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METHODS

Regional sustainability: How useful are current tools of sustainability assessment at the regional scale?

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ABSTRACT

Sustainability assessment methods are primarily aimed at global, national or state scales. However, modelling sustainability at finer spatial scales, such as the region, is essential for understanding and achieving sustainability. Regions are emerging as an essential focus for sustainability researchers, natural resource managers and strategic planners working to develop and implement sustainability goals. This paper evaluates the effectiveness of current sustainability assessment methods – ecological footprint, wellbeing assessment, ecosystem health assessment, quality of life and natural resource availability – at the regional scale. Each of these assessment methods are tested using South East Queensland (SEQ) as a case study. It was selected because of its ecological and demographic diversity, its combination of coastal and land management issues, and its urban metropolitan and rural farm and non-farm communities. The applicability of each of these methods to regional assessment was examined using an evaluation criteria matrix, which describes the attributes of an effective method and the characteristics that make these methods useful for regional management and building community capacity to progress sustainability. We found that the methods tested failed to effectively measure progress toward sustainability at the regional scale, demonstrating the need for a new method for assessing regional sustainability.

1. Introduction

Sustainability is an essential goal for planning and natural resource management at all spatial scales, as it requires development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987 p43). Strategic planning and natural resource management are now being focused on the regional scale, which refers to the spatial scale below a state or province and usually includes two or more communities. This scale is the most appropriate for natural resource management and for progressing sustainability, because it is at this scale where ecological functioning and human activities most intensely interact (Coelho et al., 2006) and where a balance between the two is critical to studying and resolving natural resource and sustainability issues (Brunckhorst, 2000; Forman, 1995; Kim and Weaver, 1994; Norton and Ulanowicz, 1992). It is also at this scale where the most difference can be made by decision making and community choice (Clark and Dickson, 2003; Hoppe et al., 2007; Kates et al., 2001).

Regional sustainability requires the human population to live within the limits of the region's supporting systems

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(social, economic and ecosystem), ensuring equitable sharing of resources and opportunities for this and future generations in the region (Graymore, 2005). If planners and regional planning frameworks are to achieve sustainability, defined in this way, a reliable and valid method is needed to measure and monitor changes associated with sustainability strategies and policies. The methods should provide information about the interaction of ecological and human systems, including the social and economic systems, and their overall impacts on regional sustainability. As well as monitoring sustainability, these assessment methods need to provide information that can guide decision making and policy development required for community and regional governance (Hoppe et al., 2007). They should raise awareness about sustainability through social learning to increase participation and advocacy, and be useful for sustainability research and analysis (Parris and Kates, 2003).

Many methods have been developed for sustainability assessment with over 600 projects listed on the Compendium of Sustainable Development Indicator Initiatives (IISD, 2006). Although many are reported as effectively measuring sustainability at the regional or finer scales, most were generally produced for global, national and state scales and have not been tested at finer scales. Without testing, there is no way of knowing if these methods are effective in assessing sustainability at the regional scale.

Sustainability assessments range from single indicators to prescribed sets of multi-disciplinary indicators focusing on either the whole system or parts of the system, such as the economy, society or environment. Each of these approaches has advantages and limitations. For example, single indicators, such as the ecological footprint (Wackernagel et al., 1993), are able to provide information about the sustainability of part of the system, highlighting specific sustainability issues. However, this approach is piecemeal as it moves from one system part to another combining a number of 'part focused' single indicators. While holistic methods can produce more comprehensive sustainability assessments, they require large data sets that make such assessments unattractive to regional managers due to data availability and the time and costs involved in doing the assessment.

Another issue with holistic methods is the way information is brought together to provide an assessment of overall sustainability. Some authors have developed a sustainability/performance scale in an effort to standardise indicator data so that indicators can be compared. One such example is the Wellbeing Assessment (Guijt and Moiseev, 2001; Prescott-Allen, 2001). By doing this, the indicators can be aggregated to produce an overall sustainability index and sub-systems indices. Some aggregation methods attempt to take into account the interactions between the indicators and/or the difference in the impact of indicators on sustainability using indicator weightings, (e.g. the Wellbeing Assessment). These approaches reduce subjectivity in the interpretation of system sustainability and make it easier to communicate to a range of audiences. Other methods only present the trends and condition of a set of indicators without any aggregation, such as Quality of Life Assessment (e.g. Henderson et al., 2000). The user, with this strategy, is left with interpreting the combined performance of individual indicators and relating that to sustainability. This approach prevents the loss of information and false assumptions about the interactions between indicators and their impact on sustainability, but the assessment suffers from subjectivity. Thus, each approach has advantages and limitations for sustainability assessment. Therefore, the aim of this paper is to evaluate the effectiveness of these approaches at the regional scale for sustainability monitoring, regional management and raising awareness and capacity in the community around sustainability.

Five commonly used sustainability assessment methods were evaluated for their effectiveness at assessing regional sustainability. They were also evaluated in terms of their usefulness as a tool for regional managers to monitor sustainability, guide policy development and decision making, and in the wider community, to raise awareness and understanding about sustainability. Regional managers, need a method that will provide information about the region's sustainability at different levels (from indicator to overall system sustainability) so they can highlight areas where management action is needed to help produce well informed strategic planning and decision making. To raise community understanding about sustainability, the method needs to provide results that are easy to interpret and are able to show the critical link between sustainability and human activities.

This paper proceeds in four sections. Section 2 describes the five sustainability assessment methods that were evaluated. Section 3 focuses on the evaluation process, describing the case study region, SEQ, and discussing the evaluation criteria matrix and how it was applied. Section 4 presents the evaluation, highlighting the capabilities and limitations of each method as a tool for: assessing regional sustainability; guiding regional managers to help progress sustainability; and raising community awareness. Finally, Section 5 explores the implications of these results for regional sustainability assessment.

2. Sustainability assessment methods

The sustainability assessment methods chosen for analysis were those commonly found in the literature and reported to be effective at various scales, including the regional scale. Furthermore, they were methods that used relatively simple calculations without the need for specialised software or knowledge. The five sustainability assessment methods are described below.

2.1. *Ecological footprint*

This method provides a single sustainability indicator, that was developed to determine the amount of land area required to support a nation (Wackernagel et al., 1993). The approach involves estimating the area of productive land needed to supply food, forest products, housing and infrastructure and to assimilate the waste products generated by consumption, particularly carbon dioxide, and compare it to the ecologically productive land available. Thus, the ecological footprint is equal to the 'appropriated carrying capacity' of the population, or the amount of land required to support the population's activities.

The method used for the ecological footprint evaluation was described by Simpson et al. (1998). Land use was split into fossil energy use (energy land), built environment, gardens,

crop, pasture, managed forest categories. Data was collected on the consumption of these land uses in terms of food, housing, transportation, household consumer goods and government expenditure. The value for each category was the land area used for consumption, production and maintenance of the item in hectares per capita, which is summed to produce a per capita ecological footprint.

The per capita ecological footprint can be used to evaluate the sustainability of the region's consumption and waste generation. This is done by comparing the region's combined footprint to the ecological productive land available in the region to see if the population is drawing on resources from outside its boundaries, and thus, exceeding its ecological carrying capacity. This method can also be used to evaluate the population's use of Earth's ecological carrying capacity.

2.2. *Wellbeing assessment*

This method was developed by the World Conservation Union (Guijt and Moiseev, 2001; Prescott-Allen, 2001) to be used at various spatial scales. It takes a holistic systems approach to sustainability assessment using a large set of indicators to assess all parts of the systems sustainability. By using an aggregation method that utilises performance criteria to standardise each indicator's data to allow indicators to be aggregated using a weighted average, unweighted average or veto (lower score overrides a higher score) method, dependent on the indicator's relationship to sustainability. This produces an assessment or wellbeing index of both ecosystem and human sub-system health.

We used the method described by Prescott-Allen (2001), with indicators chosen by the authors to assess the sub-system dimensions: health and population; wealth; knowledge and culture; community; equity; land; water; air; biodiversity; and resource use. The performance criteria used were those developed by Prescott-Allen (2001), where applicable, or based on guidelines or targets in the literature, or on trends in the data. Using the performance criteria, a score was calculated for each indicator, which was then used to calculate a sustainability rating for each dimension, sub-system and the overall system. The sustainability ratings were then graphed to visually represent system sustainability. This is called the barometer of sustainability (see Fig. 1). The sustainability ratings and barometer of sustainability generated by this method indicate how sustainable the region is as a whole.

2.3. *Quality of life*

A 'Quality of life' assessment is based upon trends and conditions associated with indicators such as crime, participation in cultural and recreational activities, health, education, income, housing affordability, unemployment, water quality, air quality and amount of open space. These indictors are used to assess different aspects of 'quality of life' including health, population, wealth, community, knowledge, culture and recreation, equity, resource use, natural environment, transport and urban development (CCHC, 2001; City of Winnipeg, 1997; Gatt, 2001; Henderson et al., 2000; JCCI, 2001; Pierce County, 1998). Each indicator's effectiveness is assessed by measuring conditions and trends over ten year periods against a specified target. Generalisations about quality of life were then based on how many indicators either met their target or were improving. Because quality of life is an essential aspect of sustainability, it can be used to reveal information about regional sustainability.

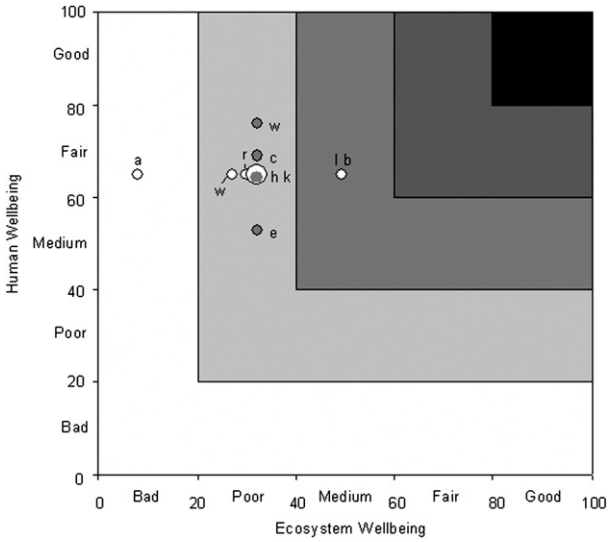

Fig. 1 – The barometer of sustainability for SEQ in 2000–01. This shows the scores for each dimension and system. The ecosystem dimensions are white dots (on the horizontal axis) a = air, w = water, r = resource use, l = land and b = biodiversity, and the human system dimensions are grey dots (on vertical axis) w = wealth, c = community, h = health and population, k = knowledge and culture and e = equity. The 'egg of wellbeing' is the ecosystem (egg white — Ecosystem Wellbeing Index) surrounding the human system (grey egg yolk — Human Well being Index). The place where these intersect is the overall Wellbeing Index. This is in the poor sustainability range for SEQ, showing that the region is almost unsustainable.

2.4. *Ecosystem health*

The approach used for ecosystem health assessment is similar to that of quality of life assessment, where conditions and trends measured by environmental indicators are used to measure ecosystem health. We followed the method used in the State of the Environment report developed by the OECD (1993). The indicators were chosen from the literature covering five environmental elements: air; land; inland water; coastal and marine systems; and ecosystem services. Each indicator was assessed based on a target, where applicable, and whether or not its condition was improving. This was used to make an assessment of the health of the region's ecosystems. Ecosystem health assessment can be used to see if a system is sustainable, as sustainability requires the human system to be within the limits of the ecosystems they live in to prevent a decline in ecosystem health.

2.5. *Natural resource availability*

The approach taken by Natural Resource Availability is a group of single indicators that measure the amount of selected

resources available in a region. By comparing resource availability and a region's consumption rates, an indication of regional sustainability is produced by determining the region's 'resource carrying capacity, that is, how many people the region's natural resources can sustainably support. For this paper, the method used was based on the resources that can be limited at a regional scale. That is, land, which cannot be imported, and water, which would incur considerable cost to import. The method followed that of Newman and colleagues (1994).

3. Evaluation method for sustainability assessment methods

Each of the above sustainability assessment methods were applied to the SEQ study region using secondary data and the methods described above (for further details see Graymore, 2005). These data were collected directly from government and non-government bodies for 2001 (or the closest available year). For the quality of life and ecosystem health assessments, data were collected for the ten-year period to 2001. Other sources of data include government reports, private consultants' reports, annual reports, books and published and unpublished research. When no data was available at the scale required for a particular indicator, data describing the next available spatial scale (part of the region, state or nation) was used to fill the gap, so the assessment could be completed. Each sustainability assessment method was evaluated using the evaluation criteria matrix described below.

3.1. *Evaluation criteria matrix*

An 'evaluation criteria matrix' was developed to objectively compare and contrast the effectiveness of each sustainability assessment method when applied at the regional scale. See Table 1. The matrix was built from literature describing the characteristics of an effective sustainability assessment, the definition of regional sustainability and the requirements of potential end uses. Its basis were the Bellagio Principles, as they provide a guideline for the whole assessment process, from choosing indicators to their interpretation and communication of results (Hardi and Zdan, 1997 p1). These principles were expanded using a range of sustainability assessment literature, including Anderson (1991), Reed et al. (2006) and Moffatt (1994). The matrix also included criteria on its usefulness for end users such as regional managers and the wider community.

The first set of criteria in the matrix (see Table 1) refers to the effectiveness of the sustainability assessment. The first test of the assessment was whether it was *really* assessing regional sustainability. Thus, Criterion 1 asks if the assessment, evaluates equity, level of human activity, the pressure being placed on the supporting systems (e.g. the ecosystems, social and economic systems) and the state of these supporting systems. Criterion 2 was based on data availability and accessibility, since data availability affects the quality of the sustainability assessment produced. Criterion 3 evaluates how easy the assessment method was to use, since ease of use should encourage uptake of the method.

The second set of criteria examines methods used by the sustainability assessments. Criterion 4 addresses the objectivity of the method(s). For instance, does the aggregation method used produce an overall sustainability score/index? Was the assessment carried out objectively, without the need of the user to make judgements about the sustainability of indicators or the region? The need to be an integrated assessment, taking into account the relationships between the indicators used and their impact on sustainability, are also criteria for evaluating each of the assessment methods. Criterion 5 evaluates the loss of important information during the aggregation process. Was the indicator, sub-system/dimension and overall system sustainability performance reported? For example, at what levels was information reported? and was all useful information included in the final results? Criterion 6 looked at the transparency of the method. How clear and well documented was the method? How logical was the aggregation method? How transparent was the way the results were determined, what were the simplifications and assumptions, and how did they impact results?

The final section of the matrix, Criterion 7 and 8, address the general usefulness of the results for communication and potential end uses. Criterion 7 evaluates how easy the results are to communicate to a range of audiences, from the wider community to managers. If results are going to be used for raising community awareness or for strategic planning, they must be easy to understand and interpret. Results also need to be produced at different levels (i.e. from indicator to whole system) appropriate for communication to a range of audiences.

Criterion 8 addresses how useful the results are for regional managers for strategic planning and management to progress sustainability and for building community capacity about sustainability. To be useful for regional managers the method must be time and data efficient. It must also be able to specify where management actions are needed and use targets or thresholds to help managers gauge how the region is performing. From the perspective of community capacity building, is the method useful and meaningful for community groups and schools, among others? Finally, can the results of the method be successfully communicated to and understood by the wider community?

The matrix in Table 1 is used to assess each method. Each criterion dot point was given a score of 1 if it met the criterion, 2 if it partially met the criterion or a 3 if it didn't meet the criterion at all. If the dot point was not applicable to the method in question it was not included in the evaluation matrix for that method. Also, the criterion and dot points were assessed in context with the aims of the method. For example, for natural resource availability, instead of asking was sustainability reported at indicator, sub-system, and overall sustainability levels for Criterion 5, the levels were indicator, local government area and region. The overall criterion score was dependent on whether all of the criterion's dot points were met. If one of the dot points was partially (or not) met, then the criterion was given a score of 2 (partially met). If the average of the dot points was closer to 3, then it was given a score of 3. Only if all the dot points were met was the criterion given a score of 1. To be judged an effective regional

Table 1 – The evaluation criteria matrix for the five sustainability assessment methods

Evaluation criteria	Ecological footprint	Wellbeing assessment	Quality of life	Ecosystem health	Natural resource availability
A. Overall effectiveness of sustainability assessment at regional scale	2	2	2	2	2
1. Assesses regional sustainability	2	2	2	2	2
•Equity intergenerational and intragenerational	2	2	2	n/a	n/a
•Level of human activity	1	2	2	2	1
•Level of pressure on supporting systems	2	2	2	2	2
•Status of supporting systems	n/a	1	2	2	2
◦Ecosystem	n/a	1	2	1	1
◦Social	n/a	1	1	n/a	n/a
◦Economic	n/a	1	2	n/a	n/a
2. Data availability and accessibility	2	2	2	2	2
•Uses existing data	2	2	2	2	2
•Data is locatable and accessible	2	2	2	2	2
•Data describes the region	2	2	2	2	2
•Data collection is cost effective (money and time)	2	3	3	3	1
•Ability to assess sustainability without all data	3	2	2	2	2
3. Assessment is easy to use	2	2	2	2	1
•No complicated calculations	2	1	1	1	1
•No specialist knowledge required (eg. matrices)	1	1	1	1	1
•No specialist software required	1	1	1	1	1
•Easy to follow method	3	1	1	1	1
•Easy to use	3	1	2	2	1
•Small indicator set (i.e. manageable data set <40 indicators)	3	3	3	3	1
•Not time intensive (i.e. less than 3 months to complete)	3	3	3	3	1
B. Method	2	2	2	2	2
4. Assesses sustainability directly	2	2	2	2	2
•Produces an overall sustainability score/index through aggregation of indicator data	1	1	n/a	n/a	2
•Aggregation method is logical	1	1	n/a	n/a	1
•Objective assessment of sustainability	1	2	2	2	2
•Integrated assessment including relationships between indicators	3	2	3	3	2
5. Information not lost during aggregation of data	2	1	n/a	n/a	2
•Indicator performance is reported	3	1			1
•Sub-system/dimension performance is reported	1	1			2
•Overall system sustainability is reported	1	1			2
6. Transparency in method used to produce results	2	1	2	2	2
•Method was clear and well documented	3	1	2	2	1
•Easy to understand how final results were derived from indicator data	3	1	1	1	1
•Simplifications and assumptions kept to minimum to reduce impact on results	3	1	1	1	2
C. Usefulness of results	2	2	2	2	2
7. Simplifies complexity of sustainability and facilitates communication to a range of audiences	2	1	2	2	2
•Easy to understand and interpret what results mean for regional sustainability	1	1	2	2	1
•Result can be described in a single page report card	1	1	2	2	1
•Able to visually represent the results	1	1	1	1	1
•Sustainability reported at a range of levels	2	1	2	2	2
◦Detailed indicator performance	3	1	1	1	1
◦Sub-system/dimension performance	1	1	1	1	2
◦Overall system sustainability	1	1	2	2	2
8. Usefulness of the sustainability assessment results	2	2	2	2	2
•Time and data efficiency of assessment	3	3	3	3	1
•For regional managers	2	1	2	2	2
◦Sustainability reported at a range of levels	1	1	2	2	2
◦Relates to policy, strategic planning, decision making	3	1	1	1	1
◦Points out where management actions are needed	3	1	1	1	1
◦Targets or thresholds to measure against	1	1	2	2	1
◦Can be used to assess trends overtime	1	1	1	1	1

Table 1 (*continued*)

Evaluation criteria	Ecological footprint	Wellbeing assessment	Quality of life	Ecosystem health	Natural resource availability
8. Usefulness of the sustainability assessment results					
•For community capacity building, social learning	2	2	2	2	2
◦Result easy to understand	1	1	2	2	1
◦Simple to use	3	1	2	2	1
◦Data accessible	3	2	2	2	2
◦Demonstrates links between sustainability and community activity	1	2	2	2	1

The scores are 1=meets criteria, 2=partially meets criteria and 3=does not meet criteria.

sustainability assessment method and a useful tool for regional managers and the community it must achieve a score of 1 for each criteria set. Each of the methods was tested using the SEQ region. SEQ's characteristics and sustainability issues are described briefly below.

3.2. *The SEQ case study region*

SEQ was chosen to test these methods because it is representative of many regions around the world, in terms of its ecological and demographic diversity, its combination of coastal and land management issues, and its urban metropolitan, rural farm and non-farm communities. The SEQ region is located in the southeast corner of Queensland (Fig. 2). It covers 2.25 million hectares and includes the state's capital, Brisbane, the tourist areas of the Gold Coast and Sunshine Coast, the Moreton Bay islands and the Moreton Bay Marine Park. It has 18 local government areas with a population of around 2.46 million people (PIFU, 2003). Eighty percent live in coastal areas, mainly in urban communities, but there is also a significant rural farm and non-farm community in the region (PIFU, 2003). For the last 50 years, it has been one of the fastest growing metropolitan regions in the developed world with an increase of around 1000 people every week (Barker et al., 1998; Minnery and Barker, 1998; PIFU, 2003; Wyeth et al., 2000). The population is expected to reach 3.71 million by 2026 (PIFU, 2003). The region's growth is significantly impacting the coastal ecosystem health as it is occurring along the coast and in areas that are easily accessible to Brisbane.

There are other land management issues related to agriculture, industry, forestry, mineral and extractive industries (BRMG and BRMBWMS, 1997; EPA, 1999) such as salinity, erosion and land use conflicts. The region's agricultural production is being impacted by the loss of good quality agricultural land to urban expansion. This is an economic issue for the sustainability of the region, since the region produces 12% of the gross value of the agricultural production in Queensland through production of sugar, dairy, beef, grain, fruit and vegetables (OESR, 2002a,b).

The land use changes in SEQ are major challenges for the region's sustainability. The region is one of the biodiversity 'hot spots' of Australia due to the unique combination of climate, landform and soil formed by overlapping tropical and temperate climates, known as the Macleay–McPherson

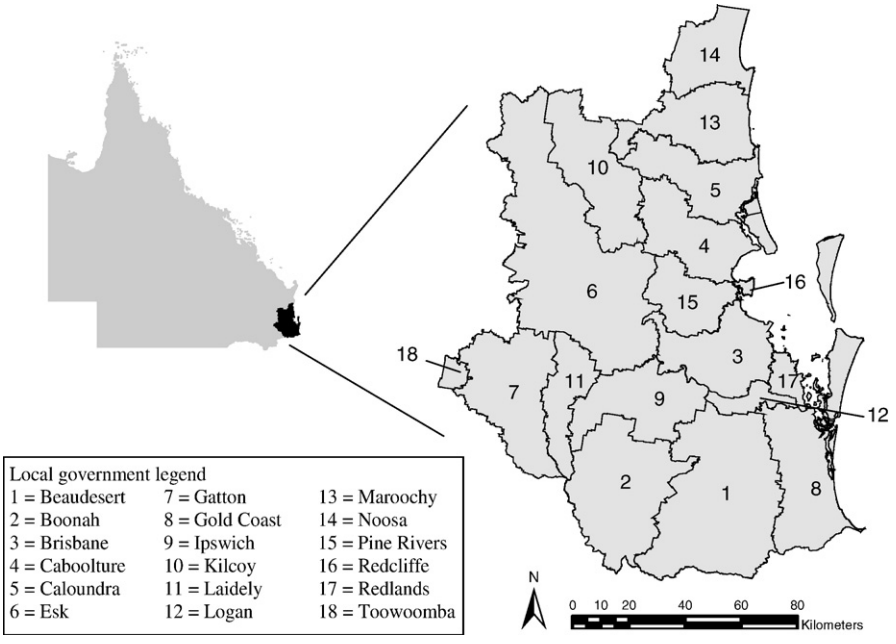

Fig. 2 – Map of SEQ's location showing the Local Government Areas, Moreton Bay islands (source: constructed by author using data from EPA (2001)).

overlap. There are a large number of endemic species, and species at either their northern or southern limits (Sattler and Williams, 1999). For these reasons, tourism is important in the region. In some of region's rural areas two thirds of businesses rely on tourism (CRA, 1999). Therefore declining ecosystem health, loss of habitat and species caused by increasing populations and land use changes are more than just environmental issues, as they are effecting tourism, which is important for the local economy.

Other sustainability issues impacting upon residents' quality of life and the region's ecosystems are water shortages and water quality issues like toxic blue-green algae (*Lyngbya majuscula*), which blooms in estuaries and along beaches. Traffic congestion, insufficient infrastructure, air quality decline and housing affordability are other key regional issues (BCC, 2001; Regional Coordination Committee, 2002; Thomas, 1997).

4. Evaluation of current sustainability assessment methods

The evaluation matrix was used to assess how each of the five sustainability assessment methods performed at the regional scale. This was able to give an objective and consistent evaluation of how effective the method was for the assessment of regional sustainability. This evaluation (see Table 1) showed that each of the methods partially met all the criteria in the matrix. The Wellbeing Assessment was the only method that fully met a number of the criteria including information not lost during aggregation, transparency in the method and simplifies the complexity of sustainability and facilitates communication. The evaluation of each method is discussed below.

4.1. *Ecological footprint*

The ecological footprint partially met each of the criteria, in terms of its ability to assess the sustainability of consumption and waste generation of a regional population. However, it insufficiently addressed the major regional sustainability issues identified in the evaluation matrix, has a limited data available for measuring sustainability at the regional scale and is difficult to use.

The ecological footprint model provides a comprehensive assessment of the amount of land required to support a population, but it fails to encompass the forms of ecosystem and natural resource use that are critical to and impact upon regional sustainability. For example, the land or water required to provide vital ecosystem services essential for human survival such as air and water purification, climate regulation, cycling of nutrients and water storage (Daily, 1997) are not included. Neither is the ecosystem area needed for waste assimilation of pollutants other than greenhouse gases and packaging waste. Thus, it fails to comprehensively assess the pressures placed on the region's supporting systems by human consumption and waste generation, even though this is the aim of the method. This means the ecological footprint is unable to fully assess regional sustainability leading to an underestimate of the amount of ecologically productive land required to fully support the human population.

Furthermore, the aggregation method used for the ecological footprint has a number of problems: it does not take into account the differences in impact of land uses; it is not transparent; and it causes the loss of important information. Thus its aggregation method and the amount and type of data required by the ecological footprint limit its suitability for application at regional levels. However, it is an effective awareness raising tool in communities as it can help people understand the links between their activities and regional sustainability.

4.2. *Wellbeing assessment*

This was the most effective method evaluated, as it fully met three of the criteria and partially met the rest. Because of its holistic assessment method, covering environmental, economic and social sustainability, including equity within the population, with indicators used tailored to the region, it is more relevant to local communities than the other methods. It is the most effective method we tested for assessing regional sustainability.

The aggregation method employed is one advantage of this method. It is transparent without the loss of information and it attempts to take into account the relationships between the indicators and sustainability. This helps to demonstrate the links between human wellbeing, ecosystem health and sustainability making it useful for communication. However, its ability to assess regional sustainability is limited by its inability to assess intergenerational equity directly. It measures equity indirectly by assessing how sustainable resource use gives an indication of future resource availability. Also, it does not completely measure all pressures on the region's supporting systems, mainly because of limited data for this type of indicator, causing it to rely on indicators that measure only the symptoms of this pressure.

While this was the most effective and useful method for regional sustainability assessment, data availability, the large indicator set (115 indicators) and the reliance on symptomatic indicators, instead of indicators measuring the level of pressure, make this method only partially effective for regional sustainability assessment. However, the framework and the aggregation method which focuses on pressure indicators could be useful components for a regional sustainability assessment model.

4.3. *Quality of life*

This method, a transparent way of assessing quality of life, illustrates trends in quality of life indicators over ten years. However it only partially met the criteria, even after taking into account the method's aim. It does not measure all aspects of regional sustainability, as it does not fully assess the level of pressure or the status of the environmental and economic systems supporting quality of life. The effectiveness of this method was also influenced by data availability because it uses 128 indicators that need at least ten years worth of data. This meant that there was a lack of time series data for many indicators; 25% of indicators relied on only one or two data points to determine trends, and over 50% had only three to five data points. Thus trend analysis for many of the indicators

was unreliable since a time series should have at least four to five data points to provide a complete picture of change (Ott and Longnecker, 2001).

The large indicator set, together with no formal method of bringing the information together in an objective and meaningful way, made it difficult to draw conclusions about overall quality of life. This introduced an element of subjectivity to the results and made it difficult to communicate to the community. Thus the quality of life assessment is only partially effective at the regional scale, principally because of the large indicator set and its inability to assess overall quality of life effectively. Furthermore, without combining it with effective measures of the 'state of the environment' pressure levels on supporting systems or expanding the indicator set further, the community's quality of life may improve at the expense of the environment or the economy.

4.4. *Ecosystem health assessment*

This method is only partially effective at the regional scale as a sustainability assessment because it does not meet all criteria sets. As an assessment of regional ecosystem health it is able to provide some important information about the state of the region's environment over a ten-year period. However, it does this by concentrating on the symptoms of ecosystem health rather than the pressures causing ecosystem health degradation. This limits the usefulness of the results for regional managers because it does not identify what is causing the problems. It also means that it is only partially assessing this aspect of regional sustainability, since it concentrates on the state and not pressure indicators. This is due, in part, by the data available, as data collections are often developed to measure the state but not the pressures. Also, time series data was often not available — with only 57% of indicators had more than five data points.

Ecosystem health assessment partially meets the criteria for usefulness for communication and potential end users. The main communication issues are the interpretation of what the results mean for overall sustainability or ecosystem health, and the ability to condense the results into a report card that is easy to understand. But with 90 indicators it becomes difficult to draw conclusions about the overall state of the ecosystem in a meaningful and easily understood way. This affects the ability to disseminate the results to the community. But without this information it is difficult for the community to understand exactly how they affect ecosystem health and regional sustainability. The typically large size of most "State of the Environment" reports produced around the world illustrates the problem. The 2003 Queensland State of the Environment report (EPA, 2003), for example, had over 200 pages.

4.5. *Natural resource availability*

With this method one can estimate the level of natural resources available to a population and the carrying capacity of the resource at a regional scale. However, by only looking at the direct consumption pressure on the resource this method is unable to take into account the pressures causing resource degradation/availability or non-consumptive resource uses, such as recreation.

Access to data was also a problem when applying this method at the regional scale. Few local government areas in SEQ had data on water use, so the rest were assumed to have the same consumption rate as the average of the known areas. Given the variation in land use across the region, this assumption would not hold true, particularly since the areas that had data were largely urban. Data were not available on future releases of land not already earmarked for future urban development or potential future water sources. Thus, assumptions were made about consumption rates and availability of the land and water to calculate the carrying capacity of the resource. Therefore the resultant carrying capacity for each resource was inaccurate, particularly at the local government level and can only be used as an indication of capacity.

Once the data were sourced the method was easy to use because few data are needed and the calculations are simple. This method is limited because it does not take into account all the pressures on the land and water supplies or the quality resources. The estimation of sustainability of resource use given by the carrying capacity calculation could be used to determine a sustainable level of consumption for a given population. But, the assumptions and uncertainties in the calculation caused by not knowing future changes in consumption and availability impact on the method's transparency. By using this method one is able to report on resource availability at the indicator level (resource available and consumption rate), the local government and the regional scale without the loss of information and, therefore partially meets the method criteria. However, the inability to cover a wide range of resources at the regional scale and the failure to take into account all pressures on the resources assessed means that it is only partially effective at the regional scale.

5. Regional sustainability assessment: lessons learned

Regional sustainability is increasingly an aim of strategic planning, particularly for natural resource management. To ensure this aim is achieved, a regional sustainability assessment method is needed to monitor: 1) progress to sustainability; and 2) the performance of regional planning. However we found that current assessment methods are partially effective, at best, in assessing regional sustainability, even though they are reported as being useful at various scales. Thus we do not have an available method that can assess regional sustainability because most existing sustainability assessment methods are based on a top-down definition of sustainability and fed by national-level data (Riley, 2001). These data are not always available at the regional scale, as they are typically aggregated at the national and/or state levels. Therefore these methods are ineffective at the regional scale because data availability prevents them from describing the regional situation.

Regional scale assessments are critical since it is at this level where the largest steps towards sustainability can be achieved, due to the fact that this is the scale where the community is more easily mobilised for collective action (Armstrong and Stratford, 2004; Fung and Wright, 2003). It is also at this scale where there is opportunity for local government: to establish a

dialogue with the community; to build trust; and to work together to progress sustainability (Smith and Scott, 2006). Therefore it is essential that there is a sustainability assessment method available to use at the regional scale for local government and regional planning and management agencies.

If a sustainability assessment method is to be useful in guiding well-informed policy development and decision-making, it must provide information about: 1) the whole system's progress to sustainability, 2) what pressures exist on supporting systems (social, economic and environmental); 3) the conditions of these supporting systems; and 4) inter- and intra-generational equity. Of the five methods evaluated, only the Wellbeing Assessment took a holistic approach assessing social, economic and environmental sustainability. Unfortunately this method was unable to fully assess pressure, required too much data, and took too long to complete to make it an effective regional tool. However, the easy calculations used to aggregate the indicators without the loss of important information makes it attractive as a template for developing a new assessment method. Because of this aggregation method, results derived can be easily communicated to a range of audiences with the appropriate level of detail.

Aggregation reduces subjectivity and increases consistency in the interpretation of what the results mean for sustainability. However, the method of aggregation has to be chosen carefully to ensure that important information is not lost in the process, as it is with the ecological footprint. Transparency in the method of aggregation is important so that people can see how the conclusions about regional sustainability were made. The method used in the Wellbeing Assessment was reasonably transparent, again supporting the use of this aggregation method.

To effectively direct sustainability policy and decision making, information is needed about trends, conditions and targets that planners and others have established. Only two methods, ecosystem health and quality of life, use trends in their assessment, but the lack of a consistent way of drawing the information together limits their usefulness. All of the other methods focus on current conditions for their assessment. To get information about trends, these methods require the assessment to be carried out over a number of years. However, methods with large indicator sets, like the barometer of sustainability, make this approach unsuitable due to the time and cost involved. Thus, methods need to be relatively simple with a small set of indicators (no more than 40) if regional sustainability trends are to be assessed.

For an assessment method to be useful for raising community awareness about sustainability, it needs to link human activity to impacts on environmental, social and economic sustainability. At the regional scale, it must do this by assessing the level of pressure human activities are having on the region's supporting systems so that the community can understand the impact they are having on the region's sustainability. The ecological footprint attempts to do this by showing how lifestyle choices, consumption and waste generation patterns are linked to the amount of land it takes to support them. However data limitations at the regional scale prevent this method from being used to assess regional communities. The regional sustainability assessment method must be developed within the limits of regional data availability.

Our analysis suggests that there are limits in using current sustainability assessment methods at the regional scale. The limitations of these methods suggest the need for a new method for assessing regional sustainability. The development of such a method has to be guided by the lessons learned here about what makes a sustainability assessment effective at the regional scale. This will make the method useful for guiding decision making and policy development to progress sustainability, and raising awareness about sustainability in the community. It must be holistic with a small set of indicators (less than 40) and relatively simple calculations so it can be easily repeated annually to establish trends. The aggregation method must make the result easy to understand and communicate to the wider community and decision makers. In addition, it must demonstrate the link between human activity and regional sustainability. This method would ideally provide: 1) a summary of the sustainability of the region using a report card with a visual representation of regional performance that could be used to raise awareness about sustainability in the community, and 2) in-depth results needed by decision makers.

6. Conclusion

Politicians, managers and decision-makers are increasingly recognizing that models of sustainability must be applied at the regional level if they are to achieve sustainability goals (Clement and Hansen, 2001; GHCMA, 2003; Kneucker, 1998; OUM, 2005; Todes, 2004). However, this is only possible if there are applied models that can be effectively, efficiently and easily applied at the regional level. To this end, we evaluated five sustainability assessment methods as tools for assessing regional sustainability. We found that none of them were completely effective at the regional scale. Data limitations played a large role in the reasons why these methods were not effective, as the data required are not often collected or aggregated at the regional scale. Also, the limitations in the ability of the methods themselves to assess sustainability in a way that is meaningful, easily understood, and useful for directing policy and decision making were shown. The method found to be most effective was the Wellbeing Assessment; however, it requires a very large indicator set making it too time and data intensive to be useful at the regional scale, particularly if trend data are required.

Thus, to achieve sustainability at the regional scale, a new method for assessing sustainability is needed. The lessons learned from this evaluation will be invaluable for the development of a regional sustainability assessment method. The development of such a method was the second part of this overall research effort and will be the subject of a subsequent paper.

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REFERENCES

Anderson, V., 1991. Alternative economic instruments. Routledge, London.
Armstrong, D., Stratford, E., 2004. Partnerships for local sustainability and local governance in a Tasmanian settlement. Local Environment 9, 541–561.
Barker, R., Ward, G., Moore, I., 1998. 1996 Census findings on interstate migration to Queensland focusing on South East Queensland. People and Place 6 (4).
BCC (Brisbane City Council), 2001. Brisbane state of the environment 2001. Brisbane City Council, Brisbane.
BRMG (Brisbane River Management Group), BRMBWMS (Brisbane River & Moreton Bay Wastewater Management Study), 1997. State of the Brisbane River, Moreton Bay & Waterways. Department of Environment, Brisbane.
Brunckhorst, D.J., 2000. Bioregional planning: resource management beyond the new millennium. Harwood Academic Publishers, Australia.
Brundtland, G.H., 1987. Our common future. Oxford University Press, New York.
CCHC (Colorado Center for Healthy Communities), 2001. The Colorado index. Colorado Center for Health Communities, Carbondale.
City of Winnipeg, 1997. City of Winnipeg quality of life indicators. IISD, Winnipeg.
Clark, W.C., Dickson, N.M., 2003. Sustainability science: the emerging research program. Proceedings of the National Academy of Science 100 (14), 8059–8061.
Clement, K., Hansen, M., 2001. Sustainable regional development in the Nordic countries Nordregio Report 8 Nordregio, Stockholm.
Coelho, P., Mascarenhas, A., Vaz, P., Beja, I., Dores, A., Ramos, T.B., 2006. A methodological framework for indicators of sustainable development at the regional scale: the case of a Portuguese region (Algarve). Proceedings of 12th Annual International Sustainable Development Research Conference 2006, Hong Kong.
CRA, 1999. South East Queensland comprehensive regional assessment. Commonwealth of Australia & Queensland Regional Forest Agreement Steering Committee, Brisbane.
Daily, G.C. (Ed.), 1997. Nature's services: societal dependence on natural ecosystems. Island Press, Washington, D.C.
EPA, 1999. State of the environment Queensland 1999. Queensland Environmental Protection Agency, Brisbane.
EPA, 2001. Regional environmental planning mapping and analysis tool. Version 1. Queensland Environmental Protection Agency, Brisbane.
EPA, 2003. State of the environment Queensland 2003. Environmental Protection Agency, Brisbane.
Forman, R.T.T., 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge.
Fung, A., Wright, E.O. (Eds.), 2003. Deepening democracy: institutional innovations in empowered participatory governance. Verso, London.
Gatt, L., 2001. Quality of life in New Zealand's six largest cities. Auckland City Council, Christchurch City Council, Manukau City Council, North Shore City Council, Waitakere City Council, Wellington City Council, Auckland.
GHCMA (Glenelg Hopkins Management Authority), 2003. Regional Catchment Strategy 2003–2007. Glenelg Hopkins Catchment Management Authority, Hamilton.
Graymore, M., 2005. The journey to sustainability: small regions, sustainable carrying capacity and sustainability assessment methods. Doctor of Philosophy. Australian School of Environmental Studies, Griffith University, Brisbane.
Guijt, I., Moiseev, A., 2001. Resource kit for sustainability assessment: part A. IUCN, Gland. Switzerland and Cambridge, UK.
Hardi, P., Zdan, T., 1997. Assessing sustainable development: principles in practice. International Institute for Sustainable Development, Winnipeg.
Henderson, H., Lickerman, J., Flynn, P. (Eds.), 2000. Calvert-Henderson quality of life indicators: a tool for assessing national trends. Calvert Group, Bethesda.
Hoppe, P., Rickson, R.E., Burch, D., 2007. Governing rural landscapes and environments: the strategic role of local community and global corporate partnerships. In: Cheshire, L., Higgins, V., Lawrence, G. (Eds.), International perspectives on rural governance: new power relations in rural economies and societies. Routledge, London.
IISD, 2006. Compendium of sustainable development indicator initiatives. International Institute of Sustainable Development. Accessed 21/08/06. http://www.iisd.org/measure/compendium/.
JCCI (Jacksonville Community Council Inc.), 2001. Quality of life in Jacksonville: indicators for progress. City of Jacksonville, Jacksonville.
Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G., Grubler, A., Huntley, B., Jager, J., Jodha, N.S., Kasperson, R., Mabogunje, A., Matson, P.A., Mooney, H.A., Moore III, B., O'Riordan, T., Svedin, U., 2001. Sustainability science. Science 292, 641–642.
Kim, K.C., Weaver, R.D. (Eds.), 1994. Biodiversity and landscapes: a paradox of humanity. Cambridge University Press, New York.
Kneucker, R., 1998. Introduction. In: Gabriel, I., Narodaslawsky, M. (Eds.), Proceedings of Regions — cornerstones for Sustainable Development Conference proceedings, Graz, Austria, October 28–30, 1998.
Minnery, J., Barker, R., 1998. The more things change. Brisbane and the South East Queensland. Urban Policy and Research 16 (2), 147–152.
Moffatt, I., 1994. On measuring sustainable development indicators. International Journal of Sustainable Development and World Ecology 1, 97–109.
Newman, P., Bathgate, C., Bell, K., Dawson, M., Hudson, K., Lehman, J., Mason, S., Myhill, P., McEnaney, L., McCreddin, C., Pidgeon, C., Pratt, C., Ringrose, C., Ringvall, K., Sargent, M., 1994. Australia's population carrying capacity: an analysis of eight natural resources. Institute for Science and Technology Policy, Murdoch University, Perth.
Norton, B.G., Ulanowicz, R.E., 1992. Scale and biodiversity policy: a hierarchical approach. Ambio 21 (3), 244–249.
OECD, 1993. OECD core set of indicators for environmental performance reviews. A synthesis report by the group on the state of the environment. OECD, Paris.
OESR, 2002a. Queensland regional profiles June 2002: Brisbane and Moreton statistical divisions. Office of Economic and Statistical Research, Queensland Treasury, Brisbane.
OESR, 2002b. Queensland regional profiles June 2002: Darling Downs statistical division. Office of Economic and Statistical Research, Queensland Treasury, Brisbane.
Ott, R.L., Longnecker, M., 2001. An introduction to statistical methods and data analysis. Duxbury Press, Pacific Grove, USA.
OUM (Office of Urban Management), 2005. South East Queensland Regional Plan 2005–2026. Queensland Government, Department of Local Government, Planning, Sport and Recreation, Brisbane.
Parris, T.M., Kates, R.W., 2003. Characterizing and measuring sustainable development. Annual Review of Environment and Resources 28, 559–586.

Pierce County, 1998. Pierce County quality of life benchmarks annual report 3rd edition. Department of Community Services, Pierce County.
PIFU, 2003. Queensland's future population 2003 edition Department of Local Government and Planning, Brisbane.
Prescott-Allen, R., 2001. The wellbeing of nations: a country-by-country index of quality of life and the environment. Island Press, Washington.
Reed, M.S., Fraser, E.D.G., Dougill, A.J., 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. Ecological Economics 59 (4), 406–418.
Regional Coordination Committee, 2002. South East Queensland performance monitoring report 2001. Information Paper No. 1. Queensland Department of Local Government & Planning, Brisbane.
Riley, J., 2001. Multidisciplinary indicators of impact and change: key issues for identification and summary. Agriculture, Ecosystems & Environment 87 (2), 245–259.
Sattler, P.S., Williams, R.D. (Eds.), 1999. The conservation status of Queensland's bioregional ecosystems. Environmental Protection Agency, Brisbane.
Simpson, R., Petroeschevsky, A., Lowe, I., 1998. The ecological footprint of Australia, with a focus on the South-East Queensland region. Griffith University, Brisbane.
Smith, G., Scott, J., 2006. Living cities: An urban myth? Government and sustainability in Australia. Rosenberg Publishing, Kenthurst, New South Wales, Australia.
Thomas, E. (Ed.), 1997. Gold Coast City Council: State of the environment. Gold Coast City Council, Gold Coast.
Todes, A., 2004. Regional planning and sustainability: limits and potentials of South Africa's integrated development plans. Journal of Environmental Planning and Management 47 (6), 843–861.
Wackernagel, M., McIntosh, J., Rees, W.E., Woodland, R., 1993. How big is our ecological footprint? A handbook for estimating a community's appropriated carrying capacity. (Discussion draft) for the Task Force on Planning Healthy and Sustainable Communities.
Wyeth, E., Minnery, J., Preston, A., 2000. Application of quality management criteria to regional growth management: lessons from South East Queensland. Cities 17 (2), 111–121.