Journal of Environmental Management (1994) **41**, 187–198

Multivariate Approach for Suitability Assessment and Environmental Conflict Resolution

Luis A. Bojórquez-Tapia, Enrique Ongay-Delhumeau and Exequiel Ezcurra

Centro de Ecología, Ciudad Universitaria UNAM, Apartado Postal 70-275, México, D.F. 04510, México

Received 28 *April* 1993

Mexican environmental legislation mandates public participation in regional development planning, so sectoral interests must be taken into account. A multivariate statistical procedure is presented for classifying land units into suitability groups, according to sectoral interests. This method provides information that is both legally defensible and accurate. The method is demonstrated by a study case.

Keywords: Mexico, environmental assessments, land use planning, regional development.

1. Introduction

An essential component in environmental planning is to ponder people's concerns and expectations for natural resources management (Kessler *et al.*, 1992). Thus, methodologies for regional suitability assessments must take into account the different values and interests of the implicated social actors (that is, socio–economic sectors and interest groups).

Suitability can be defined as the fitness of a particular area for a defined use (Steiner, 1983). However, sectoral values and interests generate environmental conflicts (Crowfoot and Wondolleck, 1990). Such conflicts appear whenever sectoral activities jeopardize or reduce the capacity of the land for other social actors (Bojórquez-Tapia and Ongay-Delhumeau, 1992). Rather, land use aptitude is relative to the needs and possibilities of social actors. Consequently, suitability analyses must provide information for selecting land uses that reduce intersectoral conflicts.

This paper describes a multivariate method used for assessment of land suitability in the Cape Region, Mexico, where a regional tourist development is being planned. The objective was to determine where environmental conflicts were likely to occur by overlapping land uses, through divisive polythetic techniques (Noy-Meir, 1973; Pielou, 1984) and a principal components biplot ordination (Digby and Kempton, 1987).

Environmental planning must involve public perceptions to, ideally, achieve an impartial determination of land suitability. But suitability assessments rely on experts'

0301 4797/94/070187+12 $08.00/0

knowledge, impartiality may not be obtained because of experts' biases (Organización de los Estados Americanos, 1987). Multivariate statistical methods provide an heuristic framework for detecting the biases and, thus, facilitating better appraisal of environmental conflicts.

2. Study area

The Cape Region is located at the meridional tip of the Baja California Peninsula, México (Figure 1). It is an arid and semi-arid area of approximately 19 000 km^2. Four major landforms are present: mountains, hills, plateaus and flatlands.

The Sierra de La Laguna mountainous range is the dominant physiographic trait. This sierra is located at the middle portion of the Cape Region and runs in a north–south

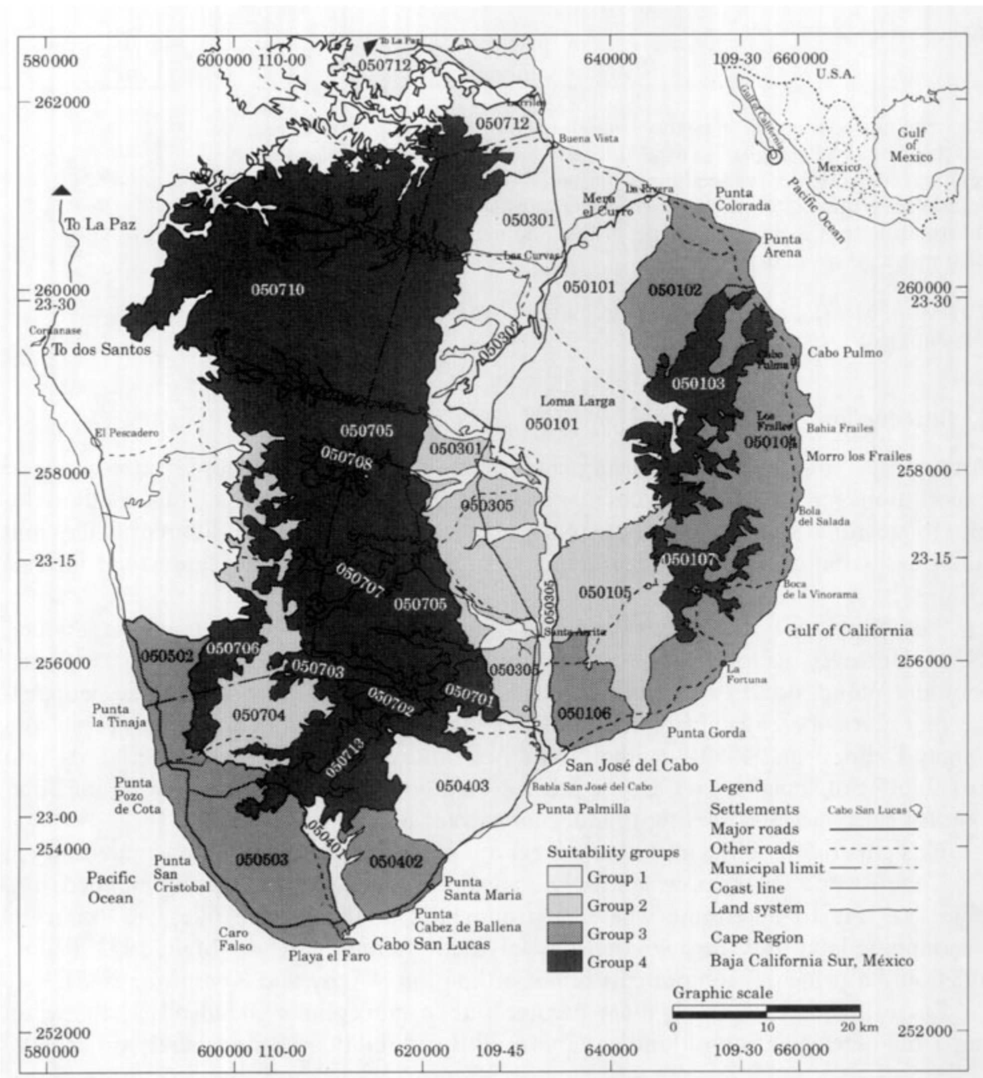

Figure 1. Map of the Cape Region, Mexico, showing the land systems and the suitability groups. The last three numbers of each land system correspond to the ones used in other figures, tables and text.

direction. Highest peaks reach 2000 m above sea level. It is the principal zone for groundwater recharge in the Cape Region. Because of the rain-shadow effect of the Sierra, mean annual precipitation ranges from 200 mm in the lowlands to 600 mm in the highlands. Most of the rainfall (70–80%) occurs as summer tropical storms.

Predominant soils in the Region are Xerosols, Regosols and Lithosols. Cambisols and Phaeozems are present in the Sierra de La Laguna. All these soils are loose in texture and become easily eroded by wind and rain.

The Cape Region is biologically important. Geological events, such as tectonic uplift, peninsular drift and isolation, have generated the conditions for the development of high endemism. Besides the typical desert scrub vegetation, grasslands and tropical deciduous forests are found at the lowlands, and pine-oak and pine forests cover highland on Sierra de La Laguna. Likewise, the Region contains the Cabo Pulmo coral reef at the Gulf of California coast.

The total population is around 46 000. Though 60% of the population inhabits the cities of San José del Cabo and Cabo San Lucas, more than 300 urban and rural settlements exist in the Cape Region.

Tourism is the major economic activity in the Cape Region. Tourist resorts are being constructed along the highway from San José del Cabo to Cabo San Lucas. Incipient tourist developments are located north-east of the study region, at Los Barriles, Buenavista and La Rivera. Also, agriculture is an important economic activity in the cities of Santiago and San José Viejo. Other human activities in the study area are organic agriculture, cattle ranching, sport fishing, urban development and non-governmental organizations for conservation of biodiversity.

3. Methods

Suitability assessment for the Cape Region was carried out in two stages: (1) identification of environmental criteria for different land uses; and (2) classification and ordination.

3.1. Identification of environmental criteria for land uses

The study area was divided into 32 land systems following Secretaría de Desarrollo Urbano y Ecología (1988) and from topographic maps (scale 1:250 000). A base map was prepared at scale of 1:150 000 (Figure 1).

Consultations with federal, state and local policy makers, representatives of socio-economic sectors and non-governmental organizations (NGO) spokesmen were conducted to identify the principal social actors in the region. Then, an interdisciplinary team was assembled. Local experts and decision makers "represented" the different social actors in the analysis and were organized into an "analytical" group. Team members were selected because of their experience, technical capacity and knowledge of one or more social actors' interests.

Through interdisciplinary meetings, the experts identified the land uses and listed the physical, biological and socio-economic characteristics—or environmental criteria—needed to assess suitability for those uses. Later, the experts ranked the environmental criteria for each land use. Conditions or states of favorability–unfavorability were defined for each criterion as in Betters and Rubingh (1978). Next, a binary matrix was prepared for each land use: the rows listed the ranked environmental criteria; the columns listed the land systems; and, in each cell, a 1 indicated presence of a favorable condition, while a 0 indicated absence of a favorable condition. Baseline information consisted of readily available inventories or, otherwise, information that could be easily obtained.

3.2. CLASSIFICATION AND ORDINATION

In matrix algebra, $\mathbf{B}_i$ was a binary matrix of presence–absence of favorable states of environmental criteria for land use i, where $i = 1,2,3,\ldots,m$ were land uses (for example, forestry, cattle ranching, tourism, etc.). Dimensions of $\mathbf{B}_i$ were $c \times n$, where c was the number of environmental criteria, and n was the number of land systems.

To weight the rank of each environmental criterion for a specific land use, a $\mathbf{x}_i$ vector, of dimension c, was obtained by subtracting the rank number of each criterion from the total number of environmental criteria. Since the importance or rank of environmental criteria changed between different land uses, the suitability vectors were calculated by:

$$\mathbf{y}_i = \mathbf{B}'_i \, \mathbf{x}_i,$$

where $\mathbf{y}_i$ was the suitability vector of the n land systems for land use i.

The suitability vectors $\mathbf{y}_i$ were merged into a suitability matrix $\mathbf{A}$ of dimensions $m \times n$, where m is the number of land uses and n is the number of land systems. Thus, row 1 in $\mathbf{A}$ corresponded to the first land use vector $\mathbf{y}_1$, row 2 corresponded to $\mathbf{y}_2$, row 3 corresponded to $\mathbf{y}_3$, and so on. Accordingly, a_{ij} was the suitability score of land use i for land system j. The matrix $\mathbf{A}$ was classified by a divisive polythetic classification method,

TABLE 1. Definitions of the land uses employed in the suitability analysis of the Cape Region, México

Land use	Definition
Agriculture	Extensive and intensive agricultural practices to produce grains, forages, fruit bearing plants and horticulture
Cattle ranching	Territory used to rear and exploit domestic animals and their byproducts
Conservation of biodiversity	Established or proposed protected areas and activities related with the conservation of biological diversity
Forestry	Extraction of timber and non-lumber species for different purposes and uses
Hunting	The necessary space to carry out this activity
Industry	Spaces assigned to industrial activities
Sport fishing	Spaces where fishing infrastructure and their related activities are settled in relation with the exploitation of marine resources
Tourism	Territorial appraisal where people have recreative activities outside their communities in which they reside. It also includes the necessary infrastructure to provide goods and services to this activity
Urban development	Appropriation of territory to establish a human settlement with a minimum infrastructure
Water use	Research, selection, construction and operation of infrastructure of groundwater recharge areas for different purposes

following the Noy-Meir's partitioning method (Noy-Meir, 1973; Pielou, 1984). Results were transferred to a map.

To compare aptitudes between groups resulting from the classification, a matrix of mean group suitability **Z** was computed using the score values on **A**. Dimensions of **Z** were $g \times m$, where g was the number of groups and m was the number of land uses. Matrix **Z** was adjusted by rows and columns following Gower's double-centering procedure (Gower, 1966; Digby and Kempton, 1987):

$$z_{gm} = x_{gm} - \bar{x}_{g.} - \bar{x}_{.m} + \bar{x}_{..},$$

where z_{gm} was the adjusted mean value of group g for land use m, $\bar{x}_{g.}$ was the mean of group g for all land uses, $\bar{x}_{.m}$ was the mean of land use m for all groups, and $\bar{x}_{..}$ was the mean of the whole matrix. A positive value of z_{gm} indicates a high mean suitability of group g for land use m, while a negative value denotes the opposite.

A graphical representation of the relationships between land systems and land uses was obtained by a biplot ordination (Digby and Kempton, 1987). Thus, **A** was subjected to principal-component analyses (PCA). The significance criterion for contribution to the variance explained by any given axis was a percentage value above 100/rank of the matrix. The program ORDEN Version 2.1, programmed by E. Ezcurra, was utilized for all the statistical analyses.

Following the concept of multiple use (Brooks *et al.*, 1991), environmental conflicts were identified whenever a land system was suitable for competitive uses. A final set of interdisciplinary meetings were organized to derive management guidelines for the resolution of environmental conflicts.

4. Results

The following land uses were evaluated: agriculture, cattle ranching, urban development, industry, hunting, forestry, water use, bioconservation (or conservation of biodiversity), tourism and infrastructure for sport fishing (Table 1). A total of 57 environmental criteria were considered (Table 2). Accordingly, 10 binary matrices $\mathbf{B}_i$ (57×32) were prepared and a suitability matrix **A** (10×32) was obtained.

The classification analysis of **A** (Table 3) generated four groups at a similarity level of one-half the total Euclidean distance (Figure 2). With the exception of hunting and forestry, land systems of group 1 obtained the highest suitability scores, particularly for tourism and sport fishing. In contrast, the lowest scores of group 2 were the ones associated with the two later land uses. When compared with the rest, group 3 presented intermediate ratings for all land uses, although some land systems obtained high values, especially for hunting and conservation of biodiversity. For group 4, the highest suitability scores corresponded to hunting, forestry, water use and conservation of biodiversity, while the rest of the grades were low or moderate.

Matrix **Z** (4×10) revealed the general differences between groups (Table 4, Figure 2). Hence, group 1 was composed of bajadas, alluvial plains and shore lines predominantly suitable for tourism and sport fishing, industry, water use, agriculture and cattle ranching, and unsuitable for hunting, forestry, water use and bioconservation. Group 2 comprised bajadas and hills primarily suitable for agriculture, cattle ranching, urban development, hunting, forestry and water use, and inappropriate for industry, bioconservation, tourism and sport fishing. Group 3 consisted of low-altitude sierras and bajadas with principal suitability for hunting, bioconservation, tourism and sport

TABLE 2. List of the 57 environmental variables used in the suitability analysis of the Cape Region, México

1. Agricultural yields (horticulture)	29. Marine, salinity
2. Agricultural yields (forages)	30. Marine, currents
3. Agricultural yields (fruit-bearing plants)	31. Population growth rate
4. Agricultural yields (basics, corn and wheat)	32. Population (No.)
5. Aquifers	33. Private properties
6. Biological diversity	34. Productive organizations
7. Climate	35. Protected areas (established and proposed)
8. Communal lands	36. Rainfall
9. Communications, aerial	37. Sewage systems
10. Communications, maritime	38. Slopes, topographic
11. Communications, services (telecommunications)	39. Slopes, marine
12. Communications, terrestrial	40. Soils
13. Education	41. Species, commercial
14. Electricity	42. Species, hunting
15. Elevation	43. Species, endemic, threatened or endangered
16. Employment (primary sector)	44. Substrate
17. Employment (secondary sector)	45. Temperature, atmospheric
18. Employment (tertiary sector)	46. Temperature, sea
19. Federal lands	47. Transport
20. Geomorphology	48. Vegetation
21. Health	49. Vegetation cover
22. Housing	50. Water, dissolved oxygen content
23. Housing quality	51. Water, transparency
24. Infrastructure, industrial and commercial	52. Water, management
25. Infrastructure, tourism	53. Water, potable
26. Infrastructure, agricultural and cattle ranching	54. Water, quality
27. Infrastructure, cultural and recreational facilities	55. Water, wells (No.)
28. Investment	56. Water, coliform
	57. Wilcox's saline classification

fishing. Group 4 aggregated high-altitude sierras and canyons most suitable for hunting, bioconservation, forestry and water use.

The ordination analysis depicted two gradients (Figure 3): the first principal-component axis was related to topography, and the second principal-component axis to intensity of use. The first principal component separated the lowlands (coastal zone, bajadas and alluvial plains) on the negative side, and the highlands on the positive side. The second principal-component axis divided the high-intensity uses on the negative side, and the low-intensity uses on the positive side. The variance explained by the two axes was 84%; all other axes were discarded because they explained less than 10% of the total variation.

The biplot (Figure 3) simplified the identification of primary suitability for individual land systems within each group (Table 3). Additionally to the mean suitability, land systems within groups were divided as follows (Figure 1): group 1 presented land systems with predominant aptitudes for agriculture and cattle ranching, urban development and industry (101, 301, 302 and 712) and tourism and sport fishing (304, 401, 403), note that land system 302 also presented a high suitability for water use (Table 3); group 2 included land systems with main suitability for agriculture and cattle ranching (303, 305 and 306), water use (105), forestry and hunting (704), hunting (306, 501) and conserva-

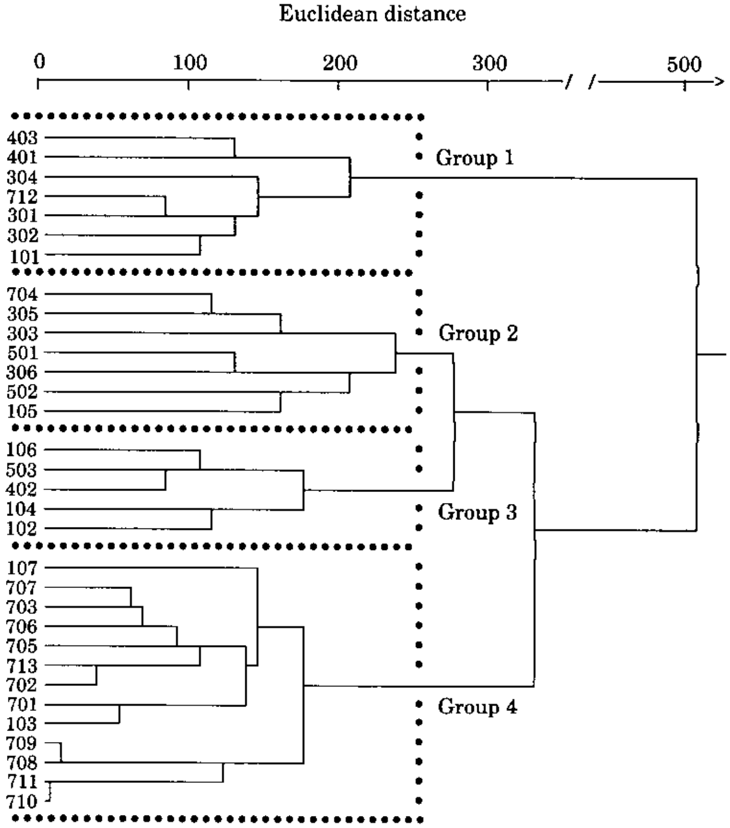

Figure 2. Dendrogram from cluster analysis for the suitability assessment of the Cape Region, Mexico. The dotted line shows the four groups at 50% the mean intra-group Euclidean distance.

tion and hunting (502), although this case was considered a misclassification; group 3 contained land systems with primary capacities for bioconservation and hunting (104 and 503), tourism and sport fishing (102, 106 and 402); and group 4 encompassed land systems with principal aptitude for water use (103, 107, 701, 702 and 713) and bioconservation (703, 705, 706, 707, 708, 709, 710 and 711).

5. Discussion

Land use aptitude is relative to the needs and possibilities of social actors. Therefore, suitability assessments must be based upon social actors' interests and values about the land, so that alternatives can be formulated to minimize environmental conflicts generated by regional development projects.

However, suitability analyses are sensitive to the ability of an interdisciplinary team to both reflect public perceptions and aspirations, and achieve a rigorous and transparent synthesis of information. On one hand, this implies that attention has to be given to the way a team of experts is assembled. On the other, it means that evaluations have to originate from strict definitions of issues and appraisal criteria.

Canter (1991) suggests that selection of team members should be based upon expertise. However, data on human uses and impacts are usually unavailable (Price, 1990), or do not encompass sufficient temporal and spatial resolution for planning

TABLE 3. Land use suitability scores centered by column per land system for the suitability analysis of the Cape Region, México

Land system	Land use									
	AG	AC	UR	IN	HU	FO	WU	CO	TO	SF
Group 1										
101	10	10	9	9	7	8	9	9	8	9
301	10	10	10	10	7	8	9	9	10	9
302	10	8	8	10	7	7	10	9	8	9
304	9	8	8	8	6	7	9	9	10	9
401	8	8	9	9	5	5	7	8	10	9
403	7	7	10	9	7	8	9	9	10	9
712	9	10	10	9	7	8	9	9	10	9
Group 2										
105	8	9	7	5	8	8	10	9	5	5
303	9	9	9	8	7	8	8	8	6	4
305	8	9	7	7	7	9	8	8	4	3
306	8	8	6	5	10	7	8	6	5	3
501	8	8	7	6	9	8	8	8	6	3
502	9	8	5	5	10	8	8	10	5	6
704	8	9	8	7	9	10	8	8	4	3
Group 3										
102	6	7	7	5	9	8	8	8	6	7
104	5	6	6	5	9	7	8	9	6	7
106	8	7	6	6	9	7	8	8	8	6
402	6	7	7	7	9	8	8	8	8	8
503	8	7	7	6	9	8	9	10	8	7
Group 4										
103	5	7	6	5	9	8	7	8	4	3
107	6	6	6	5	9	6	8	7	5	2
701	6	7	6	5	9	9	7	8	4	3
702	6	6	4	4	9	8	8	7	4	2
703	5	5	4	4	9	7	7	7	4	3
705	6	5	4	3	9	8	7	9	4	2
706	5	5	5	4	9	8	7	8	4	2
707	5	5	4	4	9	8	8	8	3	2
708	4	4	4	3	9	7	6	8	3	2
709	4	4	4	3	9	7	6	8	3	2
710	4	4	4	3	9	7	6	8	6	2
711	4	4	4	3	9	7	6	8	6	2
713	6	6	5	4	9	8	8	7	4	3

AG, agriculture; CA, cattle ranching; UR, urban development; IN, industry; HU, hunting; FO, forestry; WU, water use; CO, conservation of biodiversity; TO, tourism; SF, sport fishing.

(Cowan and Turner, 1988). Given the limitations on information, an additional and crucial consideration is the experts' local experience. As Amir (1990) points out, local experts provide creditable and reliable information, and avoid the need for long periods of observations and large-scale data gathering.

Results of the Cape Region study supported Amir's (1990) point of view. Local experts' and decision-makers' experience was decisive for a qualified assessment, since they were able to generate suitability criteria effectively in a short time. Furthermore, these criteria could be directly related to the social actors identified within the Cape Region.

TABLE 4. Matrix **Z** of mean land use suitability scores per group of land systems, adjusted by rows and columns, for the Cape Region, México. Positive values indicate a high suitability for the corresponding land use, and vice versa

Group	Land use									
	AG	AC	UR	IN	HU	FO	WU	CO	TO	SF
1	0·4	0·0	0·9	1·5	−3·2	−2·0	−0·6	−0·9	1·6	2·2
2	1·0	1·2	0·1	−0·1	0·3	0·7	0·2	−0·2	−1·5	−1·7
3	−0·8	−0·7	−0·4	−0·6	0·6	−0·2	0·0	0·1	0·6	1·3
4	−0·6	−0·6	−0·7	−0·8	2·3	1·5	0·5	1·0	−0·8	−1·7

AG, agriculture; CA, cattle ranching; UR, urban development; IN, industry; HU, hunting; FO, forestry; WU, water use; CO, conservation of biodiversity; TO, tourism; SF, sport fishing.

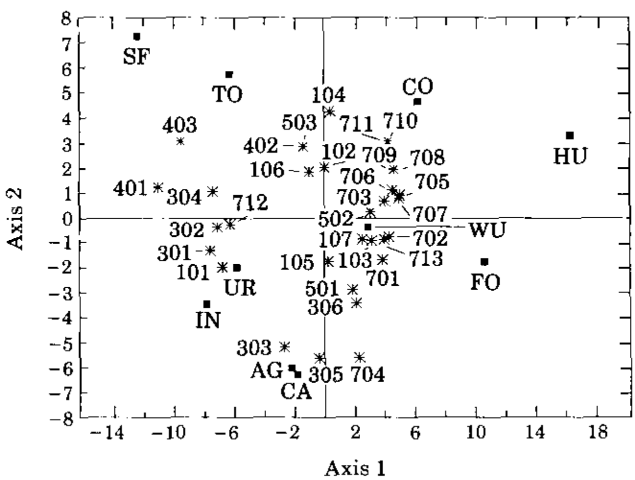

Figure 3. Biplot of the principal component analysis of land systems and land uses for the Cape Region, Mexico. Asterisks and numbers indicate land systems, and solid squares indicate land uses (AG, agriculture; CA, cattle ranching; UR, urban development; IN, industry; HU, hunting; FO, forestry; WU, water use; CO, conservation of biodiversity; TO, tourism; SF, sport fishing).

Since the analysis was based upon experts that represented social actors, it can be argued that impartiality might not be obtained because determination of suitability could be influenced by experts' own biases, as has been the case in previous studies (Organización de los Estados Americanos, 1987; Xiang *et al.*, 1992). Nonetheless, consultations with policy makers, socio–economic sector representatives and NGO spokesmen allowed the inclusion of sectoral perspectives into the analysis. Similar consultations have been useful for environmental planning elsewhere (Biodini and Giavelli, 1992). Experts' subjectivity was also lessened by the approach for determining suitability through multivariate methods, which fostered strict definition of issues and variables.

Ordination and classification techniques have been widely employed to assess land suitability (Betters and Rubingh, 1978; Omi *et al.*, 1979; Steiner, 1987; Price, 1990), and to determine homogeneous environmental units (Cowan and Turner, 1988; Calvo *et al.*, 1992; Bos, 1993). These approaches are based upon the relative importance of the variables considered, so assessments are simplified to a few factors without sacrifice of important information (Omi *et al.*, 1979).

A notable difference of the Cape Region study from previous applications of multivariate statistics was the use of a combination suitability criteria (physical, biological and socio–economic variables) that were directly related to social actors. For example, variables related to infrastructure and services were associated with urban development and tourism, while physical and biological variables were associated with biodiversity conservation (Table 2). Ranking of variables was also an important suitability criteria, since the relative weight of each variable for a specific land use depended upon the order in matrix $\mathbf{B}_i$.

Although Betters and Rubingh (1978) considered a minimum suitability score to measure land systems aptitude for a given use, this procedure was not used in the Cape Region study, because suitability scores might not directly reflect sectoral preferences. Rather, suitability scores were regarded as a means for weighing the relevance of land systems for different social actors (Tables 3 and 4; Figure 3).

Classification of land systems into similarity groups provided a consistent framework for a better understanding of the relative importance of land systems for different land uses. For example, land systems of group 1 presented high suitability scores for most land uses when compared with other groups (Table 3); however, when matrix **Z** (Table 4) and the biplot (Figure 3) were taken into account, it was obvious that, in general, group 2 was more suitable for agriculture and cattle ranching, and groups 3 and 4 were more suitable for bioconservation.

The ordination analysis revealed the underlying structure of the data set, which helped to understand the bases for suitability appraisal. Thus, the experts could discuss the logic behind the criteria used for assessing suitability. For example, since the assessment was chiefly based upon elevation and land use intensity, general suitabilities for tourism and conservation were related to low-intensity uses, but segregated by topographic position; nonetheless, coastal land system 104 presented special characteristics (the Cabo Pulmo coral reef) that made it relevant for conservation (Figures 1 and 3).

Therefore, results on land use suitability provided a formal framework for identification of environmental conflicts during the interdisciplinary sessions. Environmental conflicts were detected when a land system presented similar suitability for competitive land uses. After Brooks *et al.* (1991), a competitive relationship between land uses was distinguished when production for a given land use reduced yields of other land uses. Additional production relationships were also taken into account: complementary (when production for a land use raised production of another), and supplementary (when production for a land use has a null effect on others). For example, land system 301 (group 1) was suitable for urban development, tourism, sport fishing, agriculture and cattle ranching (Tables 3 and 4; Figures 1 and 3). Then, a competitive relationship, and therefore a conflict, was detected between agriculture and tourism, while it was judged that complementary relationships existed between urban development, tourism and sport fishing, and a supplementary one between agriculture and cattle ranching.

Once environmental conflicts were established, the cause–effect relationship between competitive uses were diagnosed and appropriate management guidelines were generated. An important consideration for generating guidelines were the sectoral interests for specific land systems. For example, conflicts between agriculture and tourism in land system 301 was diagnosed to be caused by competition for water. Thus, guidelines were formulated to address the problem of water rights and differential consumption rates, in accordance with the Mexican legislation.

The procedure described in this article allowed a new role for the experts in the Cape Region suitability assessment. Instead of concluding the aptitude from physical, biological and socio–economic variables directly, the experts' role was to interpret the needs and possibilities of the involved social actors. Proper identification of management guidelines for minimization of environmental conflicts was possible because of the heuristic character of the approach. The results fulfilled the necessary conditions to furnish guidelines that could be related to fair compromises between social actors (Organización de los Estados Americanos, 1984; McNeely, 1990): (1) the relevant actors were identified and shared the same information; (2) broad objectives of development were agreed by all the sectors; (3) the problems were defined in ways that are mutually agreed; and (4) cause–effect relationships between sectors could be detected.

Furthermore, the Cape Region study fulfilled another requisite: a suitability analysis that developed from legally defensible and accurate methods (Steiner, 1983). From the legal viewpoint, the mandate for public participation in environmental planning was achieved through the consultations (Diario Oficial de la Federación, 1988; Secretaría de Programación y Presupuesto, 1989; Secretaría de Hacienda y Crédito Público, 1992). Accuracy was attained from the explicit hypothesis (the needs and possibilities of social actors), and the strict rules of inference (the multivariate analysis).

6. Conclusions

Suitability analyses should provide information for selecting land uses that reduce environmental conflicts. Consequently, suitability analyses need to include public perceptions for proper and impartial determination of land capability. However, impartiality may not be obtained because of experts' biases.

In the Cape Region suitability analysis, experts' biases were lessened through consultations to policy makers, socio–economic sectors' representatives, and NGO spokesmen. Thus, data used in the analysis were directly related to the social actors.

Likewise, classification and ordination methods provided a scrupulous framework for the integration of physical, biological, and socio–economic data. The approach fostered strict definition of issues and suitability criteria, and revealed the underlying structure of the data set. This facilitated a better appraisal of environmental conflicts.

The heuristic character of the methods used for the Cape Region study fulfilled the necessary conditions to furnish management guidelines that could be related to fair compromises between social actors.

We gratefully would like to acknowledge the insightful and critical comments from M. Bellón, G. Segura and D. P. Guertin on an earlier draft of the manuscript. Part of this research was carried out as part of the technical co-operation accord between the Mexican government and the Secretary General of the Organization of the American States entitled "Proyecto de Ordenamiento Ecológico de Regiones Geográficas con Actividades Productivas Prioritarias". This article was a contribution to the second author's M.Sc. thesis, presented at the Facultad de Ciencias, UNAM.

References

Amir, S. (1990). Evaluation of environmental impacts of large scale physical developments in central Galilee: role of experts and policy makers. *Environmental Management* **14**, 823–832.

Betters, D. R. and Rubingh, J. L. (1978). Suitability analysis and wildland classification: an approach. *Journal of Environmental Management* **7**, 59–72.

Biodini, A. and Giavelli, G. (1992). Multicriteria analysis as a tool to investigate compatibility between conservation and development on Salina Island, Aoelian Archipelago, Italy. *Environmental Management* **16**, 633–652.

Bojórquez-Tapia, L. A. and Ongay-Delhumeau, E. (1992). International lending and resource development in Mexico: can environmental quality be assured. *Ecological Economics* **5**, 197–211.

Bos, J. (1993). Zoning in forest management. *Journal of Environmental Management* **37**, 127–145.

Brooks, K. N., Ffolliot, P. F., Gregersen, H. M. and Thames, J. L. (1991). *Hydrology and the Management of Watersheds*. Iowa: Iowa State University Press/AMES.

Calvo, J. F., Palazón, J. A., Esteve, M. A., Suárez, M. L., Torres, A., Vidal-Abarca, M. R. and Ramírez-Díaz, L. (1992). The use of multivariate analysis for the ecological characterization of landscape: the Mula River watershed, south-east Spain. *Journal of Environmental Management* **34**, 297–308.

Canter, L. W. (1991). Interdisciplinary teams in environmental impact assessment. *Environmental Impact Assessment Review* **11**, 375–387.

Cowan, J. H. and Turner, R. E. (1988). Modeling wetland loss in coastal Louisiana: geology, geography, and human modifications. *Environmental Management* **12**, 827–838.

Crowfoot, J. E. and Wondolleck, J. M. (1990). Citizen organizations and environmental conflict. In *Environmental Disputes, Community Involvement in Conflict Resolution* (J. E. Crowfoot and J. M. Wondolleck, eds), pp. 1–16. Washington: Island Press.

Diario Oficial de la Federación. (1988). *Ley General del Equilibrio Ecológico y Protección al Ambiente*, pp. 23–58.

Digby, P. G. N. and Kempton, R. A. (1987). *Multivariate Analysis of Ecological Communities*. London: Chapman and Hall.

Gower, J. C. (1966). Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* **53**, 325–338.

Kessler, W. B., Salwasser, H., Cartwright Jr., C. W. and Caplan, J. A. (1992). New perspectives for sustainable natural resources management. *Ecological Applications* **2**, 221–225.

McNeely, J. (1990). How conservation strategies contribute to sustainable development. *Environmental Conservation* **17**, 9–13.

Noy-Meir, I. (1973). Fatal transformations in ecological ordination I. Some advantages of non-centering. *Journal of Ecology* **61**, 753–760.

Organización de los Estados Americanos. (1984). *Planificación del Desarrollo Regional Integrado: Directrices y Estudios de Casos Extraídos de la Experiencia de la OEA*. Washington: Departamento de Desarrollo Regional, Organización de los Estados Americanos.

Organización de los Estados Americanos. (1987). *Estudio de Casos de Manejo Ambiental: Desarrollo Integrado de un Área en los Trópicos Húmedos-selva Central del Perú*. Washington: Departamento de Desarrollo Regional, Secretaría para Asuntos Económicos y Sociales, Organización de los Estados Americanos.

Omi, P. N., Wensei, L. C. and Murphy, J. L. (1979). An application of multivariate statistics to land-use planning: classifying land units into homogeneous zones. *Forest Science* **25**, 399–414.

Pielou, E. C. (1984). *The Interpretation of Ecological Data; a Primer on Classification and Ordination*. New York: J. Wiley & Sons.

Price, A. R. (1990). Rapid assessment of coastal zone management requirements: a case study from the Arabian Gulf. *Ocean and Shoreline Management* **13**, 1–91.

Secretaría de Desarrollo Urbano y Ecología. (1988). *Manual de Ordenamiento Ecológico del Territorio*. México: Dirección General de Normatividad y Regulación Ecológica, Subsecretaría de Ecología.

Secretaría de Hacienda y Crédito Público. (1992). *Plan Nacional de Desarrollo 1989–1994; Informe de Ejecución 1991*. México: Poder Ejecutivo Federal.

Secretaría de Programación y Presupuesto. (1989). *Plan Nacional de Desarrollo*. México: Secretaría de Programación y Presupuesto.

Steiner, F. (1983). Resource suitability: methods for analyses. *Environmental Management* **5**, 401–420.

Steiner, F. (1987). Agricultural land evaluation and site assessment in the United States: an introduction. *Environmental Management* **11**, 375–377.

Xiang, W-N., Gross, M., Fabos, J. G. and MacDougall, E. B. (1992). A fuzzy-group multicriteria decisionmaking model and its application to land use planning. *Environment and Planning B: Planning and Design* **19**, 61–84.