Australasian Journal of Environmental Management

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tjem20

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Published online: 02 May 2013.

To cite this article: S. Larson, N. Stoeckl & B. Blanco-Martin (2013): On the use of socioeconomic typologies for improved integrated management of data-poor regions: explorations from the Australian north, Australasian Journal of Environmental Management, DOI:10.1080/14486563.2012.763145

To link to this article: http://dx.doi.org/10.1080/14486563.2012.763145

Australasian Journal of Environmental Management, 2013
http://dx.doi.org/10.1080/14486563.2012.763145

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On the use of socioeconomic typologies for improved integrated management of data-poor regions: explorations from the Australian north

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Managers operating in data-poor environments are often required to use data from one region to draw inferences about another. The quality of decisions made using this 'typology' approach will depend, at least in part, upon the degree of similarity between the two regions. Using data from a variety of sources relating to several different domains in 55 separate catchments in northern Australia, this paper uses statistical clustering techniques to test if it is possible to identify socioeconomically 'similar' catchments. It finds that regions which are socio-economically 'similar' are not always adjacent, and that assessment of 'similarity' depends upon the type of data used. Evidently, the typology approach offers itself as a useful framework for management, but still requires reliable baseline data with which to construct the typologies.

Keywords: cluster analyses; data gaps; integrated catchment management; social impact assessment; multidimensional scaling

Introduction

Agencies and organisations dealing with the management of natural resources are facing increased pressure to consider the social dimensions of resource management (see Higgins & Lockie 2002; Stanley et al. 2004; Nelson et al. 2006). As a result, ecological, economic and social data are more frequently being included in the assessment and monitoring of resource status (Berkes et al. 2002; Millennium Ecosystem Assessment 2003), and the methodological approaches that integrate social, economic and ecological concerns on an equal footing, and promote sustainable development, are gaining in popularity (Larson 2009).

However, the financial and human resources required for assessment and management are limited. Furthermore, relevant socioeconomic datasets available for analyses are often limited in quantity, quality and relevance, thus impairing the ability of decision makers to design appropriate policy and achieve management outcomes (Fenton 2008). This is particularly so in developing countries (Larson & Larson 2007), but also in some remote and peripheral regions of the developed world (Stafford Smith 2008).

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The key questions, then, for decision makers in such situations are: 'Can we learn from other similar regions to inform the decision making in our region?'; and 'Can we still reach meaningful conclusions with the socioeconomic data we have?'.

Benefit transfer method is one example of a technique used for the extrapolation of economic data. Although the approach can be used in various policy-making processes, it has been most extensively used and tested in the estimation of the perceived benefits provided by the natural environment (Bateman et al. 2000). The method allows for the transfer of existing estimates of non-market values to new contexts (Boyle & Bergstrom 1992). However, the assumption of transferability in methods such as benefit transfer might not hold in practice due to, amongst other things, differences in the socioeconomic characteristics of the relevant populations, physical characteristics of the study and policy site, differences in the proposed change and market conditions applying to the sites (Bateman et al. 2000). Thus, for this and other data extrapolation methods to be valid, the transfer should occur across regions that are 'similar' (TEEB 2009).

The 'typologies' approach is one method that allows for identification and classification based on common characteristics. This approach has generated significant interest in Australia in recent years (Holmes 1996; Baum et al. 2007; Maru & Chewings 2008), in particular in the areas of decision-making and policy support (Vanclay 2005; Porter et al. 2007), natural resources management (Emtage et al. 2006; Robins & Dovers 2007), and land management and landholder participation (Morrison et al. 2008; Emtage & Herbohn 2012). The approach proposes that, if we can develop a limited set of 'typologies' (groups of people or geographic areas that share similar characteristics), we could explore how certain perturbances or impacts will propagate through the system in a way that is more targeted than a 'one size fits all' approach and more cost-effective than an approach that requires detailed data on individuals or individual regions. Typologies help us to better understand key factors and interactions between key factors that influence the character of a region, and thus potentially allow for the extrapolation of data from an existing context to new but socioeconomically similar contexts. Nonetheless, such an approach might be rather precarious, as use of incomplete or inappropriate data might lead to the development of 'wrong' typologies, which in turn might lead to misguided decisions. It is, therefore, essential to check the efficacy of typologies before using them to justify transfer approaches.

In this article we explore the relevance of a typologies approach in improving our understanding of regions for which there is limited socioeconomic data. We also explore variables that are key to determining classifications, and the significance of existing data gaps.

Our explorations are set in relatively data-poor regions in the Australian north and include data from 55 river catchments. The next part of this article describes the study area in more detail. The conceptual model used for the socioeconomic profiling, types of data that should be included in assessments for well-informed decision-making, and the significant data problems that eventuated in our study region are then discussed. The results section presents typologies of the catchments in the north, and tests for robustness by conducting statistical analyses on different groups of data using different statistical approaches. The implications of our findings for natural resource and catchment assessment, planning and management are discussed in the concluding section of the article.

Overview of the study region

The Tropical Rivers (TR) region of northern Australia (Figure 1) includes all river catchments that drain into the Timor Sea or the Gulf of Carpentaria. Stretching from Broome in western Australia to Cape York in Queensland, the region includes 55 river catchments and covers an area of more than 1.3 million km^2.

The hydrology of the rivers of the TR region is determined by a short and distinct wet season, followed by a longer dry season. Consequently, there are vast differences between outflow volumes in the wet and the dry seasons. Indeed, these river systems are amongst the most flow-variable in the world (Kennard et al. 2010).

Another extreme climatic characteristic of northern Australia is that of high temperatures coupled with high humidity. Such extreme climatic conditions are not only unpleasant for humans, but are also reported in the literature as one of the causes of animal stress leading to low livestock productivity (Moran 2009) and low reproduction rates (Turner 1982).

Given the biophysical conditions of the TR region it is not, perhaps, surprising to find that it is home to less than 3 per cent of Australia's population, a quarter of whom are Indigenous – despite the fact that it accounts for more than 25 per cent of the continent's landmass (Carson et al. 2009). There are only three settlements across this vast area with more than 10,000 inhabitants: Darwin, with more than 100,000; Mount Isa with around 21,000; and Broome, with approximately 15,000. Across the bulk of the region, population density is less than one person per km^2 (Stoeckl & Stanley 2007).

Methods

Conceptual framework: the 'wish list'

The conceptual framework developed for this study was grounded in social impact assessment theory and methodologies (Vanclay 2003). A review of the social impact assessment literature identified several domains common to most investigations, including those covering variables related to demographics, economy and livelihoods, infrastructure and services, and institutional arrangements and social capital.

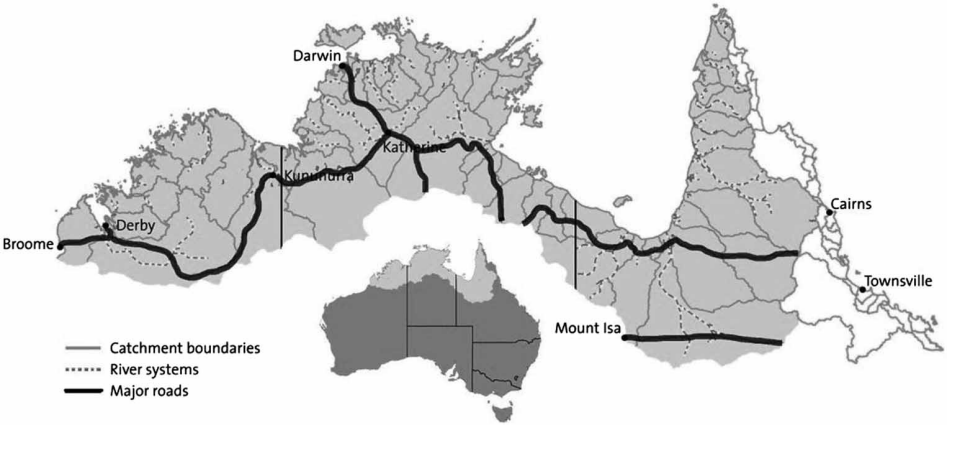

Figure 1. The Tropical Rivers region. Source: Land and Water Australia 2005.

Considerations of individual wellbeing, perceptions and values of stakeholders, land use and environmental risks, and cultural considerations, were also included in some but not all of the frameworks.

Conceptual models developed for similar purposes in other research areas, such as adaptive capacity (Lemos 2007; Bohensky et al. 2010), social resilience (Cuthill et al. 2008; Gooch & Warburton 2009), or institutional analysis (Ostrom 2007) also include domains contextually similar to those presented in Table 1. Most of these frameworks stem from the economic 'five capitals' production model, which distinguishes between human, social, financial, produced and natural capital (Ellis 2000; Porritt 2007); however, concerns specifically related to perceptions of the system by stakeholders are increasingly considered (see, for example, Taylor et al. 2004; IFC 2003; Inter-organisational Committee on Principles and Guidelines for Social Impact Assessment 2003).

Based on this review, a conceptual framework for profiling of tropical rivers was developed. This included eight commonly identified domains: demography; economy and livelihoods; infrastructure and services; institutional arrangements and social capital; individual wellbeing; perceptions and values; land use and environmental risks; and Indigenous and cultural considerations. Each domain was then populated with a list of relevant variables, thus creating a 'wish list' of data to be included for each catchment.

Secondary data collection and identification of data gaps: the 'reality'

The main source of data was the Australian Bureau of Statistics 2006 census; however, several other data sources were also included: the Australian Community Guide 2006; Bureau of Rural Sciences ACLUMP 2006; Australian Schools Directory 2008; Health Wiz 7.3; ICOLD dam register; Australian Natural Resources Atlas; Department of the Environment, Water, Heritage and the Arts data; and specific data from relevant state and territory departments and agencies, as available (see Larson & Alexandridis 2009 for details). The data were organised geographically into relevant catchments, and variables were spatially linked to geographic information system (GIS) maps.

A comparison of the 'wish list' of variables developed at the start of this project and the variables that we were able to populate with the secondary data we managed to source, revealed some important concerns about data availability and reliability, including:

- data not available at all (for example, data relating to the mining industry – from water use by industry, to economic parameters, to pollution – was patchy at best and not available at all in most cases);
- data available but potentially unreliable (e.g. some of the census data on Indigenous communities; see also Herr 2007);
- data available but dated (e.g. most data on the health status of individuals had been collected up to a dozen years ago);
- data available in some catchments but unavailable in a comparative form across the whole region (for instance, data on perceptions and values were available for a few individual catchments [work on Indigenous values and

Table 1. A comparison of domains of interest in social impact assessment literature

Meta theme (domain)	Olsen & Mervin 1977	Taylor et al. 2004	Burdge 2004	Vanclay 2003 (for IAIA)	Inter-organisational Committee on Principles and Guidelines for Social Impact Assessment 2003	IFC 2003	Stanley et al. 2004 (Queensland state guidelines)
Demography	Demography	Demography	Population impacts		Population change	Demographic profiles History and distribution of population	Demographics Population movement Household characteristics
Economy and livelihoods	Economy	Economy	Economies of communities in transition			Economic environment Livelihood systems Household incomes	Regional economic production External linkages Income Employment
Infrastructure and services	Public services	Health	Community infrastructure needs		Political and social resources Infrastructure needs	Access to services	Natural and physical infrastructure Social infrastructure Housing

Institutional arrangements and social capital	Social structures Collective responses Social wellbeing	Social organisation	Community and institutional arrangements	Political systems Personal and property rights Community (cohesion, character)	Political and social resources Community and institutional structures and resources	Social organisations at communal level Vulnerable groups	Social capital Social fragmentation
Individual wellbeing Perceptions and values		Lifestyle Health Attitudes, beliefs and values	Individual and family impacts	Way of life Health Fears and aspirations	Individual and family changes Identity and attitudes toward resource	Quality of life Health Perceptions (of opportunities and impacts)	
Land use and environmental risks		Land use		Pollution Waste disposal Risks		Land use Resources condition	Land tenure NRM data
Indigenous and cultural considerations				Culture	Native peoples' responsibilities	Cultural properties Archaeological sites	Indigenous Cultural diversity

perceptions by Strang 2005; Jackson 2006], but no comprehensive data existed that would allow for a cross-catchment comparison).

As a result, the initially-developed conceptual framework had to be reconsidered. The resulting five domains, containing key variables that could be populated by data available and thus included in the analysis, are presented in Table 2.

Data gaps identified during this research are in line with previous work from Nelson and colleagues (2006), who described existing data collection systems in Australia as fragmented across institutions, disciplinary perspectives and scales. They also identified the need and the significant opportunities for greater collaboration and integration. Indeed, the Land and Water Australia Resource Audit found that many of the socioeconomic indicators for the north cannot be completed as the data collections listed in protocols are either incomplete or do no yet exist (Australian Government 2008).

Data analyses

Similarities among catchments were investigated using hierarchical clustering. Catchments were clustered based on the quantitative catchment descriptor variables presented in Table 2 using three agglomeration methods: average; complete; and Ward. In all cases Euclidian distance was used as a measure of dissimilarity, and statistical support for the clusters was computed via multiscale bootstrap resampling (Shimodaira 2004).

To assess the descriptor variables that primarily determined the cluster typology of the catchments, heat maps were built. The hierarchical clustering methods described above were used for one axis, while for the other the descriptor variables were clustered using a distance metric derived from the Spearman's rank correlation coefficients between variables. Additionally, principal component analysis and non-metric multidimensional scaling were used to further explore the importance of the cluster descriptor variables by examining the loadings of the major components. Hierarchical clustering was also conducted on the first 14 principal components; these eigenvalues were greater than one and explained about 84 per cent of the total variance in the dataset.

All of the clustering methods that were tested yielded similar results, and thus only the results obtained from the hierarchical clustering using the Ward's agglomeration method are presented in this article.

Results

Typologies of catchments in the Tropical Region

This section presents results of the cluster analyses based on a combined set of variables from all five domains explored (as per Table 2): demography; economy and livelihoods; infrastructure, services and housing; individual wellbeing and social capital; and environment, land use and heritage. Several strongly supported clusters ($p > 90\%$) emerged. Table 3 shows these results, listing variables determining cluster membership, revealed by the heat maps.

Table 2. Socioeconomic variables included in catchment profiling

Domain	Subdomain	Variables
A: Demography	People	Total population
		Aboriginal people
		Torres Strait Island people
		Median age of population
	Mobility	Lived at different address five years ago
		Change in % Indigenous population
		Change in % non-Indigenous population
B: Economy and livelihoods	Employment	Unemployment rate
		Median income per person
	Sectors of economy	Employment in:
		- agriculture, forestry and fishing
		- mining
		- manufacturing
		- utilities (electricity, gas and water)
		- construction
		- government services (education, health and public service)
	Service oriented and mining businesses	Numbers of mines
		Resource extraction
		Numbers of service-oriented businesses
	Remoteness	ARIA remoteness index
C: Infrastructure, services and housing	Transport	Airports
	Educational facilities	Schools
	Housing infrastructure	Homes with no internet connection
		Number of persons in the household (HH)/per bedroom
		Homes fully owned
		Homes being purchased
		Homes rented commercially
		Homes rented from community organisation
		Homes with no motor vehicles
D: Individual wellbeing and social capital	Community organisations	Number of community organisations registered
	Social cohesion	% volunteering
	Families and households	Income per family
		Medium HH mortgage loan
		Medium HH rent
		Average HH size
		One parent families
		Married people
		Families with no children
		Families with more than three children

Table 2 (*Continued*)

Domain	Subdomain	Variables
	Educational status	Degree
		Year 10 or less
		No schooling
	Religion	No religious affiliation
	Cultural background	English only spoken at home
		Born in Australia
E: Environment, land use and heritage	Water as a resource	Outflow
	Environmental risks	Probability of cyclone
	Heritage sites	Historic sites
		Indigenous sites
		Natural significance
	Land use	Land in natural condition
		Land under conservation
		Indigenous use
		Production from unchanged land (grazing)
		Dryland agriculture
		Irrigated land
		Intensive use (urban, mining, industrial)

The key variables determining the cluster membership identified in this analysis came from all five domains explored. Hence, to test the sensitivity of the results to the data included in the analyses, the analyses were repeated with the data for each domain only. The results of these explorations are presented in the next section.

Sensitivity to data used in the analyses

The second research question that was explored relates to the significance of data gaps as they are typically encountered in more remote regions. Comparison of catchment clusters obtained using different subsets of data available explored the role that the presence/absence of data plays in the determination of different 'types' of catchments. Results of the cluster analyses based on a combined set of variables, as described in the previous section, were compared to the results of the cluster analyses performed using data for each specific socioeconomic domain only: demography (A); economy and livelihoods (B); infrastructure, services and housing (C); individual wellbeing and social capital (D); or environment, land use and heritage (E).

A schematic of this comparison is presented in Figure 2, and for the purpose of clarity contains a representative subset of catchments explored only. The thick line in Figure 2 indicates the first split of catchments (into two main clusters), while the thin lines indicate subsequent lower-level cluster memberships.

It could be concluded from the results that for a majority of catchments (e.g. Finiss, Fitzmaurice, Moyle) their clustering membership at the first level of division is consistent for all types of data used for comparison. However, some of the catchments changed their cluster membership even at the first level of division (e.g.

Table 3. Main clusters of catchments in Tropical Rivers region with similar socioeconomic characteristics

		Key variables determining similarities		
Clusters of catchments		High	Medium	Low
	Finniss/ Elisabeth/ Howard (Darwin area)	Population Number of businesses and community organisations % employed in manufacturing, construction and utilities % land under dryland agriculture Number of registered heritage sites		% homes with no vehicles or no internet connection % of people with no schooling Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families % population who are Indigenous
*	Flinders/ Mitchell	Number of businesses and community organisations % of land under 'natural production' (cattle grazing) % of people employed in mining industry Number of mining reserves and number of mining sites Number of registered heritage sites	% of residents who speak English only	% homes with no vehicles or no internet connection % of people with no schooling Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families. % population who are Indigenous
**	Settlement Creek/(Qld) Staaten/Keep (WA)/Gilbert/ Holroyd/ Norman	% of land under 'natural production' (cattle grazing) % of people employed in agriculture Population mobility % of people owning their own homes	% of residents who speak English only	% homes with no vehicles or no internet connection % of people with no schooling Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families % population who are Indigenous

Table 3 (*Continued*)

Clusters of catchments		Key variables determining similarities		
		High	Medium	Low
* #	Fitzroy/Cape Leveque Coast/ Ord (WA)/Daly	Population mobility Number of registered heritage sites River outflows	% people employed in construction and utilities % of people owning their own homes	% homes with no vehicles or no internet connection % of people with no schooling. Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families % population who are Indigenous
#	Embley/ Leichardt	Population mobility % of people employed in mining industry Number of mining reserves and number of mining sites Number of registered heritage sites River outflows	% people employed in construction % of people owning their own homes	% homes with no vehicles or no internet connection % of people with no schooling. Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families % population who are Indigenous
**	East Alligator/ Roper/Victoria/ Keep (NT)/Ord (NT)/ McArthur/ Robinson	% of land under 'natural production' (cattle grazing) Number of registered heritage sites % of people employed in government % of people with no schooling % people renting their own home % of women with three children or more and the % of one parent families	% homes with no vehicles or no internet connection Household sizes and numbers of people per bedroom % population who are Indigenous	% land under Indigenous traditional use

Table 3 (*Continued*)

Clusters of catchments		Key variables determining similarities		
		High	Medium	Low
*	Jardine/King Edward/ Coleman/ Bathurst and Malville Islands/ Watson	% population employed in government % population with no schooling % people renting their own home	% homes with no vehicles or no internet connection Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families **Medium to high** % population who are Indigenous	Population mobility Incomes % population employed in agriculture, manufacturing or mining % population who own their own homes % land under Indigenous traditional use
	Fitzmaurice/ Goomadeer/ Koolatong/ Goyder/ Liverpool/ Moyle/Blyth/ Walker	% people renting their own home % population with more than 10 years of schooling Household sizes and numbers of people per bedroom % of women with three children or more and the % of one parent families. % land under Indigenous traditional use	% homes with no vehicles or no internet connection **Medium to high** % population who are Indigenous	Population mobility Incomes % population employed in agriculture, manufacturing or mining % population who own their own homes % of people who speak only English

Notes: $^{**}P > 95\%$, $^{*}P > 90\%$ computed via multiscale bootstrapping resampling; # in the multidimensional scaling analyses, those two clusters appeared more disperse than other clusters.

Coleman, Victoria, Embley), thus indicating that for such catchments it is vitally important to understand the types of variables that drive their similarities and differences, and, consequently, determine their cluster memberships.

Membership of clusters at finer levels of resolution (5–8 clusters, thin lines in Figure 2) changed considerably for the majority of catchments, depending on the type of data used for analysis.

Discussion and policy implications

Biophysical, human, social, institutional and cultural differences play a large role in determining both the opportunities for development as well as capacities of the communities to identify and capitalise on opportunities. Yet managers are often asked to develop policies and/or make decisions without having access to information

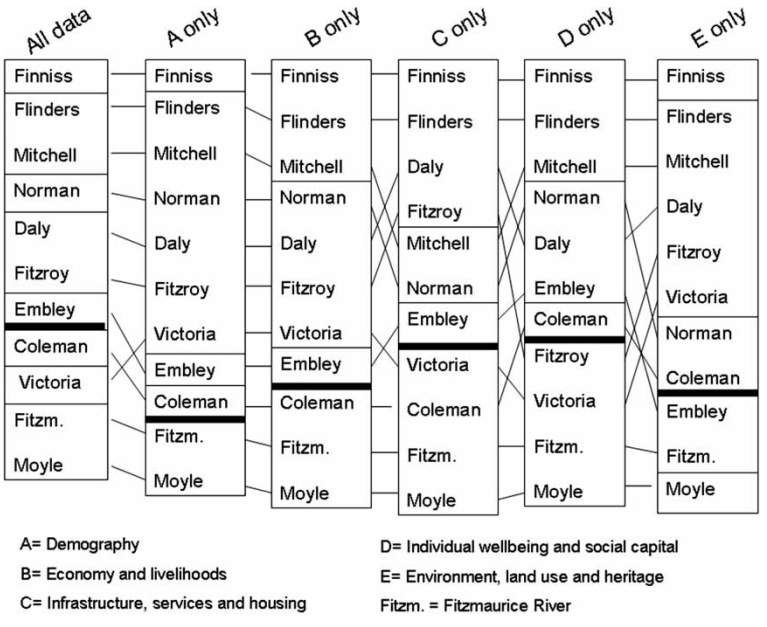

Figure 2. Comparison of cluster memberships of selected number of catchments, based on data domain used for clustering. Thick line indicates first split into two main clusters; thin lines indicate subsequent cluster memberships.

about these key variables. The 'typologies' approach offers itself as one, potentially cost-effective means of dealing with this problem, and it is on the issue of regional 'typologies' that this article is focused.

We found that expansive dryland agriculture and high rates of home ownership were identifiable characteristics of one 'cluster' of catchments (containing Settlement Creek and Staaten, Keep, Gilbert and Holroyd rivers). Two other clusters were characterised by the fact that they had a high percentage of persons employed in mining and a large number of mining sites present (these catchments included the Flinders and Mitchell rivers; and Embley and Leichardt rivers). Socioeconomic disadvantage (e.g. having a high percentage of one parent families, or large number of residents renting their homes, having low or no schooling, and receiving government support as their main source of income) was a core characteristic of other clusters including rivers such as Fitzmaurice, Goomadeer, Koolatong, Goyder and Moyle.

Our analysis thus suggests that it is possible to identify factors that characterise groups of catchments in Australia's north, implying that learnings and data from one catchment might be validly used to inform decision-making in other similar regions. Moreover, the defining characteristics of clusters could potentially be used to identify opportunities for development, and to provide specific themes for discussing capacities of the resident communities to capitalise on opportunities. Evidently, management approaches which work effectively in some catchments might also work in others, indicating that the 'typologies' approach has the potential to provide an improved understanding and management of natural resources issues in other rural and remote regions of Australia and internationally.

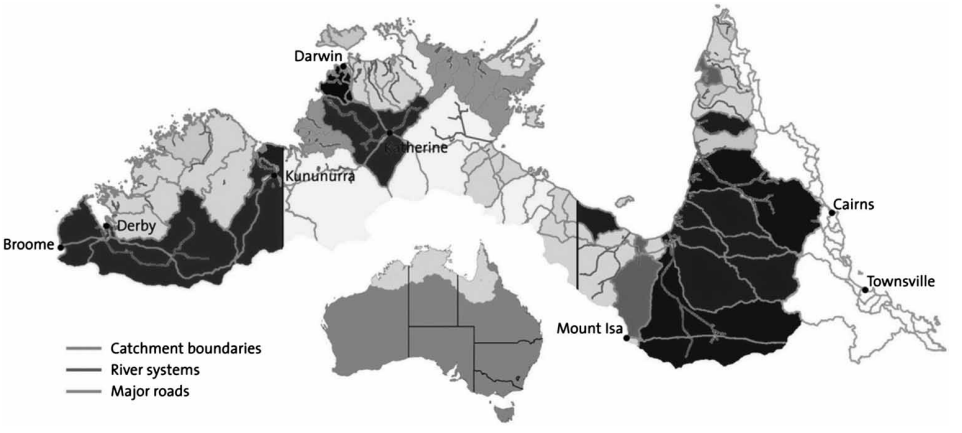

Figure 3. Clusters of similar and different catchments in the Tropical Rivers region of northern Australia (the same shading indicates the same cluster membership).

However, many of the catchments that we found to be socioeconomically 'similar' were not adjacent to one another. Indeed, some similar catchments were thousands of kilometres apart. This is a very interesting finding with implications for data transfers and management, as it suggests that socioeconomic characteristics do not necessarily 'spill over' into adjoining regions, but rather re-occur at intervals throughout the system (Figure 3). Thus, one cannot simply assume that regions which are geographically 'close' are also socioeconomically 'similar', and it is important to determine the point at which agglomeration of joined geographical areas into one management region, for the ease of management and the minimisation of transaction costs, ceases to be the most informed and meaningful way to manage.

Significantly, some of the variables that emerged as important determinants of cluster membership – specifically the numbers of businesses and community organisations present in the catchment or the presence of significant sites in the landscape – were not readily available across all catchments. Thus, those who wish to use clustering to develop typologies for decision making need to proceed with caution: incomplete or inappropriate data might lead to the placement of regions into a 'wrong' cluster.

Our analysis of the socioeconomic data available in the tropical regions of Australia reveals several major data gaps, two of which seem particularly pertinent in this context – those relating to mining activities, and those on the 'values', perceptions and cultural considerations relating to water.

Mining plays a crucial role as the main economic sector and the main employer in several parts of northern Australia (Fargher et al. 2003; Burnside 2007). Furthermore, the majority of existing mines and of identified mineral reserves are located in the upper reaches of river catchments, where there is generally relatively little streamflow (Northern Australia Water Futures Assessment 2009) and where aquifers are either fully exploited or relatively unproductive (Stoeckl et al. 2006). That there is so little information available on an industry which has such a significant impact on the economy, environment and society, is thus a potentially vitally important omission.

The other significant gap relates to the lack of information on the perceptions, values and cultural considerations related to the water. However, as need for

improved understanding of community views, values and priorities is becoming increasingly recognised in contemporary Australian policy development (Stanley et al. 2004; Nelson et al. 2006), new studies in this arena are being conducted and relevant results are becoming available. For example, in their recent publication, Stoeckl et al. (2012) report on the range and relative importance of values associated with water held by different stakeholder groups across northern Australia, as well as on the willingness of different stakeholder groups to trade-off those values against different types of economic development. Knowledge about preferences and values of Indigenous Australians is also improving (see, for example, Jackson. 2008; Zander & Straton. 2010; Finn & Jackson. 2011). Increasing availability of funding for such work is an encouraging development.

Thus, whilst our analysis suggests that the 'typologies' approach may, indeed, have much to offer and the clustering analysis identified considerable similarities and differences between catchments in northern Australia, our results also show that the efficacy of the approach depends, crucially, upon the quantity and quality of the data used. The potential implications of data deficiencies, and of the risks associated with decisions that are made with limited or deficient datasets, stands as an issue worthy of further investigation.

Acknowledgements

We gratefully acknowledge Tropical Rivers and Coastal Knowledge (TRaCK), CSIRO Sustainable Ecosystems Division and James Cook University for funding this study. TRaCK receives major funding for its research through the Australian Government's Commonwealth Environment Research Facilities initiative, the Australian Government's Raising National Water Standards Program, Land and Water Australia and the Queensland Government's Smart State Innovation Fund. We also thank Dr Kostas Alexandridis and Ms Michelle Esparon for assistance with data collection and analyses. Useful comments on earlier drafts were kindly provided by Dr Kirsten Maclean and Ms Ally Lankester.

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