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Land Use Suitability Analysis Using Multi Criteria Decision Analysis Method for Coastal Management and Planning: A Case Study of Malaysia

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ABSTRACT

There is an urgent need to evaluate the land use suitability in coastal area because of increasing population, providing place for naturally protective coastal ecosystem and improving cumulative impacts. This study presented an application of multi criteria decision analysis technique as an approach to deal with regional coastal management and planning. Analytical Hierarchy Process (AHP) technique has been used to obtain preference weights of land use suitability criteria in a study area located in Marang region in Malaysia. AHP technique is a useful tool to deal with the problem to design the alternatives which optimize the objectives. Furthermore, this technique can be used by researchers to make a precise decision and acceptable personal judgements together with expert knowledge.

Key words: Multi criteria decision analysis, analytical hierarchy process, land-use suitability analysis, coastal planning

INTRODUCTION

Land has been considered as an important natural resource that provides basis of life to flora and fauna (Giriraj *et al.*, 2008). The need for information on land has emerged due to the fast growing population in the world and the rapid growth in coastal cities. Hence, there is an urgent need to collect data regarding planted areas, preservation of the existing land sources, other issues on protection of nature and the information about the coastal area (Ordu and Demir, 2009). The land use change is an important factor in many risky events like flood, sediment yield and erosion, ecological and environmental dynamics and soil properties changes (Solaimani *et al.*, 2009). Human activities along the coast, such as port development, land reclamation, settlement and sand mining also cause serious damages in coastal area (Armah, 2011).

Basically, land suitability assessment can be defined as suitability of particular kinds of land use based on socio-economic and natural attributes. It is similar to select an appropriate location and the goal is to map a suitability index for the certain study area (Joerin *et al.*, 2001). It is an important subject of overall land use planning and the fundamental work, which needs a scientific
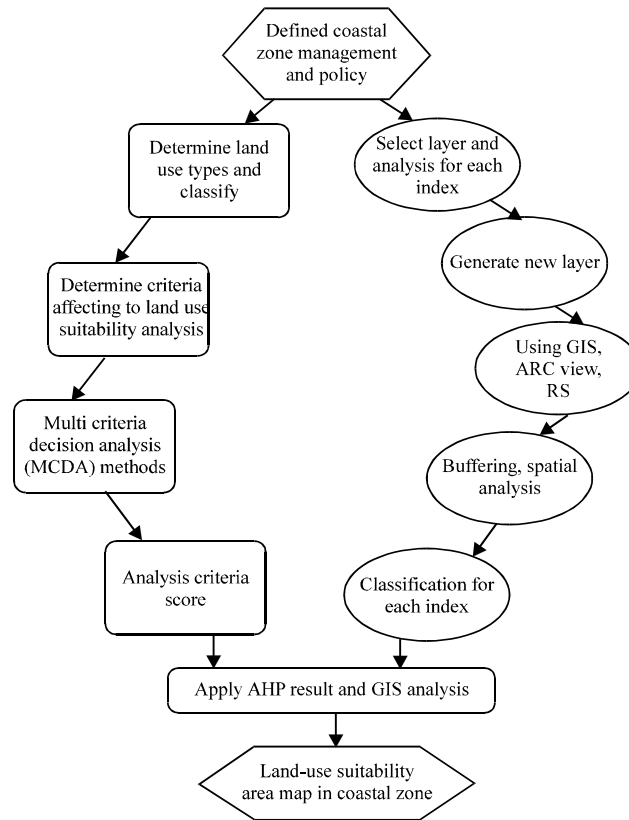
Fig. 1: Land-use suitability analysis process

approach to avoid errors in decision-making, guide development and over-investment, for sustainable use of land (Yu *et al.*, 2009).

The general process for land-use suitability analysis is shown in Fig. 1. This process includes grouping and evaluation of specific areas of land with regard to their suitability for a certain use. The principles of sustainable development make land-use suitability analysis more complex because of different criteria consideration (Duc, 2006).

Multi Criteria Analysis (MCA) is a well known method to handle land suitability evaluation. In many situations, it is so difficult to define relative weights to the different criteria involved in decision making on suitability of land mapping unit. Hence, it is very important to choose a technique, which allows an estimation of weights. Analytical Hierarchy Process (AHP) is one of these techniques. It is a widely used multi criteria techniques in decision making processes which includes multiple actors, scenarios and criteria. Paruccini (1994) and Beinat and Nijkamp (1998) noted that MCA is a decision-making tool which can be applied to evaluate problems where one is faced with a number of different alternatives and desires to find optimal solutions in terms of several conflicting criteria. The usefulness of MCA to support decision making for sustainable development, where conflicting ecological, societal, economic and technical objectives and multiple interest groups are involved has been extremely acknowledged (Antunes *et al.*, 2006).

Land suitability maps can help planners. These maps must integrate all the relevant data for the analysis of the given territory. As long as a significant amount of work would be necessary to

develop these types of maps, they would be useful for several years and many decisions. Updating the maps would surely need much less work than was required at first to produce those (Joerin *et al.*, 2001).

Even though, Malaysia is a comparatively new entrant into tourism activities as compared to its Asian neighbors, the industry has grown greatly over the years. In 2005, tourism industry was a key foreign exchange earner for Malaysia, contributing to over 40% of the country's balance of payment (EPU, 2006). Malaysia's marine assets have always been major draw cards for attracting tourists to the country. The building of resorts, hotels, chalets and other form of accommodations in the coastal areas is the most investment intensive sub-sector of the marine tourism sector. However, development in coastal area needs the long term sustainability of the sector from economic, social and environmental points of view (Basiron, 1994).

The environmental costs of resort development in coastal area have a direct bearing on the sustainability of the projects. Because the main attractions of coastal area resorts are their natural assets such as; clean beaches, scenic beauty, unpolluted and clear water and undisturbed coral reefs. Thus, it is important that in developing these resorts environmental management and nature conservation be primary issue (Basiron, 1994). We have faced many environmental, social and economic damages due to unsuitable selection of area for sustainable activity. Hence, to make a planning decision, suitable areas for development of building hotels or resorts in the coastal area should be considered.

Land-use planners often make complex decisions within a short period of time when they must take into account sustainable development and economic competitiveness. To illustrate the feasibility of this approach, a land suitability map for housing was realized for a small region of Terengganu State. The aim of this study was to apply AHP technique for land-use suitability analysis on coastal area of Marang in Malaysia. This study focused on the usefulness of the AHP as a method for obtaining expert knowledge on environmental systems where qualitative and quantitative aspects of a problem need to be incorporated.

MATERIALS AND METHODS

The implementation of the whole methodology is expressed through Fig. 2. It shows the integration of MCDA technique in decision making for land use suitability.

Study area: This study was conducted in Marang, Malaysia in the year 2008-2009. Figure 3 shows the considered location within the Peninsular Malaysia. Marang is the region where located in Terengganu state in Peninsular Malaysia. Its people mostly live in coastal towns and fishing villages. It has a 200 mile (320 km) long coastline along the South China Sea.

Analytical hierarchy process (AHP): The AHP is one of the methodological approaches that may be applied to resolve highly complex decision making problems involving multiple scenarios, criteria and actors (Saaty, 1980). Proposed by Saaty (1970) it constructs a ratio scale associated with the priorities for the various items compared. Saaty in his initial formulation, Conventional AHP, proposed a four-step methodology comprising modeling, valuation, prioritization and synthesis. At the modeling stage, a hierarchy representing relevant aspects of the problem (criteria, sub-criteria, attributes and alternatives) is constructed. The goal or mission concerned in the problem is placed at the top of this hierarchy. Other relevant aspects (criteria, sub-criteria, attributes, etc.) are placed in the remaining levels (Altuzarra *et al.*, 2007). In the AHP method, obtaining the weights or priority vector of the alternatives or the criteria is required which Saaty has used and developed the Pairwise Comparison Method (PCM) for this purpose (Kordi, 2008).
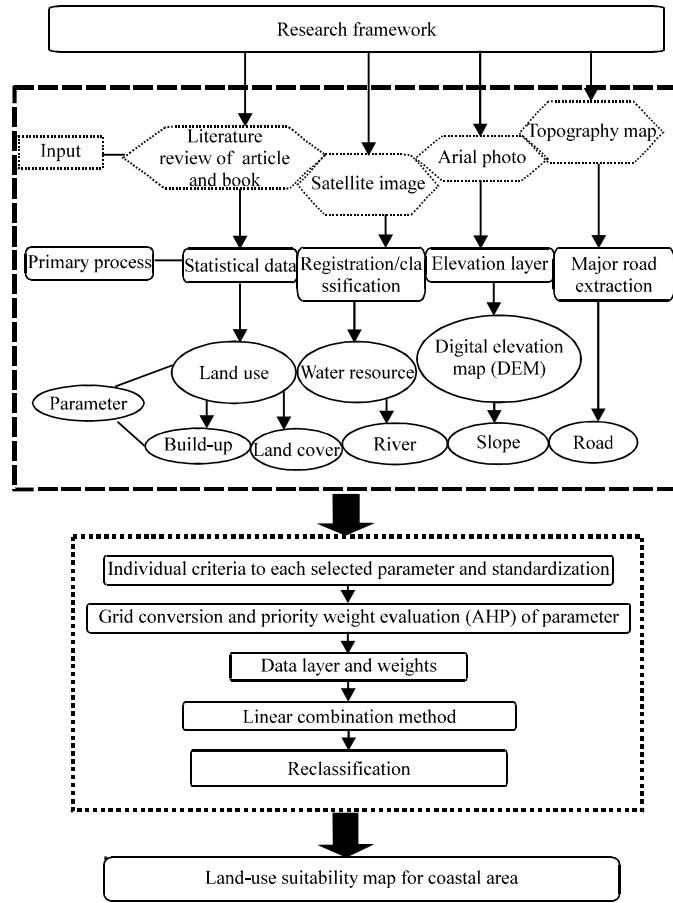
Fig. 2: General flow of study procedure

The AHP method was found to be a powerful tool to determine the weights, compared with other methods used for determining weights.

There are two important indexes in AHP method; the weight and scores of each criteria. In this study, the weight factor was calculated based on the AHP method using the Expert Choice software and the scores of each factor were calculated from the rating process. When applying AHP, constraints are compared with each other to determine the relative importance of each variable in accomplishing the overall goal. The AHP has three basic steps which have been shown in Fig. 4. Table 1 shows a constraint matrix and the sum of each column within the matrix is normalized and weights are calculated. When developing a hierarchy, the top level is the ultimate goal of the decision. The hierarchy decreases from the general to more specific until a level of attributes are reached. Each level must be linked to the next higher level. Typically a hierarchical structure includes four levels; goal, objectives, attributes and alternatives. Each layer consists of the attribute values assigned to the alternatives, which are related to the higher-level elements (Sener *et al.*, 2004). Numerical values are assigned to each pair of constraints by using guidelines established in Table 2.

Weighted linear combination: Two of the most general procedures for multi-criteria analysis are weighted linear combination and concordance-discordance analysis. In this study weighted linear
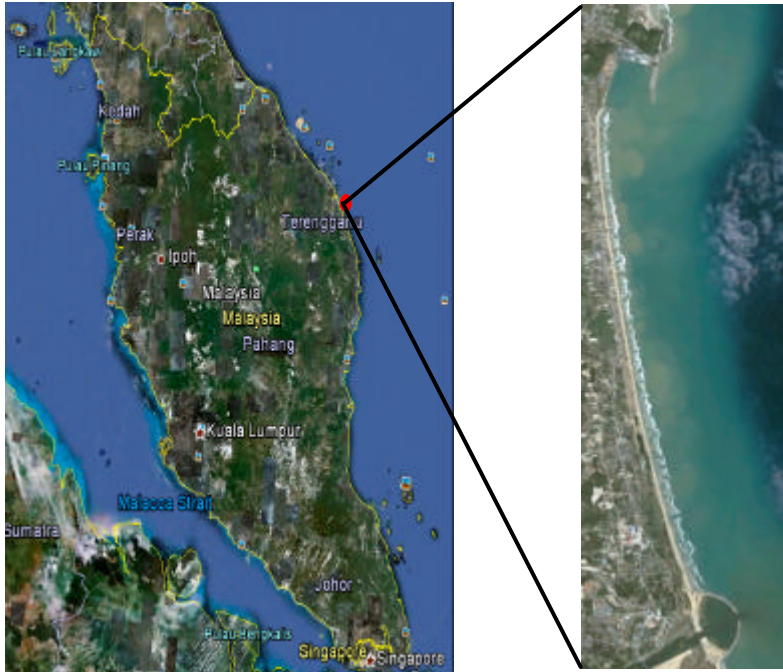
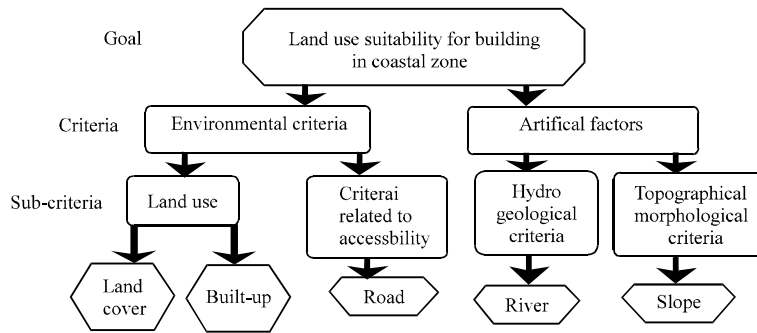Fig. 3: Specification of Terengganu location in Malaysia

Fig. 4: Land-use suitability analysis hierarchy

Table 1: Constraints matrix

	Slope	River	Road	Built-up	Landcover
Slope	1	2	5	5	1
River	1/2	1	1/2	1/3	2
Road	1/5	2	1	1/3	5
Built-up	1/5	3	3	1	3
Land cover	1/1	1/2	1/5	1/3	1

combination has been used. In every part of analysis-decision support-weight, weights were developed by providing a series of Pairwise Comparisons of the relative importance of factors to the

suitability of pixels for the activity being evaluated. Actually, it is the derivation of weights in the context of the decision objective which can provide the major challenge.

Calculation of score value for each criterion: The suitability value for sitting building and housing complexes in coastal area and the standard for each land mapping unit is determined through the maximum limitation method that affects the land use. The five representative natural physical characteristics are used in the calculation, including river, slope, land cover, built-up and road. Before applying weighted linear combination equation to calculated suitability index, these calculated scores are standardized to the measured scale 1 (low), 5 (medium), 7 (high) and 9 (very high suitability). All of the classifications and ranking values in spatial analysis are obtained according to some studies of Al-Shalabi *et al.* (2006) and Kordi (2008) and based on visiting the study area.

RESULTS AND DISCUSSION

Suitability maps resulting from MCA and multi-objective land allocation have shown different classes for which the degree of sensitivity to accept new building for example hotel estates and urban settlements vary from extremely prone areas to weakly prone. Based on relative weights of the suitability factors for development, suitability ranges were identified as shown in Table 3. Areas with high suitability are concentrated in the surroundings of main urban settlements zones. Figure 5 and 6 show the final map (land use suitability image), which divided to 5 best areas. According to this map, we have 3 colors (classes); black, green and blue which the best area for building the hotel in the selected coastal area is the blue color (class 3). After selecting the suitable areas, two factors are very important to select the best area between these sites. First, this area is the biggest area to provide more facility for tourism and second, this is the nearest area to beach because tourists prefer to stay near the beach. Therefore, we can conclude that the best area among these five areas, based on the existing information, is area 1 (2111 m) as the most appropriate one because of having good facility and being a wide open area.

Application of AHP in the process of land suitability assessment is an effective way for the residential land suitability assessment and it has been successfully applied in this research. As a result, it can be concluded that the land use suitability assessment for sitting building in coastal area is a technical basis for sensible land use planning at the regional level and AHP is a flexible and powerful decision making tool for multi criteria problems. Results of the present study are

Table 2: Weights of criteria in land-use suitability analysis

Physical environment criteria	Weight of criteria in land-use suitability analysis
Slope	1.69
River	0.47
Road	0.75
Built-up	0.99
Land-cover	1.07

Table 3: Suitability classification

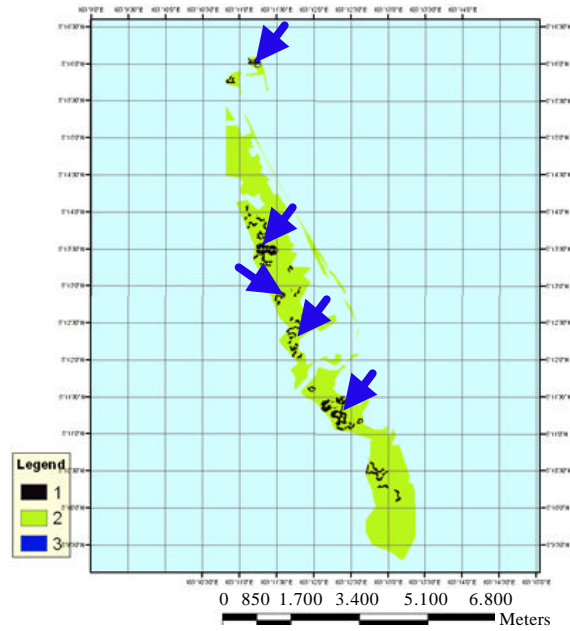| Level of suitability	Range of scores
Highly suitable	Class 3 (Blue)
Moderately suitable	Class 2 (Green)
Not suitable	Class 1 (Black)

Fig. 5: Final land-use suitability map, 1, 2, 3: Classes of area

Fig. 6: Land-use suitability image

consistent with the findings of Paruccini (1994), Malczewski (1999), Badri (1999), Weerakoon (2002), Duc (2006) and Kordi (2008). For the entire land suitability assessment process in Marang coastal area, the environmental protection areas are identified as the first step in the process which has been ignored in a lot of past studies. Excluding the important protected areas will benefit the planners in identifying the lands which have top protection priority and should not be taken up for other purposes. Even if they are suitable for land uses, they cannot be used as building areas because of their environmental protection priority. The land suitability assessment process will assess remaining area for suitability to build buildings, hotels and resorts in coastal areas. The

efforts will help the government to find out the suitable areas for the future urban development by adequately use of the limited land resources.

This study provides experiences on the topic of residential land suitability assessment which is seldom used in the urban land use planning in Malaysia, by introducing the experience in the coastal area of Marang. However, the other areas should consider the criteria for the factors based on the different local environment during land suitability assessment process.

CONCLUSION

The analysis of this study mainly focused on highly suitable areas on coastal area as these areas have highest potential for building hotel and resort. We applied AHP technique for land use suitability analysis based on five criteria layers and it was found to be a useful method to determine the weights. The sensitivity utility of the model helps to analyze the decision before making the final choice. The AHP method can deal with inconsistent judgments and provides a measure of the inconsistency. Nevertheless, the important drawback of the model is its application process, as it needs to consider the right persons with sufficient knowledge for participating in the decision-making group.

The resultant land suitability map represents land use suitability potential to build in selected coastal area, which can help the managers make better land use planning decision. Therefore, this study could be useful for land use decision-making and urban development. This is very important for planner who wants to decide whether land should be developed or conserved. It can also help to consider the strategic urban land development framework and the short-term land use policies can be formulated as well.

REFERENCES

Al-Shalabi, M.A., S.B. Mansor, N.B. Ahmed and R. Shiriff, 2006. GIS based multicriteria approaches to housing site suitability assessment. Proceedings of the 23th FIG Congress, October 8-13, Munich, Germany, pp: 1-17.

Altuzarra, A., J. Maria, M. Jimenez and M. Salvador, 2007. A Bayesian prioritization procedure for AHP-group decision making. Eur. J. Oper. Res., 182: 367-382.

Antunes, P., R. Santos and N. Videira, 2006. Participatory decision making for sustainable development: The use of mediated modelling techniques. Land Use Policy, 23: 44-52.

Armah, F.A., 2011. GIS-based assessment of short term shorline changes in the coastal erosion-sensitive zone of Accra, Ghana. Res. J. Envir. Sci., 5: 643-654.

Badri, M.A., 1999. Combining the analytic hierarchy process and goal programming for global facility location-allocation problem. Int. J. Prod. Econ., 62: 237-248.

Basiron, M.N., 1994. Marin tourism in Malaysia and its potential. Proceedings of the National Conference on the Contribution of the Maritime Sector to the National Economy, November 30, 1994, Kuala Lumpur, Malaysia.

Beinat, E. and P. Nijkamp, 1998. Multicriteria Evaluation in Land-Use Management: Methodologies and Case Studies. Kluwer Academic Publishers, Dordrecht, Netherlands, Pages: 17-31.

Duc, T.T., 2006. Using GIS and AHP technique for land-use suitability analysis. Proceedings of the International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences, November 9-11, 2006 Vietnam.

EPU, 2006. Economic instruments for environmental management in Malaysia. Economic Planning Unit, Prime Minister's Department, Kuala Lumpur.

Giriraj, A., S. Babar and C.S. Reddy, 2008. Monitoring of forest cover change in Pranahita wildlife sanctury Aandhra Pradesh, India using remote sensing and GIS. J. Environ. Sci. Technol., 1: 73-79.

Joerin, F., M. Theriault and A. Musy, 2001. Using GIS and outranking multicriteria analysis for land suitability assessment. Int. J. Geogr. Inform. Sci., 15: 153-174.

Kordi, M., 2008. Comparison of fuzzy and crisp Analytic Hierarchy Process (AHP) methods for spatial multicriteria decision analysis in GIS. Master's Thesis, University of Gavle.

Malczewski, J., 1999. GIS and Multicriteria Decision Analysis. John Wiley and Sons, London, ISBN: 978-0471329442.

Ordu, S. and A. Demir, 2009. Determination of land data of Ergene basin (Turkey) by planning geographic information systems. J. Environ. Sci. Technol., 2: 80-87.

Paruccini, M., 1994. Applying Multi Criteria Aid for Decision to Environmental Management. Kluwer Academic Publishers, Dordrecht, pp: 339-213.

Saaty, T.L., 1970. Optimization in Integers and Related Extremal Problems. McGraw-Hill, New York, ISBN-13: 978-0070543690, pp: 27-30.

Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York, USA., pp: 20-25.

Sener, B.M., L. Suzen and V. Doyuran, 2004. Landfill site selection by using geographic information systems. Master's Thesis, Department of Geological Engineering, Middle East Technical University, Turkey.

Solaimani, K., M. Miryaqobzadeh and S. Lotfi, 2009. Investigation of the Lar lake fluctuations using remote sensing data. Res. J. Environ. Sci., 3: 574-580.

Weerakoon, K.G.P.K., 2002. Integration of GIS based suitability analysis and multi criteria evaluation for urban land use planning; contribution from the analytic hierarchy process. Proceedings of the 23rd Asian Conference on Remote Sensing, November 25-29, 2002, ACRS Urban Planning, Kathmandu, Nepal.

Yu, J., Y. Chen and J.P. Wu, 2009. Cellular automata and GIS based land use suitability simulation for irrigated agriculture. Proceedings of the 18th World IMACS/MODSIM Congress, July 13-17, 2009, Cairns, Australia.