Prepared for the "2007 ANZSEE Conference, Re-inventing Sustainability: A climate for change" July 2007

Conference Theme: Modelling and Integrated Assessment

Producing a GIS based multiple criteria analysis tool for regional sustainability assessment: the problem of weighting

Michelle Graymore*, Anneke Richards and Anne Wallis

School of Life and Environmental Sciences, Faculty of Science and Technology, Deakin University, Warrnambool, Victoria.

Abstract

Decision support tools will be useful in guiding regions to sustainability. These need to be simple but effective at identifying, for regional managers, areas most in need of initiatives to progress sustainability. Multiple criteria analysis (MCA) is often used as a decision support tool for a wide range of applications. This method allows many criteria to be considered at one time. It does this by giving a ranking of possible options based on how closely each option meets the criteria. Thus, it is suited to the assessment of regional sustainability as it can consider a number of indicators simultaneously and demonstrates how sustainability can vary at small scales across the region. Coupling MCA with GIS to produce maps, allows this analysis to become visual giving the manager a picture of sustainability across the region. To do this each indicator is standardised to a common scale so that it can be compared to other indicators. A weighting is then applied to each indicator to calculate weighted summation for each area in the region. This paper argues that this is the critical step in developing a useful decision support tool. A study being conducted in south west Victoria demonstrates that the weights chosen can have a dramatic impact on the results of the sustainability assessment. It is therefore imperative that careful consideration be

* Corresponding author: Michelle Graymore
School of Life and Environmental Sciences,
PO Box 423, Deakin University, Warrnambool, VIC 3280 Australia
Tel. +61 3 5563 3211; fax: +61 3 5563 3462.
E-mail address: michelle.graymore@deakin.edu.au

given to determining indicator weights in a way that is objective and fully considers the impact of that indicator on regional sustainability.

Introduction

To help regional managers make decisions to progress sustainability they need tools that provide information about sustainability across the region. These tools need to integrate economic, social and environmental information based on sound principles (Buselich, 2002) in such a way that it is user-friendly, clear and robust so that decisions made are transparent and accountable. However, at this stage there a very few examples of truly integrative assessment methods, and those that are often require data not available at the regional scale, have complex methods or results, or have not considered the underlying causal relationships within the system (Gustavson et al., 1999; Bossel, 2001; Campbell et al., 2001; Prescott-Allen, 2001). This means there has not been a user friendly tool available to regional managers that is able to give reliable results about sustainability. The development of such a tool could assist in determining resource allocation to help progress sustainability.

Decisions support systems help guide decision makers when there are many often conflicting criteria and stakeholder preferences for alternative options. These tools evaluate the alternative options by simultaneously considering all the criteria to determine the ‘best’ option. They are able to combine both qualitative and quantitative information. These characteristics make decision support systems ideally suited to sustainability assessment where there are many conflicting criteria. Decision support systems are developed to help decision makers make a well-informed decision (Pietersen, 2006). To be an effective decision support system, it needs to integrate the best science available into the decision making process at a level which the decision makers understand, preventing the loss of any important information (Giampietro et al., 2006). They also have to be transparent and reliable so that the decision reached is understood by all and given support by community.

There are several steps in the development of decision support systems (see Figure 1). Once a problem has been identified stakeholder consultation is used to clearly define the problem, determine management options or alternatives and develop the criteria on which to base the decision. Data is then collected for each of the criteria and then the criteria are considered simultaneously to give a ranking of the possible options. This is done in a consistent and repeatable way to give reliable results each time the tool is used. Several methods have been used to do this final step including multiple criteria analysis (MCA), modeling predicted outcomes of the alternatives, factor analysis or fuzzy set theory (Abel 1996).

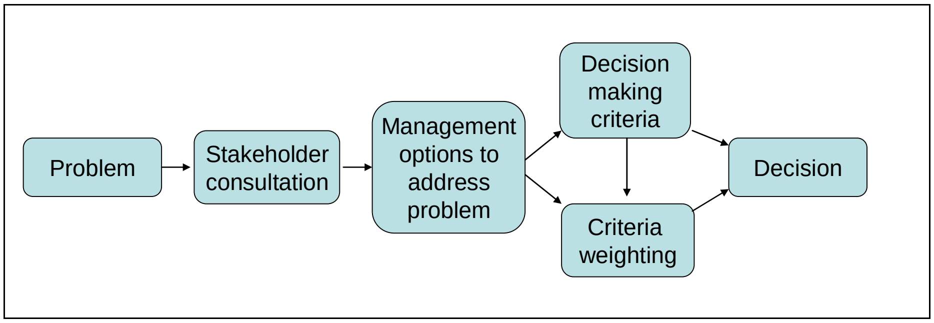

Figure 1: Decision support system framework.

Multiple criteria analysis (MCA) has been shown to be an effective tool for aiding structured decision making by helping to evaluate, prioritise and select alternative options (Pettit and Pullar, 1999; Joerin et al., 2001; Foxon et al., 2002; Hajkowicz, 2002; Klawitter, 2003). It has been used widely as a decision support tool for a variety of different applications from finding the most suitable building location to coral reef management, water resource management, sustainable forest management, transport routes determination and lake regulation (Fernandes et al., 1999; Mendoza and Prabhu, 2000; Hamalainen et al., 2001; Buselich, 2002; Foxon et al., 2002). It has been suggested that MCA would be useful for developing a decision support tool for sustainability assessment (Buselich 2002), as it allows for the consideration of all indicators simultaneously to give an answer about sustainability. However, to our knowledge this has not been done date.

There are a number of different techniques used for MCA including, weighted summation, concordance/discordance analysis, planning balance sheet and goals-achievement matrix (Malczewski, 1999; Buselich, 2002). Weighted summation is the easiest method to understand and thus it is most suited to decision making process where the community can get involved. It is a matrix based method where each criteria is weighted according to its importance. To do this each criteria has to be standardized to make them comparable by giving them a score. Then the score is multiplied by the weight for each alternative. This is summed to give a ranking of alternatives. There are a number of different methods that can be used to develop weights including paired comparisons using Analytic Hierarchy Process (AHP) (Saaty, 1980), fixed point scoring, rating, ordinal ranking, conjoint analysis and choice modelling (Hajkowicz, 2002; Hajkowicz et al., 2004). The problem with MCA is that it is difficult to develop weights without value judgments, as many of the methods used to develop weights require stakeholders or the decision maker to subjectively place importance on each of the criteria. Thus, to improve this method as a decision support system, an objective method for developing weights is needed.

To further enhance MCA as a decision support tool, it can be integrated with Geographic Information Systems (GIS) to combine geographical data with multiple criteria decision models (Carver, 1991; Crossland et al., 1995; Malczewski, 2006). This type of tool is called a Spatial Decision Support System and such tools have been developed for a number of areas including environment, regional/urban planning, natural hazard management, transport, water resource management and housing/real estate (Malczewski, 2006). These tools are able to enhance stakeholder experience with decision making tools, as the maps enable them to see what the options are, where they are located and the possible implications of the decision options (Jankowski et al., 2001). They have also been shown to decrease the time taken to make decisions (Crossland et al., 1995). Because of the increasing use of GIS software by regional managers GIS based MCA tools are becoming sort after to help in decision making. Until recently, this required the user to enter data and do the MCA in a spreadsheet software program then transfer the data to GIS to produce maps, or to write macro programs to link the GIS functions together to run the MCA, or manually running each GIS function separately for each criteria to carry out the MCA (Carver, 1991; Malczewski, 1999). But recent improvements in GIS capabilities mean that this type of tool can now be developed to be user-friendly. The usefulness of this kind of tool was demonstrated by Preda et al (2006) who built a GIS based MCA tool to analyse nutrient export potential to waterways in ArcGIS ® (V. 9.0) using Model Builder environment. This tool was able to evaluate the potential export of nutrients by sub-catchments by considering a number of variables that influence nutrient export, thus ranking sub-catchments in terms of their likelihood of exporting nutrients to nearby waterways (Preda et al., 2006).

This paper introduces a decision support tool for south west Victoria based on An Index of Regional Sustainability (AIRS) (Richards this conference) which combines MCA with GIS to produce a tool that can inform regional managers about the sustainability of sub-catchments and other smaller scale areas, such as Local Government Areas, within in a region and this will assist in prioritising where sustainability initiatives need to be implemented. A critical analysis of the tool is then undertaken by investigating the impacts of various indicator weightings on sustainability assessments, the influence of using individual sustainability pillars (sub systems) assessment compared to a holistic system sustainability assessment to develop indicator weights, and the impact of using more or less indicators in the tool.

Study area: South West Victoria, Australia

The South West region of Victoria extends from the South Australia border in the west to Camperdown in the east, and from the Central Highlands in the north to the southern coast (South West Sustainability Partnership, 2001). The Glenelg Hopkins catchment management area forms the focus of this study. The region contains three river basins with a total of 32 sub-catchments. These are the Hopkins River basin with 13 sub-catchments, the Glenelg River basin with 13 sub-catchments and the Portland basin with 6 sub-catchments (Glenelg Hopkins Catchment Management Authority, 2003). It covers an area of 2.6 million hectares with a population of 103,000 people mostly located in the urban centres of Portland, Warrnambool and Hamilton. Most of the economic prosperity of the region has come through the agricultural sector. And as such, land use, including agriculture, industry and urbanization, has had a severe impact on the natural environment. Salinisation, soil degradation, loss of habitat and biodiversity, eutrophication of waterways are some of the major environmental problems in the region. Areas in the region are also experiencing population decline, which is causing some social and economic problems for sustainability.

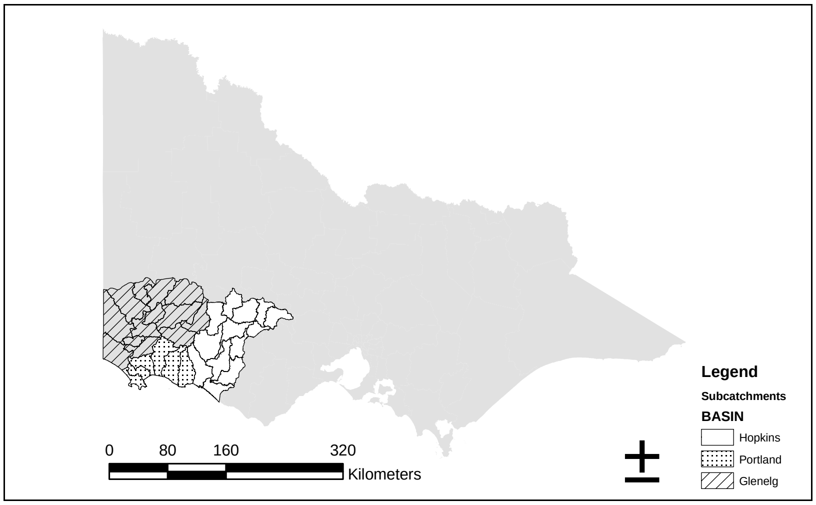

Figure 2: The South West region of Victoria, Australia

Catchment to Regional Scale Indicators of Sustainability

This project is part of a continuing study investigating catchment to regional scale indicators of sustainability for south west Victoria. In the early stages of this project, the indicators were prioritised by stakeholders from a list of indicators derived from the literature that have been used to assess sustainability (Wallis and Wallis, 2004). From this a set of key indicators (44 indicators) for assessing sustainability in the region were selected (Wallis and Wallis, 2004). Then data was collected for these key indicators to make an initial assessment of sustainability. However, there was only data available for both condition and trends covering the whole region to the sub-catchment scale for 19 of the key indicators. These indicators covered three pillars of sustainability, social, economic and environment as identified by the South West Sustainability Partnership (2001). An assessment of sustainability was made for each indicator based on the trend and condition data and expert opinion (Wallis and Barrot, 2005).

The next stage of the study concentrated on developing an objective method of assessing sub-catchment sustainability. A sustainability ranking scale was developed for each of the 19 indicators using literature on the known impacts of these indicators on sustainability and expert opinion. This enabled the standardisation of the indicators to make them comparable. The relationships between the indicators and their impacts on sustainability were then investigated to determine a sustainability impact rating for each indicator. These ratings were used in AHP (in

Expert Choice ®) to objectively weight the indicators using the size of the impact they had on sustainability and the strength of the relationships with other indicators (Richards, this conference). Through this process the indicator set was further reduced to the 10 indicators that best explained the majority of the impact on sustainability whilst maintaining an even distribution of indicators across the social, economic and environmental pillars (Figure 3). The weighting scheme developed here was the balanced pillars model of sustainability, where each pillar (social, economic and environmental) were treated as if they each had the same impact on sustainability. When all pillars were considered as one system, environmental indicators whose priority ranking from AHP were higher than the social and economic indicators were added to the indicator set making a total of 13 indicators (Figure 3). This weighting scheme is the one used in AIRS, which is based on a holistic model of sustainability. The indicators were then weighted using the AIRS weights to provide a weighted ranking of sustainability for each indicator. These rankings were then added together to produce a weighted summation sustainability score (called sustainability score from here on) for each sub-catchment. These sustainability scores allow comparison of the state of sustainability between sub-catchments. This forms a MCA based decision support tool for progressing regional sustainability and the basis for the GIS-based MCA tool described in this paper.

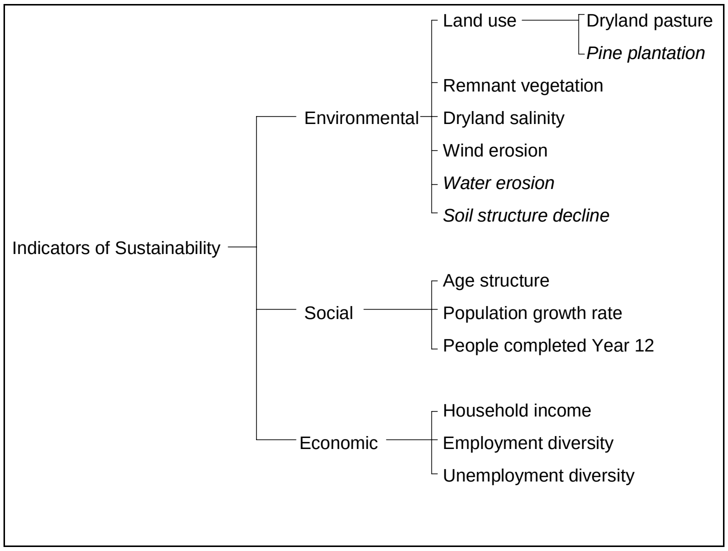

Figure 3: Indicators of sustainability for South West Victoria. Indicators in italics are the three indicators not included in the balanced pillar weighting scheme.

Method

GIS-based MCA Sustainability Assessment Tool

To produce a user-friendly decision support tool for sustainability, the AIRS tool developed by Richards (this conference) was integrated with GIS. This produced a GIS-based MCA which can be completely carried out in GIS software to enable visual representation of the results. This enhances the AIRS tool as it is able to produce maps of sub-catchment sustainability easily showing managers which sub-catchments are most in need of sustainability initiatives. The GIS-based MCA tool was developed using ArcGIS ® (V. 9.1 ESRI, Redlands, CA) in the ArcMap environment. The ArcGIS ModelBuilder environment and other data processing tools in ArcMap were utilised to undertake this task. ModelBuilder allows the user to design and use a GIS based model by interactively dragging process tools and data objects into a visual diagram of the model.

The first step in the development of the tool was to make the indicators comparable by standardising the indicator data using the sustainability ranking scale developed by Richards (this conference). Then in ArcMap, all the indicator tables were joined and the 'export data' tool in the Table of Contents (TOC) of ArcMap was used to make a new map layer containing all the indicator data. ModelBuilder was then used to apply the MCA model to the indicator data. The MCA produces a weighted summation sustainability score for each sub-catchment, as well as a weighted summation for the environmental, social and economic pillars, so information is gained about the sustainability of the sub-catchment and its economic, social and environmental condition. This ensures that a sub-catchment that is performing poorly in one pillar but doing well in the other pillars, and thus achieving a high sustainability ranking, is still identified as requiring some attention to progress sustainability. This tool enabled the user to produce a series of maps showing environmental, social and economic condition, as well as the overall sustainability of each sub-catchment. By examining these maps, recommendations can be made about which sub-catchments should be given the highest priority for implementation of sustainability initiatives to progress sustainability across the region.

To address the objectives of this paper, three different indicator weighting schemes developed by Richards (this conference) and Wallis (2004) in early parts of this study were used. The weighting schemes were:

1. Balanced pillars weighting scheme (Richards, this conference)
    - This scheme considered each of the sustainability pillars, economic, social and environmental to have the same impact on sustainability so the weightings for each pillars indicators added up to one. This was based on the three pillars of sustainability model where the three pillars are thought of as separate sub-systems (see Figure 4). This means that this weighting scheme produces sustainability scores out of 24. As stated above, this scheme uses 10 indicators (Figure 2).
2. AIRS weighting scheme (Richards, this conference)
    - This scheme weights indicators as if all indicators were part of the one system and have the potential to have the same impact on sustainability regardless of the pillar they are from. Thus, using a holistic model for sustainability (see Figure 4) on which to base the weights. Since all the indicators weights add up to one, this scheme produces sustainability scores out of 8. This scheme utilises 13 indicators (Figure2).
3. Stakeholder priorities weighting scheme (Richards after Wallis and Wallis, 2004)
    - This scheme used the stakeholder prioritisation of indicators carried out at the start of this study (Wallis and Wallis, 2004). The weights for the indicators were developed from the priority ranking given to each indicator in this prioritization in AHP by Richards (this conference). This was determined with the 19 indicators used for the initial sustainability assessment, however, for the purposes of this paper, only the 13 indicators used for AIRS were used here. This scheme was used to investigate the impacts of using more or less indicators on sustainability assessment, so this scheme was used with the 13 indicators of the AIRS scheme and the 10 indicators of the balanced scheme. Because of this the weights add up

to 0.7 for the 13 indicators to produce sustainability scores out of 6 and 0.6 for the 10 indicators to produce sustainability scores out of 5.

It must be noted that due to the differences in the weighting schemes explained above, the scales used for sustainability scores produced from each of these schemes had to be different to show the variability in sustainability across the region.

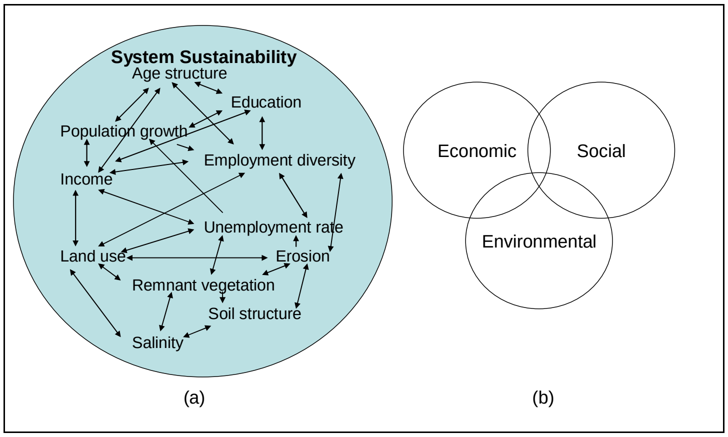

Figure 4: Models of sustainability; (a) system sustainability where all aspects of sustainability influence each other and are not separated into pillars, whereas (b) the balanced pillars model shows that each pillar is a separate system that has some influence on the other pillars.

For the first objective, the investigation of the impacts of various indicator weightings on sustainability assessment, the GIS-based MCA was carried out using the AIRS, Balanced and Stakeholder, weighting schemes described above to sustainability assessments in the form of maps of sub-catchment sustainability. These were visually compared to see what difference the weightings have on the sustainability assessment.

To investigate the influence of using individual sustainability pillars compared to a holistic system sustainability assessment to develop indicator weights the AIRS and Balanced weighting schemes were used to carry out the GIS-based MCA tool. This was used to produce maps and graphs of sustainability, as well as, environmental, economic and social condition of the sub-catchments. This enabled comparison to be made between using the balanced pillar model and the holistic systems sustainability model as the basis of the weighting scheme and determination of the impact this had on sustainability assessments. The eight sub-catchments with the lowest sustainability scores produced by each scheme were compared to see what influence the sustainability model used to weight the indicators had on their assessment. The sub-catchments with the lowest sustainability scores were used for comparison as they were considered to have the lowest level of sustainability (see Figure 5), and thus, they would be the sub-catchments most likely to be looked at by regional managers for implementation of sustainability initiatives.

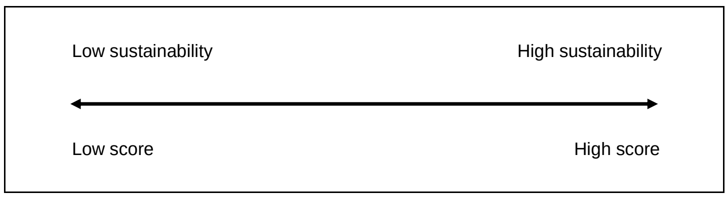

Figure 5: A relative scale for sustainability assessment.

In order to investigate the impact of using more or less indicators in the tool, the Stakeholder weights were used in the GIS-based MCA tool with 10 indicators and with 13 indicators. This produced two sustainability scores where the only difference in the way they were determined was the number of indicators used, as the weights for the indicators were identical. By comparing visually the graphs and maps produced for sub-catchment sustainability, and environmental, social and economic condition the impact of using more or less indicators became evident. This was done to determine how much impact the number of indicators was having on the differences between the AIRS and Balanced schemes compared to the impact of the different sustainability models used to produce the weighting scheme.

The three steps described here produced a critical evaluation of the GIS-based MCA sustainability assessment tool. However, it must be recognised while developing this tool some of the limitations of the ModelBuilder environment where discovered. A number of the useful data processing tools in ArcToolbox do not work well, if at all, in the ModelBuilder. For instance, the 'Make Feature Layer' tool which is supposed to make the data a feature layer, change field names, delete fields and change their order only makes the data a feature layer and does none of the other functions. Other authors have found faults in the ModelBuilder. The model components are not processed in the order they appear in the model, but in the order they were placed into the model (Barnwell 2005). This means that if the model is modified it changes the order in which the model components are processed. Also, the parameters of the some of the tools are reset each time a model is opened preventing the storage of these parameters (Barnwell 2005). But despite these issues, the ModelBuilder environment is useful for running this MCA as it automates the steps needed to carry out the analysis.

Results

The GIS-based MCA tool developed in this study produces maps showing results of sub-catchment sustainability assessment and environmental, social and economic condition. This can be used to rank sub-catchments according to their sustainability, highlighting those sub-catchments with the lowest sustainability in the region. This paper has demonstrated that the use of different weights in the tool impacts on the sub-catchment sustainability assessment produced by giving a different sustainability scores and sub-catchment ranking. It has also shown that the model of sustainability used to develop the weighting scheme influences the sustainability assessment produced by this tool. Finally, it was able to show that there was a difference in sustainability assessment produced by having more or less indicators in the weighting scheme.

The impact of different weights is shown in Figures 6 – 9. These maps demonstrate that there are some sub-catchments that show consistency in their sustainability ranking across the different weightings, such as G8 which is always amongst the top ranked sub-catchments. Other sub-catchments show considerable variability when different weights are used, for example G12, P6, G11 and G10.

The influence on sustainability assessment caused by the sustainability model used to develop the weighting scheme is shown by the differences in the AIRS and Balanced assessments (Table 1). The first major difference noted is the lowest ranked sub-catchment is different for both results with G12 the lowest for Balanced and H5 the lowest for AIRS, and neither of these sub-catchments were in the lowest 8 sub-catchments for the other assessment. Other sub-catchments that were only in the lowest 8 for one of the assessments were G4 for the

Balanced and G10 for the AIRS. The differences caused by the different sustainability models were also seen in the environmental pillar sub-catchment ranking. Again G12 was in the

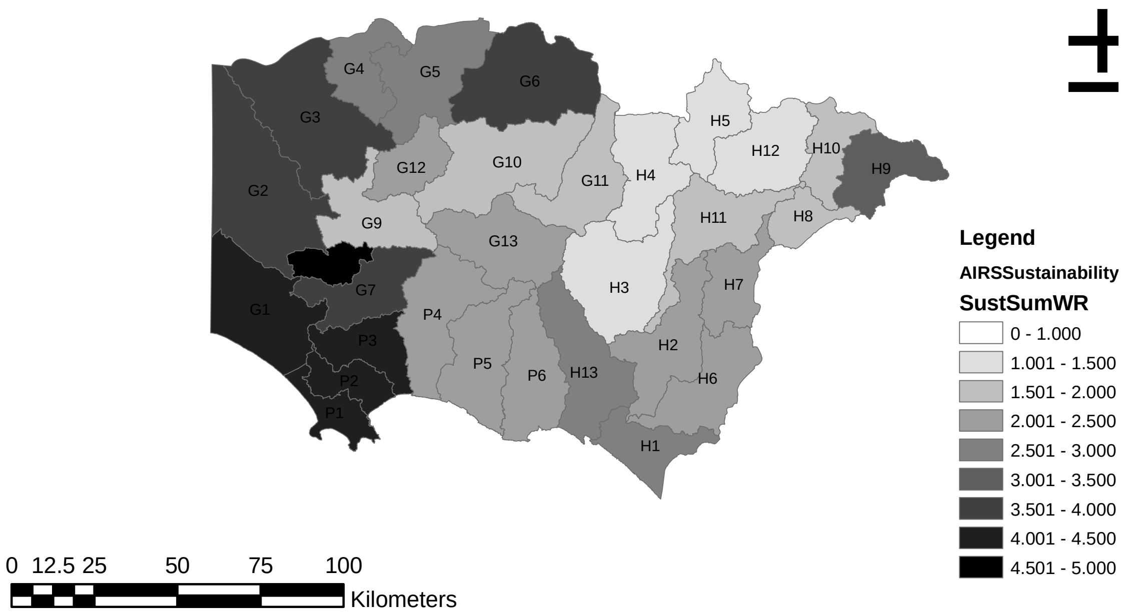

Figure 6: AIRS sub-catchment sustainability assessment with 13 indicators.

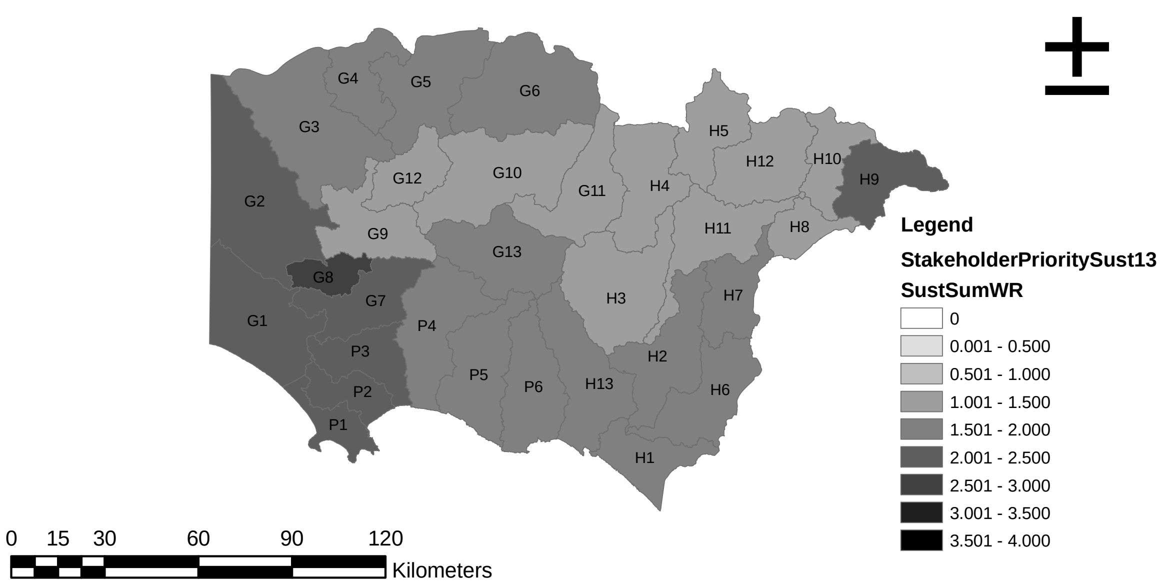

Figure 7: Stakeholder priority sub-catchment sustainability assessment with 13 indicators.

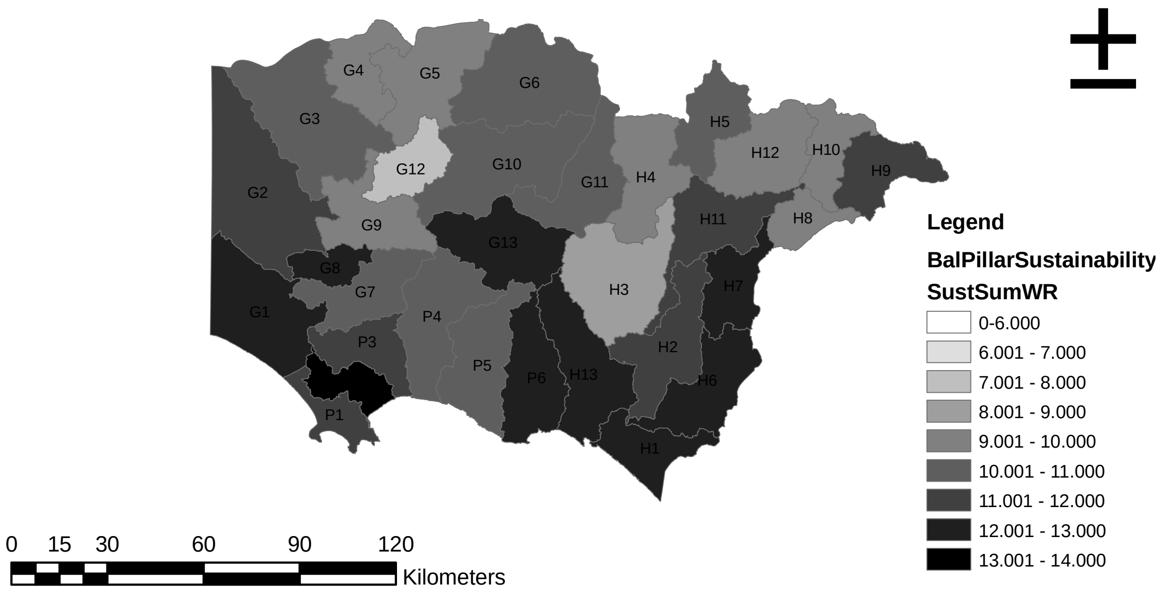

Figure 8: Balanced pillar model sub-catchment sustainability assessment with 10 indicators.

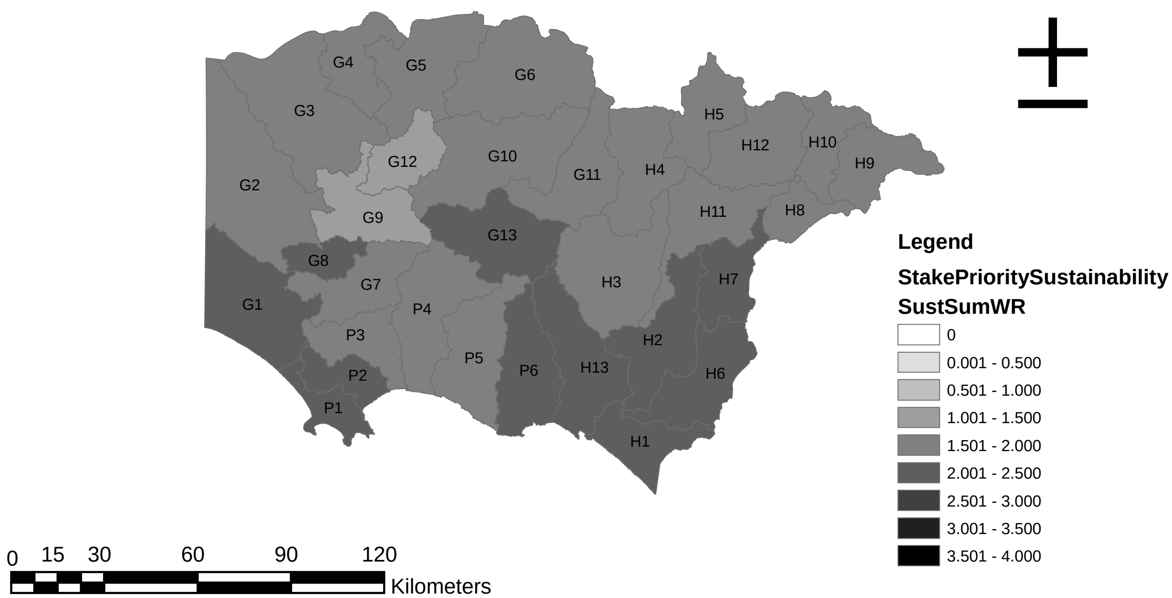

Figure 9: Stakeholder priority sub-catchment sustainability assessment with 10 indicators.

Table 1: Sub-catchments with the lowest sustainability (Sust), environmental (Env), social (Soc) and economic (Eco) condition for the AIRS and Balanced weighting schemes. This is the lowest 8 unless the 8th sub-catchment has the same score, and then it was either dropped or extra sub-catchments were included dependent on the score.

Rank	AIRS Sust	AIRS Env	AIRS Eco	AIRS Soc	Balanced Sust	Balanced Env	Balanced Eco	Balanced Soc
1	H5	H5	G12	G6	G12	G9	G12	G6
2	H3	H12	H3	G12	H3	H5	H3	G12
3	H12	H3	H9	H10	G9	G12	H9	H10
4	H4	H4	H8	G8	G4	H12	H8	G11
5	H10	H10	P5	G2	H12	H10	P5	G8
6	G9	G9	G4	H8	H10	G5	G4	G2
7	H8	H8	P1	G3	H4	H4	P1	H8
8	G10	G10		G11	H8	G4 H3		G3

Balanced assessment lowest 8 but not in the AIRS. G4 and G5 were also in the Balanced lowest 8 but did not make an appearance in the AIRS. Instead of these sub-catchments G10 and H8 were found in the lowest 8 of AIRS. Despite these differences in the sustainability and environmental rankings, the social and economic pillars had the same sub-catchment rankings for both assessments.

The impact on the sustainability assessment caused by having more or less indicators was seen through a comparison of Stakeholder weightings for 10 and 13 indicators (Table 2). The first notable difference is the lowest ranked sub-catchment produced was different, G12 for 10 indicators and H12 for 13 indicators. A number of sub-catchments were not found in the lowest sub-catchments for both assessments with G12, G4 and G5 not in the lowest 8 sub-catchments for 10 indicators and H4, H5 and G11 not in the lowest for 13 indicators. For the environmental pillar, the sub-catchment rankings were also found to be different with a number of sub-catchments only found in one of the assessments lowest 8. When 13 indicators were used, H3, G11 and H4 were in the lowest 8, but when only 10 indicators were used G5, G12 and G4 were found in the lowest 8. Once again the economic and social rankings were identical, but this was because the indicators and the weightings for these pillars for both 10 and 13 indicators were the same.

Table 2: The sub-catchments with the lowest sustainability (Sust) and environmental condition (Env) for the Stakeholder weightings (SP) with 10 and 13 indicators.

	10 Indicators		13 Indicators	
Rank	SP Sust	SP Env	SP Sust	SP Env
1	G12	G9	H12	H5
2	G9	H5	H10	H12
3	H3	H10	G9	H10
4	G4	G5	H3	G9
5	H12	G12	H5	H3
6	H10	G4	H4	H4
7	G5	H12	G11	G10
8	G10	G10	G10	G11

Discussion

The critical evaluation of this GIS based MCA tool has demonstrated that the sustainability assessment produced using this tool was impacted by the weighting scheme used in the tool. It is also influenced by the sustainability model (sustainability pillars compared to holistic systems model) used for developing the weights. Using more or less indicators was also seen to impact on the sub-catchment rankings produced.

The different weightings schemes used in the project have shown that the GIS-based MCA tool developed here is sensitive enough that changes in the weights used are reflected in the sub-catchment sustainability rankings. This highlights the importance of producing a weighting scheme which is objective and based on the best available science to ensure that the resultant sustainability assessment is accurate as possible. Hajkowicz and colleagues (2004) and others ((Malczewski, 1996; Buselich, 2002; Malczewski, 2006) also pointed out the impact weighting has on MCA results, thus, emphasising the importance of ensuring the weightings are appropriate through evaluation similar to the one carried out in this project.

Thus, the method used to develop the weights is of critical importance to the accuracy of the GIS-based MCA tool for progressing regional sustainability. It needs to be based on the best science available to ensure it reflects the real situation. Since sustainability is contextual the real situation will be different in different places. This leads us to ask what model is most suited to the situation in south west Victoria? This project has shown that that sustainability model used to base the weighting scheme on influences the results of sustainability assessment. For south west

Victoria, the best model for basing weighting schemes on for sustainability assessment is the holistic system sustainability model rather than the balanced sustainability pillar model. The weighting scheme developed using the systems model (AIRS) demonstrates that the environmental indicators have a larger influence on the sustainability of south west Victoria than the economic or social indicators, and thus, the balanced pillar model is not the best fit for the region. This was also reflected by the sustainability impact ratings developed for the indicators where the top 9 (out of 19) key indicators were environmental indicators. Thus, it is more appropriate for this region to use the holistic sustainability model for sustainability assessment to ensure the indicators that have the most impact on sustainability are used and the most appropriate weighting scheme is developed. The use of this model for developing sustainability assessment methods has also been argued by Bossel (2001) who states that a systems based approach for sustainability assessment ensures that all important aspects of system viability, performance and sustainability are included. This approach also recognises that a system can not be assessed in isolation from the systems its dependent on (Gustavson et al., 1999; Reed et al., 2005). Therefore, sustainability assessments need to take into account the relationships between the indicators and their impact on sustainability using a holistic systems based approach to produce the most effective and accurate assessment framework.

The number of indicators used in the weighting scheme impacted on the sustainability assessment, changing the sub-catchment rankings. The most noted difference was G12 becoming the lowest ranked sub-catchment when 10 indicators were used, but when 13 indicators were used this sub-catchment was not even in the lowest 8 sub-catchments. This was due to this sub-catchment having little soil structure decline compared to other sub-catchments in the region, despite its bad performance with other environmental indicators. This demonstrates that the addition of the three environmental indicators provides the sustainability assessment with important information for making an accurate assessment of sub-catchment sustainability. Again, showing that the environmental indicators have a large impact on sustainability in south west Victoria. This may not be the case in other regions, but in this region with a history of agriculture and environmental degradation through landscape change, the condition of the environment has been found to be a significant indicator of sub-catchment sustainability. Thus, this shows that the 13 indicators are needed to make the most accurate assessment of sustainability, ensuring no important information is lost. Gustavson and colleagues (1999) found when modeling sustainability indicators that having a small number of indicators which could be linked was the best approach to sustainability assessment. Although, this study also supports this by showing that a small set of indicators that have been shown to link to each effectively assesses sub-catchment sustainability, however, caution must be shown when reducing the indicator set to ensure no important information is lost.

The critical nature of developing the weighting scheme for MCA sustainability assessment tool has been clearly demonstrated by this evaluation of the GIS-based MCA tool, since the model used to base the weighting on, the number of indicators included and the actual weights assigned all impact on the sustainability assessment produced, changing the ranking of sub-catchments. Therefore, this has shown that it is important to base the weightings on the most up to date science available and critically evaluate the tool developed so that it is as accurate as possible.

This project has demonstrated that the GIS-based MCA tool developed for sustainability assessment is an accurate and robust decision support system for south west Victoria. This tool has shown that the integration of a MCA sustainability assessment tool with GIS can be done. This type of tool can help regional managers make decisions about implementation of sustainability initiatives. This is because the tool ranks sub-catchment sustainability, as well as environment, social and economic condition highlighting sub-catchments that have a lower sustainability. This can help managers prioritise where sustainability initiatives should be implemented to have the greatest impact on regional sustainability. For those familiar with GIS this tool is easy to use and adaptable. For those involved in decision making it fills the gap posed by the lack of a user-friendly tool that is able to give reliable results about regional sustainability.

The adaptability of this tool means that it could be used for different boundaries within the region, such as Local Government Areas, simply by changing the boundaries in GIS and cutting the indicator data to these new boundaries. Other indicators could be added to the tool when new data becomes available by collecting the data, investigating the relationships it has with the other indicators and using Expert Choice to assign a weighting. The indicator data can then be added to ArcMap, to join it to the table with the other indicators and additional processes added to the ModelBuilder to calculate the weighted rank for the indicator.

This tool could be further developed by testing it in other GIS software, such as MapInfo ® and IDRISI, which also have a decision support tools module. This would ensure that all regional managers could use the tool independent of the software they were using for GIS. Also, the tool could be further developed by customising the user interface in ArcMap using Visual Basic and ArcObjects. This could be done to ensure consistency in the output and produce greater stability in the tool Barnwell et al (2005). It would also allow the tool to run independent of ModelBuilder and would help to fix some of the problems with using this environment, making it a tool that is more flexible and easier to use. There may also be some ability to develop a link between Expert Choice and the tool in ArcMap or to develop an AHP tool in ArcMap to enable the development of weights when indicators are added.

Conclusion

This paper introduced a new GIS-based MCA decision support tool for sustainability assessment for south west Victoria. This tool, which is based on AIRS (Richards this conference) can be used to show sub-catchment sustainability across south west Victoria and from this enable sub-catchments to be prioritised for initiatives to progress regional sustainability. The critical evaluation of this tool demonstrated that the weighting scheme used in the MCA tool is critical to the ranking order of sub-catchment sustainability, and thus, requires an objective method for development which considers the interactions of the variables on each other and on sustainability. It also showed how the sustainability model used to develop the weights can influence the ranking of sub-catchment sustainability, proving that for south west Victoria the model that reflects sustainability most accurately is the system sustainability model, where all variables are interacting with each other to influence sustainability to varying degrees. The impact of using more or less indicators was also demonstrated, showing that in this case, the 13 indicators provided the most accurate assessment of sub-catchment sustainability. Thus, this paper has shown the need to carefully consider the method used for weighting in an MCA tool for sustainability assessment to ensure the tool developed is a useful and accurate decision support tool for regional managers. By doing this, the GIS-based MCA tool based on AIRS proved to be a fully integrated sustainability assessment that is user-friendly, robust and transparent and useful for helping regional managers make decisions to progress sustainability.

References

Bossel, H., 2001. Assessing viability and sustainability: a systems-based approach for deriving comprehensive indicators sets. Conservation Ecology [online] URL http://www.consecol.org/vol5/iss2/art12/ 5 (2), 12.

Buselich, K., 2002. An outline of current thinking on sustainability assessment. A background paper prepared for the Western Australian State Sustainability Strategy, Institute for Sustainability and Technology Policy, Murdoch University, Perth.

Campbell, B., Sayer, J. A., Frost, P., Vermeulen, S., Ruiz Perez, M., Cunningham, A. and Prabhu, R., 2001. Assessing the performance of natural resource systems. Conservation Ecology [online] http://www.consecol.org/vol5/iss2/art22 5 (2), 22.

Carver, S. J., 1991. Integrating multi-criteria evaluation with geographical information systems. International JOurnal of Geographical Information Systems 5 (3), 321-339.

Crossland, M. D., Wynne, B. E. and Perkins, W. C., 1995. Spatial decision support systems: an overview of technology and a test of efficacy. Decision Support Systems 14, 219-235.

Fernandes, L., Ridgley, M. A. and Hof, v. t., 1999. Multiple criteria analysis integrates economic, ecological and social objectives for coral reef managers. Coral Reefs 18, 393-402.

Foxon, T. J., McIlkenny, G., Gilmour, D., Oltean-Dumbrava, C., Souter, N., Ashley, R., Butler, D., Pearson, P., Jowitt, P. and Moir, J., 2002. Sustainability criteria for decision support in the UK water industry. Journal of Environmental Planning and Management 45 (2), 285-301.

Giampietro, M., Mayumi, K. and Munda, G., 2006. Integrated assessment and energy analysis: Quality assurance in multi-criteria analysis of sustainability. Energy 31, 59-86.

Glenelg Hopkins Catchment Management Authority, 2003. Glenelg Hopkins regional catchment strategy 2003-2007. Glenelg Hopkins Catchment Management Authority, Hamilton.

Gustavson, K., Lonergan, S. and Ruitenbeek, H., 1999. Selection and modelling of sustainable development indicators: a case study of the Fraser River Basin, British Columbia. Ecological Economics 28, 117-132.

Hajkowicz, S., 2002. Regional priority setting in Queensland: a multi-criteria evaluation framework. CSIRO Land and Water for the Queensland Department of Natural Resources and Mines, Brisbane.

Hajkowicz, S., Temple-Smith, D. and McDonald, G., 2004. Defining an Environmental Benefits Index: a conceptual framework for the Wet Tropics. Rainforest CRC, FNQ NRM Ltd, CSIRO Sustainable Ecosystems Brisbane.

Hamalainen, R. P., Kettunen, E. and Ehtamo, H., 2001. Evaluating a framework for multi-stakeholder decision support in water resources management. Group Decision and Negotiation 10, 331-353.

Jankowski, P., Andrienko, N. and Andrienko, G., 2001. Map-centred exploratory approach to multiple criteria spatial decision making. International Journal of Geographical Information Science 15 (2), 101-127.

Joerin, F., Theriault, M. and Musy, A., 2001. Using GIS and outranking multicriteria analysis for land-use suitability assessment. International Journal of Geographical Information Science 15 (2), 153-174.

Klawitter, S., 2003. A methodical approach to multi criteria sustainability assessment of water pricing in urban areas. In: Jacob, K., Binder, M. and Wieczorek, A. (Eds.), Governance for industrial transformation. Proceedinghs of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change. Environmental Policy Research Centre, Berlin, pp. 277-294.

Malczewski, J., 1996. A GIS-based approach to multiple criteria group decision making. International JOurnal of Geographical Information Systems 10 (8), 955-971.

Malczewski, J., 1999. GIS and multicriteria decision analysis. John Wiley & Sons, New York.

Malczewski, J., 2006. GIS-based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science 20 (7), 703-726.

Mendoza, G. A. and Prabhu, R., 2000. Development of a methodology for selecting criteria and indicators of sustainable forest management: A case study on participatory assessment. Environmental Management 26 (6), 659-673.

Pettit, C. and Pullar, D., 1999. An integrated planning tool based upon multiple criteria evaluation of spatial information. Computers, Environment and Urban Systems 23, 339-357.

Pietersen, K., 2006. Multiple criteria decision analysis (MCDA): A tool to support sustainable management of groundwater resources in South Africa. Water SA 32 (2), 119-128.

Preda, M., Wright, P. and Gimber, C., 2006. Analysis of nutrient export potential to waterways using a GIS-based multiple criteria approach. In: EIANZ (Ed.) Proceedings of Environmental Institute of Australia and New Zealand Conference, Adelaide.

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., Fraser, E. D. G., Morse, S. and Dougill, A. J., 2005. Integrating methods for developing sustainability indicators to facilitate learning and action. Ecology and Society [online] URL: http://www.ecologyandsociety.org/vol10/iss1/resp3/ 10 (1), r3.

Saaty, T. L., 1980. The Analytical Hierarchy Process. McGraw Hill, New York.

South West Sustainability Partnership, 2001. South West Sustainability Blueprint. South West Sustainability Partnership, Hamilton, Victoria, Australia.

Wallis, A. and Barrot, M., 2005. Is South West Victoria Sustainable? A report on sustainability indicators. School of Ecology and Environment, Deakin University, Warrnambool.

Wallis, A. and Wallis, R., 2004. Catchment to regional scale indicators of sustainability. In: Proceedings of Hong Kong.