Balancing Tourism and Conservation in the Tianmu Shan Biosphere Reserve, China

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Abstract

This paper explores the use of a GIS-based land allocation model, combined with Multiple Criteria Analysis, as a tool to assist with the effective management of land resources in the Tianmu Shan Biosphere Reserve in Zhejiang Province, China. UNESCO granted Tianmu Shan its Biosphere Reserve designation in 1996, largely in recognition of its unique and rare plant and animal species, especially the ancient stands of Ginkgo biloba and Chinese cedar. In addition, the temples of Tianmu Shan reflect its long cultural and religious heritage. The same beautiful and fragile landscape that merits such protected status also attracts an ever increasing tourist population, especially during the summer months. Thus, like most reserves, Tianmu Shan is faced with the challenge of carefully managing and monitoring land use activities to ensure a balance between on-going economic uses, based on the development of tourism resources, and conservation of the natural environment.

The aim of the land allocation model is to identify the optimum use for each parcel of land in the reserve, based on its suitability to meet the primary land use activities, and to ensure adequate land area is set aside to meet the demands of each use. Three kinds of land uses will be studied in the reserve: land for conservation, land for tourism development and land for agriculture activities. The factors contributing to the suitability of land for each purpose were identified based on The Management Plan of the Tianmu Shan Biosphere Reserve, and field study in summer 2000. For example, areas highly ranked for conservation may have a dense presence of rare species, steep slopes where human disturbance would inevitably create erosional problems, and be situated near to the core zone. Similarly, factors contributing to the other two land uses are identified. Digital maps were then prepared for each factor using the IDRISI GIS program. The factor maps were standardized to a common scale of measurement, and combined to produce suitability maps for each land use. With these suitability maps as input, IDRISIs multi-objective land allocation (MOLA) model was used to create the final map depicting the optimal land uses throughout the reserve. Such a model provides a flexible tool for land managers since variables in the model can easily be adjusted to accommodate changing priorities or to compare different scenarios.

Keywords: Geographic information systems, land allocation, multi-criteria evaluation, Biosphere Reserves, land management

1.0 Introduction

Resource allocation is a global concern. Both first and third world countries are facing this problem over numerous environments and at several spatial scales (Moss 1985). With population growth and expanding economic needs, resources are under increasing pressure (Bhadra et al.

1993; Brandon and Ramankutty 1993). The nature of a land allocation problem is essentially one of competing needs. This is reflected in growing conflicts between environmental protection and economic development (Bhadra et al. 1993). Resource allocation problems involve many complex factors among which the consideration of multiple and conflicting planning objectives must be dealt with (Diamond and Wright 1989). Making decisions about land allocation is one of the most critical elements of land management and development. The objective of land allocation is to resolve conflicting demands for land. Geographic information systems (GIS) are designed for the acquisition, management, analysis and display of geo-referenced data (Clarke 1990; Gumbricht 1996). Recently, much attention has been given to the potential use of GIS, combined with Multi-criteria analysis (MCA) techniques, in land use management and planning (Carver 1991). In particular, the integration of GIS and MCA has become a focus for the development of land use planning tools and methods that can assist resource allocation decision making. These developments are reflected through the procedures for Multi-criteria evaluation and Multi-objective land allocation in GIS (Carver 1991).

This paper explores the use of a GIS based land allocation model, combined with MCA, as a tool to assist with the effective management of land resources in the Tianmu Shan Biosphere Reserve in Zhejiang Province, China. UNESCO granted Tianmu Shan its Biosphere Reserve designation in 1996, largely in recognition of its unique and rare plant and animal species (UNESCO, 1999). The beautiful and fragile landscape that merit such protected status also attracts an ever increasing tourist population, especially during the summer months. Thus Tianmu Shan is faced with the challenge of carefully managing and monitoring land use activities to ensure a balance between on-going economic uses, based on the development of tourism resources, and conservation of the natural environment.

2.0 Land allocation

Making decisions about land allocation is one of the most critical elements of land management and development (FAO 1976). Land use management is based on the recognition that land serves a variety of functions, that there are competing or conflicting needs for land, that more than one sector of society has interests in land use decisions, and that diverse social, economic and environmental considerations influence current and future land uses (FAO 1976). Land allocation is the process by which a land area is designated for a particular use according to criteria set by the decision-makers (Diamond and Wright 1989). Within society, disputes over land often involve two or more mutually exclusive assessments of need or end objectives (Diamond and Wright 1989). The land use allocation process seeks to resolve these conflicting needs and objectives by dividing land among uses based its suitability criteria and its ability to meet the desired objective (Diamond and Wright 1989).

3.0 Factors affecting land allocation

In order to build an effective model of natural system, all the processes involved in shaping the system must be identified (Chang et al. 1995). Moss (1985) noted that for a complete process model, the evaluations of both quantitative and qualitative factors are important. Previous research favored a more secular approach, in which physical or human impacts were analyzed but never coordinated (Moss 1985). Numerous authors have undertaken to develop comprehensive outlines for environmental evaluation (Campbell et al. 1992; Chang et al. 1995; Gumbricht 1996). This research was spurred by a growing awareness that the environment is a complex, interconnected system. The factors affecting the natural system can be broken down into several general types, including geophysical, socio-economic, ecological, and institutional factors (Densham and Goodchild 1989).

4.0 Approaches to land allocation

From the literature discussing land allocation techniques, there are three main approaches to gather, evaluate information and guide the whole land use planning process (Francis 1992; Fuhu Ren 1997): 1) expert-based, 2) informant-based and, 3) combination of expert and informant-based input. The expert-based approach normally involves an inventory and assessment of physical and culture factors of the land unit in order to provide a spatial description of land unit characteristics and their relative significance. The informant-based approach relies mainly on community involvement to gather land use information and assess the relative significance or values connected with these land uses. A variety of ways can be used in this approach, such as newsletters; community meetings and questionnaires (Peine 1998). The combination approach involves gathering information for land units using expert input and then using the public input to verify the information. The fundamental importance of this approach is to build a consensus among all stakeholders (Peine 1998).

5.0 A GIS-based method for land allocation

A GIS is a software system designed for the acquisition, management, analysis and display of geographically referenced data (Clarke 1990;Gumbricht 1996). GIS is increasingly used for inventory, analysis, understanding, modeling and management of natural environment (Burrough 1986; Densham and Goodchild 1989; Clarke 1990). The advantages of using a GISbased system include its ability to store large amounts of spatial data from many different sources and to represent the real world through integrated layers of spatially oriented information (Goodchild 1991; Campbell et al. 1992; Fischer and Nijkamp 1992). GIS gives users a powerful capability to process a wide variety of social, economic, environmental and physical data (Burrough 1986; Ding and Fotheringham 1992; Maidment 1993,1995; Gumbricht 1996). Land use planning is an obvious field to benefit from GIS.

The traditional spatial analytic functionality of GIS consists mainly of the ability to perform overlays, spatial queries, buffer operations, etc. Such functions are of limited use when multiple and/or conflicting mapped criteria or objectives are involved (Carver 1991). MCA linked to GIS can provide a valuable addition to its standard functionality (Carver 1991). This combination of GIS and MCA becomes the tool for emphasizing land value and importance, and providing guidance in assessing mapped criteria for land use decision making (Shakya and Leuschner 1990). MCA developed from a mechanism for the selection of the best alternative from a set of competing options, to a range of decision aid techniques (Shakya and Leuschner 1990). MCA is a way of approaching complex decision problems. It can support the organization of a decision problem, the exploration of the role of decision factors, and the evaluation of alternatives under different perspectives (Nijkamp et al. 1990).

GIS software has led to dramatic improvements in the capabilities for resource allocation when combined with MCA. These developments are viewed through the procedures for Multi-criteria evaluation and Multi-objective land allocation in GIS (Fedra and Reitsma 1990; Schaller 1990; Carver 1991). For example, in the IDRISI software program, two evaluation modules for land allocation decision making, Multi-criteria evaluation (MCE) and Multi-objective land allocation (MOLA), are included. These procedures emphasize the aggregation of evidence of varying degrees of trade-off among criteria, and can be used for conflict resolution and conflict avoidance in multiple objective decision problems (Fedra and Reitsma 1990).

5.1 Multi-Criteria Evaluations (MCE)

Multi-Criteria Evaluation is designated to characterize specific land-uses, to meet a specific objective (Zeleny 1982). In the process of land allocation decision making, normally several factors will need to be evaluated. The factors then have weights attached to them, which relate to the type of use being characterized (Zeleny 1982; Carver 1991; Gumbricht 1996). In the IDRISI system, MCE is most commonly achieved by one of two procedures. The first involves Boolean overlay, whereby all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operations such as AND or OR. The second is weighted linear combination wherein continuous factors are standardized to a common numeric range, and then combined by means of a weighted average. The result is a continuous map of suitability that may then be masked by one or more Boolean constraints to accommodate qualitative criteria.

5.2 Multi-Objective Evaluation (MOE)

Multi-objective decisions are very common in environmental management. Multi-Objective Evaluation is a method that aids decision making on land use issues when multiple objectives are involved, and concern with the final decision making process may involve several land uses (Field 1973; Diamond and Wright 1988). This approach recognizes the diversity among individuals within the organization and the potential for conflict when striving for optimal solutions (Field 1973). GIS is a way for problem solving and decision making while accommodating the multiplicity of stakeholders in the decision making process (Goicoechea and Duckstein 1976). Multi-objective evaluations may be both complementary and conflicting (Field 1973). Complementary objectives result when land units satisfy more than one objective (Goicoechea and Duckstein 1976). Thus an effective allocation would be one in which both objectives were satisfied to the greatest degree (Campbell et al. 1992). Conflicting objectives compete for the availability of land, which can be used for one or the other, but not both uses (Campbell et al. 1992). The multi-objective decision making problem can be solved by the MOLA procedure in the IDRISI system.

6.0 Case Study: Tianmu Shan Biosphere Reserve

The Tianmu Shan Biosphere Reserve is located in Linan county, Zhejiang Province, China. The total area of Tianmu Shan Biosphere Reserve is 4284 hectares. It has three zones: the core zone (1191 hectares), the buffer zone (381 hectares) and the transitional zone (2712 hectares). The tourism industry is the largest and most rapidly growing industry in Tianmu Shan. In recent years, considerable concern has been expressed about the expansion of tourism. While it is recognized that the development of tourism represents a major economic source, there is concern about encroachment on forested land and agriculture land, hence a loss of rare plants, animal species and a very traditional lifestyle in the cultural heritage of Tianmu Shan. Thus Tianmu Shan is faced with the challenge of carefully managing land use activities to ensure a balance between on-going economic uses, based on development of tourism resources, and conservation of the natural environment. Three types of land use are present in the reserve: land for conservation, land for tourism development and land for agriculture activities. The aim of the land allocation model is to identify the optimum use for each parcel of land in the reserve, based on development of tourism resources, and conservation of the natural environment.

The IDRISI system, a raster-based GIS, is used in this research. The main functions of GIS in this study include database creation, incorporating information from both experts and local people, producing multi-criteria suitability maps and a final land allocation map. These latter tasks were accomplished with the MCE and MOLA modules in the IDRISI system.

Identifying the management issues (resource conflicts, research objectives, significant land uses and important factors for each land use) in meeting the conservation and tourism development functions based on The Management Plan and field work, is the first step of this land use management study.

The information related to the land use for tourism and conservation was entered into a digital database. The inventory of the data was completed in two parts: identification and collection of existing information, and ground truth checking, a process that will help to verify the data throughout the inventory process. Seven maps were digitized in the inventory process. These include the boundary map, function map (core area, buffer zone and transition zone), the forest distribution map, the animal distribution map, the existing roads, trails and water, the location of tourist attraction zones.

The next stage is to establish the factors and constraints for each land use. This stage is critical, requiring the identification and analysis of the important factors associated with a particular land use. The factor information for the desired land uses is used in the suitability analysis. The factor maps can be combined to show, for example, where new tourism development is most suitable and where it is the least or totally unsuitable. In this case study, four factors were identified as being relevant to the land use of tourism development: proximity to the road, proximity to existing tourist attractions, proximity to the location of rare forests, and proximity to the core area. For land for conservation, three factors were identified: slope gradient, proximity to the core area of the reserve and the proximity to the location of rare species. For land use of agriculture, two factors are considered: slope gradient and proximity to water. Using the spatial analysis functions in IDRISI, such as DISTANCE, OVERLAY, and RECLASS, the factor maps were created. In the GIS system, factors are criteria are continuous in nature and thus act as continuous modifiers to the suitability of a location for the objective in question (Zeleny 1982; Carver 1991;).

The next step involved using the MCE module to assess the suitability of the land for the development of tourism, for conservation and for agriculture activities. All the factor maps were standardized to a common scale of measurement , and a set of weights was developed to indicate the relative influence of each factor for a given objective. A suitability map for each land use was produced with the MCE procedure by combining the factor maps according to the factor weights.

The final phase involved developing a GIS-based model using MOLA routine to assist with the goal of balancing tourism development and conservation. In this process, the suitability maps are combined to arrive at an optimum land allocation pattern for the three land uses. Important characteristics that need to be defined at this stage are land use targets, and land use priorities which makeup a stakeholders rating of land for each objective (Campbell et al. 1992). In this study, MOLA requires the three suitability maps as input, along with the relative weights assign to each. Two weighting scenarios were completed: 1) conservation, tourism development, and agriculture are weighted equally ; 2) the conservation objective is given a greater weight than tourism development and agriculture. Through the MOLA procedure, the land allocation model depicting the optimal land uses for tourism and conservation were created for each scenario. Such a model provides a flexible tool for land managers since variables in the model can easily be adjusted to accommodate changing priorities or to compare different scenarios.

7.0 Results

The final maps depicts the optimal land use of development of tourism, conservation and agriculture throughout the reserve, according to the assigned land use priorities and area targets. They will be compared with the actual land-use patterns that exist currently in that region, examining the level of divergence that occurs between the theoretical land use and what is actually occurring on the ground.

This paper explores the use of GIS base land allocation model, combined with MCA, as a tool to assist with decision making using a case study. This method allows exploration of a variety of rationales and perspectives in suitability evaluation and land allocation, and thus can accommodate a variety of decision strategies in resource management.

In developing the GIS model, the management plan of Tianmu Shan is a useful resource. At the same time, assessment by local experts is very important in the process of identifying the factors associated with a particular land use, weighting the factors, and evaluating the final result.

8.0 References

Bhadra, D., A. Salazar, P. Brandao. 1993. Urbanization, Agriculture Development, and Land Allocation. World Bank Discussion Papers. #201, 65p.

Brandon, C. and R. Ramankutty. 1993. Toward an Environmental Strategy for Asia. World Bank Discussion Papers. #224, 210p.

Burrough, P.A. 1986. Principles of Geographical Information Systems for Land Resources Assessment. New York: Oxford University Press Inc.

Campbell, J.C., J. Radke, J.T. Gless and R.M. Wirtshafter. 1992. An Application of Linear Programming and Geographic Information System: Cropland Allocation in Antigua. Environment and Planning. 24: 535-549.

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

Chang, Ni-Bin, C. G. Wen and S. L. Wu. 1995. Optimal management of environmental and land resources in a reservoir watershed by Multi-Objective Programming. Journal of Environmental

Management. 44: 145-161.

Clarke, M. 1990. Geographic information systems and model based analysis: towards effective decision support systems. Geographical Information Systems for Urban and Regional Planning. 16(1):165-175.

Densham, P.J. and Goodchild, M.F. 1989. Spatial Decision Support Systems: A Research Agenda. Proceedings GIS/LIS 89. pp. 707-716.

Diamond, J.T. and J.R. Wright. 1989. Efficient land allocation. Journal of Urban Planning and Development. 115(2): 81-96.

Ding, Y. and A.S. Fotheringham. 1992. The integration of spatial analysis and GIS,. Environment and Urban Systems. 16: 3-19.

FAO, 1976. A Framework for Land Allocation. Soil Bulletin 32, Food and Agricultural Organization of the United Nations, Rome.

Fedra, K. and Reitsma, R.F. 1990. Decision support and geographical information systems, in H.J. Scholten, J.C.H. Stillwell (Eds.) Geographical Information Systems for Urban and Regional Planning. Kluwer, Dordrecht.

Field, D.B. 1973. Goal programming for forest management. Forest Science. 19 (2): 125-135.

Fischer, M.M. and P. Nijkamp. 1992. Geographic information systems and spatial analysis. Annals of Regional Science. 26: 3-17.

Francis, G. 1992. Applying landscape ecology to biosphere reserves. In: Landscape Approaches to Wildlife and Ecosystem Management, Proceedings of the 2nd Symposium for Landscape Ecology and Management. Eds. Ingram, B. and M. Moss. Montreal: Polyscience Publications Inc. pp.241-247.

Fuhu Ren. 1997. A training model for GIS application in land resource allocation. Journal of Photogrammetry and Remote Sensing. 52 (1997): 261-265.

Goicoechea, A. and L. Duckstein. 1976. Multiobjective programming in watershed management: a study of the Charleston watershed. Water Resource Research. 12 (6): 1085-1092.

Goodchild, M. 1991. Geographic information systems. Journal of Retailing. 67: 3-15.

Gumbricht, T. 1996. Application of GIS in training for environmental management. Environmental Management. 46: 17-30

Maidment, D.R. 1993. Developing a spatially distributed unit hydrographic by using GIS. In:

Application of Geographic Information Systems in Hydrology and Water Resources Management. Hydro GIS 1993. Eds. Kover, K. and H.P. Nachnebel LAHS Publication No. 211. pp. 181-192.

Maidment, D.R. 1995. GIS/Hydrologic models of non-point source pollutants in the vadose zone. Processing Bouyoucos Conference. May 1995, Riverside, CA.

Moss, M.R. 1985. Land Processes and Land Classification. Journal of Environmental Management. 20: 259-319.

Nijkamp, P., Rietveld, P., Voogd, H. 1990. Multicriteria Evaluation in Physical Planning. North Holland, Amsterdam.

Peine, J.D. 1998. Ecosystem Management for Sustainability. New York: Lewis Publishers. pp. 3-6, 350-366.

UNESCO. 1999. UNESCO MAB Biosphere Reserve Directory. <http://www.unesco.org/mab/br/brdir/asis/chi.htm>. Assessed December 2000.

Schaller, J. 1990. Geographical information system applications in Environmental Impact Assessment. In H.J. Scholten, J.C.H. Stillwell (Eds.) Geographical Information Systems for Urban and Regional Planning. Kluwer, Dordrecht.

Shakya, K.M. and W.A. Leuschner. 1990. Applying multiple objective planning model for Nepalese hill farms. Agriculture System. 34: 133-149.

Zeleny, M. 1982. Multiple Criteria Decision Making. New York: McGraw-Hill.