Scalar considerations in carrying capacity assessment: an Australian example

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Abstract

Regional resource self-sufficiency has been proposed as a way to improve food security by lessening the demand on long-distance transport. An online tool, the Carrying Capacity Dashboard, was developed for Australian conditions in order to gauge self-sufficiency at three different scales: regional, state and national. It allows users to test a variety of societal behaviours such as diet, biofuel production, farming systems and ecological protection practices. Analysis developed from the Dashboard tests the effects of various resource consumption patterns on land carrying capacity. Findings reveal that Australia’s current carrying capacity is estimated to be over 40 million but if calculated on a regional basis, this is reduced by almost half.

1. Introduction

Land carrying capacity assessment, by definition, suggests that a population is assumed to be reasonably self-sufficient within a defined boundary (Price, 1999). Critics of small-scale carrying capacity assessments (Whyte & Beuret, 2004) point out such scales may not currently reflect existing resource utilisation practices when the trade of resources for many people in the world often occurs at larger scales, such as in national or global markets. For example, the Persian Gulf states now import 90 percent of their food requirements (Malik & Awadallah, 2013) through global supply chains and yet, their abundant oil reserves make them amongst the wealthiest societies on earth. In this case, a lack of one resource is compensated by the abundance of another. The Australian context also provides further evidence of this current situation, though in reverse, with an oversupply of food being exported (ABARES, 2011), and a shortfall of oil imported (ABARES, 2010). Complete national or local self-sufficiency may appear improbable so carrying capacity analysis may not be reflective of existing current resource utilisation configurations. However, just because international trade currently helps to adjust various contemporary global resource imbalances, this situation is not necessarily sustainable, nor does it provide equitable or environmentally sound outcomes. In fact, global systems of resource utilisation can result in unacceptable environmental degradation such as climate change (Garnaut, 2008; Moir & Morris, 2011; Pandey, 2011), resource depletion such as peak oil (Brandt, 2007; Friedrichs, 2010; Hughes, 2013; McNamara, 2007) and escalating social inequities (Catton, 1982; Dilworth, 2010). An ever-increasing global population (United Nations, 2011) only serves to magnify this problem.

The greatest vulnerability to international trade is its almost-complete dependence on the ready-availability of cheap fossil fuels, chiefly oil used in the transport industry (Nygren, Aleklett, & Höök, 2009). In Australia, 74 percent of all petroleum usage is for transportation and 90 percent of the energy used by Australia's dispersed agricultural production also comes from petroleum (McNamara, 2007). A societal system less reliant on long-distance road transport is thus one way to help improve resource security at a local level (Dilworth, 2010; Future Directions International, 2012). The Transition Town movement (Hopkins, 2011), Permaculture (Holmgren, 2002) and locavore (Peters, Bills, Wilkins, & Fick, 2009) initiatives are all reflective of this renewed local focus. Local self-sufficiency is thus seen as one way in which population can meet the challenges of future global resource security.

A second reason put forward for future localisation of societal systems is that of community responsibility and empowerment. For instance, local resource utilisation can engender greater environmental and ethical responsibility in local populations because impacts are often more immediately obvious and behavioural change, more willingly undertaken (Ostrom, 1990).

Even though trade currently facilitates resource utilisation at national and global scales there are compelling reasons to also evaluate carrying capacities at much smaller scales. Accordingly, in order to ensure more equitable and sustainable future land-use patterns directly linking populations to the regions which sustain them is of future societal importance (Lane, 2010). The immediate role of carrying capacity modelling is thus to prompt societal examination of the degree to which localised self-reliance is possible by surveying the productive capability of a region and comparing potential population capacities to existing population numbers. This paper describes results of the Carrying Capacity Dashboard, a tool for estimating local self-sufficiency, and analyses the effects of a range of resource consumption patterns on carrying capacity, highlighting the degree to which regions are under or over population capacity at varying scales.

2. Background

Key to the estimation and subsequent explanation of any carrying capacity assessment is the determination of a relevant and valid scale of analysis. Carrying capacity assessments, by their very nature, necessitate the delineation of geographic boundaries within which a population is relatively self-reliant for their resources (Fearnside, 1986).

The position and scale of the boundary around which any carrying capacity study is drawn can have a significant impact on the outcome.

2.1 Scalar considerations

The scale of analysis is a significant determinant of carrying capacity results. For instance, a carrying capacity assessment of a city would be much smaller without the inclusion of any productive hinterland, and obviously the carrying capacity of a fertile river basin is likely to be larger than that of a desert of equivalent size. Cohen (1995) argues that the systems-modelling of populations is often best approached at small geographic scales while Rees and Wackernagel (Wackernagel, 1994) devised Ecological Footprint analysis in order to measure globally scaled carrying capacities. There is no obvious limit in potential size of carrying capacity assessments, notwithstanding the obvious constraint of the global dimension, and perhaps a piece of land too small, inhospitable or inaccessible for any form of production. However, the accuracy and usefulness of the assessment may differ depending on where the boundary is placed. An ideal carrying capacity model should best reflect the most appropriate delineation from both a biophysical and societal perspective (Cohen, 1995).

At present, Ecological Footprint analyses provide indications of self-sufficiency mostly at a world-wide scale (Close & Foran, 1998), where online users of interactive tools such as the Footprint Calculator (Global Footprint Network, 2011) can adjust various consumption parameters to derive results based on global yield data. Also known as appropriated carrying capacity (Wackernagel et al., 1999), this approach is actually an inversion of the carrying capacity methodology. While carrying capacity assessment assumes fixed landscape delineation to derive a population outcome, Ecological Footprint assumes that the population number is a constant in order to estimate total land requirements, usually given in global hectares (Wackernagel & Rees, 1997). Given the globalised nature of modern trade, proponents of this approach (Dietz, Rosa, & York, 2007; Sutcliffe, Hooper, & Howell, 2008; Wackernagel, 2009) argue that Ecological Footprint analysis is thus an accurate representation of existing circumstances where the geographic scale of consumption is variable while the global scale of production is fixed. In isolated cases, smaller-scale production data has also been incorporated into Ecological Footprint methodologies, with Lenzen and Murray (2001) and Bicknell et al. (1998) utilising national production data for their assessments of Australia and New Zealand. For example Lenzen and Murray found that Australia's Ecological Footprint of 13.6 hectares per person was larger than results from previous alternate studies partly because specific areas of Australian and New Zealand land used for agriculture and forestry were examined instead of areas converted to globally-averaged productivity (Lenzen & Murray, 2001). Such sub-global studies indicate a convergence of Ecological Footprint and carrying capacity analyses where both derive a locally-scaled result. However, in the assessment of self-sufficiency, the carrying capacity approach is the more appropriate option because it inherently assumes fixed landscape boundary delineation within which all resources are notionally generated and waste assimilated. Any inclusion of land outside a predetermined localised boundary, such as that which is appropriated by Ecological Footprint analysis, contradicts the concept of self-sufficiency.

2.2 Boundary delineation

The placement of a landscape boundary within which carrying capacity modelling and ultimately self-sufficiency might occur also significantly impacts subsequent results. Mochelle (2006) proposes aligning regional boundaries and establishing local precincts or planning cells on the basis of water sub-catchments or tributary basins, suggesting it would reflect an approach grounded in the goals of long-term sustainability, democratic participation and equitable access. This process would involve identifying and mapping all ridge-lines and water-ways and then considering an appropriate scale of delineation. Williams and Walcot (1998) also suggest that catchment areas defined by watersheds are a logical division of the landscape. Some regional delineation has occurred in Australia according to geographically defined criteria including the Natural Resource Management (NRM) system which divides Australia into 56 zones (Figure 1) and also the Interim Biogeographical Regionalisation of Australia (IBRA) which identifies 85 different zones. While the regions defined by these maps are generally larger than those recommended by Mochelle, the IBRA delineation, more so than the NRM mapping, provides an insightful representation of geographically-defined boundaries. The IBRA map disregards political alignments such as states and councils, instead defining boundaries by regional differentiation of climate, geomorphology, landform, lithology and characteristic flora and fauna (Australian Government, 2005)

Birdsell (1953) suggests that a landscape-based approach to regional delineation was also traditionally adopted by Australian Aboriginal communities, noting a high degree of correlation between language group boundaries and geographical features such as mountain ranges, rivers, general ecological and plant associational boundaries, microclimatic zone limits, straits and peninsulas.

While geography may best dictate the placement of carrying capacity boundaries, choices for the scale of such self-sufficient populations might be determined by other societal factors. Firstly, transportation choices in the context of future energy constraints should be a priority. For instance, what will be the likely availability, speed and convenience of future transport options? Are the most viable options public transport, bicycles, private vehicles or walking and what is the maximum suitable distance between key destinations within the region by its inhabitants? Social function and equitable access should also be assessed. For instance, consideration should be given to sufficient internal enterprise for a wide range of human abilities and interests in addition to the optimal population sizes to effectively deliver social service diversity such as medical facilities. Another determinant of self-sufficiency is resource usage such as land requirements for localised production and assimilation of most resources including food production (Hopfenberg, 2003) and water capture and storage (Mochelle, 2006).

Politically aligned boundaries are the most common form of delineation for contemporary carrying capacity analyses, be it national (Fairlie, 2007), state (Peters, Wilkins, & Fick, 2007) or local government jurisdictions. The carrying capacity assessments of the Douglas (Banfield, 2000) and Noosa Shires (Summers, 2004), for example, were defined by local government authorities but in both cases, these jurisdictions were subsequently amalgamated with other local councils,[1] thus highlighting the susceptibility for politically-orientated boundary alteration, which potentially complicates ongoing analysis.

Questions of human nature may also help to determine the scale at which communities endeavour to become self-reliant. Optimal sizes for governance structures and decision-making processes would thus be important considerations. Consequently, the designated community boundary should encompass the production and consumption of most resource requirements; capture the environmental assimilation of wastes; allow a safety margin for seasonal and climate variability, possible resource interruptions, exports, imports and visitor influxes; and include land set aside for natural habitat

[1] The Noosa and Douglas shire councils were amalgamated into larger jurisdictions in 2008 but both subsequently de-amalgamated in 2014.

within the defined precinct to facilitate biodiversity and ecosystem services. Given that these aspects will generate a wide variety of possible design outcomes dependent on each specific locale, ideally carrying capacity assessments should incorporate a degree of scalability from large-scale to regional to local to micro-local.

3. Method

A recent innovation in the field of carrying capacity assessment is the Carrying Capacity Dashboard (Lane, 2012) which allows users to test various resource-based parameters in Australia at various scales and timeframes. The Dashboard translates human resource requirements into land-usage areas, generating a carrying capacity population figure for each user-chosen configuration. The aim of this openly accessible simulation is to better define and publicise how the process of carrying capacity modelling can operate and to give a broad audience the experience of testing various degrees of resource self-sufficiency in their own locations. The model accounts for various societal and agricultural systems, environmental protection processes and a range of lifestyle choices such as energy and food consumption.

The Dashboard gives users the ability to manipulate 17 resource-usage parameters (Lane, Dawes, & Grace, 2014) including choices in the consumption of animal products, red or white meat, textiles, liquid fuel and timber (Table 1) and five land-use types (cropping, pasture, non-agricultural, infrastructure and nature reserve land) against 60 different Australian regions (Figure 1) so the potential to generate a variety of output is considerable. Given the dynamic nature of agricultural production, technological possibilities and resource constraints, the Dashboard also offers users the ability to consider long-term default settings. However, for the purposes of this paper, only estimates of current production and consumption patterns are discussed, so our carrying capacity estimates should be viewed within this scope.

Carrying capacity analyses, by definition, are reflective of particular pieces of land at a particular time, and any region invariably possesses its own unique physical characteristics, resources and environmental responsiveness. Consequently, the Dashboard estimates maximum population thresholds based on the unique biophysical characteristics of specific geographical regions within Australia. The Dashboard accommodates an Australia-wide context with analysis at both nation-wide and sub-national scales. While geographically determined boundaries for such delineation was sought, ultimately data availability led to compromises in this regard so state boundaries are used for large scale analysis and NRM boundaries define the regional scale. The Australian Bureau of Statistics (ABS) release yearly data for agricultural commodity yields (Australian Bureau of Statistics, 2008a, 2008b, 2009, 2010, 2011) at these scales so this factor most heavily influenced scalar delineation for modelling. ABS commodity yield data for Statistical Districts is also available but the boundaries employed in this analysis is entirely politically orientated so was deemed less useful than the NRM data.

The basic calculation of carrying capacity is derived by dividing land availability by per person area requirements (Fearnside, 1986). Applied to species with limited resource variety demands within a fixed area (such as cattle within a paddock), this equation is straightforward. However, applying such an approach to the human species involves considerable complexity. The Dashboard reduces some of this complexity by narrowing the focus to only essential human resource needs (e.g. food, fibre, timber) and of those parameters, a series of procedural steps are applied in order to derive a carrying capacity outcome.

The determinant of land availability is largely sourced from publicly accessible data (Australian Bureau of Statistics, 2008a, 2008b, 2009, 2010, 2011) according to five land-use types. This categorisation allows distinctions to be made in the viability of particular resource production, given that the quality of grazing land in Australia, for instance, might not support the growing of crops (Gutteridge, 2005).

A number of processes are involved in the calculation of per person area requirements in Dashboard modelling; one set related to anticipated consumption amounts, another set calculating the area requirements for production. For food consumption, historic Australian eating patterns (Australian Bureau of Statistics, 1995) and recently released dietary guidelines (Byron, Baghurst, Cobiac, Baghurst, & Magarey, 2011) were used. Alternatively, a 5-year average of Australia's agricultural yields were sourced from the ABS (2008a, 2008b, 2009, 2010, 2011). In this instance, each commodity was incorporated separately, in accord with the consumption pattern. For example, it was estimated that the average Australian consumes a particular amount of potatoes each year, and based on existing agricultural yield data, this quantity would require a certain amount of land to produce. Each consumption amount was also adjusted for losses in transport, retailing, processing and preparation. The land areas for each commodity were then summed in order to derive an estimate for the total area of land that each individual might require.

The five land types used in the modelling reflect land usability, inferring a hierarchy in quality. As such, cropping land, normally occurring on the better quality agricultural land, is assumed to support the production of most resources including the grazing of animals, but pasture land is assumed not suitable for cropping. This hierarchy is used in the modelling to allocate land to the most appropriate type of resource production. It also inevitably means that once all cropping land is fully allocated within a designated boundary, that carrying capacity is reached, regardless of whether there is still land of lesser quality available. In the modelling, this left-over land is referred to as excess and can be comprised of all other land types apart from cropping land. The occurrence of excess land could be viewed as one indicator of the efficiency by which the population utilises its land. This process of land allocation is the final step in Dashboard modelling prior to the generation of a population estimate.

4. Results

Each of the 17 resource-usage parameters affects the population carrying capacity to greater or lesser degrees. For instance, it was found that diet and biofuel production can impact significantly on land-usage while textile production exerts less influence. Results from existing Australian consumption and production patterns generates an Australian population capacity of just over forty million people, almost twice the current population of 22.3 million.

4.1 Australia's existing carrying capacity

The Dashboard compares the current population of each region with the estimated carrying capacity population based on the parameters chosen by the user and then gives an indication of the degree to which the region is either under or over capacity. Modelling reveals a range of carrying capacity populations between various regions and states. For instance, New South Wales is found to be the state with the largest carrying capacity at just over ten million people, with the current population representing 74% of this capacity (Table 2). The only states deemed currently over-capacity are the Northern Territory and Tasmania. While usually not considered unproductive nor highly populated, Tasmania has a high proportion of nature reserve land and a low proportion of cropping land which restricts its carrying capacity to 223 thousand people even though its current population is almost half a million.

In a state-wide comparison, total land requirements for the population also varies considerably from 2.3 hectares in Victoria to 38.5 hectares in the Northern Territory. This measure largely represents the productive nature of the landscape at this scale and those states with large areas of arid land and low agricultural yields such as South Australia, Western Australia and the Northern Territory all display an amount more than twice the national figure of 10.1 hectares.

On a regional basis, Dashboard results also reveal that the less productive areas through the centre of Australia and the highly populated areas of the eastern seaboard and the capital cities are all over capacity. The under capacity regions can generally be found in the areas with a reasonably high proportion of cropping land, particularly in the Murray-Darling Basin and south-west Western Australia.

4.2 Inter-regional carrying capacity-led migration

Given that analysis of Dashboard findings reveals that many regions are over carrying capacity, the question must be asked: To which other regions would the population from over-populated regions migrate if regional self-sufficiency required it?

Under the configuration which best reflects current consumption and production patterns, it was generally found that the eastern seaboard together with the north and central regions of Australia are currently over-capacity. Mapping indicates an assumed redistribution of these over-populated areas to under-populated regions (Figure 2) by assuming that an even redistribution occurs. Not surprisingly, the majority of emigration occurs in the capital city regions and this population is more evenly spread amongst the Murray-Darling Basin and South-west Western Australia (highlighted in blue in Figure 1).

4.3 Localised production

Using the Dashboard, it is possible to compare the carrying capacities within Australia, based on both small-scale and large-scale resource utilisation, reflecting the open trade of resources at an inter-regional and inter-continental scale.

In analysis (Table 2) which compares population carrying capacities on a state and national basis, the national carrying capacity, in this instance, is not just a sum of the state carrying capacity figures. Rather, the model treats the national land area as an entity unto itself. It is thus possible to compare this large-scale capacity with an aggregation of the state-based and regional figures. It was found that for the contemporary Australian context, the large-scale capacity is over 40 million, but as an aggregation of states, it amounts to 28 million and by region, it is only 23 million people (which is equivalent to the current population).

The reason for this discrepancy between national and small-scale resource utilisation is the efficiency of land-use in either instance. Under small-scale circumstances there is likely to be more land under-utilised as evidenced by analysis of excess pasture and non-agricultural land. For instance, national-scale analysis generates 1.8 million square kilometres of excess land while an aggregation of regional analyses generates 4.5 million square kilometres of excess land. This discrepancy occurs when the consumption pattern remains largely unchanged regardless of the region (minimal changes are made in the modelled consumption pattern across regions in order to accommodate climatic variability, such as assuming that bananas might not be produced in temperate locations). The population are thus assumed to be consuming a similar diet regardless of whether they live in a region with ample cropping land or very little cropping land. In the latter case, the carrying capacity is limited regardless of the amount of pasture land un-used. At a national scale, this pasture land may be utilised by someone in another part of the country but for small-scale boundary delineation, this is assumed to not occur. As such, large-scale resource usage is generally deemed to be more efficient in land usage than small-scale. It should be remembered, of course, that these projections assume complete self-sufficiency within the boundary under question (either national or regional) so excess land is treated as land which does not contribute to the productive nature of the region. This may not always be the case, because land excess to local requirements could, in reality, still be utilised for a population who fall outside the boundary. This dynamic merely reflects the nature of inter-regional trade and could potentially support populations beyond the carrying capacity of their local landscape. Alternatively, local populations could adjust their resource consumption habits, such as their diet, to reflect the productive nature of their local landscapes, although if this meant a dramatic increase in red meat consumption, health implications may also need to be taken into consideration. Of course, while this analysis shows that larger scales may produce higher carrying capacities than small-scales, the problem of continuing to effectively operate the long-distance trade implied by the continental scale in a fossil-fuel depleted future, needs also to be taken into consideration.

5. Discussion

The Dashboard explored propositions for the internal movement of Australia's population in order for it to reach carrying capacity at a regional scale. While the suggestion of a mass-exodus of populations from Australia's major cities may seem far-fetched, it is argued that some degree of de-centralisation of the population in the future may be necessary. Prior to the industrialised introduction of fossil fuels to agricultural practice in Europe, for example, only about half the population were able to be supported in non-agricultural activities by the farming population (Mazoyer, Roudart, & Membrez, 2006). Today, a mere five percent of the population is able to produce the food for the remaining 95 percent (Mazoyer et al., 2006). However, if fossil fuels are to be withdrawn from this agricultural system, it stands to reason that more human-powered labour will be needed in agricultural activities such as planting, harvesting and weeding. Given the central role of fossil fuels in Australian farming practices (McNamara, 2007), it is also possible that their withdrawal may precipitate a decline in agricultural yields and subsequent carrying capacity. Perhaps future regionalisation might not be as dramatic as pre-industrial levels, but nevertheless, it is likely to necessitate some movement of the population. If this migration is to occur at the geographic scales analysed in the Dashboard, the Murray-Darling Basin and South-west corner of Australia are regions most able to support increased self-reliant populations. In this case, however, it would be vital that increased population not jeopardise productivity by the building of non-productive infrastructure on good quality agricultural land.

Findings from the Dashboard suggest that in the absence of a widespread relocation of the population, regional self-sufficiency, particularly around Australia's large urban centres is problematic, if not impossible. However, complete regional self-sufficiency devoid of external trade may not be a realistic objective, nor may it deliver the greatest possible carrying capacity. A higher degree of regional self-sufficiency would offer urban populations greater accessibility to, and responsibility for their own food supply, alleviating possible interruptions to the existing elongated supply chain which could leave over-capacity regions under-resourced.

Analysis from the Dashboard highlights various dilemmas such as a potential regionalisation of the population in accord with resource constraints despite such an approach resulting in a smaller total population. In such instances, biophysical constraints should ultimately define the modelling choices as they will also dictate eventual outcomes. In this case, if a redistribution of the population was to take place, it would be important to recognise the possibility of localised excess land and adjust local consumption patterns as much as possible to suit local production potential. Likewise, such dilemmas may direct populations to aim for only partial rather than complete local self-sufficiency. Yet another factor contributing to this dilemma is the energy efficiency which centralised and regional populations may exhibit. This is a significant factor when choices of urban location are predicated on the future possibility of energy constraints. Weisz & Steinberger (2010) suggest that a correlation exists between centralised populations and energy efficiency with the main reasons relating to compact urban form and proximity to public transport. However, while these characteristics may not currently feature prominently in regional Australian urban fabric, there seems no reason why they might not be improved upon in the future.

6. Conclusion

The Carrying Capacity Dashboard allows self-sufficiency to be assessed at three geographic scales, regional, state and national levels. While the multi-generational trend has been towards larger-scaled resource utilisation, it has been proposed that in the future, smaller scales may be more appropriate. Complete regionalised self-sufficiency may not be an ultimate goal, but increasing it certainly should be, and carrying capacity assessment can help guide this transition. While carrying capacity assessment offers significant insights into sustainable land-use planning, to date, this potential has largely been underutilised despite the clear need for dramatic societal intervention. In recent decades a variety of carrying capacity assessment approaches have been tested (Lane, 2010) but generally the complex nature of modern lifestyles has complicated the process. For instance, in a globalised world, this form of resource accounting has presented methodological difficulties because resource production, consumption and waste assimilation are often spread across vastly differing demographic and geographic landscapes. In other words, international trade has warped the potential reliability of smaller-scale carrying capacity assessments. However, given compelling evidence of forthcoming resource depletion (McNamara, 2007) and the restrictions imposed by climate change (Moir & Morris, 2011), the question must be asked: Is it desirable, or even feasible, to perpetuate the existing highly energy-dependant globalised system of trade? If a less energy-intensive, more localised and reasonably self-reliant social configuration was adopted, how can practical planning methods be activated to help guide this transition? It is proposed that carrying capacity assessment conducted at appropriate scales of time and space may provide one such answer. The biophysical limits imposed on Australian and global populations have the potential to dramatically alter future generations' lifestyles. Carrying capacity assessments can help to guide a likely transition to a more regionally self-sufficient resource-base.

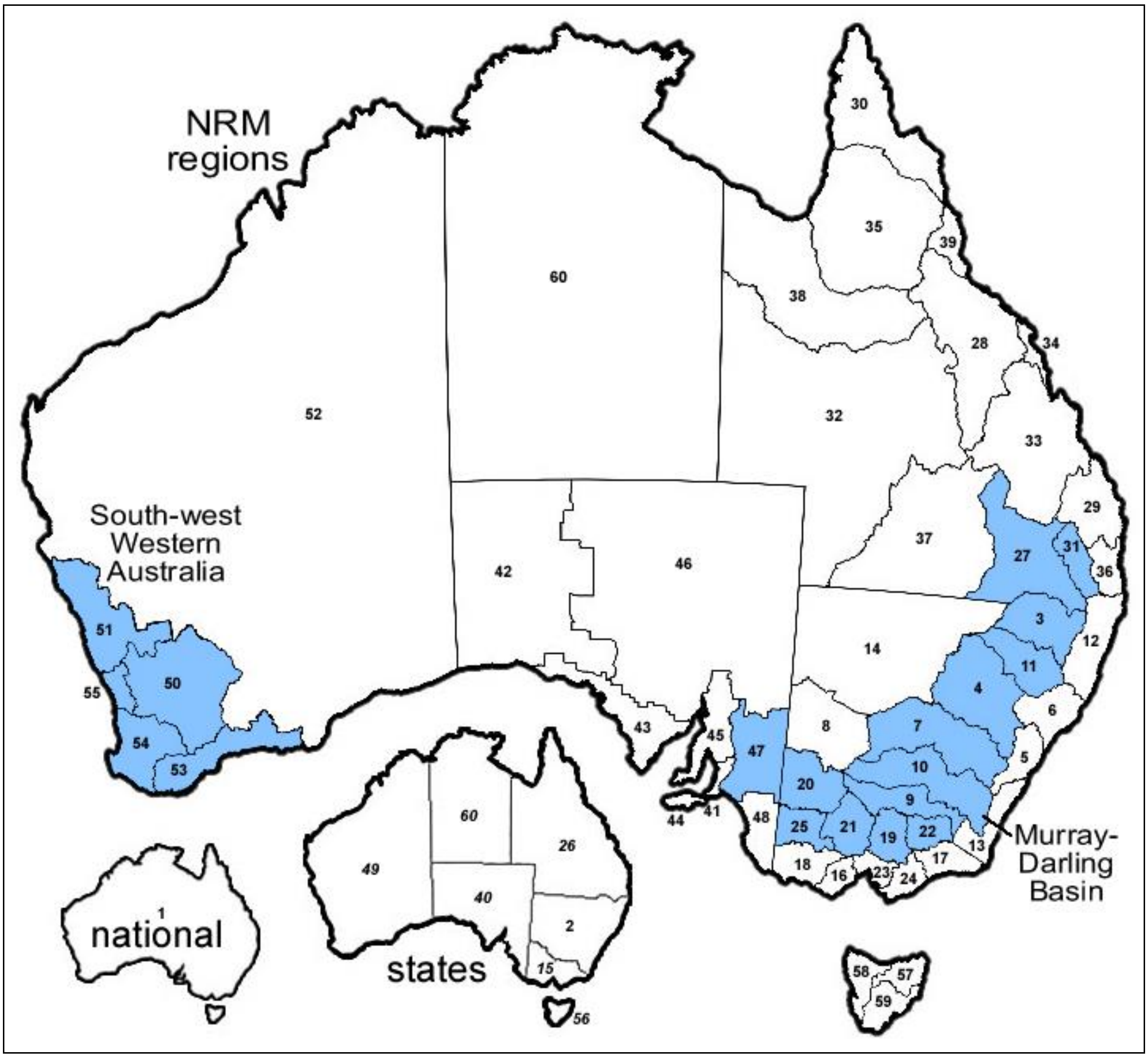

Figure 1. Map of Australia highlighting Carrying Capacity Dashboard regions (1: Australia, 2: NSW-ACT, 3: Border Rivers - Gwydir, 4: Central West NSW, 5: Hawkesbury - Nepean - Sydney, 6: Hunter - Central Rivers, 7: Lachlan, 8: Lower Murray Darling, 9: Murray, 10: Murrumbidgee - ACT, 11: Namoi, 12: Northern Rivers, 13: Southern Rivers, 14: Western NSW, 15: VIC, 16: Corangamite, 17: East Gippsland, 18: Glenelg Hopkins, 19: Goulburn Broken, 20: Mallee, 21: North Central Vic, 22: North East Vic, 23: Port Phillip and Westernport, 24: West Gippsland, 25: Wimmera, 26: QLD, 27: Border Rvs Maranoa-Balonne, 28: Burdekin, 29: Burnett Mary, 30: Cape York, 31: Condamine, 32: Desert Channels, 33: Fitzroy, 34: Mackay Whitsunday, 35: Northern Gulf, 36: South East Qld, 37: South West Qld, 38: Southern Gulf, 39: Wet

Tropics, 40: SA, 41: Adelaide - Mount Lofty Ranges, 42: Alinytjara Wilurara, 43: Eyre Peninsula, 44: Kangaroo Island, 45: Northern and Yorke, 46: SA Arid Lands, 47: SA Murray Darling Basin, 48: South East SA, 49: WA, 50: Avon, 51: Northern Agricultural, 52: Rangelands, 53: South Coast WA, 54: South West WA, 55: Swan, 56: TAS, 57: North Tasmania, 58: North West Tasmania, 59: South Tasmania, 60: NT).

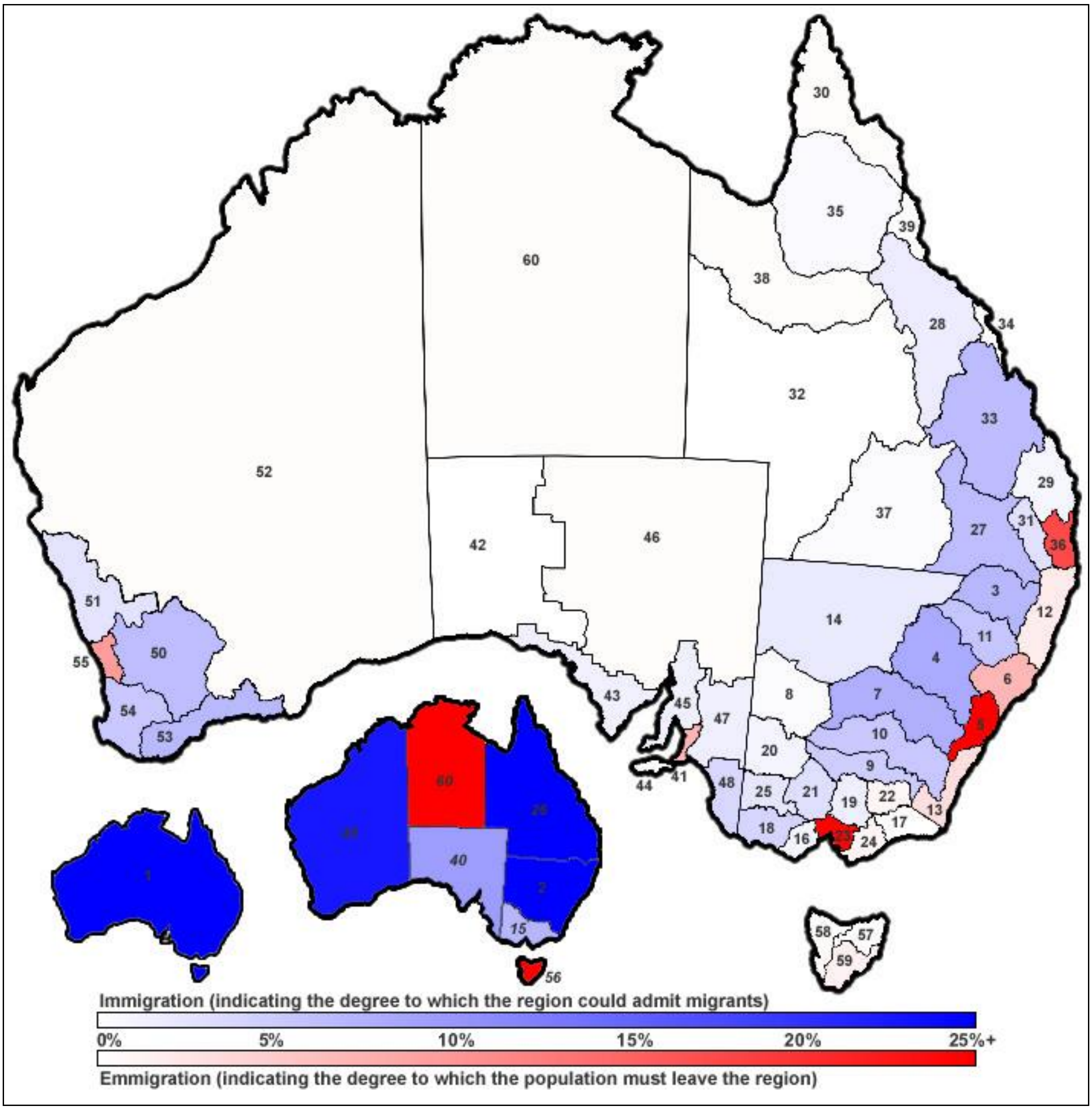

Figure 2: Amount of immigration (blue) and emigration (red) as a proportion of population movement assuming even redistribution of carrying capacity population.

Table 1. Resource-based parameters in the Carrying Capacity Dashboard modelling.

Parameter	**Description**
Climate variability	Continuous years of production in which carrying capacity is to be met
Food amount	Amount of food to be produced within the region as a percentage of the amount consumed within the region
Meat & egg	The amount of meat, eggs and dairy consumed by the population as a percentage of all food consumed
Red meat	The percentage of red meat as a proportion of all meat (red and white) consumed by the population.
Activity level	The average level of physical activity for the population. (i.e. sedentary, active, highly active).
Recycling	The average amount of recycled food wastage fed to farm animals including pigs, chickens, ducks, turkeys and farmed seafood.
Avoidable waste	The average amount of otherwise edible food that is wasted in the process of production, transportation, retailing and consumption, as a proportion of all food produced.
Organic	The percentage of organic farmland as a proportion of all farmland.
Irrigation	The percentage of irrigated farmland as a proportion of all farmland.
Liquid fuel	The amount of liquid fuel consumed by the population each year, calculated on a per person basis.
Biofuel	The percentage of biofuel consumed as a proportion of all liquid fuels.
Textiles	The amount of textiles consumed by the population each year, calculated on a per person basis.
Natural fibre	The percentage of natural fibre consumed as a proportion of all textiles.
Wool fibre	The percentage of wool fibre consumed as a proportion of all natural fibre.
Timber amount	The amount of timber consumed by the population each year, calculated on a per person basis.
Infrastructure	The amount of land required for built infrastructure for the population, calculated on a per person basis.
Nature Reserve	The percentage of protected land as a proportion of all land.

Table 2. Australian carrying capacity population nationally and state-wide. In these figures the Nature Reserve parameter has not been included in per person land requirements in order to offer figures with similar resource demands for consistent comparison.

	AUST	NSW-ACT	VIC	QLD	SA	WA	TAS	NT
Population carrying capacity	40,439,187	10,033,151	5,975,944	6,178,020	2,069,865	3,696,938	222,986	33,274
Existing population as proportion of capacity	55%	74%	91%	63%	63%	51%	213%	690%
Land required hectares / person	10.1	5.9	2.3	11.6	23.4	24.6	2.4	38.5

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