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Informing future Australian settlement planning through a national-scale suitability analysis

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ABSTRACT

Australia's population is projected to triple by 2101, yet the nation lacks coordinated planning based on systematic regional analysis. This paper documents a novel national-scale suitability analysis of Australia which identifies the most appropriate regions for future urban development. The central research question is 'Where should Australian federal and state governments encourage urban development to maximise climatic liveability, protect natural and cultural heritage, capitalise on previous infrastructure investments, and maximise economic productivity?' The results indicate that the south-east and south-west of the country, and Tasmania, are preferred. The federal government is yet to prepare a national settlement strategy and contemplates large scale urban development in areas to which it is not suited. Regional planning decisions not based on comprehensive, evidence-based analysis are likely to incur significant social, economic and environmental costs.

KEYWORDS

Australian cities; urban development; population growth; suitability analysis; multi-criteria evaluation

Introduction

By 2050 demographers predict the world's urban population will have nearly doubled, making urbanization one of the twenty-first century's most transformative trends (United Nations General Assembly 2016). Today, urban areas around the world are expanding on average twice as fast than their national populations. If current trends in population density continue then by 2030 the urban land cover will increase by 1.2 million square kilometres, nearly tripling the global urban land area circa 2000 (Seto, Guneralp, and Hutyra 2012).

Australia is a microcosm of this global situation. The high 'Series A' population projections of the Australian Bureau of Statistics (ABS) assess the national population increasing from the present 24.7 million to 49.2 million in 2066 and 70.1 million by 2101 (Australian Bureau of Statistics 2017). The ABS uses the 'cohort-component method' for developing population projections. In this method, assumptions about future fertility, mortality, overseas and internal migration levels are applied to a base population to produce a projected figure (Australian Bureau of Statistics 2017). The assumptions applied do not allow for non-demographic factors (such as climate change or wars) which means Australia's population may reach the higher figure well before 2101 (Australian Bureau of Statistics 2017).

Australia will need appropriate planning to deal with substantial population growth in this century. Nonetheless, an analysis of the various current plans for Australia's state and territory capital cities where two-thirds of the population already lives, reveals that their planning strategies do not adequately deal with long term population growth. As such, a collective shortfall of almost 9 million people exists between current overarching city planning[1] and the ABS Series A projections for the capital cities in 2066 (Australian Bureau of Statistics 2017). Moreover, only Western Australia, New South Wales and the Australian Capital Territory additionally have state- or territory-wide planning policies (Infrastructure New South Wales 2018; Western Australian Planning Commission 2012).

Planning for population growth in Australia is typically focussed on either metropolitan infill development or greenfield development. The latter, often pejoratively known as sprawl, is regarded as a necessary evil accommodating popular preferences. Planning policies to achieve urban infill development are intended to safeguard both rural and biodiverse land in peri-urban zones and minimize infrastructure costs, commuting times, and the concentration of economic and social vulnerabilities on Australian cities' fringes (Bolleter 2015; Kelly and Donegan 2015). Across the nation, State Government planning policies for the state capital cities, on average, stipulate that 60% of all new residential development should be infill development (and 40% greenfield development), yet these cities typically do not meet their infill targets (Bolleter and Weller 2013; Newton 2010; Randolph 2007). What has often been missing in these largely binary policy debates is the discussion of a third way: population decentralization to regional centres. This situation is, in part, due to neoliberalism, which has been the prevailing political orthodoxy from the 1980s. In this canon government-sponsored population decentralization is regarded as ineffective against centralizing economic forces and a 'waste of expenditure' (Painter 1979, 344)

Globally we witness a strong recent push for integrating the United Nations 2030 Agenda and the Sustainable Development Goals (SDGs) into policy frameworks as a catalyst for a revival in national urban development planning. In Australia, Federal Government interest in urban system planning has been on the wane since the 1970s (Oakley 2004). In the early 2000s when national interest in urban policies resurfaced, the focus was firmly on community prosperity and liveability largely divorced from any national population and settlement framework (Australian Government 2011) and paradoxically at a time when a national debate on Australia's future 'bigness' emerged (Australian Government 2010). However, given the continuing growth pressures, Australia is expected to face after the COVID-19 interregnum, there is increasing recognition of the benefits from a national plan for cities and regions which identifies areas with the highest capacity for urban development and possibly population decentralization. Subsequent federal, state and local government investments in enabling infrastructure, land development and employment generation could incentivise population to migrate and relocate to these areas.

The Planning Institute of Australia is promoting the need for such a National Settlement Strategy (Planning Institute of Australia 2018), which could delineate future urban growth areas and establish spatial limits for existing cities. The scale of planning envisaged would be dependent on a renewed federal government involvement in urban planning, reminiscent of the Department of Urban and Regional Development era from 1972–1975 (Oakley 2004). The problem with perpetuating a spatially fragmented, state by state approach is that state, territory and local governments are trying to plan for a future where they 'all have different views about our common future' resulting in a 'collective coverage of plans looking like a patchwork quilt' (Planning Institute of Australia 2018, 6).

In this century of irreversible climate change, and substantial population growth through migration, a federally coordinated plan would be able to direct population growth away from certain regions which may struggle to accommodate population influxes. As Laquian (2005, 416) explains, 'a national urban strategy can effectively reduce city-region populations' growth rate. It can make other urban nodes more attractive to investors by providing infrastructure, energy, housing, and other inputs.' One reason for redirecting population away from particular regions could be the effects of climate change. Indeed, climate change will likely threaten the liveability (and perhaps viability) of northern Australia, rendering it unsuitable for mass urbanization (Bolleter 2019). Another reason could be substantial infrastructure or housing deficits that would hamper accommodation of substantial population growth. Moreover, a National Settlement Strategy could serve as the basis for 'more logical, coordinated investment decisions at the national level' (Beatley 2015, 408). One example of this could be coordination of high-speed rail lines connecting state or territory capitals (Beatley 2015).

An enforceable National Settlement Strategy in Australia may prove problematic for political reasons (e.g. notably because of state governments' power vis a vis the Commonwealth under the Australian constitutional federation). Nevertheless, policymakers and planners should ensure coordinated high-level strategies (at federal, state and regional scales) are in place based on a comprehensive suitability analysis of prevailing climatic, environmental, economic and infrastructural factors. Such analyses are currently missing – and in critical places such as the latest White Paper for developing northern Australia (Australian Government 2015). This lacuna is critical because urbanization without appropriate research-driven analysis can lead to urban development outcomes that incur ongoing environmental, societal or economic costs. Poorly conceived planning can itself fail to manifest in positive urban outcomes yet still incur significant economic costs.

Against this backdrop, this paper sets out to understand which areas are most appropriate for population growth and related urban development through a high-level suitability analysis. The paper is structured in the following way. Firstly, we present our conceptual framework for the study. Secondly, we provide background on the development of suitability analysis methods and review how they have been applied in the Australian context. Thirdly, in the methods section, we set out the climatic, natural and cultural heritage, infrastructural and economic factors incorporated into the suitability analysis exercise. Fourthly, in the results section, we display suitability maps for four sub-models, and a combined, overall suitability map. Fifthly, in the discussion section, we discuss what correlation exists between federal government urban and regional planning policies with our suitability analysis. Finally, we conclude with some reflections for further research and the implications of the paper's findings.

Conceptual framework

Figure 1 displays the conceptual framework for the paper. Population growth in Australia derives from both immigration and natural population increase. State and federal government lead urban

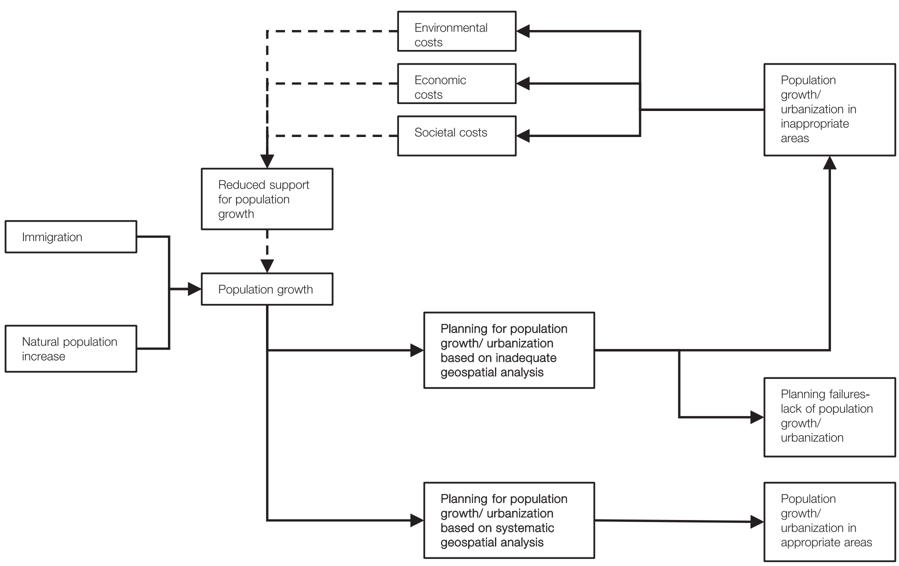

Figure 1. Conceptual framework.

planning for accommodating population growth on a spectrum defined by relative degrees of systematic analysis. Some planning occurs in the absence of comprehensive and systematic spatial analysis because many 'webs of relations are drawn into the planning process' and 'encompass the networks of landowners, developers, financiers, end-users, various third parties, different sectors of central and local government, local politics, national politics, pressure groups of all kinds' (Graham and Healey 1999, 633). In this complex web, in which planners often have limited agency, the decision-making process can be described as 'disjointed incrementalism' or 'muddling through' (Hall 2014, 397). This situation *can* lead to urban development outcomes that incur ongoing environmental, societal or economic costs due to inadequate spatial analysis. The result of poor spatial planning for population increase can be diminished liveability and support for population growth (and in particular immigration) because growth is not being 'well-managed' (Murray 2017). Given this situation, the approach is focussed on systematically assessing the Australian environment to understand where expanded and future settlement patterns should be located, given the information that is currently available.

Background

The development of suitability analysis

The origins of suitability analysis lie in hand-drafted composite overlays to delineate capacity for various land uses pioneered by early landscape architects (Collins, Steiner, and Rushman 2001). A seminal application of this technique came in a New York Housing and Regional Planning Commission report in 1926 suffused with the progressivism of Regional Planning Association of America members like Clarence Stein and Henry Wright (Sussman 1976). Fellow traveller Lewis Mumford helped articulate a philosophical basis in ecological regionalism that channelled the holistic assessment philosophy of Patrick Geddes and anticipated the sieving methodology of Ian McHarg. McHarg developed his ecological planning method as a manual overlay process superimposing factors that either constrain or make opportune urban development. As McHarg implored 'Let us ask the land where are the best sites' (McHarg 1992, 197).

McHarg's approach led the regional planning of 'The Valleys' urban development on the edge of Baltimore in the USA, and the project exemplifies his method. The plan for the Valleys employed 'physiographic determinism' to reveal the optimum pattern of development (McHarg 1992). He identified that the ranked suitability of landscapes for urban development, in decreasing order, was: flat land, forest and woodlands, steep slopes, aquifers, aquifer recharge areas, floodplains, marshes, and surface water (McHarg 1992). McHarg's method remains capable of determining where urban development, on a large scale, should not occur given landscape conditions; however, it is not so useful in terms of telling planners where development should occur (Weller 2009). Current Multi-Factors Evaluation approaches that integrate with Geographic Information Systems respond to this weakness. Multi-Factors Evaluation is a process that combines and transforms evaluation data (input) into a resultant decision (output) (Zhang et al. 2013).

Over the last forty years or so, suitability analyses have increasingly become integral components of urban, regional and environmental planning activities (Zhang et al. 2013) and suitability analysis is one of the 'most useful' applications of Geographic Information Systems for urban and regional planning (Pettit et al. 2015, 94). There is also a plethora of academic literature concerning suitability analyses relating to different geographic contexts including China (Liu et al. 2014; Wang et al. 2017; Zhang et al. 2013), India (Kumar and Shaikh 2013), Iran (Lotfi, Habibi, and Koohsari 2009), and Spain (Criado et al. 2017).

Australian analyses

Spatial mapping of growth potential in Australia has similarly deep roots. The diagrams of geographer Griffith Taylor in the 1920s that depicted much of the continent as 'almost useless' with a population carrying capacity as limited as 20 million proved highly controversial in a decade when the dominant political mood was boosterism (Strange and Bashford 2008). Harnessing sophisticated multivariate techniques, a later generation of researchers has conducted several metropolitan and district scale suitability analyses (Chen 2016; Pettit et al. 2015). Rudimentary national scale analysis has been conducted however this omitted the systematic weighting of different suitability factors (Bolleter and Weller 2013). To our knowledge, the first rigorous national scale analysis was carried out by a Commonwealth Scientific and Industrial Research Organisation (CSIRO) research team in the early 1980s (Arman et al. 1981) and reported more widely by team member Doug Cocks a decade later (1992). This was an early application of GIS at a national scale exploring the potentialities of the new Australian Resources Information System, a computerized spatial system capable of mapping bio-physical and socio-economic data on a range of digital data bases (Walker and Cocks 1984).

The CSIRO demonstration combined three sets of exclusion (e.g. water scarcity), preference (e.g. economic hotspots and coastal areas) and avoidance criteria (e.g. environmental fragility, natural hazards, population concentration and high infrastructure costs) into an overall designation of 'promising areas' (Figure 2). In contrast to McHarg, this exercise gave special weight to mapping of policy-related factors. The result was to predominantly identify prospective locations in 'the coastal rim of the Ecumene' (Cocks 1992). The most favoured were on the central Queensland coast south of Mackay, Geraldton in Western Australia, and localities close to Melbourne and Sydney.

While the CSIRO overlay mapping analysis – undertaken four decades ago – was innovative at a national scale, it cannot be considered a full suitability analysis because there was no weighting of the factors or formal sub-models that constitute the analysis; calculations which are made possible through contemporary digital processing. These methodological issues aside, the analysis also needs updating to include additional significant considerations (such as heat stress and native title).

In response to these needs, we set out to conduct a contemporary national-scale suitability analysis – based on climatic, natural and cultural heritage, infrastructural and economic factors – to locate potential regions where policymakers should guide future urban development. This analysis

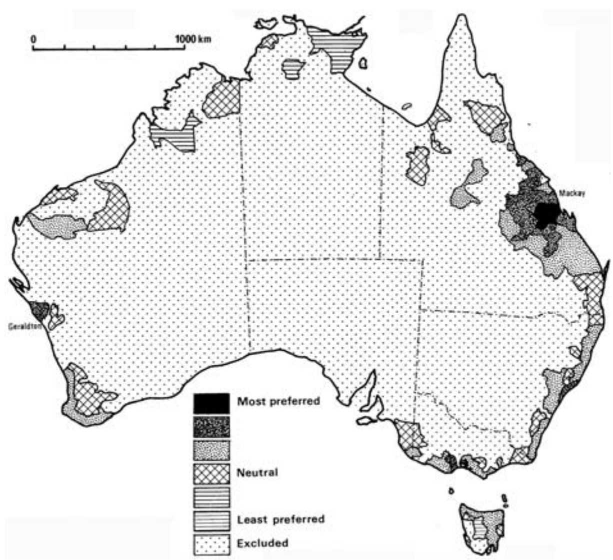

Figure 2. Commonwealth Scientific and Industrial Research Organisation determination of attractiveness for major future urbanization, 1981. Map from Cocks (1992). Use with care. Sydney: New South Wales University Press. Reproduced with permission from New South Wales University Press.

is important because existing and future populations will live with the regional planning decisions we make now as twenty-first-century population, biodiversity and climate challenges unfold (Gleeson 2015).

To engage with this complex set of issues, the research question that structured our enquiry was:

Where should Australian federal and state governments encourage urban development to maximise climatic liveability, protect natural and cultural heritage, capitalise on previous infrastructure investments, and maximise economic productivity?

Methods

To provide an answer to our research question, we conducted a suitability analysis of the Australian continent and Tasmania using the ArcMap 10.5 'overlay analysis' tool (Esri 2020b). Users typically apply this tool in optimal site selection as a technique for applying a standard scale of values to diverse and dissimilar inputs to create an 'integrated analysis' (Esri 2020b). Given the complexity of this suitability analysis, for clarity we broke it down into four sub-models: (1) climate, (2) natural and cultural heritage, (3) infrastructure and (4) economics. Subsequently, we employed M-Macbeth software to weight both the sub-models and the factors (Bana e Costa, De Corte, and Vansnick 2020). We then utilized ArcMap 10.5 to reclassify the factor maps into a standard preference scale one to eight, with a score of one denoting very low suitability, four medium suitability and eight very high suitability. The preference values were on a relative scale, meaning a preference of eight is twice as preferred as a preference of four (Esri 2020a). Finally, we applied the weighted multipliers algorithm to all grid cells to create suitability analysis maps for each sub-model, and an overall suitability analysis map incorporating each sub-model. We provide further technical details below in describing the stages in the analysis.

The methodological innovation that our analysis embodies is application at a continental scale. Most suitability analyses have been conducted at the scale of municipalities (Musselman 2003), cities (Zhang et al. 2013) or regions (Myagmartseren, Buyandelger, and Brandt 2017). The absence of modern national scale suitability analysis, in Australia and elsewhere, is noteworthy when the need for urban and regional planning at this overarching scale is consistently identified (Beatley 2015; Laquian 2005; Planning Institute of Australia 2018).

Sub-models and factors

Below we describe and explain the factors applied in each of the four sub-models. For each sub-model, we identify a set of factors that present either constraints or opportunities for urban development. All factors for the evaluation of land-use suitability fall within these two categories. However, most physical and socioeconomic factors have both constraining and permissive features for a given land-use, for example 'slope,' with a high gradient is location restrictive, and a low gradient location permissive, for urbanization (Liu et al. 2014).

Climate

Suitability analyses typically refer to climatic factors such as temperature, humidity, rainfall (Wang et al. 2017) and in some cases, prevailing winds (Lotfi, Habibi, and Koohsari 2009). Under the climate sub-model, we identify three factors that constrain future urban development in Australia (Figure 3). The first of the constraining factors is ***heat stress*** which derives from heat and humidity (Davidson 2007). We have included this because high environmental temperatures can be dangerous to humans. Extreme dry-bulb temperature increases the risk of heat illness and can exacerbate pre-existing illnesses such as heart and kidney conditions (Bi et al. 2011). In the range of 32° to 40°C humans can experience heat cramps and exhaustion while between 40° and 54°C, heat exhaustion is more likely (Luo 2017). However, the effects of

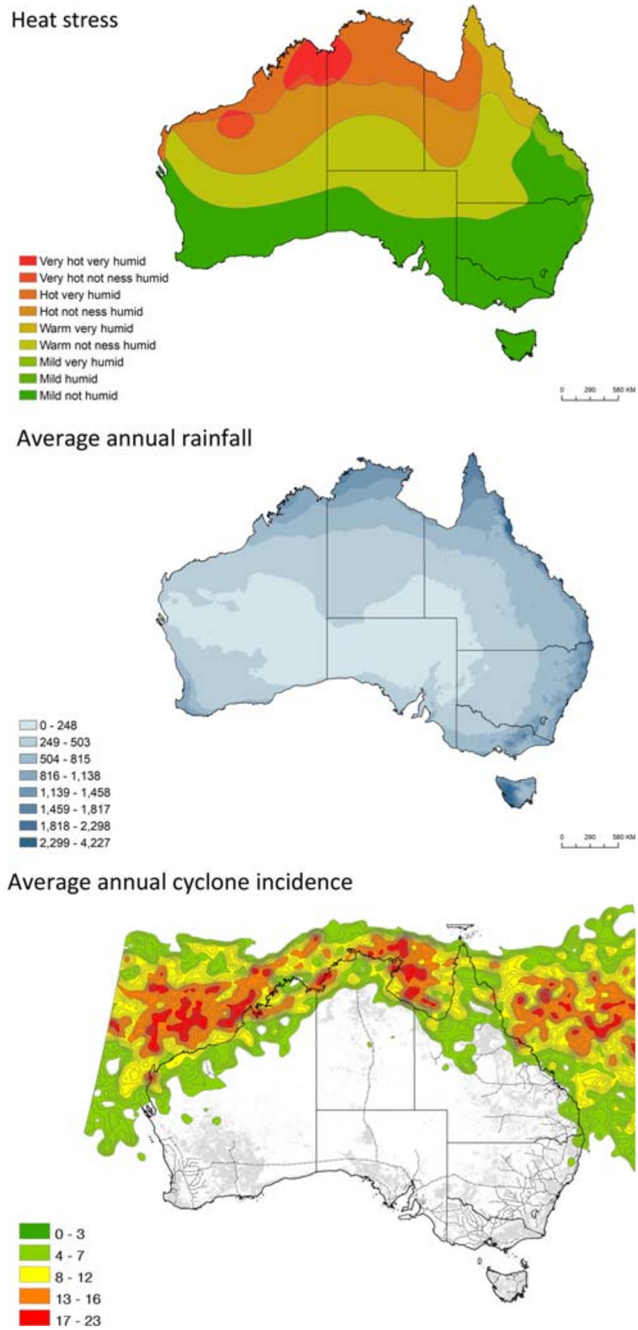

Figure 3. Geospatial layers included in the climatic sub-model. Maps by the authors.

the most lethal heatwaves are due to elevated temperatures and the effects of humidity. Extremely high heat combined with high humidity diminishes the human body's ability to regulate its temperature by sweating. Hence, hot and humid conditions can be more dangerous than equivalently hot but dry conditions (Steadman 1979). For this reason, we have employed the heat stress data set and not the dry-bulb temperature in isolation.

The second of the constraining factors is ***annual rainfall*** (Bureau of Meteorology 2020). Australia's driest capital city Adelaide currently receives a mean annual rainfall of just over 500 mm (Bureau of Meteorology 2019) and areas for future urban development could struggle if they receive less than this figure. Many thriving cities worldwide experience less rainfall than this – Dubai is one such example – but in Australia, cities have coalesced in areas that receive reasonable rainfall, and we expect this trend will continue in the future. Moreover, while desalination technology is available, it is less feasible away from the coast, reasonably expensive and has environmental implications in energy usage and hypersaline receiving waters (Waugh 2011).

Finally, we have included areas that currently experience ***cyclone risk*** (Bureau of Meteorology 2020). Most climate change models for northern Australia project that there will be a possible decrease in the total number of cyclones but an increase in the proportion of tropical cyclones in the more intense categories (Hugo 2012). Indeed, the number of category 3–5 cyclones are forecast to increase, and by 2070 there could be an accompanying 140% increase in the intensity of the most severe storms (DCCEE in Hugo 2012). Our mapping assumes more intense cyclones will occur in current high incidence locations. These severe cyclones should constrain large-scale urban development in the affected regions.

Natural and cultural heritage

Although many natural factors influence human settlements, the most fundamental are terrain, climate, hydrological conditions, and land cover, which 'play leading roles' in natural suitability evaluation (Wang et al. 2017, 2). Indeed, suitability analyses typically incorporate topographic factors such as elevation and slope (Criado et al. 2017; Kumar and Shaikh 2013; Lotfi, Habibi, and Koohsari 2009; Myagmartseren, Buyandelger, and Brandt 2017; Park et al. 2011). Hydrological factors generally include surface water, e.g. rivers, lakes and reservoirs, adjacent flood-prone land, groundwater recharge and water catchment areas (Criado et al. 2017; Liu et al. 2014; Lotfi, Habibi, and Koohsari 2009; McHarg 1992; Myagmartseren, Buyandelger, and Brandt 2017). Natural factors also include areas of ecological value, vegetation cover, soil type, geotechnical risk areas, and agricultural and cultural heritage value (Criado et al. 2017; Liu et al. 2014; Myagmartseren, Buyandelger, and Brandt 2017). Sea Level Rise is also a factor for many coastal regions, but as only a relatively narrow coastal zone will be affected in the next 100 years, we have not included it, for our scale of analysis. From this range of possibilities, for our natural and cultural heritage sub-model, we have selected four representative natural and cultural heritage factors that constrain urban development: ***significant native vegetation, hydrological features, slope, conservation reserves*** (Geoscience Australia 2018) and ***native title determinations***[2] (National Native Title Tribunal 2019) (Figure 4).

Detailed geospatial mapping of Australia's devastating recent bushfires was not yet available. Nonetheless, significant native vegetation layer is a satisfactorily proxy for such bushfire prone areas. The hydrological features include lakes, foreshore flats, flats and watercourse areas. For mapping both these factors, we have utilized Geoscience Australia 1:250,000 datasets (2018). We have identified areas with a significant slope as constrained, particularly when they have a gradient of six per cent or over. We have calculated the slope using a Geoscience Australia Digital Elevation Model (2018).

Infrastructure

Suitability analyses typically incorporate infrastructure-related factors such as distance to rail lines, major road networks, existing urban centres, water and energy networks and educational and medical facilities (Criado et al. 2017; Kumar and Shaikh 2013; Lotfi, Habibi, and Koohsari 2009; Myagmartseren, Buyandelger, and Brandt 2017; Wang et al. 2017). Under the infrastructure sub-model, we have identified seven major infrastructures that present opportunities for urban development (Figure 5). These are the proximity to ***major ports, airports, regional railway lines, water pipelines, major power lines, telecommunications*** (captured by the National Broadband Network, NBN) and ***principal roads*** (Geoscience Australia 2018). Urban development can, and will to

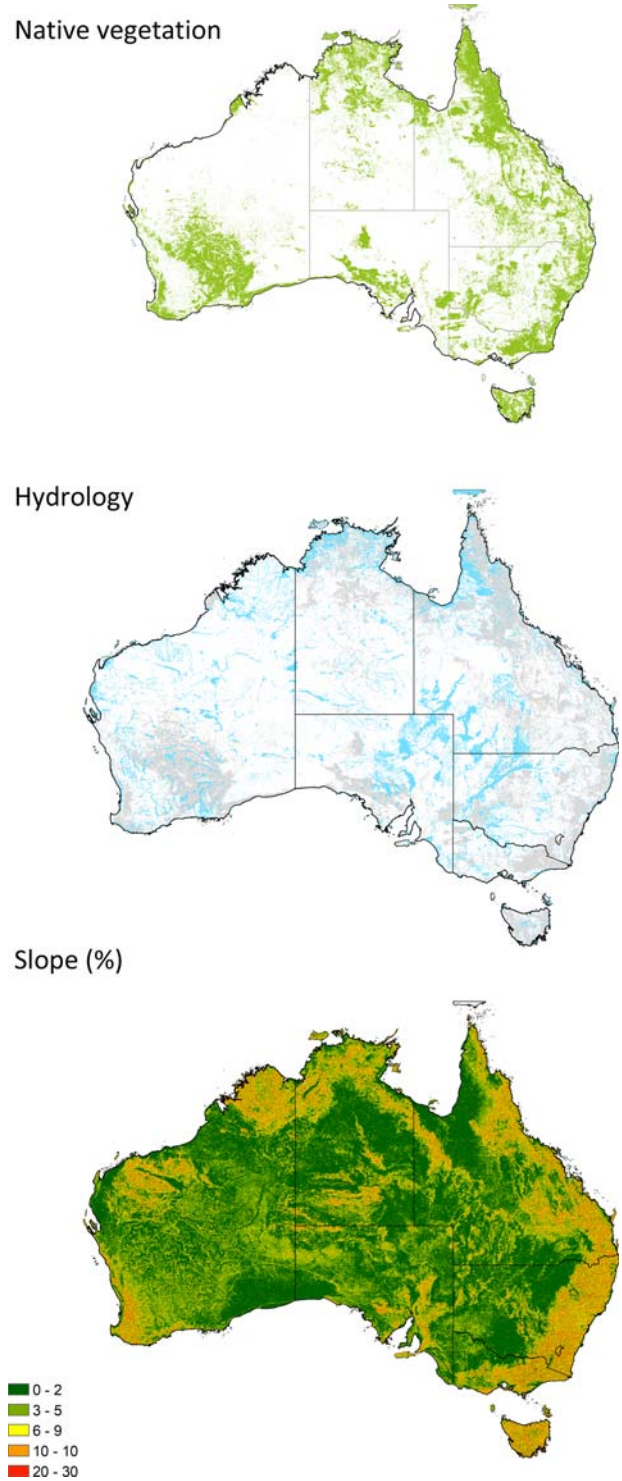

Figure 4. Geospatial layers included in the natural and cultural heritage sub-model. Maps by the authors.

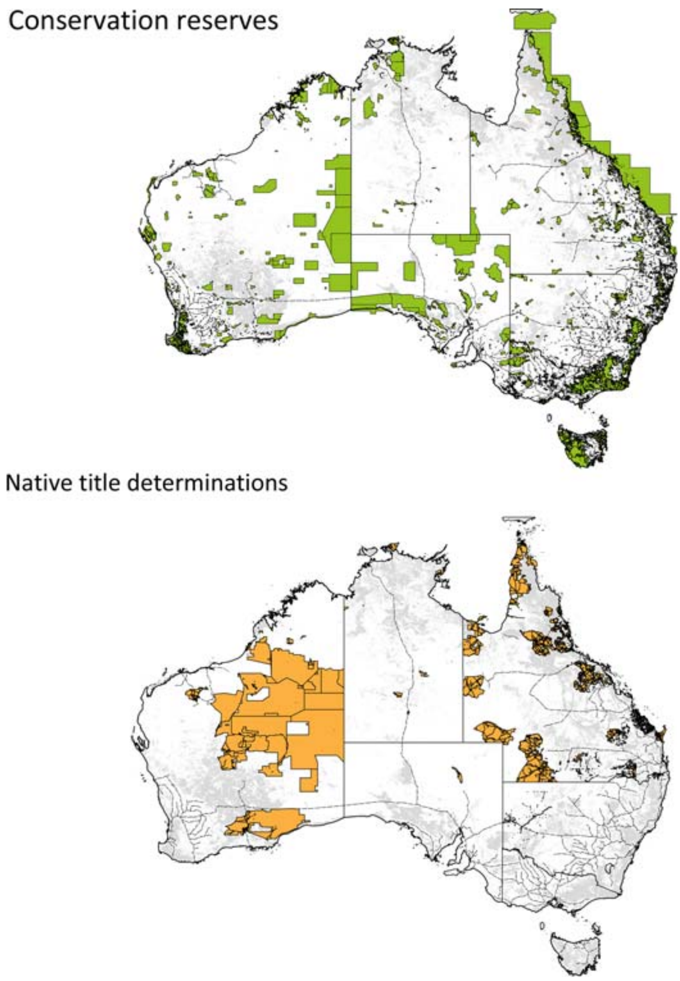

Figure 4 *Continued*

some degree, occur in the absence of existing infrastructure capacity. Nonetheless, it will be a comparatively expensive exercise, particularly given constrained government budgets, and as such, this will curtail large-scale urban development opportunities in many locations, as recognized in the CSIRO study (Arman et al. 1981). Moreover, we recognize that mapping the presence of infrastructure can overstate the actual capacity of that infrastructure to service population growth.

Economics

Suitability analyses typically incorporate economic-related factors such as per capita GDP, per capita income of local finance, and per capita investment in fixed assets (Wang et al. 2017). Under the economics sub-model, we have mapped ***average weekly household incomes*** (AUD$) (Australian Bureau of Statistics 2016) and ***proximity to the capital cities***, which are Australia's major population and employment nodes (Figure 6). In this instance, household incomes serve as a proxy for the presence of well-enumerated employment opportunities. We have included cities because 80 per cent of Australia's economic activity occurs in Australia's large cities. As Kelly and Donegan (2015, 23) explain, 'they are the backbone of our economy' and their Central Business Districts are 'critically important to the nation's prosperity.'[3]

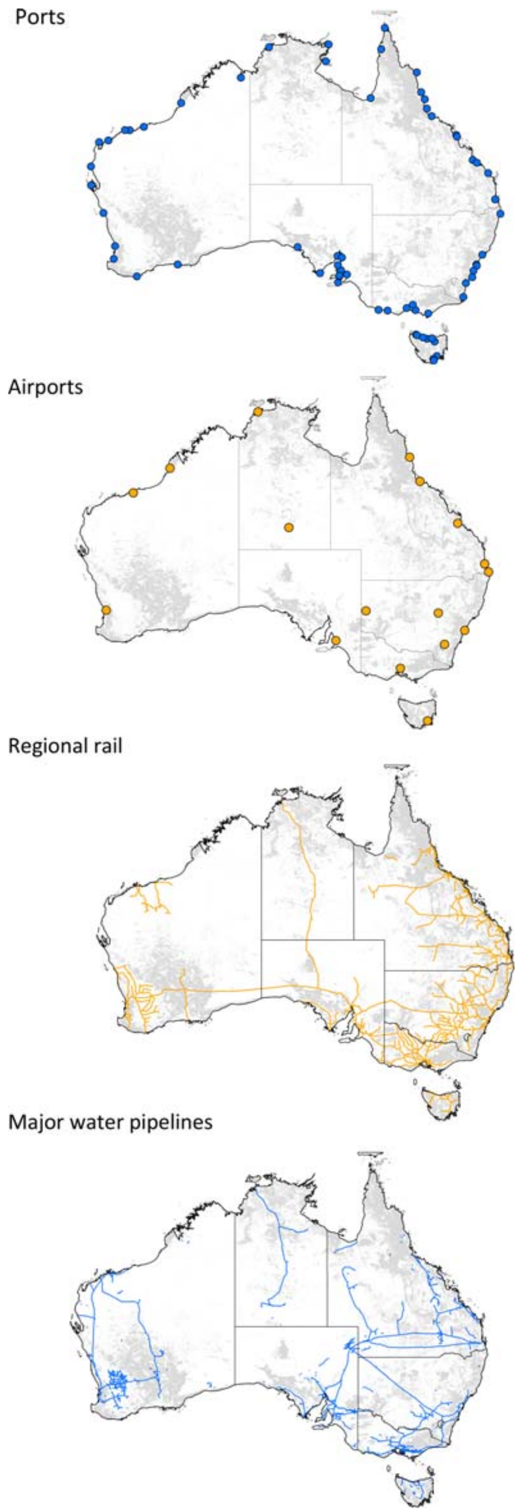

Figure 5. Geospatial layers in the infrastructure sub-model. Maps by the authors.

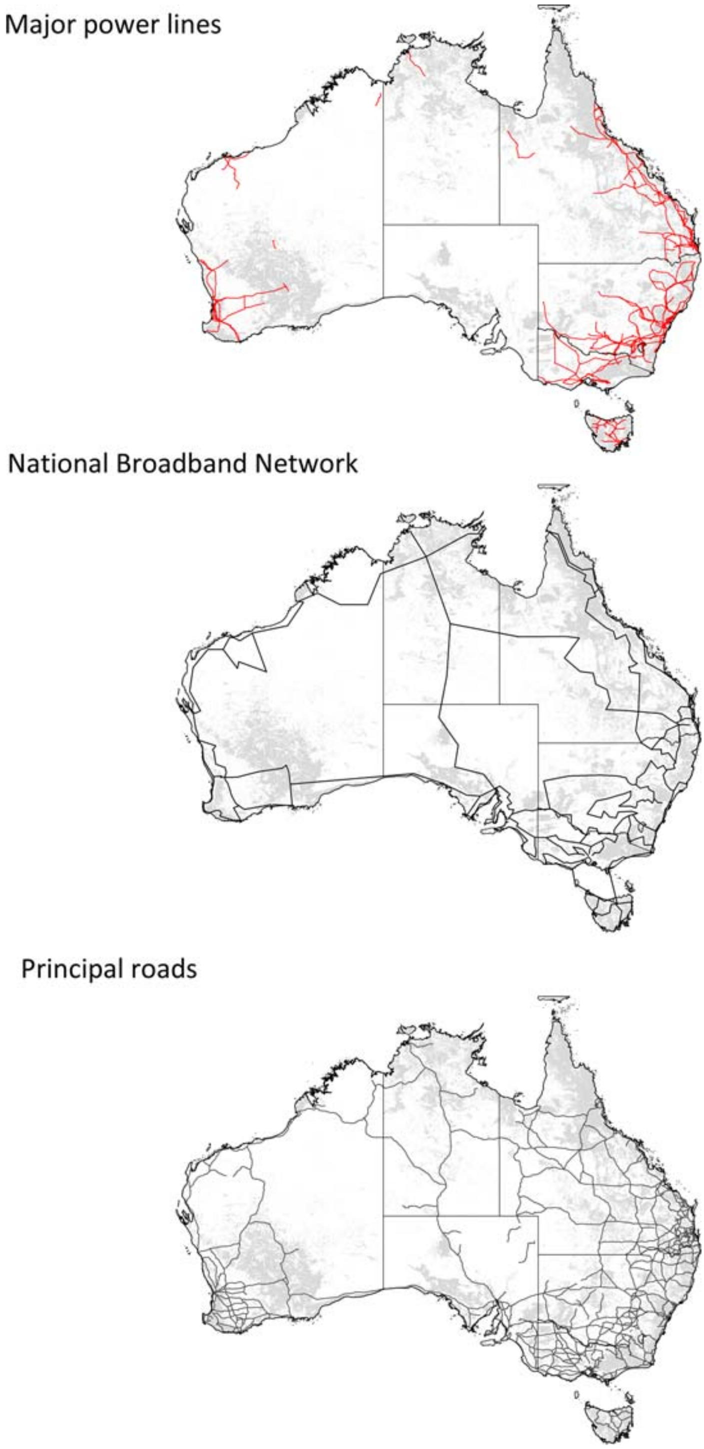

Figure 5 *Continued*

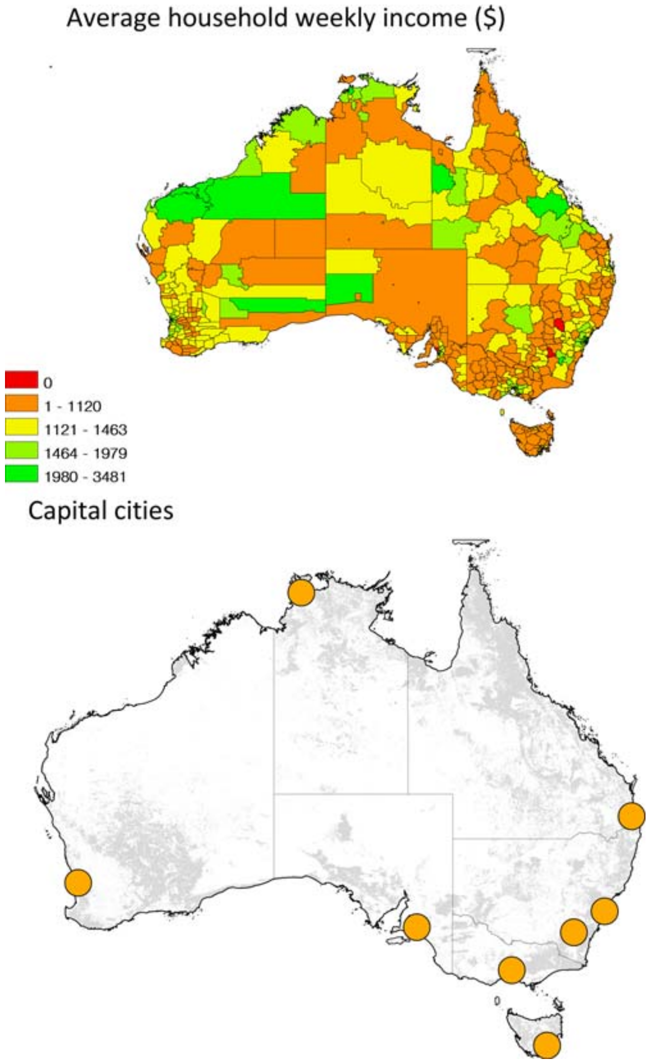

Figure 6. Geospatial layers showing the factors included in the economics sub-model. Maps by the authors.

Weighting the suitability factors

There is a consensus in the literature that weighting of the suitability factors presents difficulties as it 'introduces subjectivity into the decision-making process since the weight is [often] assigned arbitrarily to each set of factors' (Chen 2016, 50). This situation can lead to considerable variations in

Table 1. The seven-point intensity of relative importance scale.

Intensity of importance	Definition
1	Equal importance
2	Very weak importance
3	Weak importance
4	Moderate importance
5	Strong importance
6	Very strong importance
7	Extreme importance

Table by Bana e Costa, De Corte, and Vansnick (2020).

Table 2. Sub-models, geospatial layers, classifications and preference scores.

Geospatial layer	Classification	Preference score	Sub-model weighting	Factor weighting	Dataset
Climate sub-model			*0.50*		
Heat stress	Very hot very humid	1		0.58	Davidson (2007)
	Very hot not necessarily humid	2			
	Hot very humid	3			
	Hot not necessarily humid	4			
	Warm very humid	5			
	Warm not necessarily humid	6			
	Mild very humid	7			
	Mild humid	8			
	Mild not humid	8			
Annual average rainfall (mm)	0–248	1		0.33	Bureau of Meteorology (2020)
	248–503	2			
	503–815	3			
	815–1138	4			
	1138–1458	5			
	1458–1817	6			
	1817–2298	7			
	2298–4227	8			
Cyclone incidence	<4	8		0.09	Bureau of Meteorology (2020)
	4–5	8			
	5–7	7			
	7–9	6			
	9–11	5			
	11–14	4			
	14–16	3			
	16–18	2			
	18–22	1			
Natural and cultural heritage sub-model			*0.16*		
Native vegetation	Mangrove	1		0.10	Geoscience Australia (2018)
	Forest/ shrub	1			
	Rainforest	1			
	No data	8			
Hydrology (lakes, foreshore flats, flats, watercourse areas)	Lakes	1		0.42	Geoscience Australia (2018)
	Watercourse areas	1			
	No data	8			
Slope (%)	14.7–26.1	1		0.17	Geoscience Australia (2018)
	11.5–14.7	2			
	8.8–11.5	3			
	6.4–8.8	4			
	4.1–6.4	5			
	2.2–4.1	6			
	0.66–2.2	7			
	0–0.66	8			
Conservation reserves	Nature Conservation	1		0.25	Geoscience Australia (2018)
	Reserve	3			
	Forestry Reserve	2			
	Water Supply Reserve	2			
	Indigenous Reserve	8			
	No Data				
Native title determinations	Native title exists in all of the reserve	1		0.04	National Native Title Tribunal (2019)
	Native title exists in a part of the reserve	3			
	Native title does not exist in the reserve	8			
	No Data	8			
Infrastructure sub-model			*0.08*		
Ports (km)	>100	1		0.11	Geoscience Australia (2018)
	50–100	4			

(*Continued*)

Table 2. Continued.

Geospatial layer	Classification	Preference score	Sub-model weighting	Factor weighting	Dataset
	<50	8			
Airports (km)	>100	1		0.15	Geoscience Australia (2018)
	50–100	4.			
	<50	8			
Regional rail (km)	>100	1		0.29	Geoscience Australia (2018)
	50–100	4			
	<50	8			
Water pipelines (km)	>100	1		0.02	Geoscience Australia (2018)
	50–100	2			
	<50	8			
Major power lines (km)	>100	1		0.05	Geoscience Australia (2018)
	50–100	2			
	<50	8			
National Broadband Network	>100	1		0.08	NBN co. (2020)
	50–100	2			
	<50	8			
Principal roads	>100	1		0.29	Geoscience Australia (2018)
	50–100	4			
	<50	8			
Economic sub-model			*0.25*		
Capital cities (km)	>800	1		0.83	Geoscience Australia (2018)
	600–800	2			
	400–600	4			
	200–400	6			
	100–200	8			
Average household weekly income ($)	0–408	1		0.17	Australian Bureau of Statistics (2016)
	408–933	2			
	933–1145	3			
	1145–1322	4			
	1322–1539	5			
	1539–1985	6			
	1985–3649	7			
	3649–4999	8			

results depending on expert opinion (Flitter et al. 2013). A common challenge is 'how to establish weights for a set of activities according to importance' (Al-Shalabi et al. 2006, 5).

To tackle this problem, we have employed the Analytic Hierarchy Process, a 'theory of measurement through pairwise comparisons' to derive priority scales (Saaty 2008, 83). In constructing a set of pairwise comparison matrices, we used M-Macbeth software[4] (Bana e Costa, De Corte, and Vansnick 2020) to compare all possible pairs of suitability analysis criteria within a sub-model (e.g. road access to rail access, road access to airport access) and to weight the relative importance of one criterion over another (Saaty 2008). Table 1 below sets out the pairwise comparison matrix. Once this process has been carried out in the sub-models, we then carried out the same process of weighting the models themselves (e.g. climatic conditions relative to infrastructure provision).

Table 2 sets out the sub-model and factor weightings (derived from the pairwise comparison process), classifications and associated preference scores. The sub-model weightings reflect the importance of climate and economic considerations. For the former, the 'pleasantness' of a climate has proven to be a significant driver of population growth (Duranton and Puga 2013, 804). This dynamic is likely to increase as climate change compounds climate comfort issues (Australian Government 2017). The weightings also reflect the importance of economic opportunities. For the latter, failed attempts at population decentralization in Australia in the early to mid-twentieth century clearly show that without convincing economic drivers, new or expanded settlements will struggle (Bolleter 2018). Natural and cultural heritage considerations rank third in importance capturing Australia's biodiversity particularly the northern half of the continent with 'an extraordinarily vast, natural landscape with a rich biodiversity of international significance' (Woinarski et al.

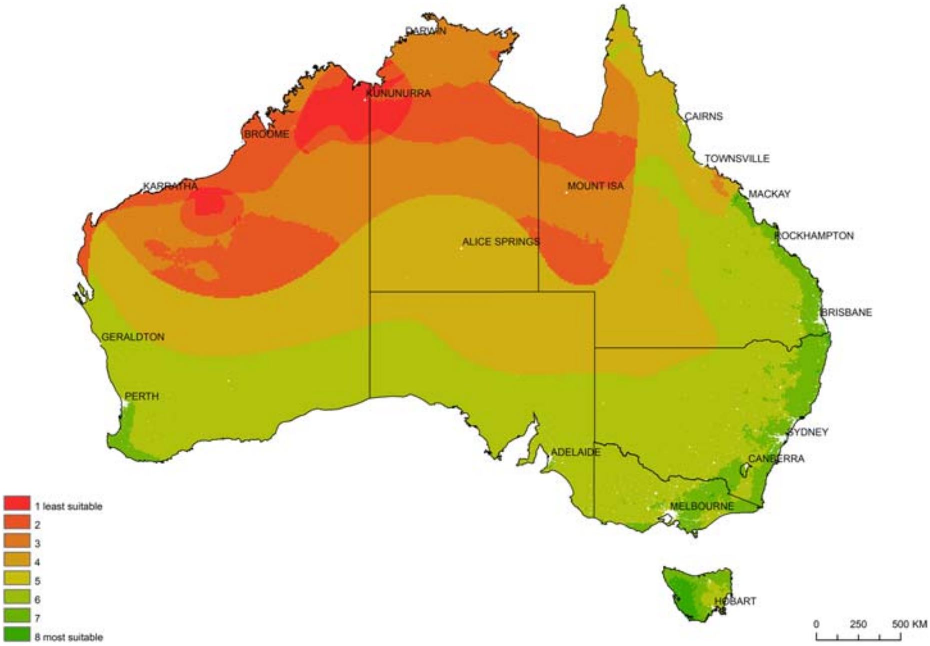

Figure 7. Climatic sub-model suitability analysis results.

2007, 85). The presence of existing infrastructure ranks fourth, which remains important regionally, despite recent innovations in decentralized neighbourhood-based infrastructure (Newman, Beatley, and Boyer 2009).

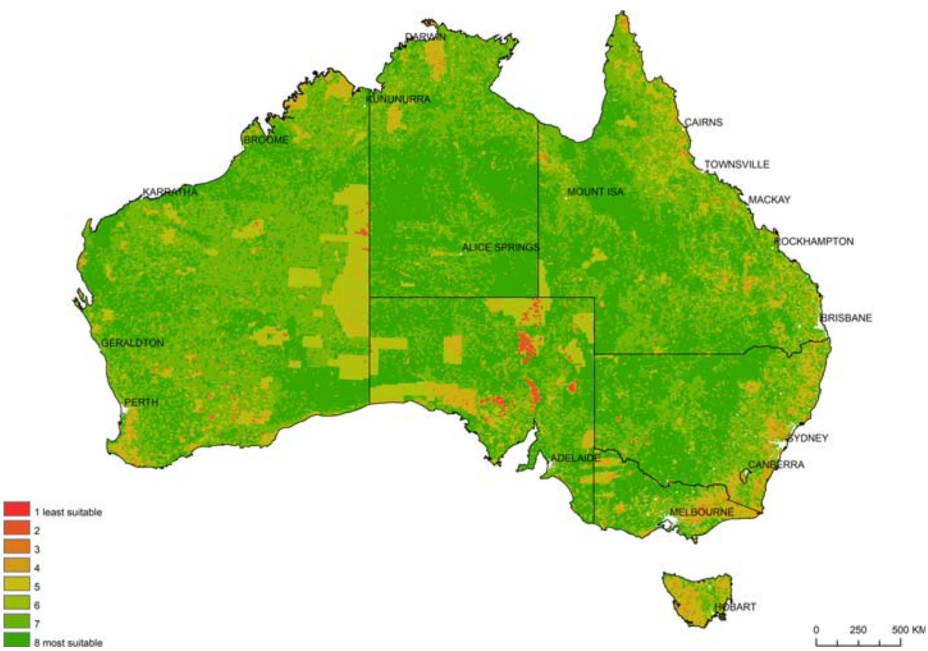

Figure 8. Natural and cultural heritage sub-model suitability analysis results.

Results

Here we present the results of our analysis of Australian regions most suited to population growth and consequential urban development. This analysis is based on climatic, natural and cultural heritage, infrastructural and economic factors, and overall suitability.

The climate sub-model map (Figure 7) reveals that most of the north, north-west, and interior of the Australian continent is broadly unsuitable for mass urban development due to the combined effects of extremely high summer maximum temperatures and humidity, and possibly decreasing rainfall (Bureau of Meteorology 2020) as well as high to very high cyclone risk (Bureau of Meteorology 2020). The south-east, south (particularly Tasmania) and, to some degree, the south-west appear most appropriate for future urban development on this criterion.

The natural and cultural heritage sub-model map (Figure 8) illustrates that some of the capital cities such as Perth are constrained by substantial native vegetation and topographic features with a significant slope, and in some cases conservation reserves (Geoscience Australia 2018). The flatness and general lack of substantial native vegetation in some interior regions mean these register moderate suitability for urban development. While this is counterintuitive, readers should be aware that the aridity of these desert and semi-desert areas is registered in the climate sub-model through the average rainfall criterion.

The infrastructure sub-model map (Figure 9) shows that areas adjacent to, and on corridors inter-connecting, existing major population centres are the best served by existing infrastructure. Areas in the Pilbara also register highly because of investments in infrastructure made by private mining companies. The relative lack of existing infrastructure in the north and interior of the continent reflects a sparse population and the lack of other infrastructure provision drivers.

The economics sub-model map (Figure 10) reveals the economic opportunities (Kelly and Donegan 2015) presented by the capital cities (federal, state and territory) which are reflected in average weekly household incomes (Australian Bureau of Statistics 2016). This situation is a continuation of Australia's perceived 'territorial imbalance.' This pattern has compounded since the 1980s due to

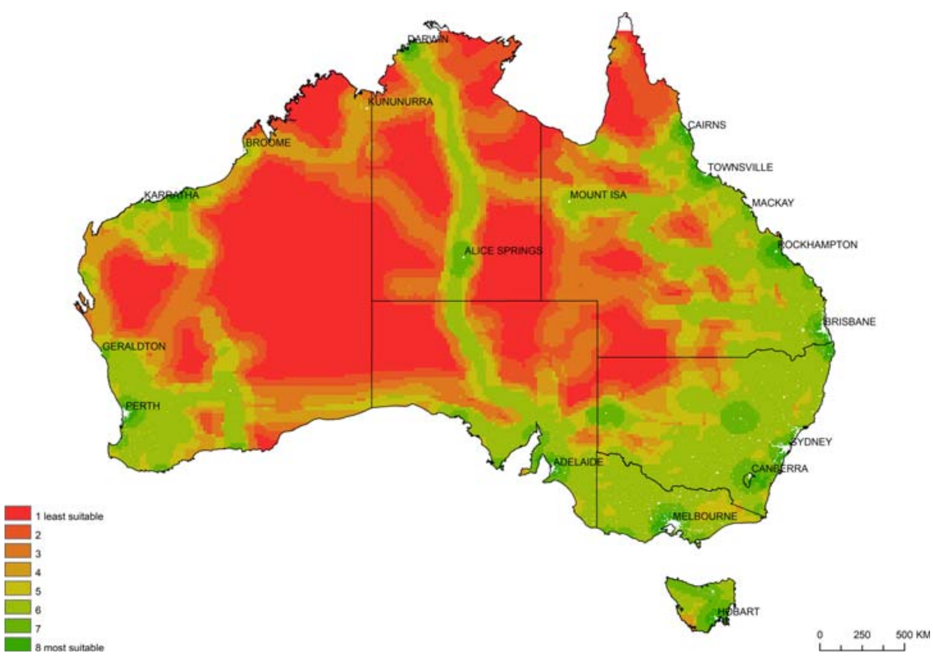

Figure 9. Infrastructure sub-model suitability analysis results.

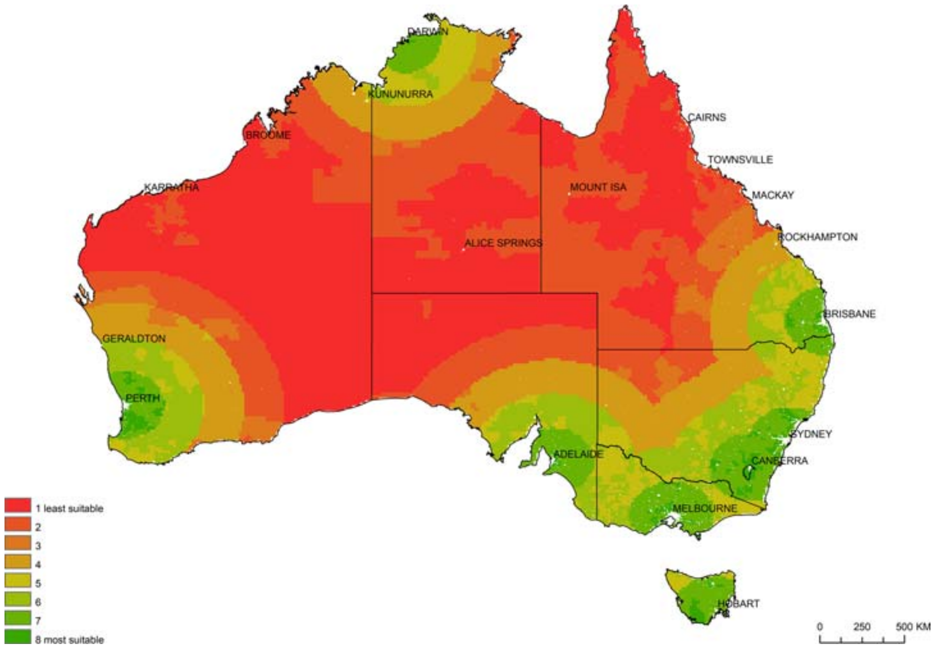

Figure 10. Economics sub-model suitability analysis results.

population flows from the inland agricultural regions to the expanding coastal urban centres, creating what Salt terms the 'empty-island syndrome' (In Kullmann 2013, 243).

The overall suitability analysis map was generated from a weighted combination of the climate, natural and cultural heritage, infrastructure and economics sub-model maps (Figure 11). This map reveals that five principal regions are most suitable for twenty-first-century Australian urban

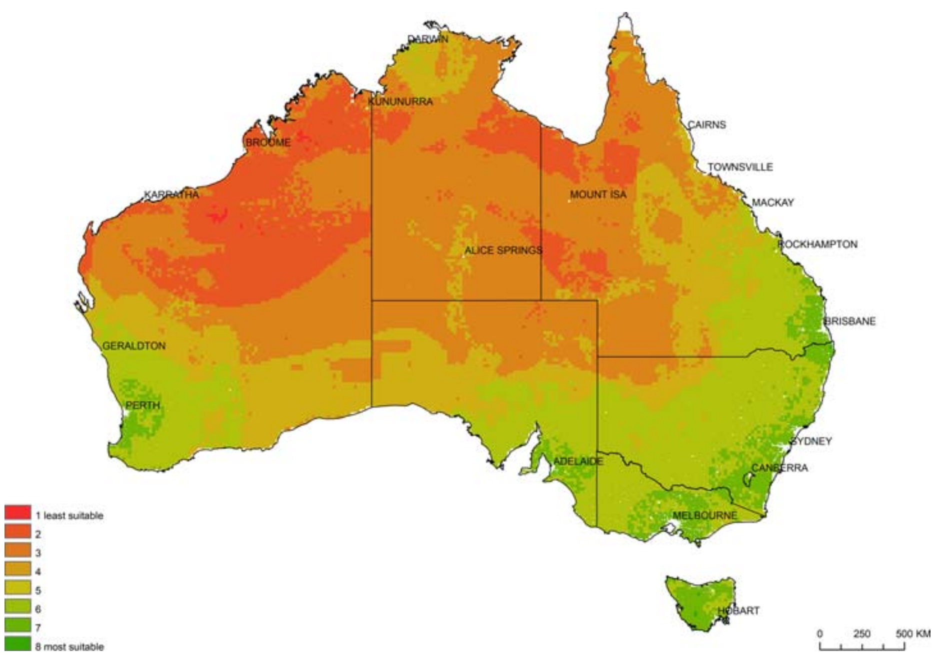

Figure 11. Overall suitability analysis map.

development. Starting from the west is a region surrounding Perth and extending southwards to the coastal town of Busselton, northwards to the coastal town of Cervantes and south-eastwards to Wagin. The second region surrounds Adelaide and extends to the Yorke Peninsula to the west. A third region to the east forms an almost contiguous area extending from Melbourne, through Canberra, Wollongong, and Sydney to Newcastle. A fourth region encompasses Tasmania. A fifth region surrounds Brisbane and extends to Bundaberg in the north and Coffs Harbour in the south.

These broad regions typically offer some proximity to the capital cities – the powerhouses of the Australian economy – and reflect proximity to employment but also existing infrastructure such as major ports and international airports. Centres on rail networks and other major infrastructures connecting Melbourne and Sydney are also well-placed for future urban development. Finally, a temperate climate and reasonable rainfall characterize the regions suited to urban growth. However much of the eastern coastal regions are constrained by existing remnant vegetation and in some cases steep slopes.

Discussion

Our suitability analysis results reveal that comparatively little of Australia's landmass is suited to large-scale population growth and accompanying urban development. This assessment reflects the enduring notion that the 'Australian landscape, beyond its few fertile clefts, tends to mock the very idea of settlement' (Bolleter and Weller 2013, 33). The economic opportunities and infrastructure provision of regions adjacent to existing cities and major towns present major urbanization incentives. This situation suggests that future urbanization should be grafted onto, or restructuring, existing settlement patterns rather than forging major new centres in areas where none currently exist. These findings have substantial implications for Australian regional planning exercises.

Our results have some correlation with the CSIRO's analysis conducted in the late twentieth century (Cocks 1992). Regardless of the enhanced technical sophistication of our study, both identify areas in the south-west and south-east of the continent – and Tasmania – as suitable for urban growth. The earlier study differs in identifying areas in northern Queensland, particularly the Mackay region, as 'preferred' for urban development. This came at a time when a surge of prosperity was evident on the back of expansion in the mining industry (Mackay Regional Council 2020). By contrast, in our analysis, this region scored comparatively modestly due to climatic and environment-related constraints, combined with the distance from the state capital of Brisbane, nearly 1,000 km to the south by road.

Readers should note the limitations of our study. Like all suitability analyses, ours relies on weightings which considerably affect the spatial distribution of suitability scores. We accept that there remains a degree of subjectivity about such weightings and proceeded with a method that makes decisions around weighting transparent. As Saaty (2008, 85) implores: 'even when numbers are obtained from a standard scale [such as in our weighting methodology], their interpretation is always, I repeat, always, subjective.'

Secondly, our study is limited to areas outside of the existing urban footprints of the state, territory and federal capital cities. Indeed, the paper has not scoped the potential of infill development to accommodate population growth within existing urban areas. This limitation is not intended to denigrate the importance of brownfield development, and we recognize that poorly planned greenfield expansion is characterized as typically unhealthy, socio-economically stratified, unsustainable and unproductive (Bolleter 2017; Kelly and Donegan 2015). Nonetheless, we do note that the projected tripling of Australia's population from 25 to 70 million by 2100 will be unlikely to be accommodated within existing urban areas. Evidence of this is the consistent failure of Australian cities to meet their targets for infill development. Thirdly, while the paper identifies greenfield development areas, it does not address the appropriate patterns, densities or issues encountered (Bolleter 2017).

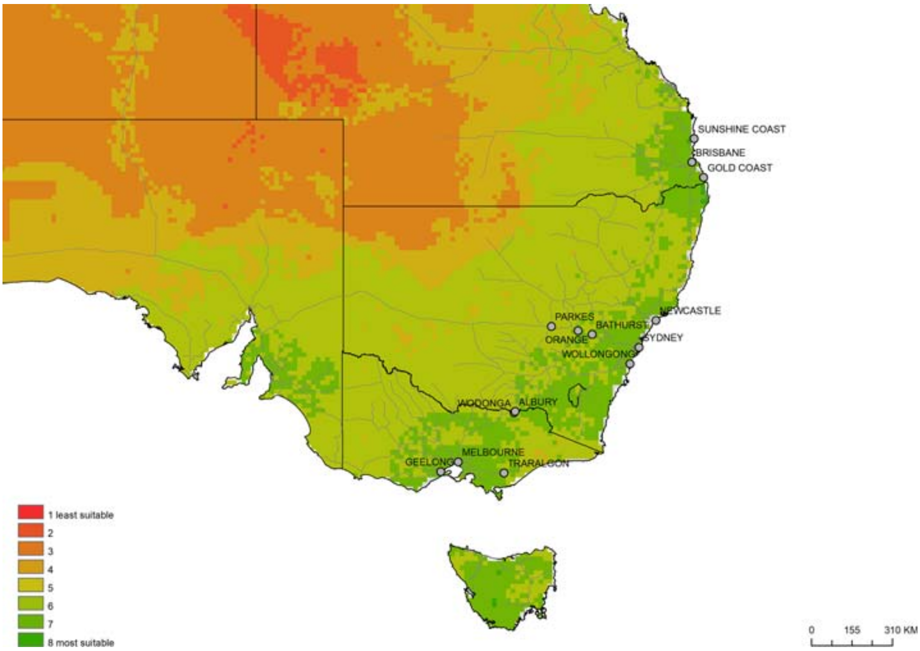

Figure 12. The Morrison Federal Government's decentralization programme centres overlain on our suitability analysis.

In the penultimate section of the paper, we discuss the alignment of the results of our suitability analysis with two current federal spatial policy initiatives.

Federal government planning for 'Australia's Future Population'

The current Federal Government's settlement policy is vague but appears to coalesce around investments (confirmed or speculative) in fast rail projects that aim to improve regional connectivity to the capital cities (particularly Melbourne and Sydney). By way of example, the Morrison Government (2018-) has promised $2 billion for a fast rail upgrade between Melbourne and the regional centre of Geelong 80 km distant to travel at an average speed of 160 km/h (Australian Government 2019) (Figure 12). Other current business cases for fast rail include Brisbane to the Sunshine Coast, Brisbane to the Gold Coast, Melbourne to Greater Shepparton, Melbourne to Albury-Wodonga, Melbourne to Traralgon, Sydney to Newcastle, Sydney to Wollongong, and Sydney to Parkes via Bathurst and Orange. Coincidentally or otherwise, most of these centres are in areas our mapping has shown to be most conducive to further urban development (with scores of 6 and above). These relatively high scores are primarily due to existing regional rail and road links, proximity to major capital cities, and a relatively benign climate. The Government's 'city deals' programme to accelerate growth through employment creation has benefitted Geelong as a regional centre alongside Townsville in northern Queensland, Launceston in Tasmania, and Darwin in the Northern Territory but also major metropolitan centres: western Sydney, South-east Queensland, Perth, Adelaide and Hobart.

White paper on developing Northern Australia

At the Federal government level, planning to populate 'the north'[5] is encapsulated in the White Paper on developing Northern Australia: *Our north, our future* (Australian Government 2015). This paper adopts a generally pro-development stance, in line with the north's conceptualization

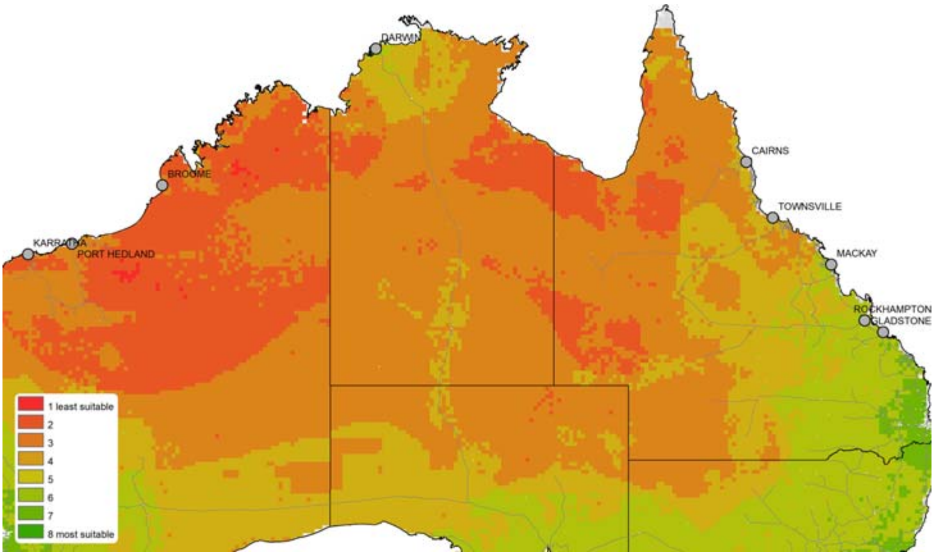

Figure 13. Northern Australia's major centres overlain over on suitability analysis.

as a place of economic bounty and opportunity. While the White Paper is mute on settlement patterns, some statements suggest the government's support for mass urban development. As the report implores:

> Development will require many more people living in the north … We need to lay the foundations for rapid population growth and put the north on a trajectory to reach a population of four to five million by 2060. (Australian Government 2015, 4)

Given northern Australia's current population of 1.3 million this aspiration represents an almost four-fold increase (an additional 3.7 million people). To fast track growth, the federal government has committed to providing a new $5 billion Northern Australian Infrastructure Facility programme to provide concessional loans for the construction of significant infrastructures such as ports, roads, rail, pipelines, and electricity and water supply (Australian Government 2015). A Designated Area Migration Agreement for the Northern Territory has also recently been introduced.

Long term, the result of such efforts could be to compound population growth in a region to which it is not suited, the upshot of which will be a massive drain on resources and limited progress on the ground. Indeed, significant urban development in the north will need to overcome many barriers that our mapping reveals, such as a lack of existing infrastructure, an inhospitable climate and a relative lack of economic opportunity (Figure 13). Indeed, existing northern cities, especially those in the north-west received modest suitability scores in our analysis – Gladstone (6), Rockhampton (6) Mackay (6), Townsville (5), Cairns (5), Darwin (6), Broome (5), Port Hedland (4) and Karratha (3). Reasons for these modest scores include Native Title Determination Areas which cover more than 30% of the Australian continent and a substantial 50% of the Northern Territory (Pearson and Gorman 2010). Particularly in coastal areas, constraints include climate change impacts – increasing temperatures (Australian Government 2017), and increasing intensity cyclones (McMichael in Hugo 2012) – and ecological constraints (mangrove foreshores and riverine flats).

Moreover, if significant urban development does occur it could have a damaging effect on remnant vegetation which underpins the most significant tract of savanna woodland in the world: 'an extraordinarily vast, natural landscape with a rich biodiversity of international significance' (Woinarski et al. 2007, 85). Our conclusion is thus ambivalent. On the one hand, while evidencing necessary larger scale national thinking on urban settlement, the territory being enthusiastically surveyed lacks high suitability for urban development.

Conclusion

At the outset, we posed the question: Where should Australian federal and state governments encourage urban development to maximize climatic liveability, preserve and protect the environment, capitalize on previous infrastructure investments and maximize economic productivity? To answer this, we have systematically conducted a suitability analysis of the Australian continent to discern, against a set of climatic, natural and cultural heritage, infrastructural and economic factors, which regions are most fertile, feasible and appropriate for urban development to accommodate future population growth. Advancing beyond the CSIRO mapping analysis which lacked a weighting of suitability factors or separately identified sub-models (Cocks 1992), this is the first time a comprehensive suitability analysis has been conducted of the Australian continent. This analysis is significant because commentators believe a national scale overview concerning settlement patterns is critical, given the challenges of this century (Beatley 2015; Laquian 2005; Planning Institute of Australia 2018). It concludes that the south-west, east and south-east fringes of the continent and Tasmania are fertile for urban development – as current settlement patterns evidence. This situation has not changed significantly since the 1980s.

However, as the previous section of the paper indicated, steps have been taken to integrate urban planning policy at a national scale. In 2018 the House of Representatives Standing Committee on Infrastructure, Transport and Cities completed an inquiry into leveraging planning intervention for the nation's cities' orderly long-term development (Australian Government 2018a). The major focus was on pathways and needs for securing sustainable urban development for both existing cities and regional centres. In May 2020 the Federal Government accepted in principle the Committee's major recommendation to develop a national plan of settlement 'providing a national vision for cities and regions across the next fifty years' (Australian Government 2020). Covid-19 has stymied progress on this undertaking and a more vigorous take-up of the SDG goals into national policy (Australian Government 2018b). The Government is nonetheless able to point to existing initiatives such as delivering fast rail connections between regional and capital cities (Australian Government 2019) and a sprinkle of 'city deals.' This situation suggests the typically binary planning discourse regarding infill versus greenfield development could be expanded to countenance regional decentralization to appropriate locations. The interest of federal (and also state and territory) policymakers for ambitious northern development is more equivocal with constraints faced that climate change is likely to compound over time. These are concerning issues which highlight the need for urban and population planning to be based on comprehensive suitability analysis.

While the analysis we have set out is substantial, given the breadth of the geographic scope ultimately, appropriately authorized, federal and state government departments should undertake similar if more detailed studies. This paper presents a model of analysis that federal or state government could take up as part of a national settlement strategy planning process. This future analysis could include employing various weightings of the sub-models to produce different suitability scenarios that researchers could, in turn, ground-truth with site conditions, and test with experts in a targeted Delphi method or with the broader Australian community through traditional survey methods. Future research could further study the relationships between population planning at a finer scale and conformity with our findings.

Notes

1. The timeframes of this metropolitan planning varies from state to state. The most long range planning is for Sydney to 2056 (Greater Sydney Commission 2018) and the shortest for Hobart to 2029 (City of Hobart 2019).
2. In addition to 'determinations' there are currently 128 outstanding native title 'claims.' Many if not most will lead to 'determinations' so our analysis somewhat underestimates aboriginal claims to native title.
3. Nonetheless, the cities themselves are excluded from our suitability analysis.

4. The Analytic Hierarchy Process (AHP) and Macbeth approaches are slightly different. AHP uses 9-point fundamental scales (ratio scale), whereas MACBETH uses seven semantic scales (ordinal scale). In addition, for calculating weight and scale, MACBETH uses linear programing method, whereas AHP uses the eigenvalue method (Rietkötter 2014).
5. Northern Australia is the region north of the Tropic of Capricorn (23.5' S latitude).

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