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Geometries in Landscape Ecology

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Abstract

In the process of landscape characterization a diversified sets of geometries need to be considered. These geometries include Land Use geometry with its permanent shifting of the habitat mosaic, Natural Resources geometry depicting the available natural resources and their degree of affectation by land uses, as well as the manifold geometries associated with the different ecological patterns and processes in the landscape (target species, fragile areas, etc.) and Socio-Economical and Political geometries and how decision making at this level reflects in the other geometries. GIS spatial analysis and modelling allows the integration of these geometries with other variables, and allows the development of simulation models for the evaluation of alternative land use scenarios, assessing the sensitivity of biodiversity indicators within different scenarios, and the integrated evaluation of the effects of different development scenarios on biodiversity, economy and cultural aspects. Examples are given on the basis of an ongoing research on Large Scale Grazing Systems (LACOPE)

Introduction

According to Forman (1981) Landscape Ecology "studies the structure, function and development of Landscapes". Leser (1997) on his side, states that Landscape Ecology "deals with interrelations of all functional and visible factors representing the landscape ecosystem". There are "three fundamental characteristics of Landscape Ecology, the space relations – landscape structure, their functional relationships - interaction, flow of material and energy and the time relations – the change of the structure, characteristics and functions" (Forman and Godron, 1986).

One important characteristic of Landscape Ecology is the fact that it is strictly bounded to the geographical objects it studies. This means that all landscape ecological concepts, models or approaches are and have to be referred to very well defined geographical objects or processes, implying strict relations between the models and characterization processes and the geographical reality.

In relation to Natural Resources geometries, the characterization of the available resources and their degree of commitment by the present land uses is one of the basic aims of the Integrated Landscape Assessment (ILA) approach (Fernandes, 1999). This framework implies that the data inventory for one area must be complemented with information on the balance of resources associated with each descriptor or descriptor combination. This is done trough the comparison between the present land use structure with the stable characteristics and landscape units that frame that landscape. These units, derived from soils, climate, morphology, geology/litology and vegetation, allow the evaluation of the use thresholds as well as of the endangering factors for the land use potentials (higher susceptibility to given degrading processes like erosion, pollution, etc.) GIS spatial analysis and modelling allows the integration of these geometries with other variables. The combined use of GIS spatial analysis techniques with system dynamic approaches allows, in the frame of the ongoing research projects on large scale grazing systems LACOPE, suitable approaches to these geometries and to a sounder spatial characterisation of ecosystems and landscapes aiming at the definition of decision support systems for the management of existing and potential areas where this land use contributes to sustainability and biodiversity.

The concept of geometry in landscape ecology

Landscape Ecology has always felt the need to develop methodological approaches to describe the landscape, its objects and functions (patterns and processes (Turner et al., 1989)). This implies the need to be able to represent different types of spatial geometries (geographical organisation and arrangement of characteristics) as well as functional processes (following defined geographical paths, directions and networks – therefore geometries).

This process of description of the landscape must not be mistaken with the reality of the landscape. It is only an effort of abstraction of a complex reality where representations of the main characteristics according to given perspectives is achieved. It must always be considered as a partial simplified translation of the complex reality of the landscape (Fig. 1).

Another important perspective when considering landscape geometries is their perception by the different "landscape actors". Indeed, the same landscape element can be differently perceived by two actors: e.g. a linear structure can be a corridor for given animals and a barrier for others, a given combination of habitats can be indispensable for a certain species (trough the warranty of complementary feeding, nesting, mating and sheltering habitats) and inadequate for other species more specialized and demanding in terms of segregated or core areas or habitats.

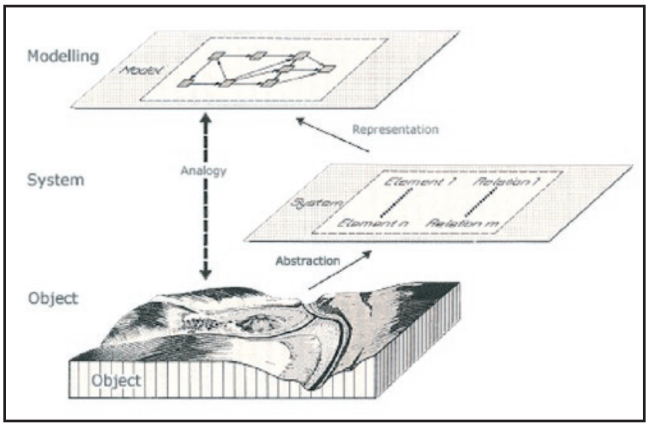

Figure 1: Landscape characterization as a translation process (Klug and Lang, 1983)

In this sense, landscape characteristics and functions like continuity, permeability, polarity, flow, complementarity, are not absolute characteristics, but relative to particular "actors" and must, therefore, be considered and characterized as so.

Spatial and functional geometries

To represent the spatial organisation of the landscape two main approaches have been proposed: a more synthetical, where the identification of homogeneous units focused the main attention of the studies, and another more analytical, where there where no preconceived geometrical objects and where different approaches from the more thematical and disintegrated to the more integrated could be identified and used. (Cendrero and Diaz de Teran, 1987)

Within the first group, the concept of Land Unit as "tract of land that is ecologically homogeneous at the scale level concerned" (Zooneveld, 1989) constitutes a particular good example of the manifold approaches proposed along the years. Nevertheless this conceptual development from Zooneveld was not followed by methodological approaches to the identification of those units, determining in certain groups a growing tendency to the use of more amorphous or "neutral" models as tools for the analysis of the landscape. (Turner et al., 1989)

The second group of approaches shows, as referred, a wider variety of conceptual and practical characterisation methods, from the simple overlay of different thematic maps, to their complex operation in order to achieve the definition of synthetical entities, like the ones proposed by Leser and Klink (1988) in their Geoecological Map 1:25000. Parallel characterisation methods like the Matrix, Patch, and Corridor framework proposed by Forman and Godron (1986), although very useful in the description of the functional role of the geographical entities are unable to differentiate the nature and character of the factors determining those entities, their more or less circumstantial character or the intensity of their role in the landscape ecological processes.

In any case the unsolved question aroused by all these methods is the existence of geographical entities with ecological significance in their content and function. These entities, present throughout the ecological theory in concepts like for example ecotope or geotope, and expressed trough natural or potential vegetation maps, soil maps or other more complex and integrated maps are, as referred, not yet identifiable through the existing methods.

Trying to analyse the factors that determine the nature of a certain site, it is clear that they have different forms and times of influence. This diversity determines that the nature of a given site at a given moment must be considered from a dynamic perspective and, therefore, the derived concept of land unit or site character as the character of adjacent sites or areas showing stronger resemblances between themselves than in relation with all other neighbouring ones, must be adapted to this reality. (Allen and Hoesktra, 1992)

The variability in the time stability and the resilience to disturbance of each factor determining the nature of one site or differentiating the border of the eventual land unit, have therefore to be considered very carefully, in order to achieve a true compression of the nature of those factors and the way they constrain its nature and the different possible forms of their evolution.

One way to try to systemise these different influences is to differentiate them between tendentialy stable (e.g. geology) and tendentialy circumstantial (e.g. land use or vegetation cover) within a given time referential. Such an approach should allow the identification of the different stabilities of each present land unit factor and the possible patterns of evolution and (or) response to management alternatives or disturbance factors. Additionally, the simultaneous consideration of the different scales of spatial concretisation of a given ecological characteristic or factor (e.g. litology, climate, soil and its differentiation degree in terms of the ecology of one site) is also of particular relevance for the ecological differentiation of adjacent sites. (Turner et al., 1989)

The main problem confronted by this approach is that the borders of each variable or landscape characteristic do not necessarily coincide or overlap themselves and the cases of coincidence don't necessarily determine equal intensity borders in terms of landscape characteristics, factors or functions.

This problem arises primarily at larger scales where a wide variety of factors contribute to the nature of the site.

At smaller scales, the importance of one or two factors (as temperature or water availability) is so prominent that the differentiation of units is no longer a problem, although the geographical reality of the exact location of their borders can not be accurately generalised to larger scales.

When considering factors like for example land use and its distribution over time, these difficulties are even larger, because of the seasonality or yearly variation of many land uses (mainly the agricultural ones). The resulting shifting landscape mosaics build dynamic ecological complexes that condition the ecological characteristics of a site and its habitat building potential, as well as the land use potential (Fig. 2).

These considerations illustrate how the thematic spatial geometries determine differentially the nature of each local and, therefore, it's dynamic and character of response to disturbance, land use or other type of resource affectation, implying the urgent need of a more systemic approach to these issues where the different types of influences and patterns of landscape constraint can be identified characterised in order to be feasible of management.

The spatial component of landscape ecology is very important and the analytical capability of this field has been greatly expanded by the advent of smaller, faster computers and Geographical Information Systems (GIS).

Stow (1996) describes the role that GIS can play in landscape ecology studies. He presents six areas in which GIS systems can complement landscape ecological analysis:

- *Database structure* – The type of data that landscape ecology uses is most efficiently stored in and retrieved from a GIS database;
- *Hierarchical format* – GIS databases can efficiently manage the multi-scale analyses required in landscape ecology;
- *Locational analysis* – Using GIS layers, a researcher can locate appropriate plots for field data sampling;
- *Support remote sensing analysis* – GIS layers can enhance remote sensing analysis by providing improved information extraction potential;
- *Spatial statistical analysis* – The inherent spatial structure of GIS databases allow the spatial statistical analysis that landscape ecologists must use to compare ecological structure;
- *Input/output for ecosystem models* – GIS databases are able to efficiently store and supply data to input into ecosystem models and for displaying outputs of the same models.

How landscape dynamics determines its spatiality

Landscape is not random, landscape has a structure, as

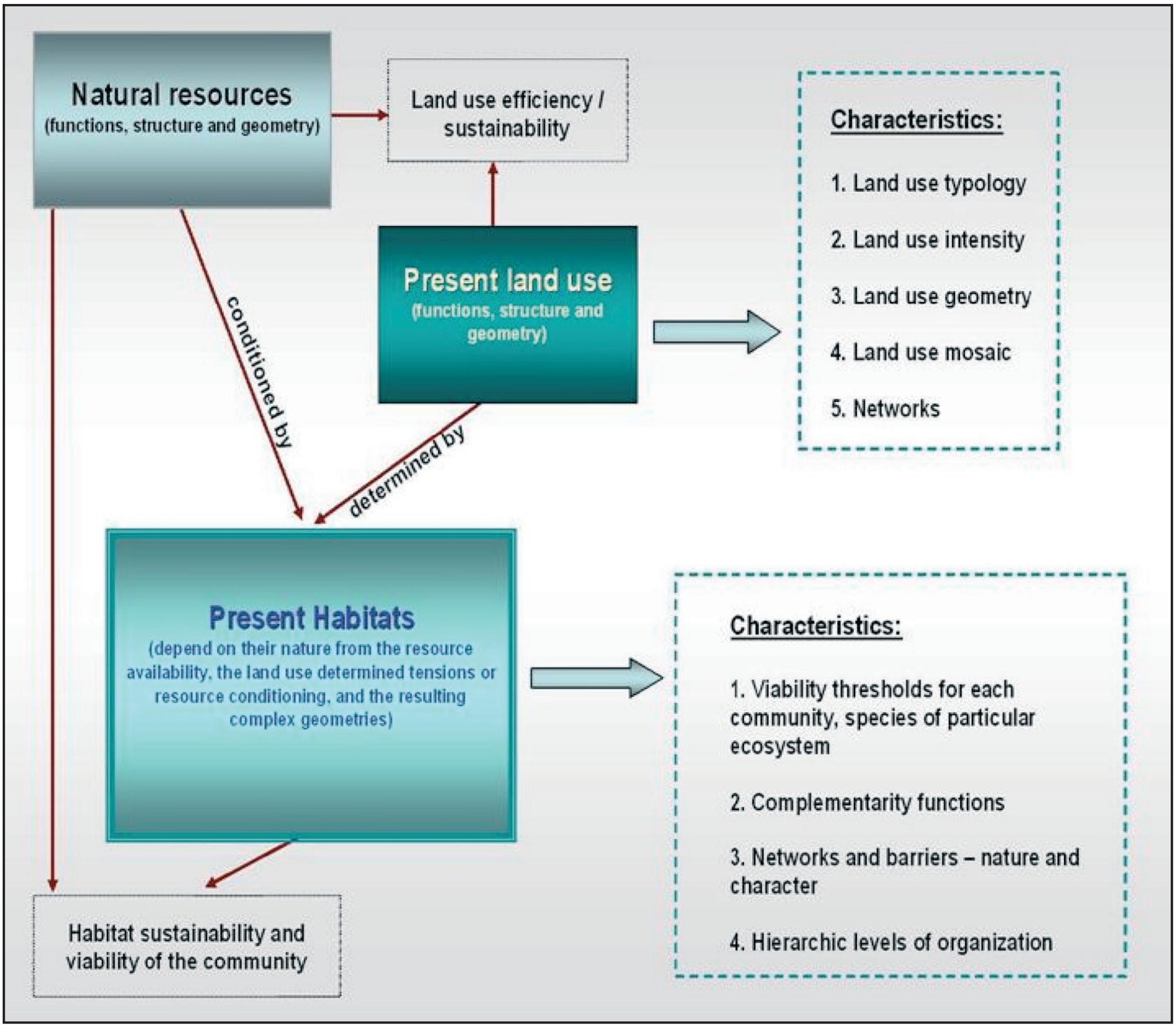

Figure 2: Factors and functions determining the character of a given Habitat

well as a functionality based on that structure. The landscape processes depend from that structure and functionality and, although those processes can show a certain degree of stochasticity, they are not random.

This stochasticity is bounded by the structure and the organisational dynamical patterns within the landscape. Therefore, every landscape ecological approach has to consider the geographical reality of the landscape and the way in which it expresses different types of influences that can be represented by different layers of information, by different layers of dynamical processes, by different layers of interaction and by different geometries derived from dynamical processes that can happen in certain areas and not in other areas because of this dependence from given landscape patterns (Fig. 3).

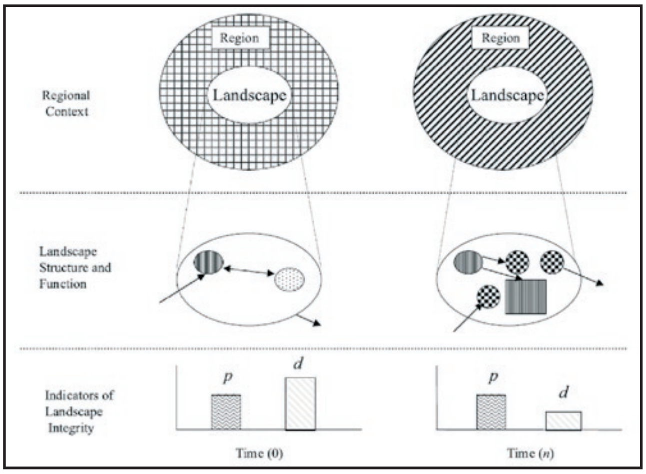

Figure 3: Diagram of Regional Context, Landscape Structure and Function, and Landscape Integrity at two time steps (Liu and Taylor, 2002)

All these interactions have to be identified and the relative degree of causality for the landscape dynamic determined. This is of particular importance given the fact that this causality bounds the degree of stochasticity susceptible of occurring in a given landscape.

Examples of this dependence are for instance soil catenas, soil patches associated with local accumulations of water derived from different infiltration conditions of the substrate, different phenology of the vegetation associated with the microclimatological patterns and processes of an area, as well as biological paths or barriers associated with land use or other more or less circumstantial characteristics of the landscape.

Other examples of this landscape dynamic derived geometries are the landscape use geometries associated, for example, with a certain animal: the use of the different habitats depends from their character at each moment, from their accessibility (and therefore from the location of the animal at any given moment), from the eventual aggressiveness of existing negative factors, etc. All these factors depend from the pattern of use of that landscape in the previous moments, as well from a given conditioned degree of stochasticity in the animal movements or preferences or, in an agricultural landscape, from the varied decisions of each farmer regarding the management of each land parcel.

Models which allow the user to explore dynamics at multiple spatial and temporal scales of analysis are important, because of the scale dependence in complex social-biophysical systems. (Walsh et al., 1999)

Conceptual issues for the definition of a practical methodology

If we try to identify what are the main factors that determine the characteristics of a given site or a given habitat we can identify a chain of relations as depicted in Fig. 2. From each one of these factors at least one different geometry can be derived.

In fact, according to each particular species, group of species or communities, we can have completely different types of spaces, relations and even geometrical scales:

- One forest, prairie, or other particular type of habitat for interior specialised species/communities.
- Particular groups of habitats or niches for species demanding the nature and complementary landscape functions or elements (nesting + pairing + feeding + propagation + barriers. (Bartowski, 1990)
- Single elements within one forest, prairie or other habitats for species with small scale specialised niches (potentially other plants, animals, groups of both and/or inert niches (e.g. rocks).
- In highly humanised environments, equivalent niches in man made structures or land uses.
- Normative and analytical regions - these have a legal existence and correspond to an administrative reality in the country or region concerned. These are clearly defined places under the control of a specific part of the public administration, in particular implementing official authority, regional policy. (EEA, 2001)

Land use geometries are good examples how complex combinations can be determined. One good example is the case of La Mancha (Spain) where different management geometries coexist: the Land Owner/Farmers geometry, expressed trough an aggregation of the land use parcels and the "Polígonos de Pastos" expressing the grazing management units, where the grazing intensity as well as the seasonal and the spatial distribution of the sheep depend from the management decision from the shepherds and the grazing resources – non manageable variable because exclusively dependent from the decisions of the individual land owners (Fig. 4).

Associated with these two different geometries several important informations are available and can be modelled:

- Land use parcels – relative availability of grazing resources (difference between pastures, agricultural fields and other non grazeable areas – expressed in amount of food resources, degree of legal availability of the resources, and period of availability – the arable lands have only grazeable resources after the harvest).
- "Polígonos de Pastos" – location of the sheepfold and delimitation of the grazing rights to each flock.

This information allows, for example, the simulation of grazing cost distance relation for each "Polígono" considering the location of the sheepfold and the potential availability of food resources as well as the simulation of the grazing potential determined by the former cost distance linked to the existing food resources – derived from the more or less stochastic decision of the land owner to grow these or that culture more or less suitable as forage.

Over these two land use geometries and depending from both (in the sense of feeding resources, disturbance intensity or absence, etc.) other geometries can be identified like the nesting, mating, feeding, resting and movement sites (land units) for, for instance, the great bustard.

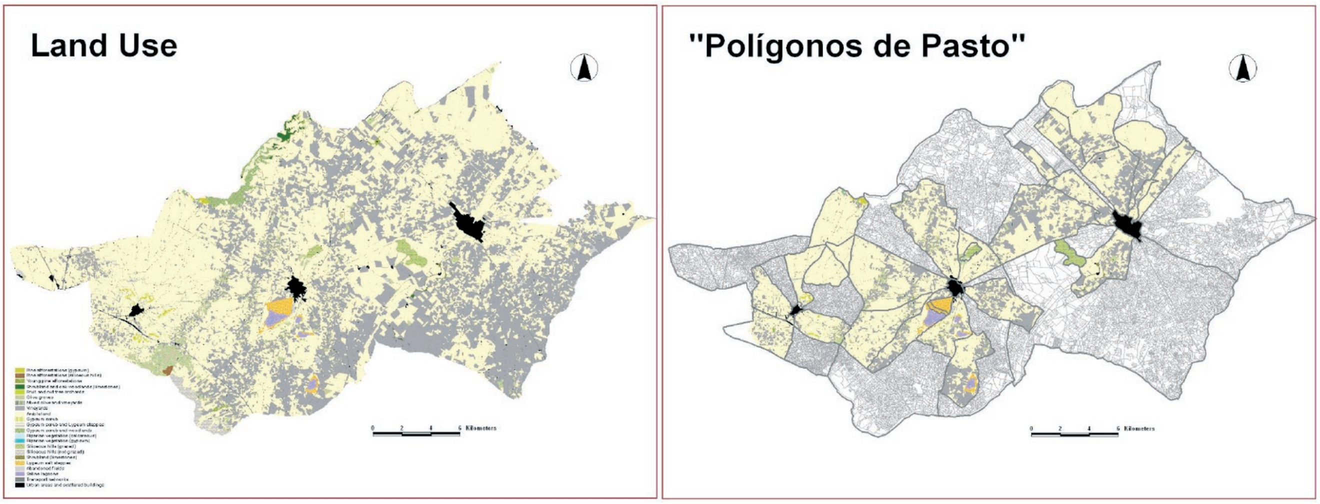

Figure 4: Diversified complementary Management Units and Geometries in La Mancha

This complexity implies that, in order to achieve a successful representation of a given landscape it is necessary to ensure the definition of innovative geometries where hierarchic relations, as well as functional interactions at the same hierarchic level can be described, evaluated and operated.

In order to be able to represent these geometries as well as the related functionality the ILA (Integrated Landscape Ecological Analysis) model has been developed (Fig. 5).

ILA is a framework for environmental characterization and evaluation. Its objectives are:

- To build a coherent characterization and evaluation framework for landscape ecological studies.
- To allow, within this framework, all types of expert knowledge or models to be operated on a coherent working background.
- The ILA model is based on the following basic ideas:
- Each landscape is determined and can be characterized by two types of environmental factors:
- Stable biophysical characteristics and related functions and processes

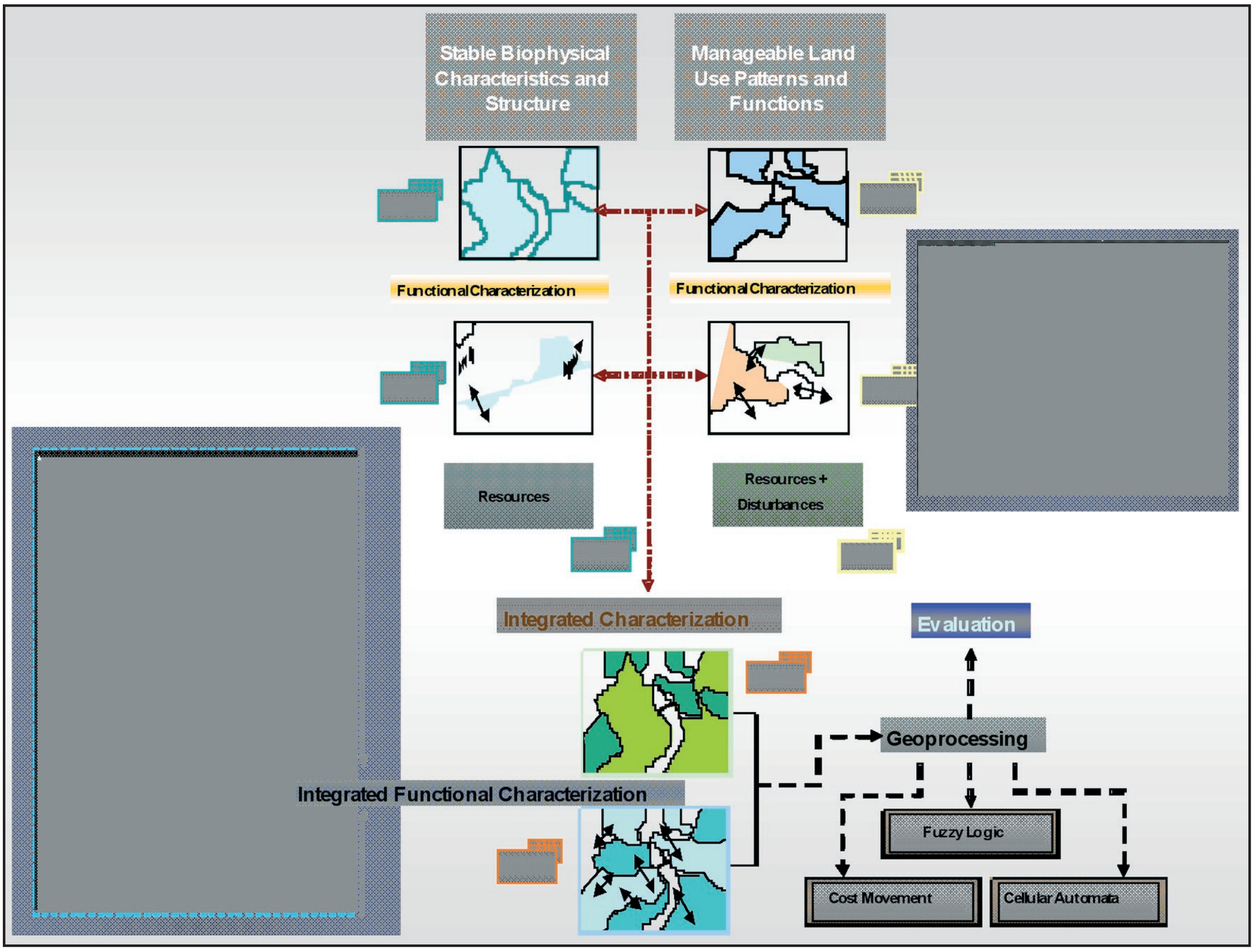

Figure 5: General structure of the ILA Model (Leser, 1997, Wenkel, 1999, Fernandes et al., 2002)

- Manageable land use patterns and related functions and processes
- The consideration of the above mentioned levels of characterization allows the definition of a homogeneous system of reference (the stable characteristics) to which every possible land use pattern can be compared trough the use of common modelation and evaluation algorithms.

ILA main advantages are:

- The use of a stable reference system allowing the comparative simulation of different land use scenarios, as well as the permanent availability of the same reference system independently from the intensity of land use changes throughout the years.
- It also allows the use of different modelation or evaluation algorithms according to different contexts or research objects, without having to repeat or adapt the characterization process.
- Trough the independent consideration of the land use scenarios, it allows those scenarios to be the object of comparative analysis or evaluations (e.g economical), without any interference with the nature or quality of the environmental information.

ILA is, therefore, a framework for data and evaluation processes where the only requirement is the availability of a stable geographical reference base that can be qualified with the same set of indicators or descriptors as the system to be evaluated.

This implies that every geographical land use/habitat or ecological/biological structural arrangement can be described by a set of indicators or other evaluation tools that can be applied, at the same time to a given stable geographical/ecological system of reference in order to determine the variation of those indicators or evaluations descriptors. As a result, for each type of study case, a particular geometry and representation scale, as well as set of elements ad functions to be represented must be identified according to the definition of the research targets. In order, for example, to be able to simulate different sets of management criteria, different representation geometries will have to be simultaneously considered and included in the research.

The main methodological advantage of ILA is the fact that on the basis of its concept are geometrical descriptions of the landscape and the effort to create a conceptual framework where given processes or characteristics can be analysed, simulated or evaluated in a consistent and coherent way, allowing, namely the combination and application of both economical and ecological models. It also allows the combination of different working scales trough the aggregation of scale –compatible or –similar units/objects in higher hierarchical units. These processes can be entirely developed in the frame of common GIS and Geo-statistical frameworks and programs.

The increasing use and capability of geocomputation tools, as well as increasing availability of land resource information offer opportunities to use such tools for the effective management of information for planning purposes. One among those is the development of spatially-based models that may be used for efficiently undertaking land suitability assessment based on available information. (Baja et al, 2001)

Biologically-Inspired computation techniques such as fuzzy logic, artificial neural networks, evolutionary algorithms and adaptive agents are considered as core concepts of ecological informatics. Figure 6 represents the current scope of ecological informatics indicating that ecological data is consecutively refined to ecological information, ecosystem theory and ecosystem decision support by two basic computational operations: data archival, retrieval and visualization, and ecosystem analysis, synthesis and forecasting. (Recknagel, 2003)

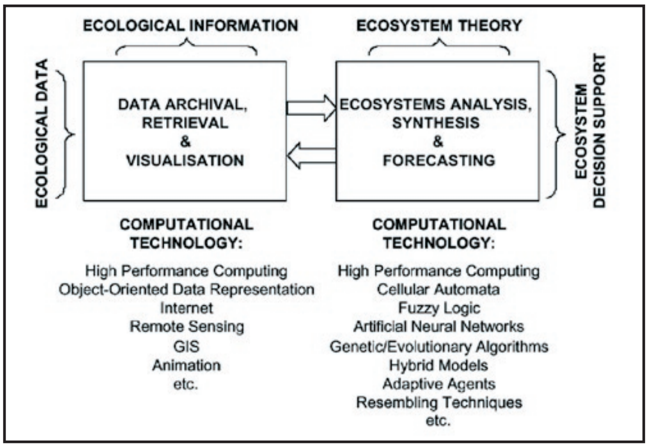

Figure 6: Scope of Ecological Informatics (Recknagel, 2003)

Functional organisation of the ILA model within a GIS

Considering the case of Natural Resources geometries, the characterization of the available resources and their degree of commitment by the present land uses is one of the basic aims of the ILA approach (Fernandes, 1999). The data inventory for any research area must be complemented with information on the balance of resources associated with each descriptor or descriptor combination. This information, derived from soils, climate, morphology, geology/litology and vegetation, evaluates the use thresholds as well as the endangering factors for the land use potentials (higher susceptibility to given degrading processes like erosion, pollution, etc.)

Figure 7 describes the general system structure based on a Geodatabase data model where the basic structure of primary data integration or thematic sources is organized to explore relations between the elements, features or layers which constitute the basic information.

The geodatabase data model brings a physical data model closer to its logical data model. The data objects in a geodatabase are mostly the same objects you would define in a logical data model, such as owners, buildings, parcels, and roads. (ESRI, 1999)

Geostatistics provide methods to both describe spatial structure and to make statistical inferences that are robust in the presence of spatially dependent relationships (Gustafson, 1998). Computational technologies like cellular automata, fuzzy logic, artificial neural networks, genetic and evolutionary algorithms, hybrid and artificial intelligence models and adaptative agents, are currently considered to be crucial for ecosystems and forecasting. (Recknagel, 2003)

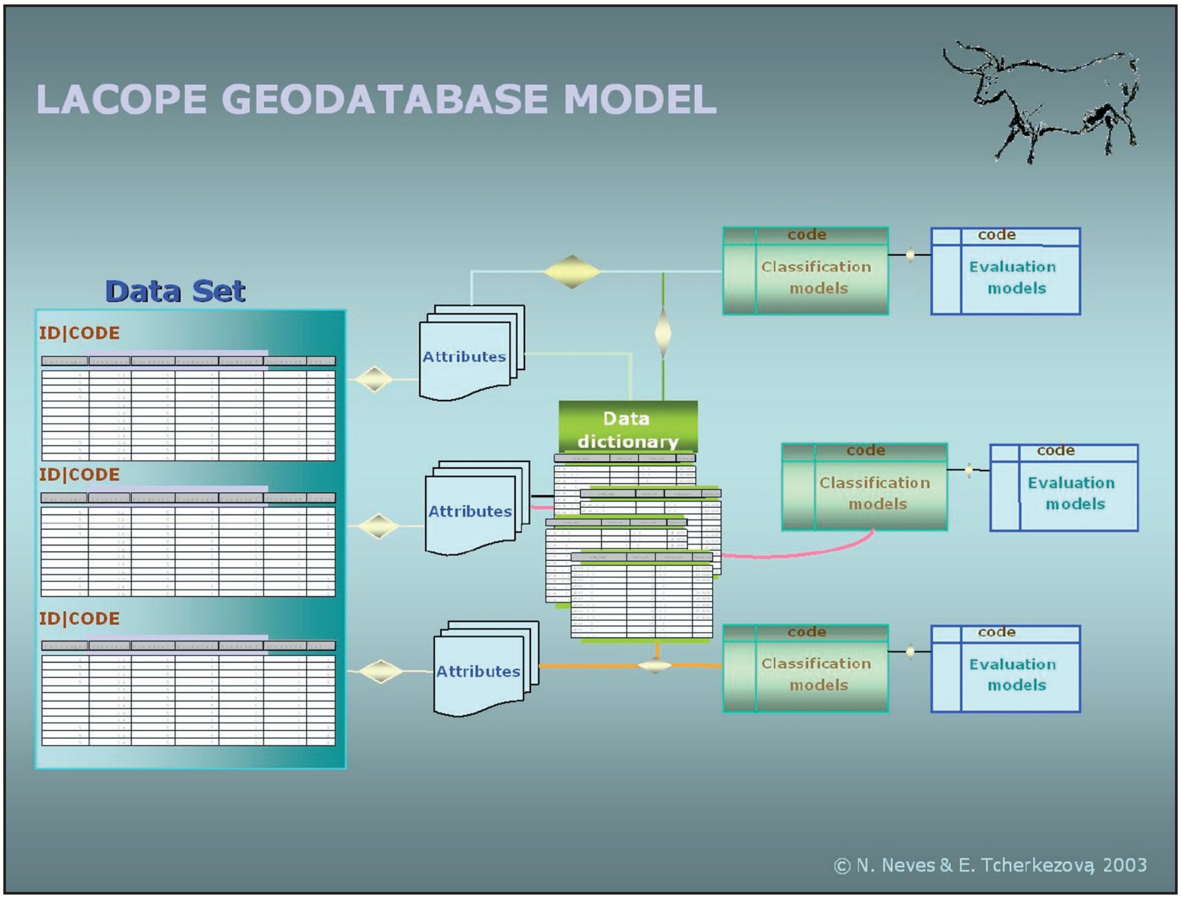

Figure 7: LACOPE Geodatabase Model.

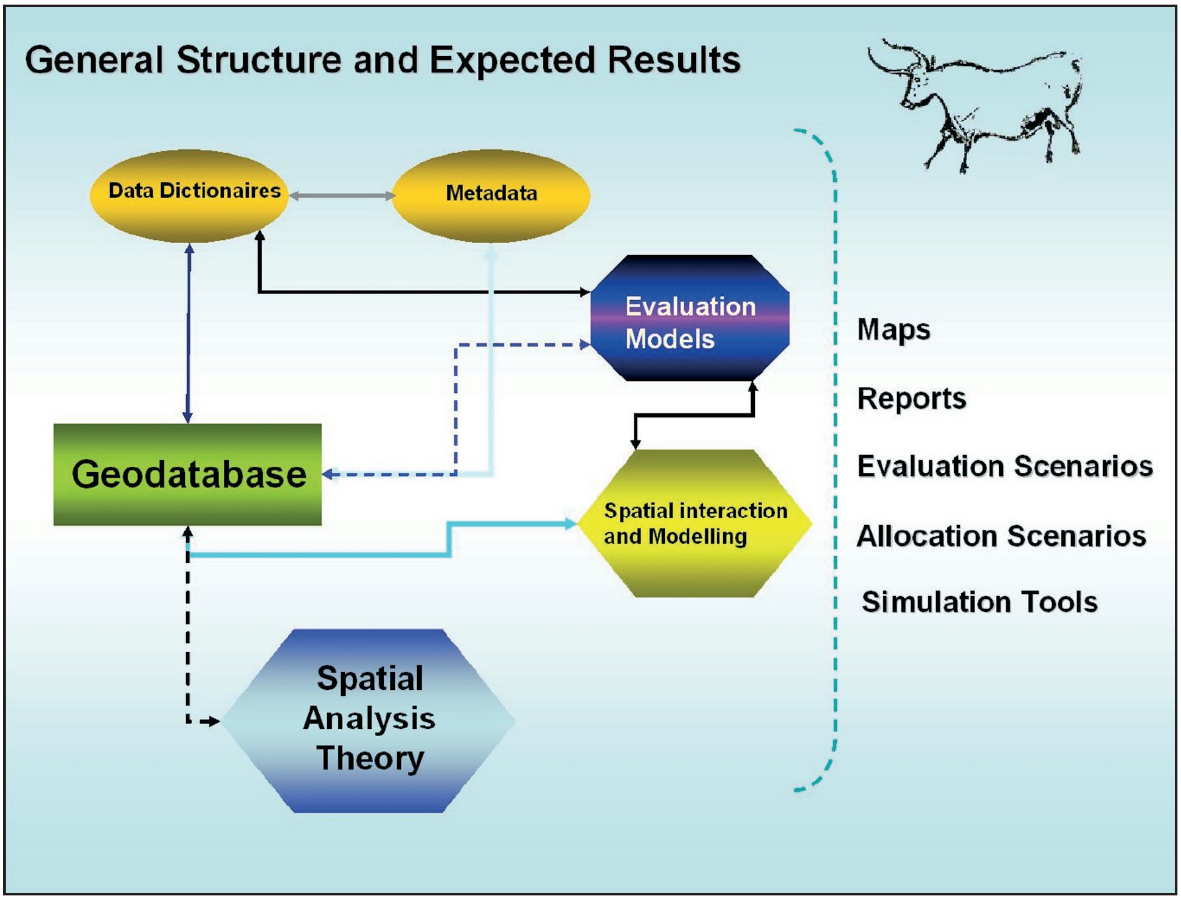

Figure 8: General structure and expected results.

Cost Movement Analysis

GIS spatial analysis and modelling allows the integration of these geometries with other variables. One of these is related with the Cost Movement Analysis (Fig. 9), since the energy spent by an individual on a determined movement from the sheepfold to the grazing area is function, not only of the covered distance, but also of its slope/aspect and land use.

Therefore models can be developed considering the three main factors that influence the movement process: Distance (measurable by Cost distance analysis), Land morphology (measurable by Slope) and a Specific impedance associate to the features of each Geographical Element. (Neves et al., 2002)

The metric relations involve the distance concept and represent the space proximity, and they also include the concept of area or angle, this last one representing the spatial orientation. But, in some cases it's not possible to use a metric, in mathematical terms. In these cases it's frequently necessary to appeal to a matrix distances – in terms of time of passage or cost – in order to obtain realistic results.

One of the modelling difficulties is linked to the fact that real slope value can't be used because it doesn't correspond to the effective slope of the track followed by the animals. Functional slope is in this sense an evaluation of the relation between the movement direction, the aspect and the real slope. The overlay of the Cost Distance geometry with the Functional Slope allows the model to understand the morphology of the landscape. (Neves et al., 2002)

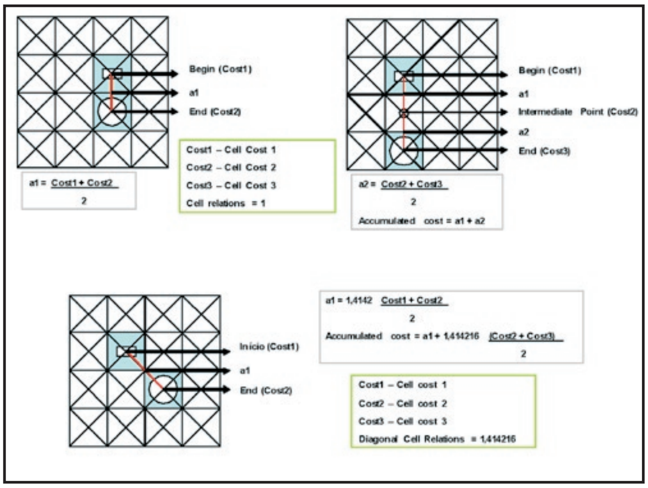

Figure 9: Formulas for the calculation of the cost of vertical, horizontal and diagonal connections trough the Cost distance extension (DeMers, 2002)

Finally, it is necessary to estimate the specific impedance in such a way that its value, or function for its calculation, can be "stored" as being associated to each type of minimum element of the studied scenario. This specific impedance represents the obstacles to the movement.

Habitat Modeling

Other important geometries are the Target Species Geometries, like the potential and real occurrence area of threatened species, as well as the spatial thresholds and other limitations for its occurrence: like coexistence of certain complementary habitats, minimal areas or lengths, absence of barriers or other disturbing factors (Fig. 10).

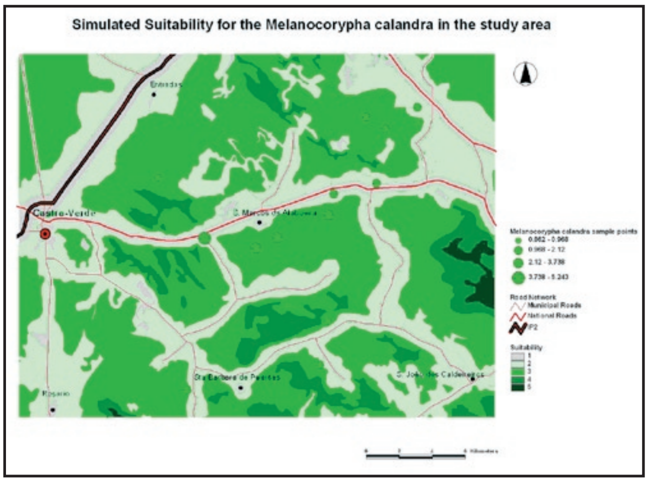

Figure 10: Simulated Suitability for the *Melanocorypha calandra* in the study area

Many methods have been used to model habitat suitability (Guisan and Zimmermann, 2000), but these methods can be classified into two groups: those requiring presence-absence data and those requiring presence-only data. Most of the commonly used statistical modeling techniques are based on multiple regression methods and require binary data (presence/absence data in this case) for model construction:

1. Logistic Regression is a statistical tool for the analysis of binary data, such as presence and absence data;

2. Discriminant Function Analysis is a multivariate classification technique that can be used to describe how two or more groups differ in relation to selected habitat characteristics and classify additional observations into one of the groups;

3. Artificial Neural Networks are patterned on the function of the human brain (Manel et al., 1999) and represent a black box approach to ecological modeling;

4. Classification And Regression Trees are multivariate techniques that result in a tree structure that branches at nodes based on the value of environmental predictors to describe the observations;

5. Cellular automata is a model embedded on a landscape rasterized into discrete cells, and been widely used for modeling spatially explicit phenomena in ecology (Jenerette et al., 2001);

6. Ecological Niche Factor Analysis is a relatively new multivariate approach developed to predict habitat suitability when absence data for the species are not available (Hirzel et al., 2002).

Examples of application

The combined use of GIS spatial analysis techniques with system dynamic approaches allows, in the frame of the ongoing research projects on extensive grazing systems LACOPE, suitable approaches to these geometries and to a sounder spatial characterisation of ecosystems and landscapes aiming at the definition of decision support systems for the management of existing and potential areas where this land use contributes to sustainability and biodiversity.

In the frame of the LACOPE research project different extensive grazing system are being studied throughout Europe. In order to be able to describe the economy and ecology of these systems and the landscapes they originate and from which they depend, the ILA approach is being applied.

For example in the Alentejo (Portugal) case study the land use organization is only organized in one type of Management Unit (MU) given the fact that the landowner is the owner of the flocks and the management of the farm is made in an integrated way and according to a sole purpose. Nevertheless, these MU are not a single block or parcel but the aggregation by one manager of different oft distant apart blocks (Fig. 11).

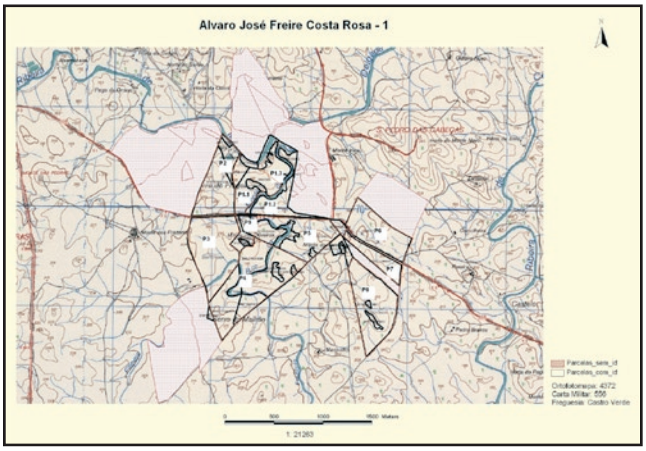

Figure 11: Example of researched MU in the Alentejo study area

The second level of information regards the rotation system. The usual rotation involves 1 or 2 years of cereal production followed by a more or less longer fallow period and a final plough before a new cycle. Some of the areas are solely dedicated to natural permanent pastures (rarely sowed) that could be fertilized or not. This shifting mosaic (along the year, because the harvested cereal areas are then grazed while the fallows are more intensively used during the growth period of the cereals, or along the rotation cycle) build different types of habitats differently used by the steppic species.

When considering the habitats for different target species as corresponding to different components of the land use mosaic, in a more or less segregated and stable way along the year, we must take into attention that all the habitats related to the cereal / fallow rotation show a permanent change in their spatial arrangement in the landscape building, therefore, more or less favourable areas for the different target species populations, with more or less important shifts in the food or space availability, or the habitat connectivity or continuity.

Analysing the more suitable geometries for the analysis of this case study, we start with the Management Unit that builds the basic geometry for the case studies. There is, nevertheless, no insurance of the long term stability of that geometry, due to the fact that many of those units correspond to aggregations of rented land.

Simultaneously, the permanent shifting of the habitat mosaic due to the traditional rotation of the land use in the cereal/fallow areas inhibit a stable consideration of the habitat availability, but only of its variation at eventual limiting threshold values. The increase of the forested areas in the different MU as an income complement in alternative to an eventual decrease of the profitability of the grazing systems or an increase of the investment risk, constitute an important disturbance factor to these habitat geometry because of its eventual marginal location to the geometry of the MU and the resulting possible fragmentation of the open landscape, and of the continuity of the steppic habitat.

In this context the grazing geometry is primarily determined by the availability of grazing resources that in this case study are determined by the land manager within the MU (with some exceptions of producers that still take their animals to other areas outside the study area to profit from the cereal stubbles).

Secondarily this geometry depends from the land management and the rotation cycle whereas the manager concentrates the animals in the fallows during the growing season of the cereal, taking the animals to the cereal areas after the harvest to eat the stubbles. The factors determining this management decisions are manifold (Figure 12) and are one important factor for the relative stochasticity of the habitat structure in these areas.

To these geometrical factors it is always important to ad the natural resources geometries that determines many of the management costs (see "Soil and Climate conditions") and the geographical arrangement of many landscape features.

Considering 2004 year rotation in one of the researched MU in Alentejo and the yearly habitat preference cycle for example of the Great Bustard (Fig. 13), it is possible to represent habitat suitability geometries, as well as complementarity geometries for the studied MU.

Generalizing these results by considering an average of two thirds of the open grassland area in the LACOPE research area in Alentejo as having a Medium High to High suitability to building habitats for the Great Bustard and combining that hypothesis with the positive effects of water surfaces and the barrier effects of roads and urban settlements, it is possible to produce hypothetical habitat geometries for this particular target species. This is not a real geometry but only a result from a stochastic model (the distribution of suitable areas was randomly generated) but allows a better evaluation of the potential population of Great Bustard considering the existing habitat restrictions (Fig. 14)

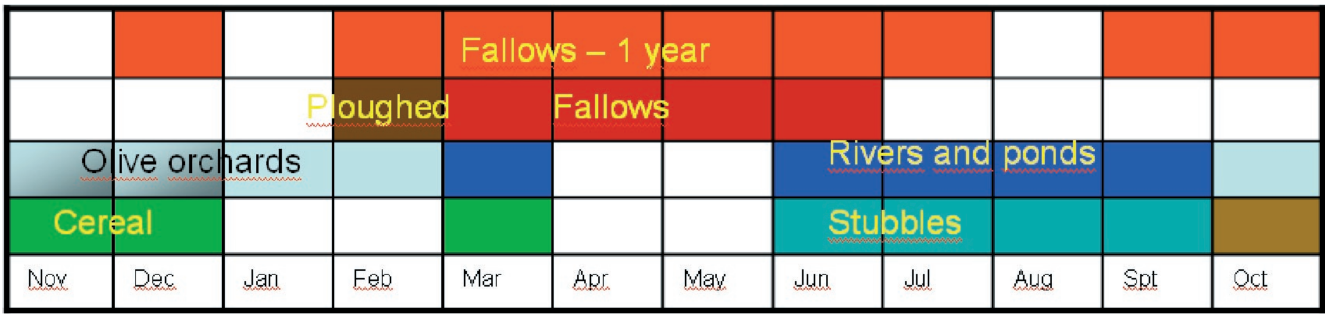

Figure 12: Yearly habitat preferences of the Great Bustard in Southern Alentejo (Morgado, 1997)

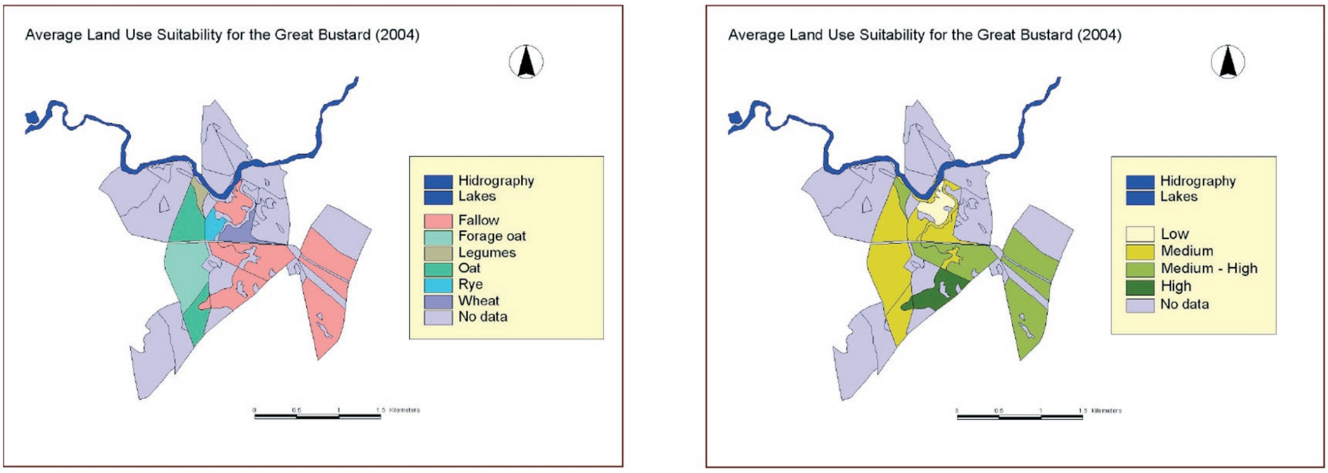

Figure 13: Average Land Use Suitability for the Great Bustard

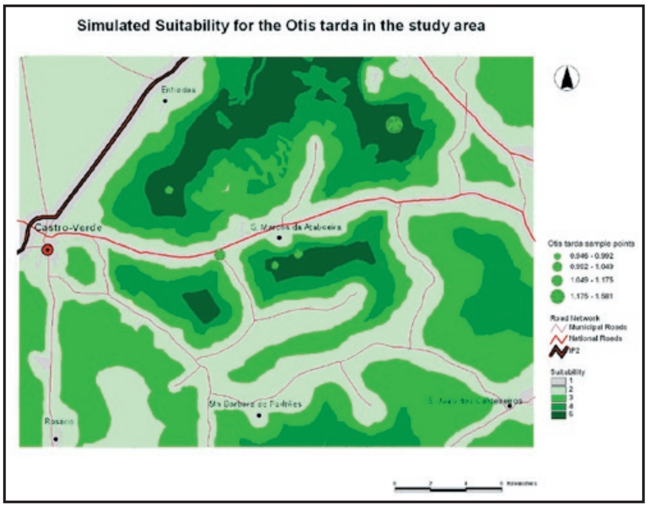

Figure 14: Simulated Suitability for the Great Bustard in the study area

The simple modification of the economical conditions determines model-feasible changes of this frame conditions and, therefore, different geometrical habitat conditions for the simulated species.

This simulation approach relates habitat restrictions with coefficient expressing the importance of accessibility and land use for the desirability of the cell for land use activity.

Final remarks

The identification and characterization of the patterns and processes in the landscape implies a very detailed characterization of the geometries determining those features given the basic factor that any one of them is strictly referred and determined to a geographical location and arrangement.

The consideration of those patterns and processes is always a simplification process where an effort has to be done in the sense of preserving all relevant data. The ILA approach is an attempt to build a conceptual framework for this purpose. The preliminary results presented although unable to illustrate all the possibilities of this framework display many of the new issues it can arise, by building an integrated informational framework where economical and ecological models can be simultaneously operated.

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