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Abstract

A case study is used to demonstrate the application of Geographical Information Systems (GIS) to inform sustainable development. The suitability of the landscape to support tourism accommodation in a Local Government Area (LGA) is modelled by integrating existing datasets, including conservation areas, residential zones, major roads and known locations of tourism operators into a logistic regression framework. By using a data-driven approach an indication of the relative importance of each explanatory variable can be accounted for, therefore informing planners of the importance of different assets. In a region where tourism is reliant upon natural features, this use of information systems in conjunction with quantitative statistical modelling can value-add to existing datasets. The provision of this kind of knowledge is important as it would otherwise not factor into the decision-making process had the datasets been considered independently of each other – a concept that applies to both the public and private sectors.

Keywords

Planning, Sustainability, Tourism, NRM, Policy

INTRODUCTION

The sustainable development of landscapes is a priority that is receiving ever increasing emphasis. Coupled with this notion is an expectation that industries and businesses are working to minimise environmental impacts. A related challenge when working towards a sustainable future for a region is to gain understanding beyond the existing datasets (i.e. define landscape function). Knowledge of this kind is required to inform decisions based on a more holistic view of what are often complex and interactive systems (de Groot 2006; Groot et al. 2007). In many cases the data required to fully inform such decisions is not readily available in a useable format or simply has never been collected. It is in this scenario that information systems, in particular Geographical Information Systems (GIS), can be used as a valuable tool.

While spatial data linked to comprehensive databases is becoming more widely-used, there are certain situations where the data, if not examined in an integrated and cohesive manner, will allow little progress to be made on the issue of interest. The onus then shifts to decision-makers and information managers to either (1) acquire this data, or (2) somehow convert the best available data into a useful format. There are challenges with both these options. Data acquisition tailored for a particular project, unless of an obviously strategic or multi-use nature, can be prohibitively expensive and therefore difficult to justify. Alternatively, the best available information does not always lend itself directly to the specific task. In turn, this compels the researcher to devise or adopt a novel approach tailored to their set of circumstances and data constraints. To overcome existing data not 'fitting' the problem at hand it is possible to incorporate the best available information into an empirical modelling framework.

In some instances the landscape functions directly relate to observable landscape features. For example, census count data (numerical) and census collection districts (spatial) are an effective way of quantifying the residential function of a landscape in a spatially-explicit fashion (Willemen et al. 2008). Likewise, in the context of groundwater management, permissive consumptive volume (numerical) and groundwater management area (spatial) provides a framework for water managers to assess and monitor groundwater extraction (SRW 2011). These examples can be described as '*completely delineated*' (Willemen et al. 2008) and are defined as a landscape function that is directly observable from the land cover or can be defined by policy regulations. These types of landscape functions can be mapped as they are spatially-explicit. However, there are instances where important landscape functions are not as easily defined.

This leads to the question: how do we best spatially express some of these landscape functions that we know are of value, but we do not have a complete dataset? Decision-makers need to know this because without quantifying and spatially expressing these functions there is a chance they will not be incorporated into the longer-term sustainable planning of landscapes. In a multifunctional landscape setting much of the heterogeneity comprises of functions that can be described as '*partially delineated*' (Willemen et al. 2008). When a function is partially delineated the location and extent of these functions is not exactly known. To assess partially delineated functions requires an approach that uses the information we do have to extrapolate some idea of the quality and quantity the landscape function (i.e. its suitability to produce a good or service).

The broad objective of this paper is to demonstrate the contribution information systems can make to the sustainable management of the natural environment. By using a case study in a Local Government Area (LGA) in Victoria, Australia, the area of suitability for tourism accommodation (i.e. the capacity of the landscape to provide areas suitable for tourism accommodation) will be generated using a logistic regression approach. The second objective of the study is to make a tangible contribution to the strategic planning in a rural LGA where tourism has been predicted to increase its share of the local economy into the future. Therefore, the identification and maintenance of resources that contribute to this industry is of strategic relevance when considering planning decisions that may impact these areas over a long-term planning horizon.

METHODS

Study Site

The Corangamite Shire is a LGA in the south west of Victoria, Australia. Covering an area of ~4600 km^2, it extends from the Southern Ocean in the south to the township of Skipton 120 km to the north (DSE 2007) (Figure 1). Prior to European settlement in the early 1800s, it is believed indigenous Australian's inhabited this area for around 50,000 years (Corangamite Shire 2009).

In south west Victoria, the dairy industry is the largest single contributor to the economy generating 21 % of the regions output and providing 13.7 % of the region's employment (O' Toole et al. 2008). In the Corangamite Shire, agriculture, forestry and fishing are the predominate industries and employed 32.5% of the working population in 2006 (Corangamite Shire 2011). Other major employers in the Corangamite Shire are retail (9%), health (8.8%), construction (7.5%), education and training (6.5%) and tourism (4.5%) (Corangamite Shire 2011).

Tourism, while proportionately does not contribute to the region's employment to the same extent as agriculture, still forms a significant and growing part of the shire's economic base (DSE 2007). The internationally recognised Great Ocean Road that borders the southern extent of the study area is highly scenic and has high biodiversity value. The Port Campbell National Park and Bay of Islands Coastal Park together form a linear reserve along the coastline. Other tourism sites in the shire also embrace the aesthetic appeal of the natural environment. Further inland, the Lakes and Craters region form part of the Victorian Volcanic Plain (VPP) bioregion. The VPP is characterised by numerous eruption points including scoria cones, stony rises and lava flows (Ollier 1971). Lake Bullen Merri and Lake Gnotuk are both internationally recognised for their scientific, environmental and landscape significance. The significance of the region's volcanic heritage has been recognised and much of the Shire is contained in the Kanawinka Geopark which is part of the Global Geoparks Network.

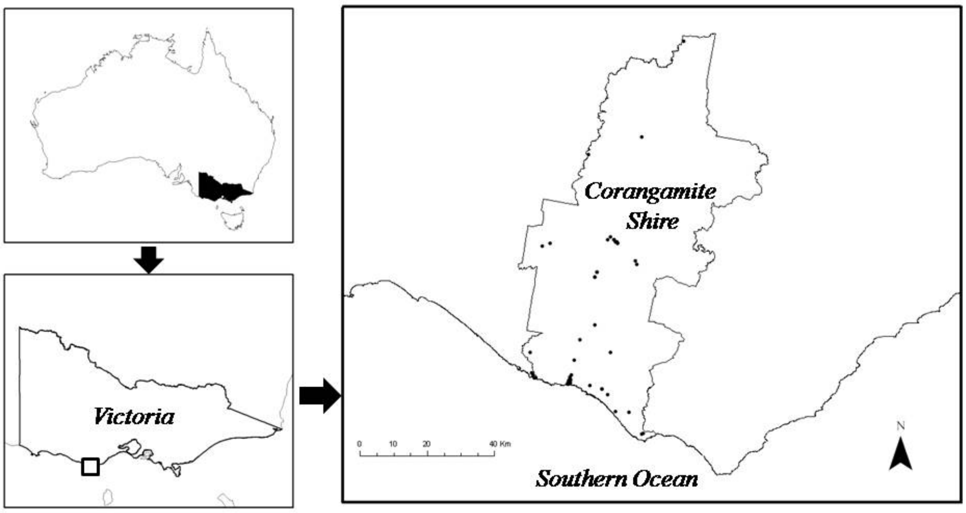

Figure 1: The study area and the locations of existing tourism accommodation sites in the Corangamite Shire.

Model Variables

The locations of tourism accommodation operators were extracted from Australian Automobile Associations (AAA) Tourism's database using postcodes to identify sites within the study area (dependent variable). The extent of the Corangamite Shire with a 1 km buffer was used for the final selection of accommodation sites used in the analyses. This was done for two reasons: (1) a number of the postcodes extended beyond the study region and (2) the coastal township of Peterborough and the Curdies River estuary lie just to the west of the study area and was considered likely to influence the suitability for tourism within the Corangamite Shire. Explanatory variables used in the initial modelling stage included eight continuous and one categorical (Table 1). The initial selection of the nine explanatory variables was guided by the Corangamite Planning Scheme (DSE 2006) which discusses considerations such as the natural and built environment, location relevant to transport routes, landscape features of the immediate environs, native vegetation, watercourses and other natural features, in addition to access from roads. All explanatory variables were converted to 100 x 100 m grids and clipped to the extent of the study area with a 1 km buffer. A total of 60 tourism accommodation sites were extracted from the AAA Tourism database (Figure 1). Some of these sites were in close proximity (i.e. occurring in the same map cell). These were reclassified as a single observation, and the total tourism accommodation sites for model training were reduced to 49. ArcGIS 9.3 (ESRI) and the spatial analyst extension were used to process model variables.

Suitability Modelling - Logistic Regression

Logistic regression modelling is a Generalised Linear Model (GLM) that can be applied to assess the suitability of a landscape function. The technique has been widely used in landscape-scale suitability investigations ranging from modelling deforestation (Schneider and Pontius 2001) and fragmentation (Echeverria et al. 2008), to changes in agricultural patterns (Lakes et al. 2009), and urban growth modelling (Luo and Wei 2009). Ecology is another discipline that has widely used logistic regression for the purpose of suitability modelling (Guisan and Zimmermann 2000).

Logistic regression modelling delivers a probability value between 0 (i.e. unsuitable) and 1 (i.e. highly suitable) of an outcome (i.e. the dependent variable) occurring based upon a series of explanatory variables. The dependent variable is a binary presence or absence event. Explanatory variables can comprise of either continuous or categorical data, or a combination of both. In this study the logistic equation delivers a probability value (i.e. the suitability) for each cell to support a tourism accommodation site as a function of the explanatory variables at that site. This modelling approach used here follows the broad framework and logic of Willemen et al. (2008) who applied logistic regression to quantify the suitability for tourism accommodation in a Dutch rural landscape, albeit with different explanatory variables and other slight methodological differences.

Model Refinement

The logistic modelling was performed using a tenfold cross-validation model approach. Each of the ten runs used a randomly selected set of 37 sites for training and the remaining 12 sites for testing (total $n = 49$). To facilitate the modelling process a set of 1000 absences (i.e. areas where there are no tourism accommodation operators) were generated randomly throughout the study area. The forced entry method of logistic regression was used in the initial modelling exercise and the nine explanatory variables were included. This was chosen in favour of a stepwise approach and is recommended for exploratory analysis (Field 2000). Each model was allowed to run until the model converged (convergence threshold = 0.001). The median p-values of the 10 model runs were used to guide variable selection for the refined model.

Model performances were assessed using the Area Under Curve (AUC) of the Receivers Operating Characteristic (ROC). The main benefit of the using the AUC to assess model performance is it delivers a single measure of model performance that is independent of any threshold (Phillips et al. 2006). The application of AUC has been demonstrated to be a useful technique when evaluating model performance in land cover studies when using logistic regression to generate suitability maps (Pontius and Schneider 2001).

Table 1: The nine explanatory variables used in the first modelling exercise. The refined model was reduced to Conservation Areas; Major Roads; and Residential Areas (* = categorical variable).

Variable	Source	Processing
Average Rainfall (1961-1990)	Bureau of Meteorology	Converted to 100 x 100 m raster
Groundwater*	Department of Sustainability and Environment	Polygon shapefile converted to raster and areas overlying Groundwater Management Areas (GMA) or Water Supply Protection Areas (WSPA) assigned a value of '1'; other areas value of '0'
Wetlands	VicMap	Named lakes extracted from dataset. Euclidean distance calculated
Watercourse	VicMap	Named watercourses extracted from watercourse dataset. Euclidean distance calculated
Conservation Areas	Bureau of Rural Science 2002 South West Victoria Land Use Map	Land use description selected by attributes: 1.1.1 Strict nature reserve; 1.1.3 National park; 1.1.4 Natural feature protection; 1.1.5 Habitat/species management area; 1.1.7 Other conserved area; 1.2.0 managed Resource Protection; 1.3.3 Remnant native cover. Euclidean distance calculated
Major Roads	VicMap	Alpha-numeric roads selected by attributes: ROUTE_NO = A, B, C. Euclidean distance calculated
Residential Areas	VicMap	Selected as an attribute from Corangamite Shire planning zones. Euclidean distance calculated
Coast	VicMap	Southern boundary of study area clipped. Euclidean distance calculated
Heritage Overlays	VicMap	Selected as an attribute from Corangamite Shire planning overlays. Euclidean distance calculated

RESULTS

Spatial autocorrelation was assessed using the Global Moran's I statistic on model residuals (i.e. the observed site minus the predicted probability of occurrence given by each modelling approach). The distance classes and Moran's I statistics were computed using SAM (Spatial Analysis in Macroecology). Global spatial autocorrelation was observed to be negligible beyond 350 m; given that the majority of tourism accommodation sites where separated by more than 350 m it was assumed that spatial autocorrelation did not substantially influence the predictive models.

The mean AUC of the ten model runs using the nine explanatory variables was 0.965, indicating the model based upon 75 % (n = 37) of the data was effective at predicting the suitability for tourism accommodation sites. The significant variables identified by the logistic regression approach were residential areas (p<0.001), conservation areas (p=0.006) and major roads (p=0.032) (Table 2). All other variables were non-significant at the p=0.05 level. The statistically significant variables were retained and used in the refined logistic regression model (Figure 2a). Using a tenfold cross-validation with the same three variables with logistic regression resulted in an AUC of 0.951 (Table 3; Figure 2a). This indicated the models were effective at being able to predict the location of tourist accommodation sites. As the three variables were significant they were subsequently all retained in the final logistic regression model used to predict tourism accommodation suitability (Figure 2b).

Table 2. Multiple logistic regression summary for the model with nine variables included from Table 1. Values based upon tenfold cross-validation with 75% of the data. Estimates of β and p-values are median values. Test AUC = 0.965 (SE± 0.019). (SE = Standard Error; *Significant p<0.05).

Variable	β	SE	p
Water course	-0.000058	0.00014	0.624
Rainfall	-0.004402	0.00419	0.304
Wetland	0.000035	0.00003	0.187
Residential	-0.000357	0.00010	<0.001*
Heritage	-0.000016	0.00005	0.743
Conservation	-0.000397	0.00015	0.006*
Coast	-0.000015	0.00002	0.413
Major Roads	-0.000576	0.00027	0.032*
Groundwater	-1.018508	0.78813	0.180
Constant	4.103652	3.99534	0.317

Table 3. Multiple logistic regression summary for the refined model with three variables. Values based upon tenfold cross-validation with 75% of the data. Estimates of β and p-values are median values. Test AUC = 0.951 (SE± 0.025). (SE = Standard Error; *Significant p<0.005).

Variable	β	SE	p-value
Residential	-0.0003	0.00008	<0.001*
Conservation	-0.0006	0.00014	<0.001*
Major Roads	-0.0008	0.00027	0.004*
Constant	0.5855	0.33772	0.083

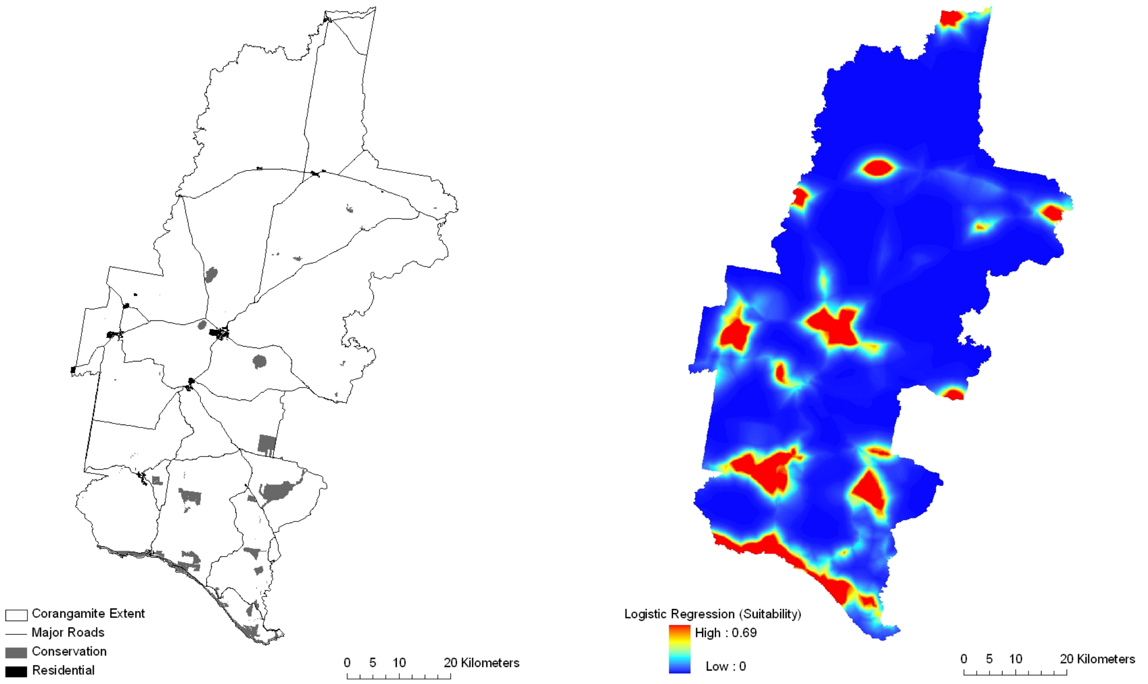

Figure 2: (a) The location and extent of the three significant explanatory variables used in the refined logistic model; (b) Modelled tourism accommodation suitability.

DISCUSSION

General

The strategic use of finite resources, in this instance land, is a cornerstone of the broader goal of sustainable development. One of the expectations of strategic planners working towards this goal is to provide direction that balances the present and future interests of the people affected by their decisions. However, these decisions are often made with substantial knowledge gaps, despite large amounts of information being available. Therefore, the broad aim of this research was to demonstrate the application of GIS to an empirical study aimed at optimising land use planning in a region where eco-tourism is a growing part of the economy. Specifically, information systems were used in a multidisciplinary framework to integrate numerous spatial datasets to produce a predictive map showing areas where tourism accommodation could potentially be viable enterprises. A major strength of the approach is the value-adding to existing datasets, that when considered in isolation, have limited utility. The model outputs and the potential influence on planning policy and private investment are discussed separately below.

Model Outputs

The first model using all of the available variables (one categorical and eight continuous) returned an AUC value of 0.965 (Table 2). Any AUC exceeding 0.5 is statistically better than random (Pontius and Schneider 2001) and 0.7 is considered acceptable for Land Use and Land Cover Change (LUCC) (Lesschen et al. 2005). Results exceeding 0.9 are classed as 'outstanding' (Hosmer and Lemeshow 2000). Although the analysis using all of the variables indicate it was highly effective at identifying suitable areas, inspection of the model output indicated not all of the variables were required (Table 2). The refined model based upon the statistically significant explanatory variables of Residential Areas, Major Roads and Conservation Areas returned an AUC of 0.951 (Table 3). In summary, both models had very high levels of performance. Although there are other socio-economic and bio-physical variables that will influence the presence of tourism accommodation, the model performances suggest the explanatory variables were very effective for identifying the location of existing accommodation sites.

A reason for the high level of model performance could be attributed to the well-defined areas in the landscape of the Corangamite Shire that have existing tourism accommodation sites. Given the relatively low density of tourism accommodation sites (49 used to inform the models across ~4600 km^2), the predominant modes of transport in this part of Australia being road-based, and the concentration of services in residential areas due to the sparse population (<4 people/km^2), it is logical that the location of existing accommodation sites will reflect these drivers.

Influencing Planning Policy

The suitability map generated here are the first attempt to make spatially-explicit the landscape function of tourism accommodation suitability in the Corangamite Shire. Although the Corangamite Shire's economy is heavily reliant upon agriculture, planning policy has formally acknowledged that tourism is a growing component of the economy (DSE 2007). To ensure this industry can grow in the longer-term it is necessary to gain an understanding of the areas most suitable for accommodation. An alternative use of this research output may be to minimise the chances of future inappropriate developments at locations proximate to highly suitable areas for tourism accommodation.

From a practical planning viewpoint, the suitability for tourism accommodation maps can be used to inform relevant local planning policy. In the context of planning in Victoria there is a hierarchical planning structure. *The Planning and Environment Act 1987* is the key legislation that sits above the Victorian Planning Provisions (VPP), which set the structure and format for all Victorian planning schemes. Local Government Planning Schemes (e.g. Corangamite Planning Scheme) guide the implementation of *The Act* with the VPP providing the scope for establishing a local framework for land use planning and development. Any amendments to a local planning scheme require strategic justification. As strategic justification in many cases involves a review of existing literature and data, the maps generated here provide another layer of information to inform this process. By quantifying and spatially expressing tourism accommodation suitability using scientifically valid techniques the Corangamite Planning Scheme may be able to become more localised in content as they reflect the true multifunctionality of the landscape not only now, but its potential for future tourism development.

Directing Private Investment

Recently the Corangamite Shire commissioned work examining tourism opportunities in the region (Urban Enterprise 2010). This document identified areas in the southern half of the shire as having the majority of the shire's tourism attractions and referred to several nodes in this area. These findings are consistent with the data-driven modelling output generated in this study. The spatial analysis presented herein is seen as complementary as well as an extension to this type of work as it begins to detail the spatial extent, rather than just identifying nodes or attractions in the landscape. Currently visitation to the Corangamite is dominated by day-trippers. Of the estimated 2.6 million visitors to the shire annually, around 400,000 stay overnight (Urban Enterprise 2010). There is an opportunity to increase the conversion of day-trippers to overnight stays in the region. If the demand for overnight accommodation increases in the shire, the suitability maps generated here can actively influence the decisions of private investors looking to apply another layer of due diligence when assessing proposals.

CONCLUSION

Geographical Information Systems (GIS) can be a powerful tool that allows us to integrate and value-add to datasets that when examined in isolation have limited utility. Ultimately this approach can contribute to sustainable use of finite natural resources – in this case, land. This multidisciplinary application of GIS used in conjunction with quantitative statistics has identified areas suitable for tourism accommodation development in a region where the industry is driven by natural attractions. As the planning documents for the study area have identified tourism as burgeoning contributor to the local economy, the map produced can assist with selecting areas where future tourism accommodation sites may be viable. In addition it can provide considered justification for updating strategic and statutory planning tools. Furthermore, the maps can also be used to direct private investment as proponents look to ensure due diligence when assessing proposals.

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