Deutscher Tropentag 2003
Göttingen, October 8-10, 2003

Conference on International Agricultural Research for Development

GIS-Landscape Modelling of a Regional Green Corridor in Tropical Argentina

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Abstract

The landscape pattern of an agricultural area has been modelled. Landscape modelling is based on landscape theory. Land use is classified according to administrative, homogeneous and functional criteria. The farm area defines the minimal administrative unit.
The landscape unit and the agricultural field defines the homogeneous land unit. A spatial functional hierarchy is established. The landscape pattern is modelled and analysed through geographical information systems (GIS). Remote sensing and participatory information provide basic information. Spatial scale analysis ranges from field to regional level. The approach is validated through a study case.
In Misiones – Argentina a regional "Green Corridor" was established. Its potential for nature conservation is analysed in the study region: the Guacuraí District. Ecological indicators (connectivity, fragmentation and variegation, among others) are calculated. The results show that connectivity between protected areas does not increase substantially. Natural ecosystem covers the area partially. The native forest is insular and variegated. Accordingly, more successful projects should concentrate on: designing and conserving local corridors, encouraging soil protection techniques and promoting individual "alternative activities" as well as nature conservation efforts. The methodology allows precise ecological analysis of farming systems down to the farm level. The results indicate that this approach is useful for land-use project analysis.
Keywords: Argentina, GIS, green corridor, landscape analysis, remote sensing.

Introduction

Land-use evaluation is an attempt to classify a region in order to predict the response of a natural system to certain type of impulses. Standard approaches begin by zoning a region into units, homogeneous to physical and natural parameters, where a certain type of response will be predicted. Purposes range from nature conservation up to engineering projects. In the field of nature conservation zoning attempts to identify a homogeneous unit for ecological behaviour. Several factors render these approaches often ineffective: borders of homogeneous and of administrative units usually do not coincide, precision may be inadequate for decisions at local level and predictions about human responses habitually are not included in the ecological analysis.

Landscape ecology emphasises broad spatial scales and the ecological effects of the spatial patterning of ecosystems (Turner, 1989). A landscape is a mosaic of patches, the components of pattern (Urban et al. 1987). A patch is a region that is more-or-less homogeneous with respect to a measured variable or a non-linear surface area that differs from its surroundings.

Three landscape characteristics useful for landscape analysis are structure, function and change (Forman and Godron 1986).

Human land-use patterns may be more variable than many natural environmental patterns, because human land use reflects not only natural constrains (Bowen and Burgess, 1981) but also financial resources and personal whims of private landowners (Urban, 1987). Farming system analysis is centred on the identification of farm-level constrains and aims (FAO, 1993). Farming system refers to a group of farming units which the inside similarity is higher than that to other farming systems. The farming unit is the basic unit which decides over the agriculture organisation (Jahnke, 1996). Actual and potential landscape pattern of an agricultural area may be successfully explained analysing the farming system path in interaction with the natural environment. The farming unit defines an area under homogeneous decision. Landscape structure, function and change will be analysed in a raster defined by the individual farming units' areas.

A GIS-landscape modelling approach for land-use evaluation is presented. The approach combines hierarchic and participatory premises. Remote sensing, participatory research and on-farm calculation are integrated into a case specific model. The agricultural activity is evaluated under farming system analysis. The ecosystem is examined under landscape theory. The results intend to prove the plausibility, validity and applicability of the GIS – landscape modelling approach for project analysis.

GIS-Landscape Analysis

The land-use analysis under the GIS-landscape modelling approach relays on the development of a case specific model (Díaz Lacava, 2003). Model development is presented in figure 1.

The model inputs are local, regional and national data. The input data is gathered from primary and secondary sources. Primary sources are landscape inventory and participatory research. Secondary sources are topographic maps, remote sensing and bibliography.

Land use is classified based on remote sensing analysis and local data.

The land-use units are modelled spatially with GIS. Homogeneous, functional and administrative grouping criteria underline the land-use classification. At the local level, main land-use units are: the agricultural field, the landscape unit and the farming unit. These units condition structure, function and change of the next level units (Urban et. al., 1987). At the regional level, main units for the case study are: protected areas, green corridor and district.

Ecological and socio-economic information is joined with the individual land-use unit. Landscape analysis is conducted with indexes, such as: fragmentation, variegation, connectivity.

The agricultural activity is evaluated with farming system analysis. Economical indexes are calculated based on the farming unit. Main indexes are: productivity, intensity and profitability.

Foremost model's result is the actual land-use analysis. Parametric variation of the model enables development of scenarios and analysis. The scenarios depict variations of the actual land use.

This study tests the applicability of the GIS-landscape approach for project analysis in the field of nature conservation. The approach is validated by assessing the nature conservation potential of a region as a green corridor. The analysis is developed on a study case: the official project "Green Corridor of the Misiones Province".

Study Region

The official project "Green Corridor of the Misiones Province" started in 1999 (Cámara de Representantes de La Provincia de Misiones. 1999). Main project objectives are to connect 15 of the 48 protected areas of the province, to protect natural forest and to promote tourism. The "Green Corridor" covers 20% of the provincial area and comprises two ecological zones: forest and savannah (fig. 2a).

GIS - Landscape Modelling Approach

INPUT

- **Secondary Source**
  - ***Local Regional National***
    - *Topographical Map*
    - *Remote Sensing*
    - *Bibliography*
- **Primary Source**
  - ***Local***
    - *Inventory*
    - *Participatory Research*

ANALYSIS

Regional Land Use Analysis

Local, on-farm Calculations

- **Landscape Analysis**
- **Farming System Analysis**

OUTPUT

Results
- **Actual Situation**
- **Scenarios**

in the form of:
- **Cartography**
- **Statistics**
- **Graphics**

Figure 1: Steps of the GIS – Landscape Modelling Approach.

The case study, the Guacuraí District, is located in the Northeast of the Misiones Province. Native vegetation is tropical forest. The climate is sub-humid, with a yearly precipitation of 1,800 mm. The altitude is 300 m. o. s.

One third of the Guacurarí District area is affected by the "Green Corridor" Project. Figure 2 (b) shows spatial agriculture distribution and present land use related to farming units' extension in the Guacurarí District portion of the Green

Corridor. In this district portion, two main types of small holders are identified, defined by their main production: extensive mate-tea and intensive tobacco production. Whole agricultural activity covers 40 per cent of the total area. Three per cent of the area is destined to intensive production. Considering the actual land use, agricultural activity is bias to extensive production.

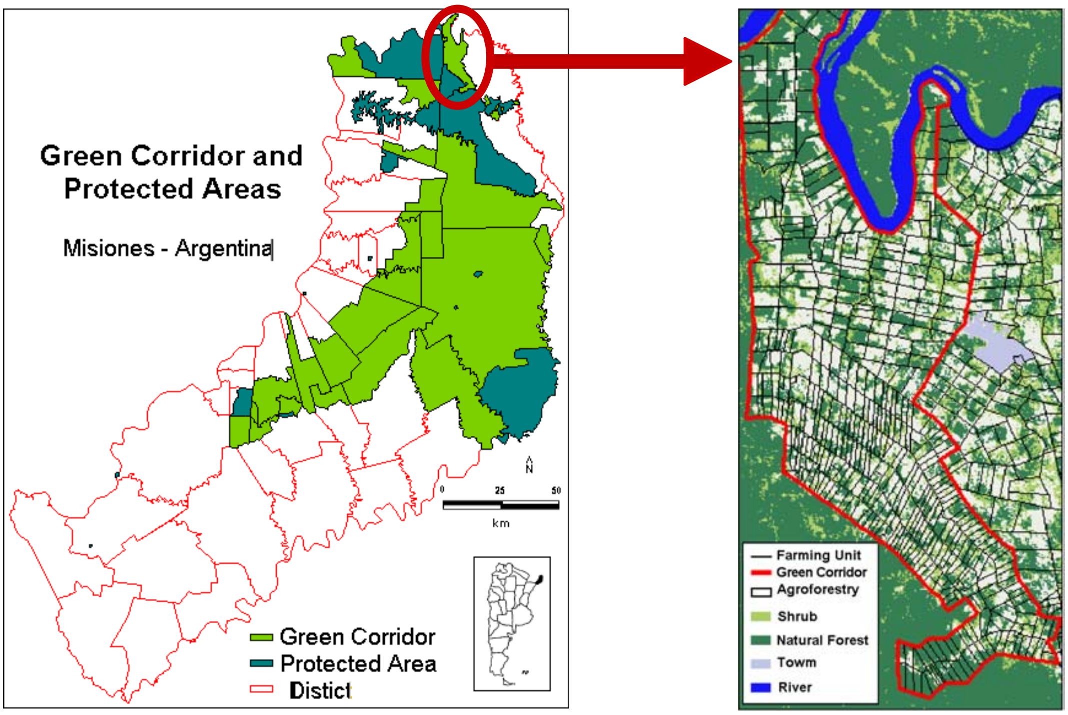

Figure 2: Green Corridor of the Misiones Province: (a) Green Corridor, protected areas and districts of the Misiones Province; (b) Green Corridor portion in the study region, the Guacurarí District, and the present land use.

Evaluation of Conservation Potential

A green corridor is an administrative land-use unit, defined to accomplish an ecological function. Ecologically, a green corridor is defined as a natural patch with a naturally existing or restored native linear landscape feature that connects two or more larger tracts of essentially similar habitat. A green corridor should function as either a movement route of individuals or as avenue of gene-flow among native fauna and flora (Harris and Scheck, 1991).

The conservation potential of the study region will be tested according to this definition. Landscape structure and function will be evaluated based on landscape theory. The spatial structure is evaluated considering land units shape, dimension and vicinity. Landscape function is analysed through fragmentation and variegation indexes. The fitness of the study region to the presented green corridor definition is presented after each result. The whole fitness is exposed in the conclusions.

The green corridor area in the Guacurarí District is composed of two sections (fig. 3). One is located along the western border of the district, including the protected area "Yacuy" and adjacent to the protected areas " Iguazú National Park " and the " Urugua_í Provincial Park". The second one is located in the south of the district. It encloses the protected area "Palms Reserve" and is adjacent to the " Urugua_í Provincial Park ". As figure 3 shows, the area itself does not build a linear patch connecting protected areas. This area does not agree with the desired green corridor shape.

The Palm Reserve (500 ha) neighbours the Urugua_í Provincial Park (84,000 ha) and the Yacuy Provincial Park (347 ha) the Iguazú National Park (55,000 ha). In figure 3, this direct connection is shown with pink rings surrounding the protected area of the Guacurarí District. These two protected areas are directly connected to larger protected areas, located at the District limit. The proposed green corridor area neighbours four already connected areas. It is to expect, that individual or gene flow will occur directly over the protected areas borders, as through the proposed agricultural region. The units' spatial distribution shows a low potential for this district area to increase connectivity between protected areas. The proposed area does not constitute a linear landscape feature that connects two or more larger tracts of essentially similar habitat.

In the following, the ecological function of the study region as a green corridor will be analysed.

In an agricultural territory, two main types of patches may be recognised: natural and artificial. Natural ones comprise the remaining portions of native ecosystems, fragmented by artificial ones: agricultural fields and streets. Streets may act as barriers or as corridors. According to the fragmentation status, the agricultural fields may act as gaps or as a matrix.

Remote sensing analysis shows that in this region, already half of the total primary cover has been removed. The original ecosystem covers 40% of the area. Figure 2b distinguishes natural from artificial vegetation. Natural vegetation is shown in green and agro forestry in white. Black empty polygons represent the individual farming units. Visual interpretation shows an agricultural matrix, embracing native vegetations patches. This interpretation is verified with landscape indexes: fragmentation and variegation.

The fragmentation index (F) relates the tropical forest area to the total area. The observation unit is the tropical forest patch, comprising all patches inside a sample unit i. The sample spatial unit is the individual farming unit. F is defined as follows:

$$F = \left(\sum_i \frac{\text{tropical forest patch size}}{\text{farming unit area}_i} \right) : i$$

$i = 1, \ldots, n$ farming units

Definitions:

$F = 1.0 \Rightarrow$ no fragmentation
$1.0 > F >= 0.7 \Rightarrow$ moderately fragmented
$0.7 > F >= 0.5 \Rightarrow$ highly fragmented
$0.5 > F \Rightarrow$ insulated

The index is evaluated along the western section of the Guacurarí green corridor portion (fig. 3).

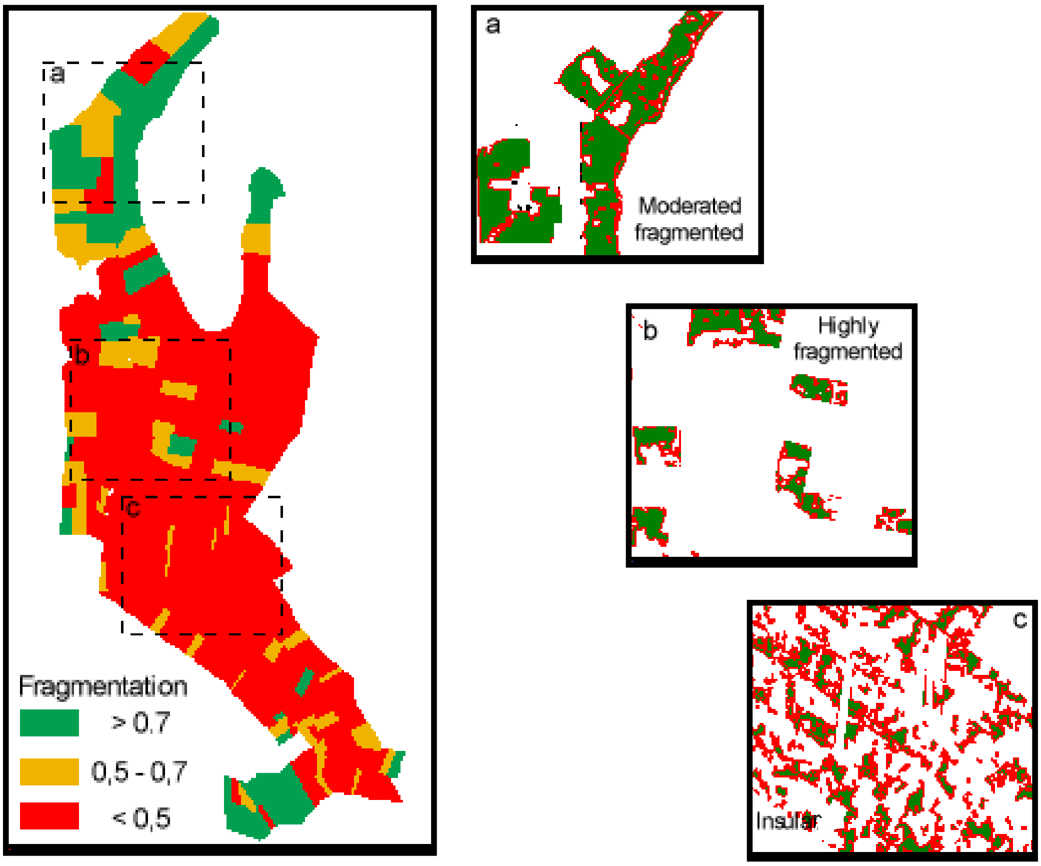

Figure 4: Native forest fragmentation, (a) area moderately fragmented, (b) area highly fragmented and (c) insular area.

The spatial distribution of the fragmentation values is shown in figure 4.

The native forest is moderately fragmented in 16% of the area, highly fragmented in 15% and insulated in 70% of the "Green Corridor" area. This fragmentation status defines this area as an agricultural matrix with gaps of native ecosystem.

The variegation index relates to the aptitude of a patch to function as a habitat. While a high variegated patch offers a higher habitat potential for edge species, a low variegated may offer more appropriate habitats for interior species. In this case, the variegation status is estimated through the amount of artificial patches inside the native patches in patches bigger than 50 ha.

The figure 5 shows natural forest patches larger than 50 hectare, classified according to the number of artificial patches. Larger patches, located in the northern section, present the higher variegation status. Patches with a lower number of interior patches remain isolated.

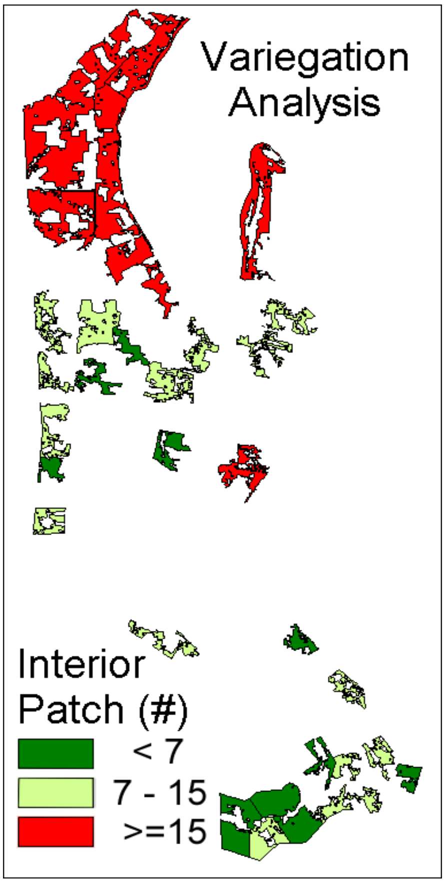

Figure 5: Variegation classes of natural forest patches.

Conclusions

The GIS - landscape modelling results allow the following conclusions:

According to the landscape analysis, the study region does not present the desired linear patch shape. Further, no increase of connectivity is expected trough the incorporation of the Guacurarí district to the green corridor area. According to the fragmentation status, the native ecosystem in this district consists of patches inserted in an agricultural matrix. Variegation analysis indicates that this remaining ecosystem is highly distributed with low potential as a habitat for interior species. For instance, the "Guacurarí" District portion does not offer a high potential for nature conservation.

The Province of Misiones counts with nature conservation regulations, independent from the green corridor project. These regulations prescribe the maintenance of stripe corridors in the agricultural area. According to the actual landscape pattern in the proposed area, it is to presume, that the official prescript stripe corridors may show a higher potential to accomplish green corridor objectives. The conservation potential of the present strip corridor matrix can be evaluated under the GIS - landscape modelling approach.

Further more can be inferred, that more successful nature conservation projects should concentrated on: adequate design and management of the prescribed strip corridors, encouraging soil protection techniques and promoting individual “alternative activities” as well as nature conservation efforts.

The methodology allows ecological analysis of farming systems and land use down to the farm level. The relationship between agricultural and conservation land use is precisely quantified. Technical predictions, local motivations and political decisions may be tested in the way of scenarios. The presentation of analysis and results is flexible and can be modified easily and without affecting accuracy. The methodology can be applied for regional land-use evaluation with local accuracy and as a communication tool for participatory project analysis. Finally, it can be stated, that the GIS - landscape modelling approach can be implemented as a valuable instrument for land-use project analysis.

Bibliography

Bowen, G. W. & Burgess, R. L. 1981. A quantitative analysis of forest island pattern in selected Ohio landscapes. Rep. #ORNL TM-7759. Oak Ridge Natl. Lab. Oak Ridge, Tennessee.

Cámara de Representantes de La Provincia de Misiones. 1999. LEY Nº 3.631. Área Integral de Conservación y Desarrollo Sustentable Corredor Verde de la Provincia de Misiones. http://www.misiones.gov.ar/ecologia/Todo/CorredorVerde/leycorredorverde.htm.

Díaz Lacava, A. N. 2003. Instrumentos para la planificación integral del uso de la tierra con sistemas de información geográfica - un caso de estudio en Argentina. Ph. D. Thesis. Humboldt Universität zu Berlin. In Print.

Jahnke, H. E. 1996. Farming systems and development paths of agriculture – the case of the seasonal tropics. Working paper 22. Wirtschafts- und Sozialwissenschaftliche Fachgebiete der Landwirtschaftlich -Gärtnerischen Fakultät der Humboldt - Universität zu Berlin, Berlin.

Harris, L. D., & Scheck, J. 1991. From implications to applications: the dispersal corridor principle applied to the conservation of biological diversity. Pages 189-220 in D. A. Saunders and R. J. Hobbs, editors. Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons, Chipping Norton, New South Wales, Australia.

Urban, D. L., O`Neil, R. V. & Shugart Jr., H. H. 1987. Landscape ecology: A hierarchical perspective can help scientist understand spatial patterns, reprint, BioScience 37(2):119-127.