Proceedings of the Fábos Conference on Landscape and Greenway Planning

Volume 6 *Adapting to Expanding and Contracting Cities* Article 42

2019

Identifying and Classifying, Quantifying and Visualizing Green Infrastructure via Urban Transects in Rome, Italy and Sydney, Australia

Simon J. Kilbane
University of Technology, Sydney, simonkilbane@gmail.com

Daniele La Rosa
University of Catania, Department of Civil Engineering and Architecture, dlarosa@darc.unict.it

Identifying and classifying, quantifying and visualising Green Infrastructure via urban transects in Rome, Italy and Sydney, Australia

Simon Kilbane[1], Daniele La Rosa[2]

[1] *University of Technology, Sydney / Broadway, Sydney 2007, NSW, Australia*
[2] *University of Catania, Department of Civil Engineering and Architecture / Catania, Italy*
Emails: simonkilbane@gmail.com; dlarosa@darc.unict.it

Abstract

Green Infrastructure is increasingly recognised as an approach to deliver a wide-ranging set of ecosystem services in cities and to operationalize concepts of urban resilience through the better delivery of urban planning, water sensitive urban design and a broad diversity of open space types. This paper argues that the first step in the delivery of effective Green Infrastructure planning and hence ecosystem services is the identification, visualisation and calculus of the full spectrum of existing open space types within urban contexts. To test this idea two case study cities – Rome and Sydney – were selected for their differing geographical origins and planning history. In each city an analysis of the urban fabric through a novel transect mapping process revealed a range of Green Infrastructure types including a diversity of open space, public parks and plazas, streetscapes, greenways and terrain vague. This began by analysing and comparing identified land-uses with existing planning rules, strategies and mechanisms within each city. Through this process we found that for each city significant differences were evident between the formally recognised urban open space and a range of potential additional Green Infrastructure candidates were identified. We then considered the potential recognition and activation of these spaces as critical pieces of overlooked Green Infrastructure into the metrics of a sustainable future city. Comparing these two cities against each other also confirmed the richness of Green Infrastructure types globally across both expanding and contracting cities and highlights differences in data precision, land policy, governance, nomenclature and urban conditions. This research posits that in the absence of the holistic and multi-faceted understanding, metrification and the visualisation of the diversity and distribution of green infrastructure in all its forms then progress towards implementation of robust and resilient cities and their urban ecosystem services will be limited.

Introduction

The research reported in this paper describes a study of two cities, Rome and Sydney undertaken to better understand existing patterns of urban Green Infrastructure (GI) through a novel transect mapping approach that examined the full diversity of open (or 'green') space types. This research sought to highlight the potential of a transect-based mapping method to better progress planning toward more resilient cities through the analysis, calculus and visualisation of GI against existing land-use data and planning policies and is presented as a method that could be adopted in other cities, globally. This paper begins by giving some background into urban resilience via GI, then introduces the key research aims and method. The results for each city are then provided and the discussion and conclusion offer a summary of key challenges and findings and reflections upon the significance of this research elsewhere.

Background

Much recent literature considers the potential for the better planning and design of cities to meet future challenges and perturbations, as 'resilient' cities (Ahern 2012; Childers et al. 2015; Garcia & Vale 2017; Walker & Salt 2006), including approaches to better integrate water and flood risk into city planning (Balsells et al., 2013). Holling defined resilience in ecological sciences as: 'measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables' (1973, p. 14), while Pickett et al. suggests that resilience is defined by the ability of a system (in this instance, the city) to adapt and adjust to changing internal or external processes (2004). Along with many other ecological paradigms and language that have attempted to make the leap from ecology to the field of urban design and planning, this term has taken upon a flexibility that is beyond its intended meaning and is discussed in this context and others at length by Brand & Jax (2007). Cities however are complex and reductive scientific reasoning is hard to apply where cities are increasingly recognised as 'systems of systems of systems' (Johnson 2012). In this urban context, the ability to measure the potential for response to change is a difficult task when initial definitions of resilience relate to change via a small number of variables, typically less than five (Walker et al. 2006).

Returning to the complex challenge of city planning toward greater urban resilience, this research regards the particular role that GI could play in the future city. Specifically, this research sought to understand how GI as a framework could be applied to engender more resilient cities. Increasingly popular in both theory and embraced by policy, GI is increasingly seen as a framework through which to plan and be retrofitted into cities to help create more sustainable and resilient cities (Mell 2009). GI embodies resistance thinking as outlined by (Folke et al. 2002; Gunderson & Holling 2002; Holling 1973; Lister 2015; Walker & Salt 2006) and the now well documented and pervasive global environmental perturbations of the Anthropocene – including climate change – have led to a range of policies which respond to environmental concerns and build upon resilience theory and systems ecology thinking (Waltner-Toews, Kay & Lister 2008). McPherson et al. suggest several benefits of GI through the specific delivery of ecosystem services (2015) while Meerow & Newell suggests suggest that these include: stormwater management; social vulnerability; green space; air quality; urban heat island amelioration; and, landscape connectivity (2017). Indeed, GI's multifunctionality is one of its most recognisable qualities (Ahern 2007; Tzoulas et al. 2007; Kilbane 2013) and the concept could be considered as 'a melting pot for innovative planning approaches in the field of nature conservation and green space planning' (Hansen & Pauleit 2014). For this research, we utilised the following very broad GI definition:

> *Green infrastructure is the ecological framework for environmental, social, and economic health – in short, our natural life-support system. (Benedict & McMahon 2006, p. 1)*

GI may also be used as a framework to understand and recognise existing and formally planned open space within a city as well as the opportunity to recognise and conceptualise the gaps within existing urban fabric, sometimes referred to as 'non-urbanised areas', 'un-built', 'friche', 'no-man's-land' or 'terrain vague' (Morales 1995; La Rosa & Privitera 2013). In recent years such spaces have been increasingly recognised and discussed despite often being overlooked, ill-acknowledged or not recorded by traditional planning methods. Typically the product of lands in transition, these represent a significant opportunity to deliver a spectrum of multifunctional benefits and ecosystem services within established cities increasingly contested urban fabric (Phelps & Silva 2018). However, frequently the identification and recognition of such spaces is difficult to achieve.

Research Aims

This paper posits that the first step in delivery of effective GI planning and the improved delivery of ecosystem services is the identification, calculus and visualisation of the full spectrum of potential urban open space candidates and for their inclusion into city planning and governance. Three key research aims considered a more holistic way to understand the full spectrum of urban GI and therefore ascertain its full potential:

1. Formulate a method to identify, map, quantify and classify urban open space as potential GI;
2. Consider ways to visualise and explain findings in an easily accessible form;
3. Present and compare findings with existing planning mechanisms.

Method

In order to understand the efficacy of any method, two specific cities – Rome, Italy and Sydney, Australia – were chosen. Selected for their differing geographical, historical and planning backgrounds these case study cities possess a range of existing GI. These included established and recognisable parks, plazas and other open spaces but also a range of potential and less formally acknowledged open space types as terrain vague. These un-built or non-urbanised areas, abandoned agricultural and industrial lands and other land-uses align with Benedict & McMahon's GI definition *(2006)*.

The selection of geographic limits of the study areas was defined in each instance by the 'urban agglomeration' area defined by the United Nations as 'the population contained within the contours of a contiguous territory inhabited at urban density' (2018) and was accompanied by the collation of supporting planning policies and mechanisms utilised to plan each city. Cognisant of the complexity and size of the cities in question, the enormous task of compiling, quantifying and classifying all GI for each cities area – a task considered beyond the time limits of our research – was instead replaced by the use of transects to instead provide a snapshot of each city's GI. Transects have been used successfully to investigate diversity, complexity and temporal change in urban environments for many years (Yu & Ng 2007; Follmann, Hartmann & Dannenberg 2018; Pickett et al. 2001; Forman & Godron 1986). The transects within each city were generated by using the *Random Transect Generator* (Geographic Business Solutions 2018), an add-in tool for ArcMAP that creates randomly located custom line transects within an area specified – in this case the 'urban agglomeration'. Two transects measuring 10,000m in length were generated for each city and a planar buffer of 500m added to create an area 10,000m x 1,000m (Figure 1). These transects were then overlaid with two key data sets. First, land-use mapping data sourced for each city; and, second, existing urban planning policies and mechanisms.

Metrics relating to land-use and planning were then derived from the lands within these differing transect locations and a series of visualisations generated to succinctly explain the results. Where significant disparities between the land-use and planning data sets existed, aerial photographs, local knowledge and other photographic resources (for instance, Google Street View) were utilised to best understand the results.

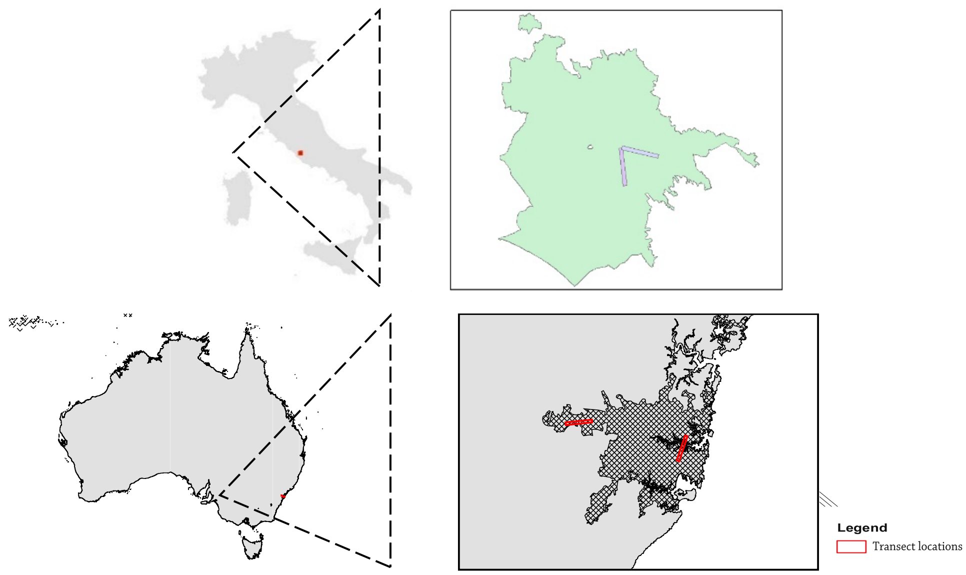

Figure 1. The study cities and the locations of their transects: Rome (top), Sydney (bottom)

Study Area 1: Rome

The metropolitan area of Rome is located in the central Italy, includes 121 municipalities and contains approximately 4.3 million people over 5,363 km^2. The capital city covers an area of 1,287 km^2 with a population of about 2.9 million people. Valuable natural and semi-natural features and archaeological elements are present in the urban area and are safeguarded by a varied system of protected areas from the more rural areas to the city centre. For the Rome case study, land-use data was obtained from the *Urban Atlas land-use layer* (European Environment Agency 2012) at an average scale of detail of 1:12,000. This provides pan-European comparable land-use and land cover information for many European urban functional areas. The source of this data is a SPOT 5 image (resolution 2.5 m). The categories of open space in the Urban Atlas include: *green urban areas, sports and leisure facilities, arable land (annual crops), pastures, complex and mixed cultivation patterns, permanent crops,* and *land without current use*. The planning information for Rome was from the recent *Land Use Masterplan* (Città di Roma 2018) and included the following categories for open space: *Protected areas, Private protected green space, Local services, Urban services, Historical residences, Urban Rehabilitation* and *New developments.*

Study Area 2: Sydney

Sydney is a city of 4.8 million people over 12,371 km^2 as acknowledged by The Australian Bureau of Statistics 'Greater Capital Cities Statistical Area' dataset that defines Sydney and its hinterlands via census and electoral boundaries (2018). However, the 'contiguous urban area' defined by Geoscience Australia (2007) is perhaps more useful as an area of 1,447 km^2 where Sydney's population continues to grow and is estimated to increase from 4.5 million in 2013 to 7.9 million by 2053 (Australian Bureau of Statistics 2015). For Sydney, land-use data was obtained from the State Government of NSW and Office of Environment and Heritage (2013) compiled at a resolution of 1:10,000 from SPOT 5 satellite imagery and Airborne Digital Sensor digital aerial imagery. The categories for the un-built land-use data comprised: *Residual native cover, Grazing native vegetation, Intensive horticulture, Intensive animal husbandry, Residential and farm infrastructure, Rural residential with agriculture, Farm buildings/infrastructure,* *Services, Public services, Recreation and culture, Landfill, Reservoir/dam, River* and *Estuary/coastal waters*. The planning information was sourced from the Department of Commerce (2018) and included the following categories for existing open space: *Business Park, Community Facilities, Correctional Centre, Educational Establishment, Environmental Conservation, Environmental Living, Local Centre, Natural Waterways, Private Recreation, Public Recreation, Special Activities, Unzoned Land,* and *Working Waterfront.*

Through analysing these cities in depth via these transects, we identified and compared the different types of existing open space types present. We then considered the existing planning rules, strategies and mechanisms within each city, comparing the potential to better recognise and activate these spaces for their greater inclusion into the metrics of a sustainable future city as critical pieces of overlooked green infrastructure and to theoretically deliver a range of beneficial ecosystem services.

Results

Rome: land-use and planning comparison

The two transects explored in Rome cover areas that vary from districts close to the city centre to the rural sectors of the city (Figures 2 and 3). They present a similar share of open space versus built up areas: in Transect 1 open spaces comprise almost 28%, while in Transect 2 they cover 18%.

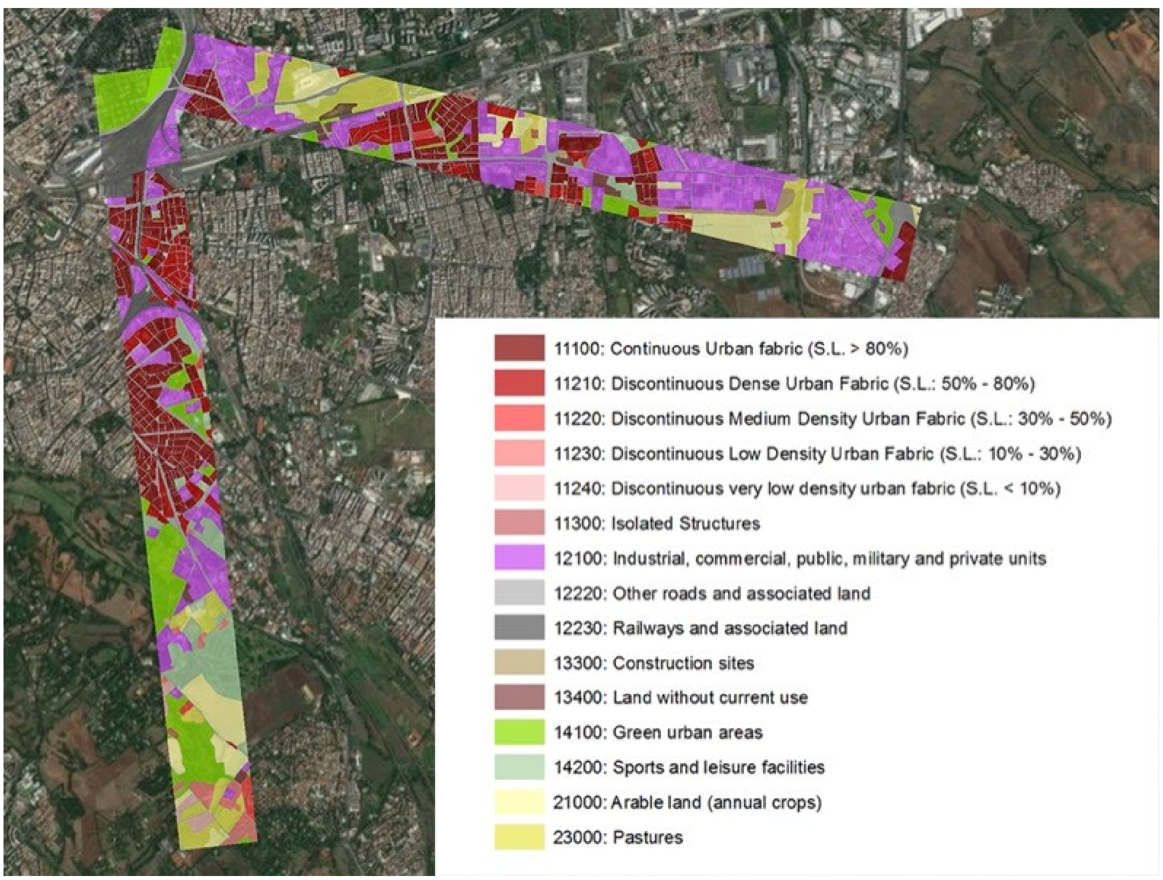

Figure 2. Land-use in the two Rome Transects

Figure 3 maps the current open space categories across Transect 1. In this, the most prevalent categories of open space found were *green urban areas* (8%) and *local and general services*, mainly comprised of those included in the peri-urban park, Parco dell'Appia Antica, where historical and archaeological sites are included in a matrix of farmlands and pastures.

Figure 3. Rome Transect 1 – Land-use map and share of land-use categories

Analysis of the planning for Transect 1 confirmed that most of the existing open space belonged to Protected Areas (77%), while the second most recurring planning category was *urban services* (16%), including small neighbouring parks or public/private sport facilities (Figure 4).

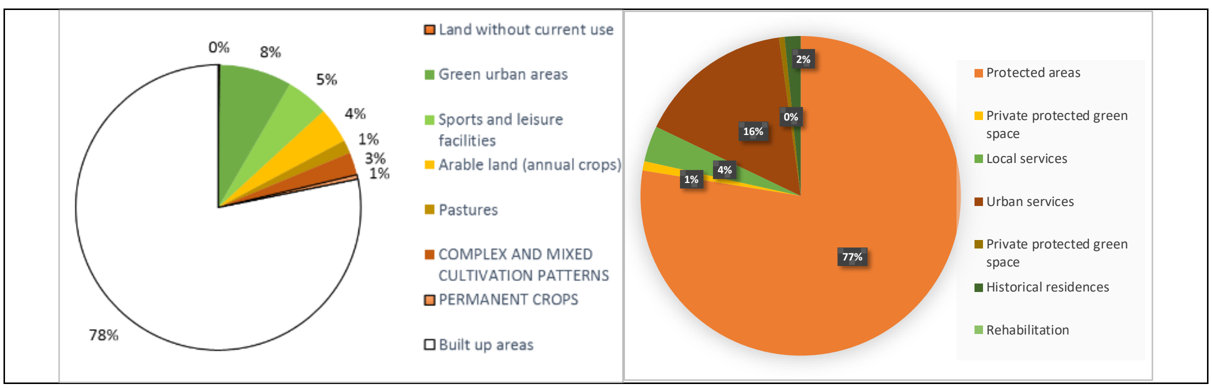

Figure 4. Rome Transect 1 – Share of Land-Use Categories (left) and Planning categories for open spaces (right)

In Transect 2, the main categories of open spaces were *pastures* (5%), *green urban areas* (4%) and *arable land* (4%) (Figure 5). The planning indications were quite different and the most frequent planning category here was *Open Spaces (unmanaged)* (46%), a very general category with imprecise indications that mainly correspond to general rural areas that are or were used for agricultural production. *Local* (31%) and more *general services* were also included in both Transects. Finally, across both transects the planning also foresees new urban expansion and development, as *new development*, that will replace some of the open spaces, thereby decreasing the possibility of their inclusion as potential GI candidates. Figure 6 documents the share of areas for the different planning categories.

Figure 5. Rome Transect 2 – Land Use map

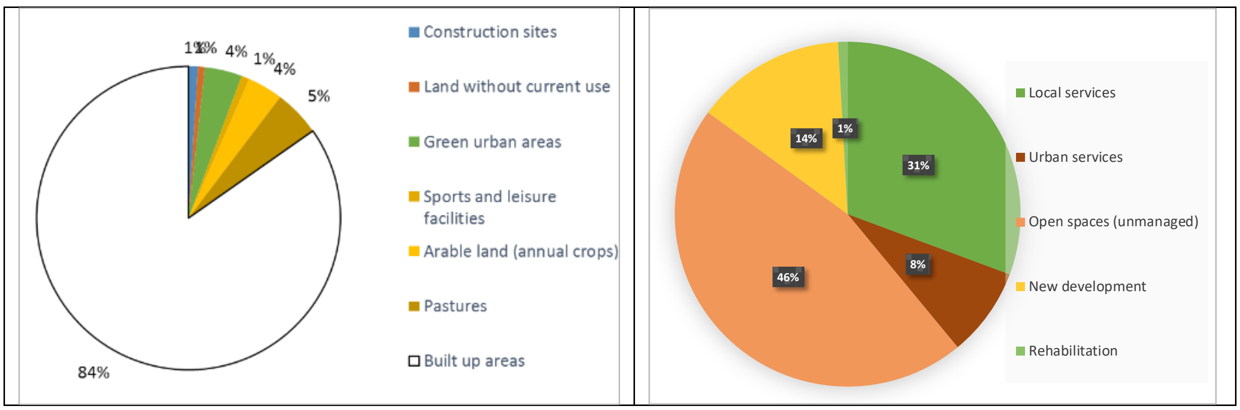

Figure 6. Rome Transect 2 – – Share of Land-Use Categories (left) and Planning categories for open spaces (right)

Sydney: land-use and planning comparison

Transect 1 was located in an inner-city location and straddled predominantly established neighbourhoods, portions of the harbour and some associated brownfield sites (Figure 7). Transect 2 was located on the cities western edge and is a suburban area with large areas of land in transition from agricultural uses to suburban and other uses.

In Transect One, four categories of open space cover 14.68% of the study area and include *Residual native cover* (1.99%), *Public Services* (5.87%), *Recreation and Culture* (6.80%) and less than 0.01% *Estuary/Coastal Waters* (Figure 8). This compares with 12.98% of the transect when the planning documentation was examined. In the denser Transect 1, green space was recognised by various official planning mechanisms and the *public services* category was further divided into multiple, more specific categories. There were also significant areas defined as *Private Recreation* (1.05%), while the land-use *Residual native cover* (1.99%) appears to translate to *Environmental Conservation* (2.09%). However, the largest notable difference was the area in the centre of the Transect 1 around White Bay. These former port lands were identified as *Public Services/Recreation and Culture* in land use data but disappeared entirely in planning information - despite these being potential open spaces embedded in current urban renewal and gentrification projects.

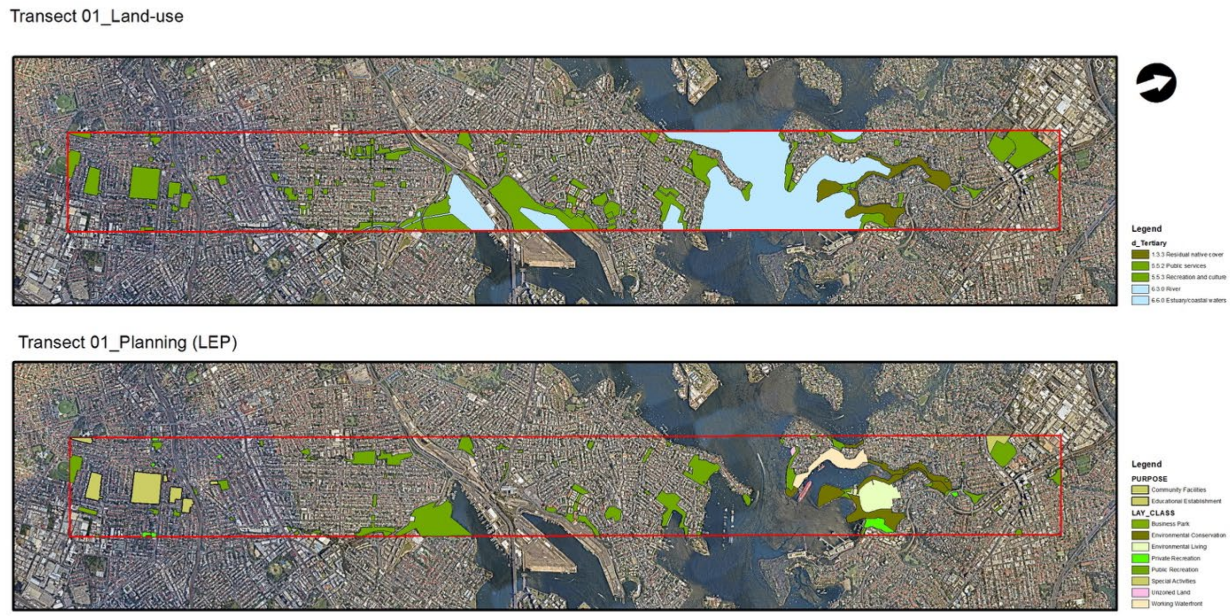

Figure 7. Sydney: Transect 1 comparison of land-use versus planning

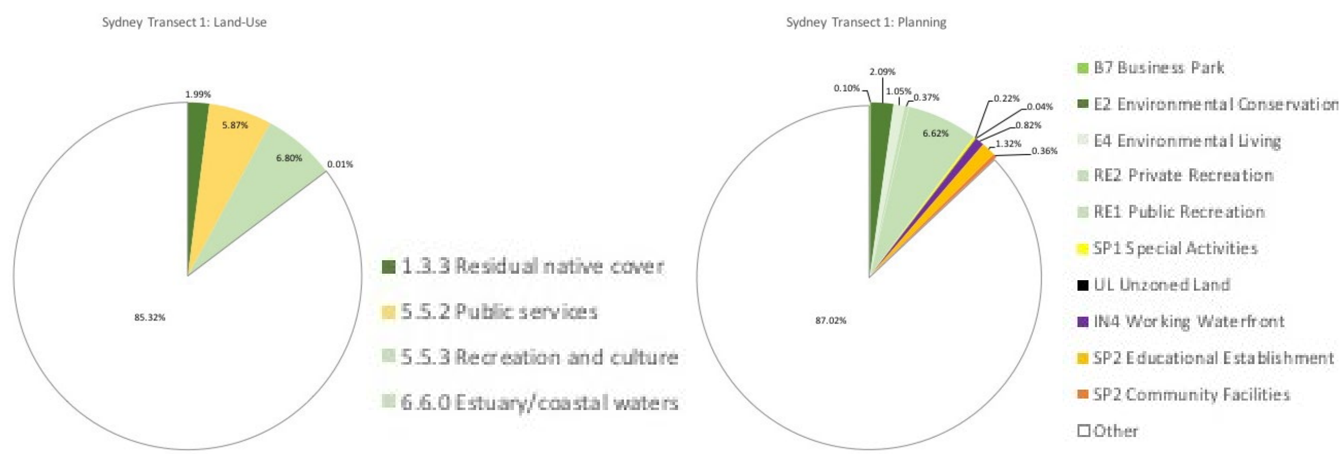

Figure 8. Comparison between Land use and Planning: Sydney Transect 1

In Transect Two (Figure 9), eleven types of open space cover 40.74% of the study area and include: *Public services* (22.25%), *Recreation and culture'* (15.96%), *Residual native cover* (1.99%), *Services 'Special Purpose'* (1.70%), *'Residential and farm infrastructure* (1.69%), *River* (0.56%), *Grazing native vegetation* (0.44%), *Farm buildings/infrastructure* (0.24%), *'Intensive horticulture'* (0.14%), *'Intensive animal husbandry* (0.11%), *Rural residential with agriculture* (0.02%)*, Reservoir/dam* (0.01%) and *Landfill* (<0.01%). This compares with 32.2% open space when the Planning documentation was examined (Figure 10), a significant difference attributed to the urbanisation of the area. Indeed, the planning documentation notes no agricultural-related land-uses whatsoever. While open space covers a significant portion of the transect, similar to Transect 1 the land-use public services were further divided into multiple, more specific categories, however we also note several other land-uses that stretch the

DOI: https://doi.org/10.7275/3dd8-dg29

definition of open space (and hence as potential GI candidates). Such unorthodox spaces including education precincts and other special purposes including *Correctional Centres* (1.88%, with expansive clear land surrounding them) as well as pastoral-type landscaped *Business Parks* (4.25%).

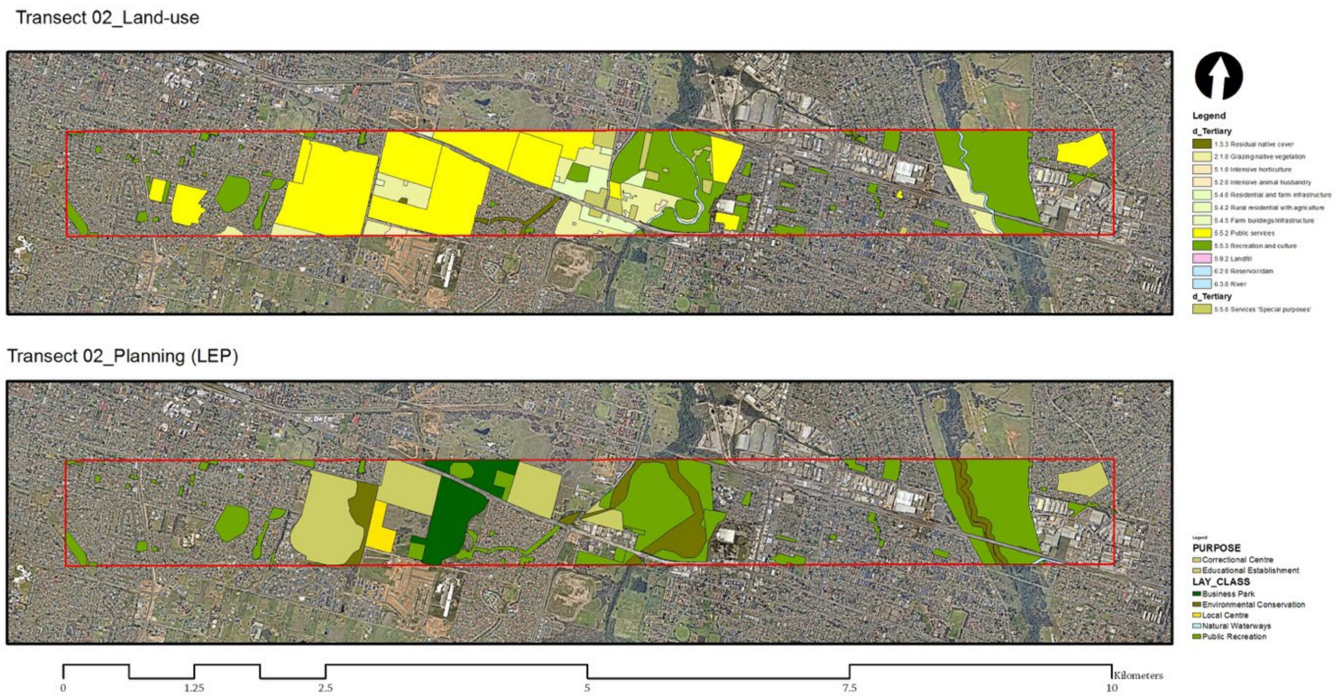

Figure 9. Sydney Transect 2 comparison of land use versus planning

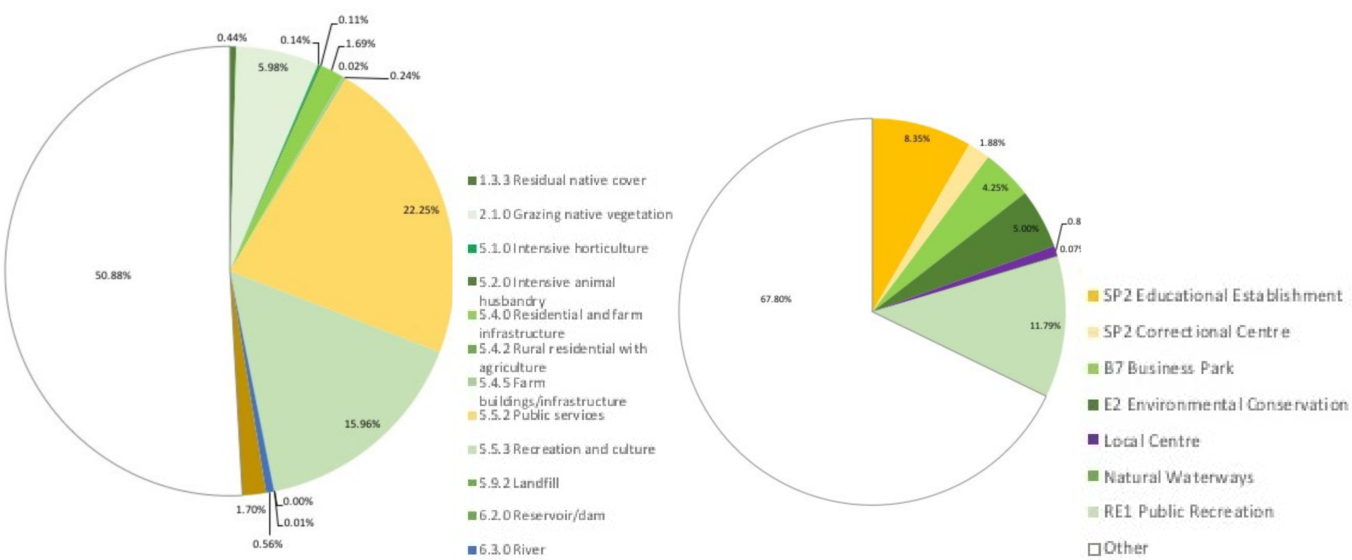

Figure 10. Comparison between Land-use and Planning: Sydney Transect 2

Discussion

The transects revealed a heterogeneity of land-uses or open space types within each and across both cities studied revealing several key differences between land-use data and policy and providing positive feedback on the mapping method and its aim to better identify GI candidates within existing urban areas.

While differences in language and types of planning documentation and governance differed across both countries, the cities shared many attributes. Some general points that were distilled from the comparison between the current amount and types of open spaces and their consideration by current planning instruments and policies across these two cities included:

- difficulties/inertia of incorporating and enabling potentialities of open spaces in a comprehensive and planned GI;
- challenges in the public acquisition of private areas to be included in a public GI due to the lack of financial resources;
- the need for multi-stakeholder participation/action (in some Rome instances, public multifunctional green spaces are managed by private bodies/NGO/local associations);
- the strategic, multi-level spatial governance required to implement GI as opposed to the varying planning objectives that are put forward by the many different municipalities that belong to one metropolitan area.

The two cities findings also showed several key differences. For both, and only for a limited number of instances did planning categories neatly match open space land-uses, thus questioning if planning instruments accurately confirmed the current situation. For instance, in Rome, although the number of categories for land-use open space were similar to those identified in planning, their characteristics were actually quite different. For example, open spaces under the land-use category of *green urban areas* was indicated by the planning categories: *Protected areas, Private protected green space, Local services, Urban services, Private protected green space,* and *Historical residences.* For Sydney, also differed and the planning categories were far more nuanced than the land-use data, mainly due to the change from rural to urban and the removal of all agricultural-type land-uses (for example in Transect 2) where these were replaced by urban areas as well as several other open space types. Similar to Rome, these included *Private Recreation* and *Public Recreation,* but also significant areas nominated for *Business Parks*. Also of note in Sydney's Transect 2 was the planning zoning of *Local Centre* (0.07%). Here a land-use change pre-empted by planning actions and presently unbuilt questions the definition of GI in a temporal sense: can such land planning uses be included as GI? Similarly, would we include *Landfill* areas as identified in the land-use data (0.01%) as potential GI candidates and part of its typology?

A range of discrepancies of the visualization of information between the two data sets were also apparent. The land-use dataset revealed higher resolution data of an urban landscape criss-crossed with roads, rail and other infrastructure that parcellated the entire study area. This was in contrast to the planning map which held simple polygons as broader, less detailed data congruent with contemporary planning methods. As such, differences between land-use and planning data could also stem from questions of data accuracy. For instance, in Sydney the land-use data was from 2013, whereas the planning information was from 2018; while for Rome the land-use data was from 2012 and the urban plan was from 2015. Subsequent development of some of the areas (for example in Transect 2 in both Rome and Sydney) could have produced differences between land use asset and planning indications. In attempt to address this issue, we

DOI: https://doi.org/10.7275/3dd8-dg29

revised the available land-use mapping with the most up-to-date aerial photograph and Google Map imagery and street views. Through considering these high-resolution photographs combined with some general knowledge or other information of the areas in question we could then understand a variety of situations on a case-by-case basis and verify the current land use. Indeed, in some cases, categories of land uses were changed according the visual interpretation of Google imagery.

The research was however overall successful in identifying a spectrum of lands for potential inclusion as new spatial components of an enhanced GI to theoretically deliver a range of beneficial ecosystem services. Some examples of existing open spaces that are currently not included in planning policies or management but could be relevant pieces of an enhanced urban GI include:

- peri-urban parks (large highly natural/semi-natural areas with relevant vegetation cover within a metropolitan context);
- new forms of urban agriculture (network of urban farms, allotments and Community Supported Agriculture);
- educational campuses and business parks (large areas with expansive open space including tree cover, remnant vegetation and grass);
- terrain vague (abandoned, natural or semi-natural lands within, around and between developed patches, mainly aimed at spontaneous re-forestation through undisturbed succession);
- informal recreation areas (green spaces available for public access and enjoyment, but with only low-key provision of facilities);
- cemeteries and other culturally significant areas often containing significant biodiversity and potential for respite;
- private recreation (e.g. Golf Courses: although private these types of lands often harbor significant biodiversity and can combat urban heat island impacts).

These observations support a view of GI as multifunctional and inclusive of the ‘abiotic, biotic and cultural’ (Ahern 2007). As complex social-ecological systems, cities should direct their efforts to have a more detailed and nuanced understanding of the complexity of urban systems to maximise the potential exchange between natural and human components. This therefore requires a better understanding of the multifaceted potentialities of open space in all its forms in order to provide to the municipalities – or other public bodies in charge of planning – a range of new possibilities and differentiated planning policies aimed at increasing the provision of GI and essential ecosystem services.

Conclusion

This research enabled the identification, classification, quantification and illustration of various metrics related to urban open space as potential GI through a comparison between land-use and existing planning datasets for Rome and for Sydney. This relied on a three-part process. First, mapping the typological diversity and distribution of existing open space and the identification of alternative GI candidates within randomly generated transects. Second, deriving areas, summarising type and investigating the disparity between land-use and planning. Lastly, the comparison and tabulation of findings against existing city data and visualising. This research posits that in the absence of the holistic and multi-faceted understandings, metrification and visualisation of the complex pattern of open spaces then progress towards implementation of robust GI and urban ecosystem services will be limited. We have demonstrated that whether formally recognised or not, the simple comparison of land-use versus planning data can help to uncover the GI that may already exist within a city and potentially unlock its benefits. This method is one that we imagine could be applied elsewhere in the world, regardless of location.

References

Ahern, J 2007, 'Green infrastructure for cities: the spatial dimension', in *Cities of the future towards integrated sustainable water and landscape management*, ed. Vladimir Novotny and Paul Brown, IWA Publishing, London, UK.

Ahern, J 2012, 'Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design', *Landscape Ecology*, pp. 1–10.

Australian Bureau of Statistics, *Population projections, Australia, 2012 (base) to 2101*, Australian Bureau of Statistics. Available from: <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/3222.0main+features52012%20(base)%20to%202101>. [8 January 2015].

Benedict, MA & McMahon, E 2006, *Green infrastructure: linking landscapes and communities*, Island Press, Washington, DC.

Brand, FS & Jax, K 2007, 'Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object', *Ecology and Society*, vol. 12, no. 1, p. 23.

Childers, LD, Cadenasso, LM, Grove, MJ, Marshall, V, McGrath, B & Pickett, TS 2015, 'An Ecology for Cities: A Transformational Nexus of Design and Ecology to Advance Climate Change Resilience and Urban Sustainability', *Sustainability*, vol. 7, no. 4.

Città di Roma, *Piano Regolatore Genearale – Sistemi e regole*. Available from: <http://www.urbanistica.comune.roma.it/prg-2008-vigente-disegno-definitivo.html>.

Department of Commerce NSW 2018, Local Environment Plan Data Package 08062018.

European Environment Agency, *Urban Atlas*, Copernicus Land Monitoring Service. Available from: <https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012>.

Folke, C, Carpenter, S, Elmqvist, T, Gunderson, L, Holling, C & Walker, B 2002, 'Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations', *Ambio*, vol. 31, no. 5.

Follmann, A, Hartmann, G & Dannenberg, P 2018, 'Multi-temporal transect analysis of peri-urban developments in Faridabad, India', *Journal of Maps*, vol. 14, no. 1, pp. 17-25.

Forman, RTT & Godron, M 1986, *Landscape ecology*, Wiley, New York.

Garcia, EJ & Vale, B 2017, Unravelling Sustainability and Resilience in the Built Environment, Routledge.

Geographic Business Solutions 2018, *Random transect generator*.

Geoscience Australia 2007, *Geodata Topo 250K Series 3, 1:250,000 scale vector map data (DVD)*, Commonwealth of Australia, Canberra.

Gunderson, LH & Holling, CS 2002, Panarchy : understanding transformations in humans and natural systems, Island Press, Washington.

Hansen, R & Pauleit, S 2014, 'From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas', *AMBIO*, vol. 43, no. 4, pp. 516-529.

Holling, CS 1973, Resilience and stability of ecological systems, IIASA, Laxenburg.

Johnson, J 2012, 'Cities: Systems of Systems of Systems', in *Complexity Theories of Cities Have Come of Age*, ed. MH Portugali J., Stolk E., Tan E., Springer, Berlin, Heidelberg.

Kilbane, S 2013, 'Green infrastructure: planning a national green network for Australia', *Journal of Landscape Architecture*, vol. 8, no. 1, pp. 64–73.

La Rosa, SD & Privitera, R 2013, 'Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts', *Landscape and Urban Planning*, vol. 109, pp. 94-106.

Lister, N-ME 2015, 'Resilience: Designing the New Sustainability', *Topos*, vol. 90, pp. 14–21.

McPhearson, T, Andersson, E, Elmqvist, T & Frantzeskaki, N 2015, 'Resilience of and through urban ecosystem services', *Ecosystem Services*, vol. 12, pp. 152-156.

Meerow, S & Newell, JP 2017, 'Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit', *Landscape and Urban Planning*, vol. 159, pp. 62-75.

Mell, IC 2009, 'Can green infrastructure promote urban sustainability?', *Proceedings of the Institution of Civil Engineers-Engineering Sustainability*, vol. 162, no. 1, pp. 23–34.

Morales, I 1995, 'Terrain Vague', in *Anyplace*, eds CC Davidson & C Anyone, Anyone Corp; MIT Press, New York, NY; Cambridge, Mass.

Phelps, NA & Silva, C 2018, 'Mind the gaps! A research agenda for urban interstices', *Urban Studies*, vol. 55, no. 6, pp. 1203-1222.

Pickett, STA, Cadenasso, LM & Grove, JM 2004, 'Resilinet cities: meaning, models and metaphor for integrating the ecologicalm, socio-economic, and planning realms', *Landscape and Urban Planning*, vol. 69, pp. 369-384.

Pickett, STA, Cadenasso, ML, Grove, JM, Nilon, CH, Pouyat, RV, Zipperer, WC & Costanza, R 2001, 'Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of Metropolitan Areas', *Annual Review of Ecology and Systematics*, vol. 32, no. 1, p. 127.

State Government of NSW and Office of Environment and Heritage (OEH) 2013, *NSW Landuse 2013*.

Statistics, ABo, *Data by Region: Greater Captial City Statistical Areas*. Available from: <http://stat.abs.gov.au/itt/r.jsp?databyregion>. [10 June 2018].

Tzoulas, K, Korpela, K, Venn, S, Yli-Pelkonen, V, Kazmierczak, A, Niemela, J & James, P 2007, 'Promoting ecosystem and human health in urban areas using green infrastructure: a literature review', *Landscape and Urban Planning*, vol. 81, no. 3, pp. 167–178.

United Nations, *World Urbanisation Prospects*. Available from: <https://esa.un.org/unpd/wup/General/FAQs.aspx>. [8th June 2018].

Walker, B, Gunderson, L, Kinzig, A, Folke, C, Carpenter, S & Schultz, L 2006, 'A handful of heuristics and some propositions for understanding resilience in social-ecological systems', *Ecology and Society*, vol. 11, no. 1, p. 13.

Walker, B & Salt, D 2006, Resilience thinking: sustaining ecosystems and people in a changing world, Island Press, Washington, DC.

Waltner-Toews, D, Kay, JJ & Lister, N-ME 2008, The Ecosystem Approach Complexity, Uncertainty, and Managing for Sustainability, Columbia University Press.

Yu, XJ & Ng, CN 2007, 'Spatial and temporal dynamics of urban sprawl along two urban–rural transects: A case study of Guangzhou, China', *Landscape and Urban Planning*, vol. 79, no. 1, pp. 96-109.