalisée en utilisant l'Outil pour l'analyse de l'adéquation spatiale (Spatial Suitability ANalysis TOol - SSANTO) pour chaque type de WSUD. Les résultats ont ensuite été combinés. Une potentielle mise en oeuvre de WSUD a été mise en évidence dans la zone ciblée par l'étude de cas. Le type de WSUD ayant le potentiel le plus élevé varie de facon significative en fonction du lieu. Tous les types, sauf un (swales), étant la meilleure option dans une partie conséquente de notre étude de cas. Ces résultats suggèrent que la variété des types de WSUD est suffisamment large pour garantir le potentiel de l'implémentation de la WSUD dans la majorité des paysages urbains. La reproduction de cette étude dans d'autres villes du monde pourrait améliorer de manière considérable notre connaissance du potentiel mondial de l'application de la WSUD.

ABSTRACT

Suitability of the urban landscape for the implementation of Water Sensitive Urban Design (WSUD) varies spatially and between WSUD types. An increasing ambition to supplement traditional urban drainage system with WSUD is observed. However, little is known about the potential for WSUD implementation in various urban settings. This study assesses whether a diverse set of seven WSUD types warrant implementation throughout an urban environment, using a case study in Melbourne, Australia. The analysis was performed using the Spatial Suitability ANalysis TOol (SSANTO) for each WSUD type and combining these results. A potential for WSUD implementation was found throughout the case study area. The WSUD type with the highest potential varied greatly with location, with all, except for one type (i.e. swales), being the best option in a considerable part of our case study area. These results suggest that the variety of WSUD types consisted is high enough to warrant the potential of WSUD implementation in most of the urban landscape. Repetition of this work in cities around the world could significantly enhance our knowledge about the global potential of WSUD practices.

KEYWORDS

GIS, suitability analysis, urban planning, water sensitive urban design

1 INTRODUCTION

Distributed and green stormwater management infrastructure, known as Water Sensitive Urban Design (WSUD) in Australia, has a reciprocal relationship to its local the urban landscape (Fletcher et al., 2014; Rijke et al., 2008; Wong and Brown, 2009). WSUD implementation therefore requires careful consideration of the needs and opportunities of a place (Kuller et al., 2017). Such needs and opportunities for WSUD comprise a variety of factors (Table 1). Suitability of a location for the implementation of WSUD infrastructure can be determined through a structured evaluation of the impact and relative importance of these factors (e.g. Fronteira et al., 2014; Makropoulos et al., 2008; Viavattene et al., 2008). Such spatial suitability analysis can be performed using a Geo-Information Systems based Multi-Criteria Analysis (GIS-MCDA) software called SSANTO (Spatial Suitability ANalysis TOol).

The diversity of the urban landscape is likely to result in significant spatial variability in needs and opportunities for WSUD. Such variability is met with a diverse set of potential WSUD infrastructure types, to fit different urban contexts (Melbourne Water, 2005). In this study, we investigate whether WSUD diversity is high enough to warrant the potential of implementation in any given location within an urban setting.

2 METHODS

SSANTO was developed to aid urban planners in their effort to strategically plan WSUD infrastructure, taking into consideration relevant factors (Kuller et al., 2018). We used SSANTO to evaluate a variety WSUD infrastructure for the case study area of the City of Darebin, a municipality in the inner north-eastern suburbs of Melbourne, Australia. Darebin is a predominately medium to low density residential municipality, with some commercial and industrial areas. The total number of inhabitants is just over 150 000.

Infrastructure types included in our study are rain gardens/bioretention systems, infiltration systems, green roofs, swales, rainwater tanks, tree pits and constructed wetlands. SSANTO follows a four-step, raster-based procedure for suitability analysis as suggested by Malczewski and Rinner (2015): (1) compiling geodatabase with all spatial input data, (2) masking out all unsuitable areas, (3) value scaling, to translate raw data values into suitability scores between 0 and 100 and (4) combination rules to combine all factors into final suitability maps, according to weights assigned by the user. For detailed information about SSANTO's methodology, please refer to (Kuller et al., 2018).

For each infrastructure type, we run SSANTO using its default settings. Thus, SSANTO masks out unsuitable areas and performs value scaling using values from governmental planning guidelines, academic literature and expert opinions. In this case study, weights (Table 1) were assigned following a brief workshop with two experts in WSUD planning from a local consultancy (Deletic et al., 2018).

Table 1 Selection of factors as used for the analysis with their expert-assigned relative weights (Deletic et al., 2018) indicating relative importance adapted from Kuller et al. (2017).

Category	Factor	Weight
Biophysical	Slope	10
	Pre-human wetland structure	3
	Distance to drainage infrastructure	9
	Roof areas	n/a*
Socio-Economic	Environmental awareness	2
	Education level	1
	Sense of community	2
Planning & Governance	Landfill sites	8
	Utility infrastructure	7
	Cultural heritage sites	3
	Natural heritage sites	3
	Geological heritage sites	2
	Distance to airports	6
	Land value	2
	Lot size	5
	Land ownership	7

*This factor was not weighted, as it is only used as a mask.

The analysis was completed for each of the seven WSUD types. Then, results for all WSUD types were compared on a cell-by-cell basis to create (i) a "maximum suitability" map, depicting the suitability values of the highest-scoring WSUD type for each location and (ii) a “best systems” map, presenting the corresponding (“preferred”) WSUD type for each location. Using these maps, we can evaluate the frequency and distribution of the most preferred system types.

3 RESULTS & DISCUSSION

Although we can observe some spatial variability in suitability, our results suggest that in most locations in the case study area at least one type of WSUD can be implemented (Figure 1a). Furthermore, only few locations (0.4%) prohibit the implementation of any type of WSUD (“Masked”).

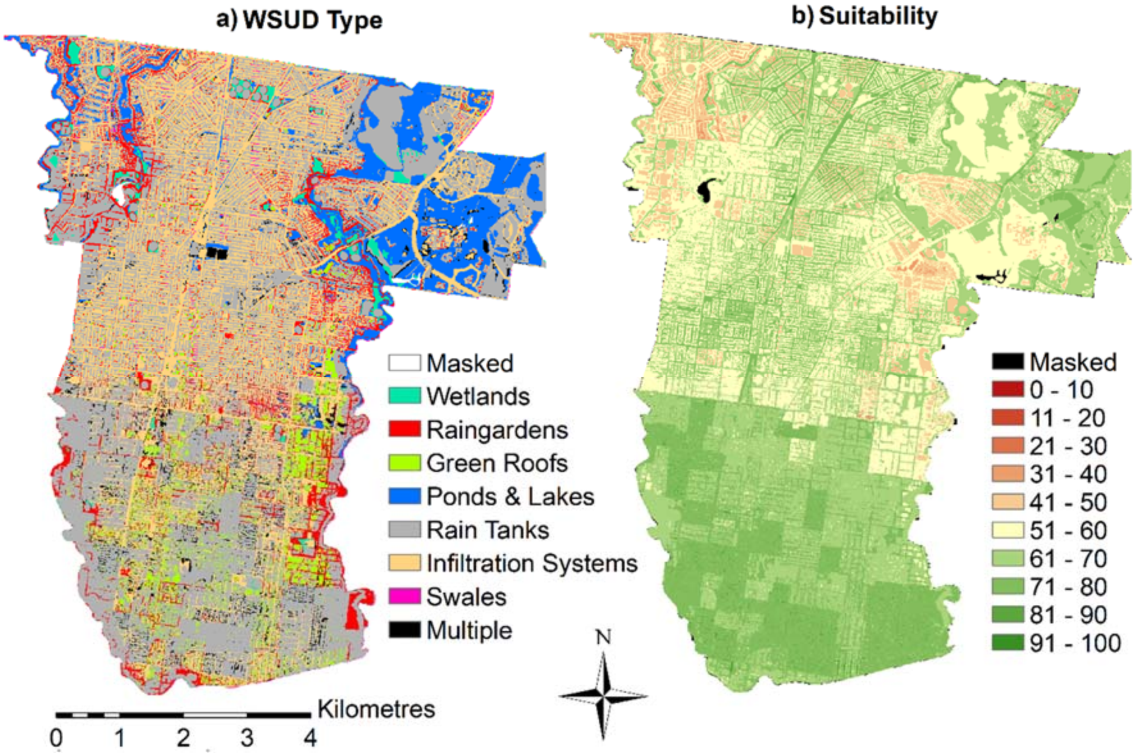

Figure 1 Most preferred system type and corresponding suitability: a) “preferred” WSUD type (WSUD type with the highest suitability score), b) maximum suitability for our selected WSUD types

In general, we observe a high variety of preferred WSUD types across the area, with no dominantly preferred WSUD type. The most frequently preferred type of WSUD are rain tanks (45.1%), reflecting their versatility and ease of introduction into diverse environments (Figure 1a). Also, infiltration systems (28.0%) and rain gardens (8.0%) are widely distributed and frequently preferred. Preference for green roofs is quite well distributed and moderately frequent (4.7%). Less distributed but frequently preferred are ponds & lakes (9.0%), predominantly located in the northeast of the case study area, where large green and open areas can be found. Also, less distributed and less frequently preferred are wetlands (1.4%). This could be the result of their relatively large footprint, which complicates their implantation in established urban environments. The only WSUD type that is rarely preferred is “swales” (0.6%).

Further research should focus on replication of this work in different urban contexts, to investigate whether the observed variety of preferred WSUD types is common. Furthermore, the results could be compared to those of a similar analysis in a greenfield area, where many factors from Table 1 do not play a role, and space not yet restricted.

4 CONCLUSION

Spatial suitability analysis of a set of seven WSUD types in a case study area in Melbourne, Australia, suggests the potential to implement WSUD in most locations. All but one WSUD type (swales) are preferred (highest suitability score out of the selected WSUD types) in a significant part of the study area, creating a diverse palette of options. Infiltration systems are most frequently preferred and most distributed across the study area, together with rain gardens. Swales are only very rarely preferred. Overall, the diversity of our seven selected WSUD types appears great enough to warrant WSUD implementation across our case study.

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