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Sustainable green systems in the urban environment

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ABSTRACT

With the increasing demand for land to accommodate residential, industrial, and commercial development within our cities, the preservation and management of our green spaces and biodiversity in the urban landscape is critical. This paper examines the complex issue of creating sustainable green systems and protecting biodiversity within the built environment. Existing green spaces and biodiversity are experiencing pressure from competing land uses and human activities predominantly in our capital cities. Our research focuses on preservation and management of green spaces and biodiversity in metropolitan Melbourne under the umbrella of the Melbourne 2030 planning strategy. We use the City of Darebin, one of thirty-one local government areas comprising metropolitan Melbourne as case study in order to develop urban green system scenarios incorporating biodiversity conservation. A geographical information system (GIS) based planning support system (PSS) tool is used to construct urban green system scenarios for the City of Darebin. Specifically, the land suitability module of the *What if?* GIS-based PSS is used to bring together a number of spatial datasets used to formulate the urban green systems scenarios. The datasets entered into the PSS encompass a wide range of cultural and natural assets data layers including: existing open spaces, waterways, threatened fauna and flora, ecological vegetation covers, registered cultural heritage sites, and existing land parcel zoning. The results of our analysis is an open space biodiversity index for the City of Darebin, which can be used to assist in assessing future land use development applications. It is recommended that such open space biodiversity indexes should be used to define and preserve green systems in the Australian urban environment.

Keywords: green space, biodiversity, geographical information systems, planning support systems

INTRODUCTION

Green systems such as parks and waterways are an important component of urban environment, especially in Australian cities. Our paper focuses on Melbourne, also known as the city of parks. Melbourne is considered as one of the most livable cities and is renowned for its world-class networks of parks and gardens. These diverse open

space networks contain areas of considerable natural and cultural values. However, these areas have experienced increasing land use pressure, particularly in the demand of land to accommodate future urban development. These demands pose risks not only to green spaces in Australian capital cities such as Melbourne, but also to remnant native vegetation, as most of these green space networks serve as habitat for biodiversity. Preserving and enhancing green systems are critical not only for sustaining and improving the quality of life of urban residents but also for conserving biodiversity. The government and community have recognised the significance of green systems and biodiversity, as well as the threat posed upon them, and have taken relative measure to preserve them.

In the Metropolitan Melbourne Strategy (2030), the importance of sustainable green systems is expressed in the vision for the city in 2030. In this vision, sustainable environment means “where ‘green’ is no longer a colour, but a way of life reflecting an environment that is valued, meaningful amounts of open space that can be enjoyed by all, and resources that are carefully deployed” (Department of Infrastructure 2002).

Sustainability of the built environment requires adequate planning and management of land uses including, importantly the conservation of green systems and biodiversity. Burke and Conroy (2000) believe that land-use and development activities should support the essential life support functions of ecosystems to implement sustainable development in planning. However, this is not addressed in most of the American urban planning (Beatley 2000, Berke and Conroy 2000).

Our research will demonstrate how using a planning support system (PSS) such as *What if?* can assist planners and decision-makers in implementing government policies by integrating biodiversity conservation considerations into urban land use strategies. Specifically, *What if?* has been used to establish the best land for extending and preserving existing open spaces within the City of Darebin.

In this paper the following questions in the municipality of Darebin, Melbourne will be examined:

- How can the conservation and extension of green systems and biodiversity in Darebin be enhanced?

- What areas should be protected for preserving biodiversity?
- What areas within the built environment could be converted to open spaces so to minimise loss of biodiversity such as remnant vegetation?

In order to address these questions, the City of Darebin in Melbourne metropolitan was chosen as a case study since it is an inner city municipality with population of diverse cultural background.

The paper will firstly present a methodology for achieving sustainable green systems incorporating biodiversity conservation. The *What if?* PSS is presented as a practical tool to achieve this goal in local government to consider and implement in land-use planning and management. Two land use scenarios with suitability analysis considering natural and cultural assets in municipality of Darebin in metropolitan Melbourne is used to demonstrate this approach. The paper concludes by offering directions in future research for achieving sustainable green systems in Australia.

BACKGROUND

Sustainability is listed as one of the core principles of Metropolitan Melbourne Strategy - *Melbourne 2030*. In this Strategy, protecting biological diversity and maintaining systems that essential to support life are regarded as one of the core objectives for achieving sustainability (Department of Infrastructure 2002a).

Biodiversity is defined in this Strategy to include genetic diversity or variability within each species, the diversity of the Earth's species of animals, plants and other organisms, and the diversity or range of different ecosystems these species form (Department of Infrastructure 2000b).

In order to minimise further loss of biodiversity in Metropolitan Melbourne and environs, careful planning of land use and the creation of additional open space and conservation areas is seen as an important challenge (Department of Infrastructure 2000b, 2000c, 2002a). Indeed, protecting native habitat and areas of important biodiversity through land-use planning is frequently cited as one of the most practical methods to achieve a sustainable city (Department of Infrastructure 2002a, City of Darebin 1999).

Currently, many government authorities such as local councils have identified strategies for planning future land use, but implementing these strategies using objective analyses tools has been limited. A number of modelling approaches have been developed to assess the impact of urban land use patterns on urban ecosystem (Alberti *et al.* 2001, 2002 & Waddell 2001). Alberti *et al.* (2002) developed a number of modelling approaches to explore the relationship between urban patterns and ecosystem dynamics in the Puget Sound Region (USA). One of these models *UrbanEco* analyses the land-use/land cover pattern, and examines the affects of land-use patterns on aquatic macroinvertebrates and avian communities. Waddell (2001) has developed *UrbanSim*, a software-based simulation model for integrated planning and analysis of urban development, incorporating the interactions between land-use, transportation, and public policy.

Computer-based land-use assessment tools have now commonly referred to as Planning Support Systems (Brail & Klosterman 2001 and Geertman & Stillwell, 2002). Yet, even though the term PSS first emerged in the literature (Harris 1989), the failure of planners to embrace computers-based tools to assist in core planning functions is an important issue that needs to be addressed (Klosterman 1997, Brail & Klosterman 2001). Our paper aims to highlight that generic PSS tools, such as *What if?*, can assist planners in defining sustainable urban green systems.

METHODS

To address the research questions specified above a case study approach has been taken focussing on the City of Darebin in metropolitan Melbourne. Darebin has been selected as a suitable case study because, like many inner city municipalities comprising Melbourne, it has a culturally diverse community. Among its 125,000 population, over one third were born overseas and approximately 30% of the population were born in non-English speaking countries, and over 40% of the population speaks a language other than English at home. Darebin residents have a diverse range of religious beliefs and lifestyles. In addition, Darebin has the largest indigenous (Koori) population in metropolitan Melbourne (Darebin City Council 2000b).

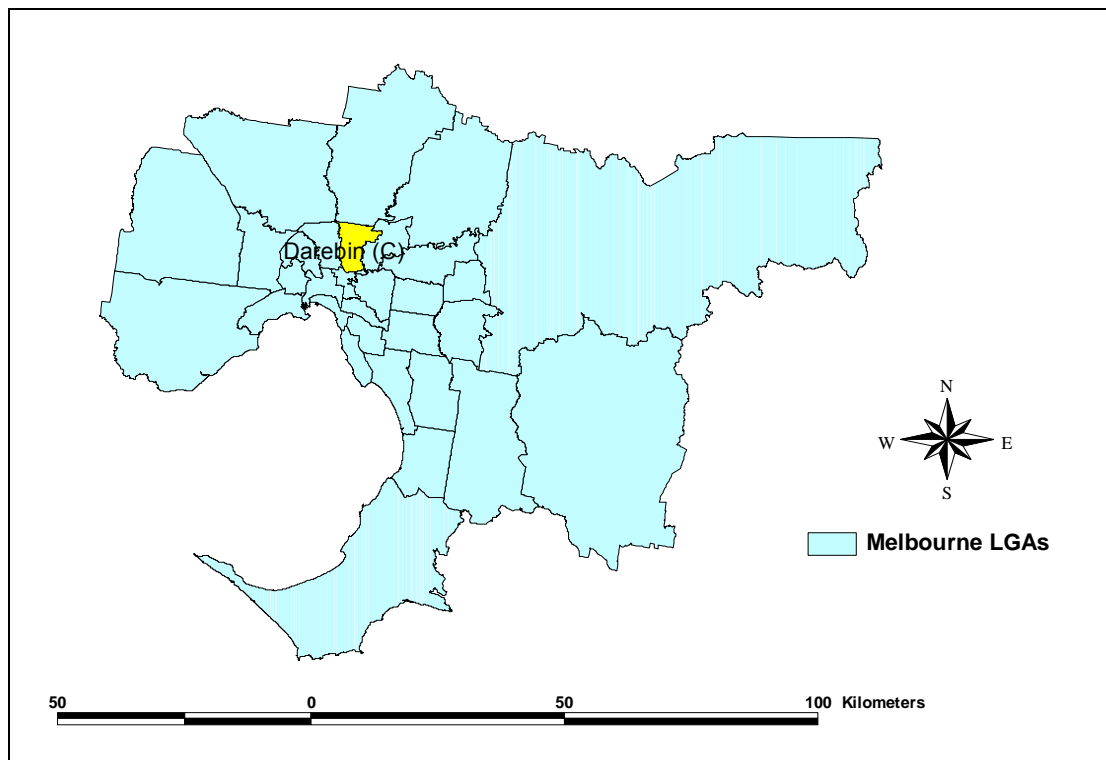


Figure 1. Metropolitan Melbourne and the City of Darebin

The municipality covers 53 square kilometres and extends from Heidelberg Road to the south to Mahoneys Road to the north, bounded by the Darebin Creek to the East and the Merri Creek to the west. Geographically, Darebin is located between Melbourne's central business district (CBD) and the City of Whittlesea growth area. As shown in Figure 1, the Melbourne CBD is located 11.1 km south of the municipal administration centre at Preston. Key transport linkages, including the Hursbridge and Epping rail lines, St. Georges Road and High Street combined with Plenty Road, provide a strong north-south transport axis. Bell Street provides the major east-west access (Darebin City Council 2000b).

The City of Darebin has diverse open space networks that are facing pressure from urban development. As shown in Figure 2, there are certain areas with environment and cultural significance in the City of Darebin need to be protected such as native grasslands, waterways (such as Merri and Darebin Creeks), and significant remnant vegetation (such as river red gums at Mount Cooper). Darebin has nearly 0.6 square metres of open space per person, a level comparable to many other inner Melbourne municipalities (AIUS and City of Melbourne 1998).

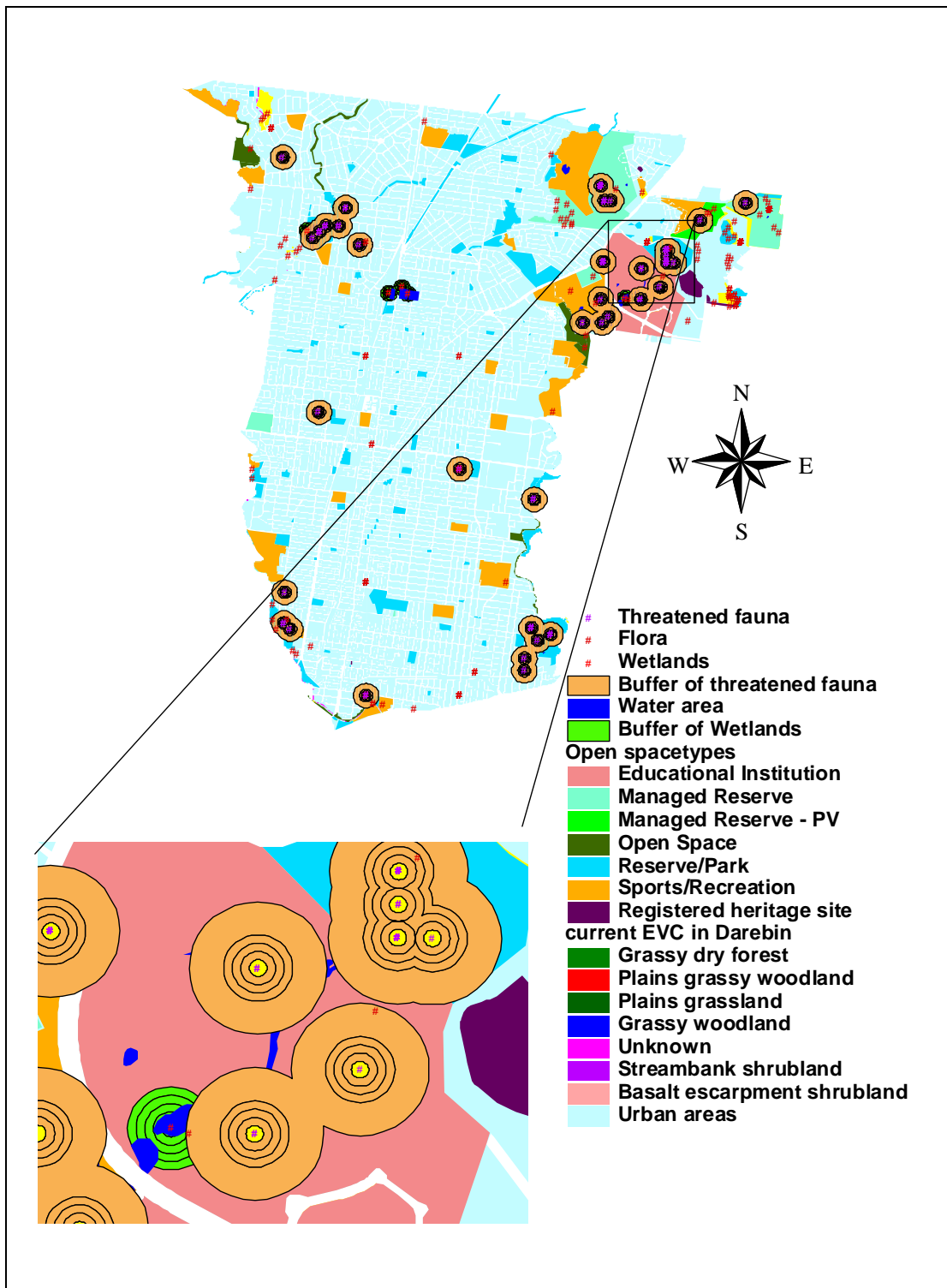


Figure 2. Suitability analysis for conservation of green systems and biodiversity

What if? PSS application

The goal of our research is to assist achieving sustainable cities by protecting and enhancing green systems (open spaces and waterways) incorporating biodiversity conservation. To achieve this goal, the spatial data for Darebin including open

spaces, waterways, biodiversity, cultural heritage, planning scheme and land parcels has been collected from various organisations. The *What if?* PSS modelling approach is employed to analyse suitable land for open space protection and development. The result of this approach is a series of maps and suitability reports that can be easily understood and presented by local government.

There are three core modelling modules in the *What if?* PSS, these are:

- A land *suitability* analysis module (which provides a spatial continuum of land least to most suitable for each particular land use);
- A *growth* analysis module (which calculates the future demand of land required for particular land-uses); and
- A land *allocation* module (which combines the projected land use growth with the suitability maps, and also incorporates land-use control and a defined growth pattern to predict the pattern of land use change and where land-use allocation occurs (Pettit 2003).

The first module provides an interface for objectively identify land suitable for a particular land use using relevant factors and their rating of importance. The growth analysis module and the land allocation module can help planners to analyse and predict future demand for particular land use and provide an allocation of these land uses based on rules relating to population growth, household factors and employment projections for specified time periods. However for this research, the growth analysis and land allocation modules have not been required as we focus on developing urban green space *suitability* scenarios.

The suitability of open spaces for land development is the principal focus of this paper as such developments are most likely to impact on biodiversity and open space values. The analysis of green systems and biodiversity data has shown that the majority of flora, fauna, and environmental significant sites are located within 100 metres of open spaces, waterways, and water bodies in metropolitan Melbourne. Hence these areas have been given some prominence in the analyses presented below.

Datasets

Several data sets were employed for the analyses including:

- Green systems data – open spaces, waterways and water areas – that were obtained from Australian Research Centre for Urban Ecology (University of Melbourne) and Land Victoria (Victorian Department of Sustainability and Environment).
- Biodiversity data – flora, ecological vegetation classes, threatened fauna - that were obtained from the Victorian Department of Sustainability and Environment.
- Cultural heritage data – registered heritage sites - that were obtained from Heritage Victoria and the Victorian Department of Infrastructure.
- Planning scheme and land parcel (cadastral) data - that were obtained from the Victorian Department of Infrastructure.

Preparation of datasets

ArcView GIS was used to prepare the above spatial data sets for input into the *What if?* PSS. First of all, the existing land-use data acquired from the Victorian Department of Infrastructure (2000) were appended to cadastral land parcel boundary data, acquired from Land Victoria, to better understand the spatial characteristics of land parcels and their associated social, economic, and environmental attributes. Secondly, according to the requirement of *What if?*, the land-use data were generalised into five categories (business, industrial, mixed use, public/infrastructure, residential) for the purpose of creating the demonstration project 'sustainable green systems scenarios'. To accommodate the analysis of suitability of land-use by protecting the natural and cultural heritage, green systems, biodiversity, and cultural heritage areas were buffered into 4 arbitrarily-defined zones (0-25, 25-50, 50-75, 75-100 metres) to classify the conservation importance of these areas in sustainable land use. It is presumed that the future land-use and urban development surrounding these areas could have impact on the cultural and environmental values of green systems, biodiversity, and cultural heritage. The proximity of the urban development especially land-use is considered as a prime parameter to evaluate this impact. This parameter is defined by 5 equally buffered zones (0, 25, 50, 75, 100 metres) to simplify computing process and analysis of result. The buffered features include open spaces, waterways, water areas, flora, threatened fauna, selected ecological vegetation classes (such as remnant native vegetation), and registered

heritage sites. Since the spatial analysis of green systems and biodiversity data of Metropolitan Melbourne has shown that biodiversity is mainly found within 100 metres of green systems, for the present analyses a classification was made to identify land within and beyond 100 metres of buffer areas. Land beyond the 100 metres buffer areas was classified as 'outside'. The buffers were linked to the land use cadastral data using Arcview GIS.

Land use suitability analysis

Sustainable green systems scenarios were developed to consider the principal of sustainable built environment, and to analyse and determine the supply of land (both quantity and location) of land that is suitable for open spaces in order to protect and enhance the existing green systems and biodiversity.

The land suitability analysis was undertaken using a weighted linear combination (WLC), multiple criteria analysis (MCA) model, which is based on the sieve mapping overlay technique advocated by McHarg (1969) and Hopkins (1977). The MCA model is a simple mathematical procedure which multiplies each suitability factor's rating by the overall weighting of importance assigned by the user and then performs an additive operation, combining all suitability factors, to derive a final potential cost surface, also known a suitability map. By using this simple MCA technique the underlying mathematical model is easily understood by most planners, decision-makers and ultimately the community.

The *suitability factors* have been formulated from a number of spatial datasets listed above using standardised factor values related to buffer distances and weightings determined by priorities in accordance to the existing Darebin Council planning policies. In summary, the suitability module enables multiple suitability factors to be synthesised in order to determine relative suitability of different locations for a particular land ('open space' in this study).

Factor weight means the relative weight that different factors should be assigned in determining the relative suitability of different locations for a given land use. The factor weights range from 1 (low) – 3 (high). Factor weights of 0 are used to designate areas in which development is to be prohibited.

Factor ratings are used to specify the relative importance of different suitability factor types in determining the relative suitability of different locations for a particular land use. The factor ratings range from 1(low) to 5 (high).

The weights and ratings assigned to each of the suitability factors are used to construct land suitability maps for open space. The suitability for open space land use for the City of Darebin was determined by the suitability factors, factor weights, and ratings as outlined in Table 1 (for scenario 1) and Table 3 (for scenario 2).

Category		Considered suitability factors and ratings						
Factors		Fauna	Flora	Land use	Water features	Heritage	EVC	Open space
Factor weight		3	1	2	2	1	1	3
Buffers (metre)	0-25	5	5	5	5	5	5	1
	25-50	4	4	3	4	4	4	2
	50-75	3	3	2	3	3	3	3
	75-100	2	2	1	2	2	2	4
	Outside	1	1	5	1	1	1	5

Table 1. Land use suitability considered factors, weight, and ratings for Darebin based on scenario 1

Another model variable *conversions* was used to identify land-uses that were candidates for conversion from the current land-use to the future use selected during the suitability analysis process. Typically in most cities not all land required for maintaining or extending urban green systems is vacant. Therefore, the requirement to resume land currently tenured for other land activities is investigated in the two sustainable urban systems scenario presented in this paper.

The decision factors for sustainable green systems include existing open spaces, waterways, water areas, flora, threatened fauna, selected ecological vegetation classes (EVC), existing land use, and registered heritage sites as shown in Tables 1 and Table 3. For example, flora, fauna, and ecological vegetation classes were given the highest weight for sustainable green systems scenario 1. The ratings indicate the relative suitability of locations for locating open spaces, using different buffers. The factor types were rated from 5 (high) to 1 (low). Rating was determined according to the buffer distance to the suitability factors that were examined (such as flora and fauna). For example, in scenario 1, for flora and fauna, buffer areas between 0-25 metres were rated 5 because they were considered highly suitable for developing as

open spaces where biodiversity conservation is a high priority. In contrast, areas beyond 100 metres of the buffers were rated 1 because they were considered to be less suitable for allocation as open spaces.

Scenario 1

From the analysis of green systems and biodiversity data of metropolitan Melbourne, green systems are vital habitat for biodiversity conservation. Victoria government has advocated the importance of protecting green systems and biodiversity in metropolitan Melbourne through recent Metropolitan Melbourne Strategy (Department of Infrastructure 2002). In accordance to government policy, scenario 1 was developed to protect the biodiversity and sites of environmental and cultural significance, and to enhance existing parks and waterways. In particular, this scenario incorporates the following assumptions:

- All seven of the suitability factors (including fauna, flora, heritage, existing open spaces, ecological vegetation classes (EVC), current land use, and water features) were considered when they are appropriate for open space land use.
- Buffer areas around these factors were given consideration to analyse the suitability in future open space development in order to protect biodiversity and enhance existing green systems.
- All current land uses were considered as candidates for conversion for the future land use as open spaces.

Generally, the factor weighting and ratings employed in these analyses need to be determined by informed decision-makers and stakeholders. These individuals and groups may include town planners, environment managers, and environment planners from local and state governments, community groups, and the public using formal approaches such as interview, public consultation, and discussions. For example, in Pettit's (2003) land-use planning scenarios for Hervey Bay, the local council planners were consulted to determine the appropriate weighting and ratings. However, since this analyses were undertaken to evaluate the approach conceptually for helping to protect green systems and biodiversity, the assigned weights and ratings in this instance have been defined by the principal author. In the future this

modelling approach will be improved by obtaining weightings and ratings through consultation with council officers, parks managers and local communities.

In scenario 1, the following factors were considered important to evaluate the suitability of land for potential open spaces: flora, fauna, heritage, open spaces, EVC, land use, and water features (including waterways and water bodies). The effective weighting of these factors is shown in Table 1, considering the flora, fauna and water features as the most important factors (weight 3), heritage and current open spaces as the second most important factors (weight 2), and EVC, land use, and flora as the third most important factors (weight 1). The ratings for these factors are illustrated in Table 1. As previously mentioned all existing land-uses were candidates for the conversion to the future open space land use. Based upon these variables, weightings and assumptions the suitability analysis was undertaken.

The suitability attribute outputs revealed that there are more than 1,650 hectares of lands surrounding open spaces, water features, flora, fauna, and cultural heritage sites are suitable with low – medium degree for developing as open spaces in order to enhance existing green systems and protect biodiversity and cultural heritages. There are also approximately 6 hectares of land not suitable or convertible for future open space development, as shown in Figure 3.

Suitability category	Suitability scores	Hectares
Not developable	NA	5.88
Not convertible	NA	0.00
Not suitable	NA	0.00
Low	1.0 to 21.0	391.28
Medium low	22.0 to 42.0	1,377.98
Medium	43.0 to 63.0	0.03
Medium high	64.0 to 84.0	0.00
High	85.0 to 105.0	0.00
Total		1,775.17

Table 2. Suitability Attribute Outputs for Darebin based on scenario 1

Scenario 2

With the protection of green systems and biodiversity as a primary aim, the second scenario is developed without considering the cultural heritage sites as a suitability factor. The aim of establishing this scenario is to stress the fact that in consideration

of land use suitability for open space for green systems and biodiversity protection, other key directions of Metropolitan Melbourne Strategy such as protection of the cultural heritage need to be addressed. In particular, this scenario incorporates the following assumptions:

- Six suitability factors (including fauna, flora, existing open spaces, ecological vegetation classes (EVC), current land use, and water features) are considered when they are appropriate for open space land use; flora, fauna, and ecological vegetation classes are considered as the most important factors in deciding the suitability for open space land use.
- Buffer areas around these factors are given consideration to analyse the suitability in future open space development in order to protect biodiversity and enhance existing green systems.
- All current land uses were considered as candidates for conversion for the future land use as open spaces.

In scenario 2, the suitability factors and their weightings are shown in Table 4 considering flora, fauna, and EVC as the most important factors (weighting 3), existing open spaces as the second most important factors (weighting 2), land use and water features as the third most important factors (weighting 1). Ratings for these factors are shown in Table 3.

Category		Suitability Factors and Ratings					
Factors		Fauna	Fauna	EVC	Open space	Water features	Land use
Factor Weights		3	3	3	2	1	1
Buffer (metres)	0-25	5	5	5	1	5	5
	25-50	4	4	4	1	5	2
	50-75	3	3	3	2	4	3
	75-100	2	2	2	3	3	3
	Outside	1	1	1	4	1	4

Table 3. Considered land use suitability factors, weights, and ratings for Darebin based on in scenario 2

The suitability attribute outputs for Scenario 2 revealed that there are more than 1,495 hectares of lands surrounding open spaces, water features, flora, fauna, and cultural heritage sites are suitable with low – medium degree for developing as open spaces in order to enhance existing green systems and protect biodiversity and

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cultural heritages. Additionally there is approximately 15 hectares of a medium degree of suitability and no land, which is not developable, convertible or suitable for future green space, as shown in Figure 4.

Suitability Category	Suitability Scores	Hectares
Not developable	NA	0.00
Not convertible	NA	0.00
Not suitable	NA	0.00
Low	1.0 to 18.0	264.87
Medium low	19.0 to 36.0	1,495.44
Medium	37.0 to 54.0	14.86
Medium high	55.0 to 72.0	0.00
High	73.0 to 90.0	0.00
Total		1,775.17

Table 4. Suitability Attribute Outputs for Darebin based on scenario 1

Results

Our research has resulted in the formulation of two preliminary sustainable green systems scenarios for testing the application of using GIS and PSS technology for managing urban open space and biodiversity in the urban environment. The resultant suitability maps as shown in Figures 3 & 4 delineate areas from the least suitable to the most suitable for resumption for future open space.

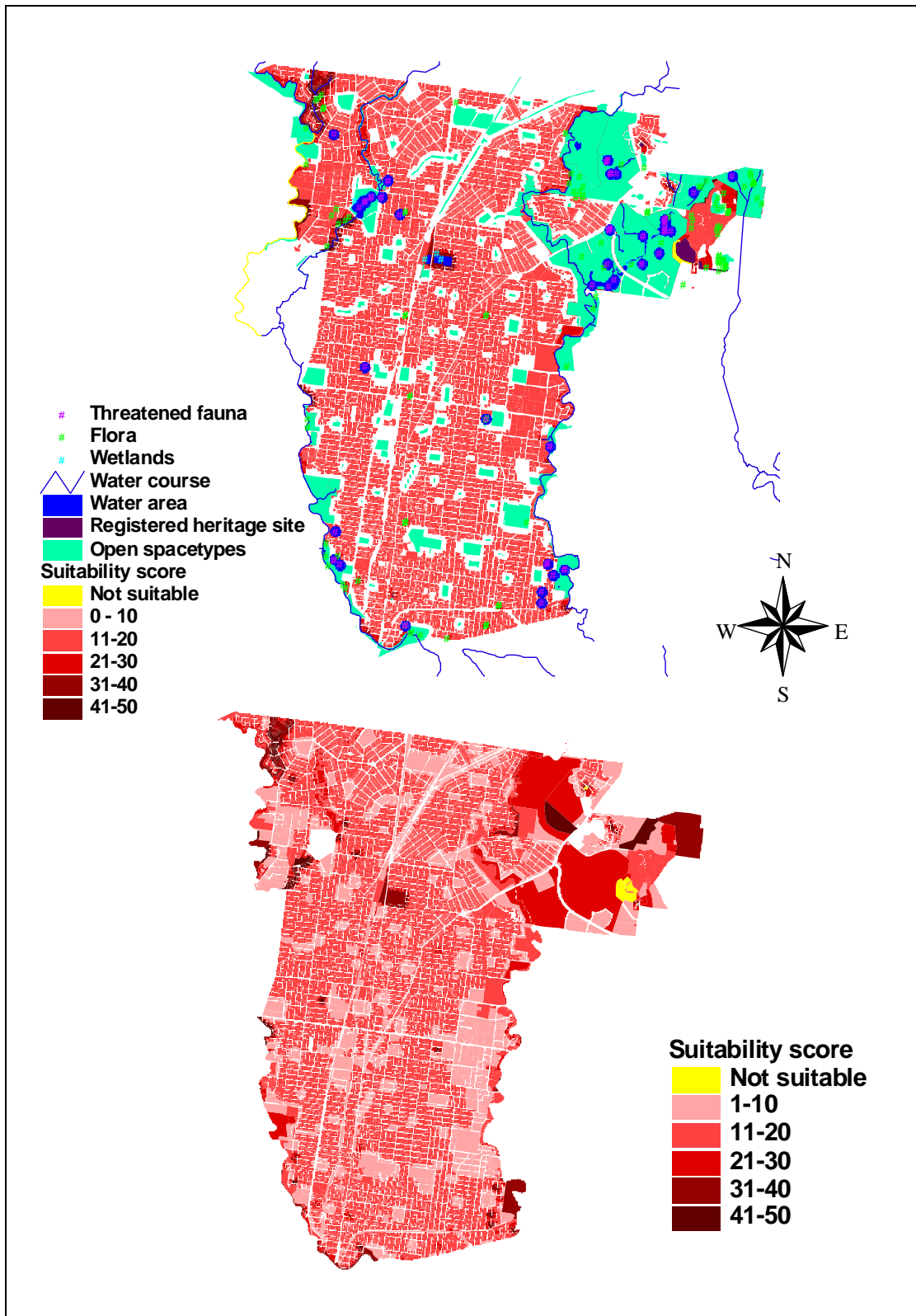


Figure 3. Land use suitability score for open spaces for Darebin based on scenario 1

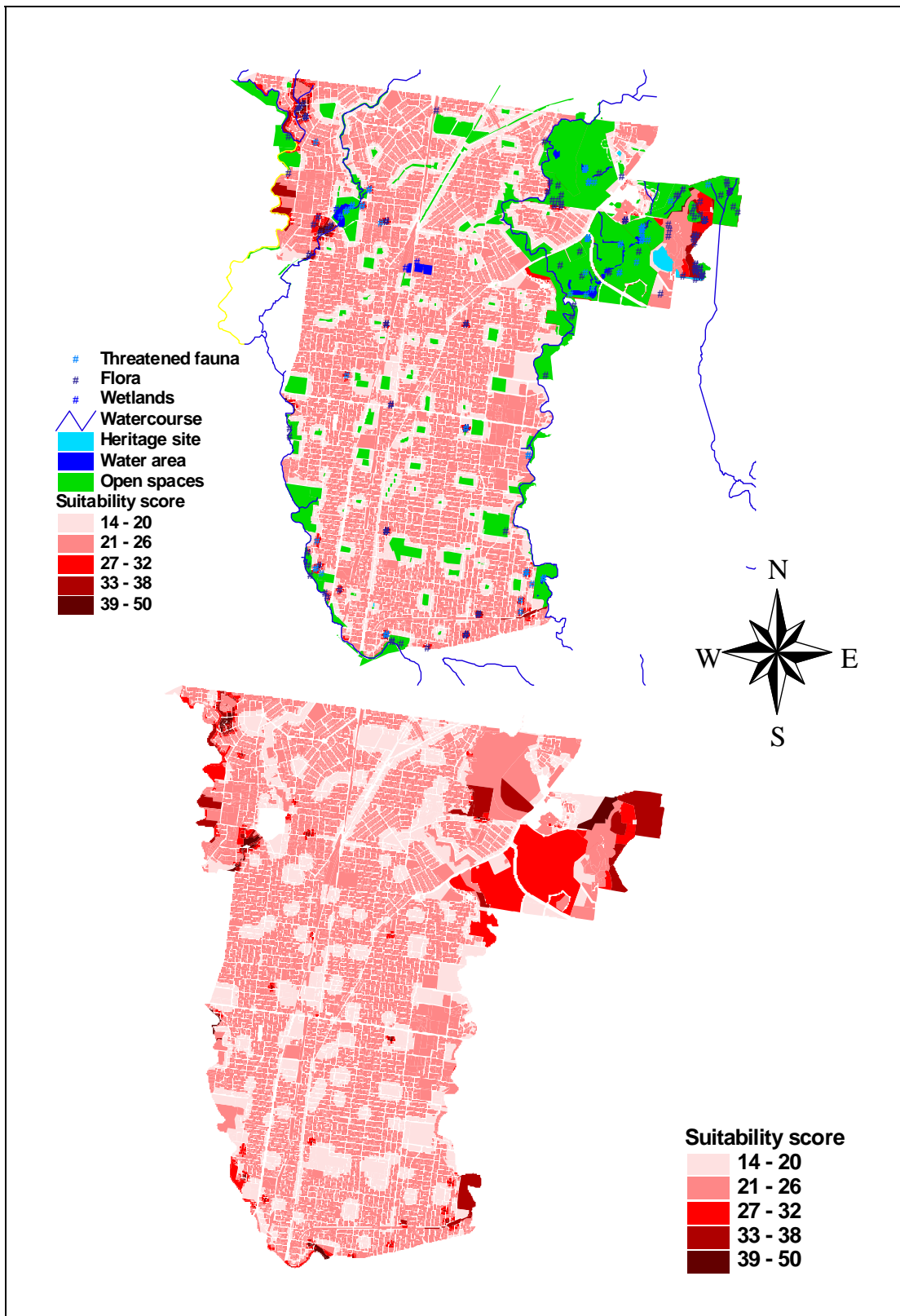


Figure 4. Land use suitability score for open spaces for Darebin based on scenario 2

The results show that, the areas around flora, fauna, EVC, water features, and registered heritage sites are suitable for open space development in scenario 1 in

order to protect biodiversity, remnant vegetation, and cultural heritage. This result is consistent with the government report and policy that green systems (including parks and waterways) serve as habitat for flora and fauna (Department of Infrastructure 2000, 2002), and should be protected and enhanced for biodiversity conservation. In this scenario, the considerations were not only given to the green systems enhancement and biodiversity conservation, but also to cultural heritage protection. This is consistent with the key directions of the recent Melbourne Metropolitan Strategy.

In scenario 2, however, as the cultural heritage sites were not considered as a suitability factor, the results show that the areas around flora, fauna, EVC, water features, including the cultural heritage sites themselves are suitable for open space development. This is not consistent with the key directions of Metropolitan Melbourne Strategy to protect cultural heritage, even though this scenario does reflect some of the key principles of the Strategy to “protect biodiversity and maintain systems essential to support life” (Department of Infrastructure 2002).

DISCUSSION

The land suitability analysis for open spaces for the City of Darebin is an example of the potential application of computer-based technology for land-use planning to achieve sustainable urban environment by enhancing green systems and protecting biodiversity. In this research, green systems (including parks and waterways) and biodiversity were considered to be important factors in land-use decision making to protect flora, fauna, and significant environmental sites. Different factors considered, their weights and ratings to these factors and their buffer areas could directly affect land-use outcomes.

Using the *What if?* spatial modelling approach, decisions on sustainable land-use can be made by potentially incorporating the opinions of different experts and decision-makers. This expert and political knowledge can be reflected through the weighting and ratings of suitable factors given, in order to predict and monitor the conservation areas objectively. Notably, buffer areas of flora, fauna, and remnant vegetation in public and private land can be clearly defined and monitored.

The suitability analysis approach has many advantages. It is objective and effective; suitability factors can be clearly defined and adjusted according to the objectives. It is transparent as it enables planners and decision-makers to formulate land-use planning scenarios by allowing decision-makers to select effective suitability factors, assign various weightings of importance to different suitability factors, and examine the results by spatial demonstration (suitability maps and reports). The *What if?* PSS provides a graphic user interface which allows planners, decision-makers and stakeholders to easily enter ratings and weightings, run a scenario, examine the results, then go back and re-adjust the inputs and run further scenarios.

This type of modelling approach could help identify implications of different land-use allocations by local government such as Darebin City Council. In addition, the approach could allow larger scale integration, across council regions, a vital perspective in environmental management. For example, Darebin and Merri Creeks lie in between the cities of Moreland and Banyule of metropolitan Melbourne. It is important for Darebin City Council to integrate their land-use planning and management with both Councils surrounding these two creeks.

The modelling approach presented in this paper considers the future land-use suitability only from the perspective of biodiversity conservation and green systems enhancement. However in reality, many other complex issues need to be considered (such as the social and economic perspective of the current land-use). For example, in scenario 2, the registered heritage sites were not considered as an effective suitability factor. The *What if?* projection for suitable open space (Figure 4) indicated that this land could be suitable for open space development. This aspect will need consideration because eventually it may result in conflicts with cultural heritage preservation. From these two scenarios and their results, it is indicated that, in protecting green systems and biodiversity, all other effective factors of existing urban land-use (such as cultural heritage) need to be considered, in order to sustainably manage and plan for future growth in our cities.

In this study, the factor weightings and ratings are only considered from the authors' analysis, however, there is a need involve key managers, stakeholders, and community groups in the selection of model inputs, factor weightings and ratings. This can be explored in future studies. Future work will see this research extended to

not only examine the suitability for open space in the urban context, but also to assist in developing regional biodiversity strategies. It is anticipated that a refined PSS modelling approach will eventually be accepted by planners and decision-makers to assist in developing land use suitability scenario that focus on minimising the impact of urban development on biodiversity. By properly considering these issues, this modelling approach can help local councils of Metropolitan Melbourne to implement the Metropolitan Melbourne Strategy (Melbourne 2030) regarding green systems and biodiversity conservation in a practical way to achieve a sustainable Melbourne in 2030.

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