Landscape analysis using GIS to ecologically oriented planning in Costa Rica

Marcela A. GARCIA PADILLA

Abstract

The current investigation was originated by the detection of voids within management plans (MPs) of protected areas in Costa Rica, which, over time, has prevented an effective landscape planning from taking place. On such account, this paper presents an approach to apply useful tools for the landscape evaluation and suggests an analysis using ecological considerations and GIS, which is illustrated in a Costa Rican case study: The National Marine Park of Las Baulas (PNMB), aimed to protect the nesting sites of the Leatherback Turtle, *Dermochelys coriacea*. The method uses strategic criteria for handling available data and applies land-suitability analysis, risk analysis and potential land-use suitability. All the latter shall contribute to support further land use policies such as landscape zoning. The aim is to evidence potential frameworks for the consolidation of landscape planning by using digital tools, as both a practical and academic opportunity, for biodiversity protection.

1 GIS and ecologically oriented planning

Landscape planning lies at the root of planning and decision making processes. This investigation was based on ecologically oriented planning (KAUIE 2000) for a careful analysis of the landscape stressing that an ecological perspective, as a major task, is to be undertaken. Although there are problems that go beyond planning, a lot of other major knotty situations might as well be solved with an identification of priorities and threats of the current status, together with an evaluation and spatial planning. The importance of classifying data for planning purposes is essential to achieve a comprehensive analysis of land-uses and natural resources that respond to contextual peculiarities. Furthermore, there are different ways of aggregation and they all refer to the spatial relationships which help to improve the decision making process (KAUIE 2000).

Additionally, Geographic Information Systems (GIS) analytical tools include procedures for handling and doing such spatial aggregation of the available information. Therefore, the combination of analysis techniques together with the landscape ecology perspective, which in turn reveals a high understanding of the environment, is proposed for this investigation.
2 Data input for the PNMB landscape analysis

There is a significant and sufficient amount of graphic information available, given that several interdisciplinary studies, regarding the management of the PNMB, have been elaborated. Therefore, the task of integrating the available digital data (see Table I) was from the very beginning assumed. Correspondingly, the jpeg and pdf files were traced and georeferenced using the software ArcGIS 9 for the gathered information to be integrated and analyzed with the already available shape files, in order to define zones within the protected area.

Two main spatial considerations were particularly included for the PNMB regarding the spatial boundaries during the landscape analysis: (1) the watershed influence area and (2) the buffer zones; both relevant for the location in terms of flows and exchange of nutrients. Both considerations refer to the integrity and compatibility with the surroundings (STEPHAN ET AL. 2002). Thus, the identification of areas beyond the immediate buffer zone, and yet within the watershed areas of influence, was used as the location limits. However, it is to be recognized that the analysis shall be done at different spatial levels and scales according to concepts of land mosaics (FORMAN 1995)

<table>
<thead>
<tr>
<th>JPG format</th>
<th>PDF format</th>
<th>SHP files</th>
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<tr>
<td>-Buffer zone with 500m -Orthophotographs illustrating 100-cm sea level rise, estimated for the end of the century. The image recreates the expected 50-m displacement of the beach landward in response to sea level rise. -Local Photographs (2000-2010)</td>
<td>-Roofed areas -Beach access -Discharge into the watershed system -Location of waste water -Location of preferred nesting sites -Fragility areas -Underground water recharge areas -Archaeological sites</td>
<td>-marine area and continental area -roads -buffer zone 500m -forest area -watershed area -political-adm division -Local towns</td>
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<td>-Fragility Areas</td>
<td>High, moderate and low</td>
<td>-Conflicts of use Overuse, Subuse and adequate use</td>
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Tab. I: List of available digital data and base maps used as reference for the investigation. Sources: Tropical Scientific Centre (2004), GeoCAD (2009), Fonseca, A. & C. Drews (2009) and The Leatherback Trust.
3 Land Suitability, Risk Analysis and Potential land-use suitability using ecological principles

Among the methods in planning processes suggested by KAUIE (2000) to evaluate existing environmental factors, Land Suitability, Risk Analysis and Potential land use suitability were selected. For the first, the existing land use, land cover and land use capability were included. For the second one, the identification of potential threats involved considering the conflicts of use (overuse, adequate or sub use), fragility areas (erosion; hydrological and biological, urban influence and extreme vulnerability) together with saturated conditions of groundwater recharge areas. As to the third one, the potentials areas are aimed at restoration and connectivity of the landscape elements by establishing:

- **Priority area for high ecological value**: where high impact construction should not be allowed due to extreme vulnerability and fragility of erosion.
- **Potential area for protection**: identifies biological (inland) fragility areas and the zones with priority for reforestation inside farming areas and outside the PNMB.
- **Area of urban influence**: aggregates the areas near the existing urban developments that might be subject of expansion and thus dominate the local function of the zone.
- **Area of hydrological fragility**: zones where water recharge capacity is threatened.

As a descriptive map interpretation, the existing lands use confirms that, as a result of former land-use practices (e.g., livestock farming), the surrounding area of the PNMB is mostly classified as pasture; whereas as for the conflicts of use the map shows that many of these can be used as potential areas for reforestation. However, using ecological principles provides a further lecture of the analysis when the areas are considered patches, corridors and buffers (DRAMSTADT, OLSON and FORMAN 1996). This is evidenced when the ecological principles are applied in the map of potential land use suitability for the improvement of the local landscape-ecology (TURNER 2001). For example, the urban patch at the south of the PNMB separates the unique zones of mangroves-estuary and causes the urban influence fragility to increase, which in consequence makes the park even more vulnerable to isolation. The possibility of interconnection supports the existing forest patches of primary and secondary level with intermittent scrublands and identifies potential areas for integration with other reforested areas. This could also help repair the evident lack of green coverage near most of the river corridors, increase the area of green buffer and, thus, reduce the hydrological fragility (saturated levels of recharge for groundwater) located in the unique zones. Therefore, the areas for high ecological value connect the mangrove-estuaries and the coast together with the forest areas. These priority areas (even outside the existing PNMB boundaries) enhance connectivity in order to strengthen the integrity of the habitat and for it not to be absorbed by the urban use.
4 Application of landscape analysis

4.1 Definition of Landscape planning objective

The landscape analysis, using ecological principles, reinforces the need to increase connectivity, avoids spatial fragmentation and isolation of high ecological value areas and reduces the edge effect of external influence (Turner 2001). Such situation clearly establishes the landscape planning objective for the case of the PNMB and surrounding areas:

To reinforce the landscape conditions of the PNMB through the suggestion of zones which integrate the existing and potential areas with ecological value.
4.2 Landscape zoning proposal

The landscape planning objective can be included in the PNMB Management Plan (MP) and translated into a landscape zoning proposal through a clear spatial framework which describes what can or cannot occur where and how (PADILLA 2010). In other words, the zoning determines what is allowed to take place (e.g. activities, type of land-use, etc.) throughout the different geographical areas of the protected territory. Zoning plans can be seen as an important instrument to facilitate the conservation and use of protected areas, since they are recommended by international guidelines from the IUCN (THOMAS, LEE & MIDDLETON 2003).

As a main contribution of this investigation, a proposal for a landscape zoning map for the PNMB is suggested (see Fig. 3) which basically translates the spatial limits through the definition of six zones according to the landscape use which are: protection, restoration, potential for protection, limited development areas, archaeological sites and buffer zones. Each of these zones is defined to have purposes according to landscape ecology criteria.

For instance, a major re-definition presented by the landscape-zoning proposal is the core zone; which is the current legally constituted PNMB, and is surrounded by buffer zones and potential areas for protection. The landscape planning objective is spatially translated as an increase of the PNMB area. This is justified through the criteria of ecological robustness using protective transition membranes that permeate the adjacent urban dominance over the fragility areas. Therefore, the zoning map reflects the relevance of considering the landscape behaviour beyond the existing park’s limits. There are also the buffer zones that are specifically intended for the unique areas such as the estuaries and help to consolidate the green corridors along the coastal fringe.
Fig. 3: Map showing a landscape zoning proposal which includes areas beyond the park’s limits.
5 Conclusion

Planners can deal with integrative considerations using a holistic vision about the involved factors and, at the same time, apply an analytical process. GIS does, indeed, offer a valuable and practical input when it comes to the aggregation, storage, analysis and display of information (e.g., the overlaying of data of diverse nature). However, the selection of criteria for effective analysis is a key factor for handling the information, particularly when there are issues on the data availability and the planner has to elaborate effective and creative classification criteria. For example, this research demonstrated that buffer areas are much more than an “offset” command. The integration of scientific knowledge is necessary for the technical definition and justification of buffer zones and not simply using the software tool. Possible more substantial achievements can be reached by having clear planning objectives supported by theory concepts.

Nevertheless, there are still many difficulties for establishing reliable data sources in countries such as Costa Rica where there is a lack of institutional framework for regional planning and technological support. Also, the integration of socio-cultural factors and definition of spatial planning scales in protected areas is still a bigger challenge. There is a lack of tools for linking, implementing and monitoring management policies in terms of spatial conditions according to technical analysis. However, it is clear that a definition for the adequate land-use is not possible without an interdisciplinary approach.

All the above represent an enormous potential for landscape professionals in planning to reaffirm their contribution beyond perception approaches. Territorial planning using digital tools can open new opportunities for introducing the evaluation of the landscape near protected areas and carrying out multi-criteria analysis using GIS systems in ecological rich countries to reduce the loss of biodiversity. Costa Rica has a quarter of its territory under protection and has made great efforts for the implementation of laws. Nevertheless, the country still needs suitable applications for the data evaluation before consolidating national policies.

6 References


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