Planning in ecological network
PLANECO Project

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University of L'Aquila
Department of Architecture and Planning
Monteluco di Roio- 67040 L'AQUILA - Italy
Tel. ++39 862 434113 Fax ++39 862 434143

PLANS FOR NATURE AND RECREATION IN THE GELDERSE POORT

Bert W. Arms

The new outline land-use plan for the Gelderse Poort must accommodate both nature conservation and recreation objectives for the area. To aid decision-making, DLO Winand Staring Centre has developed three design concepts, two of which have been worked up into possible plan alternatives: 'Macrogradients' and 'River Dynamics'. The consequences for plants and animals of both these alternatives were calculated by the knowledge-based model LEDESS. The results revealed large differences in impact: one alternative led to a wide diversity of species, the other to the formation of large habitats for river species. A combination of both alternatives would be an optimal strategy for all the species.

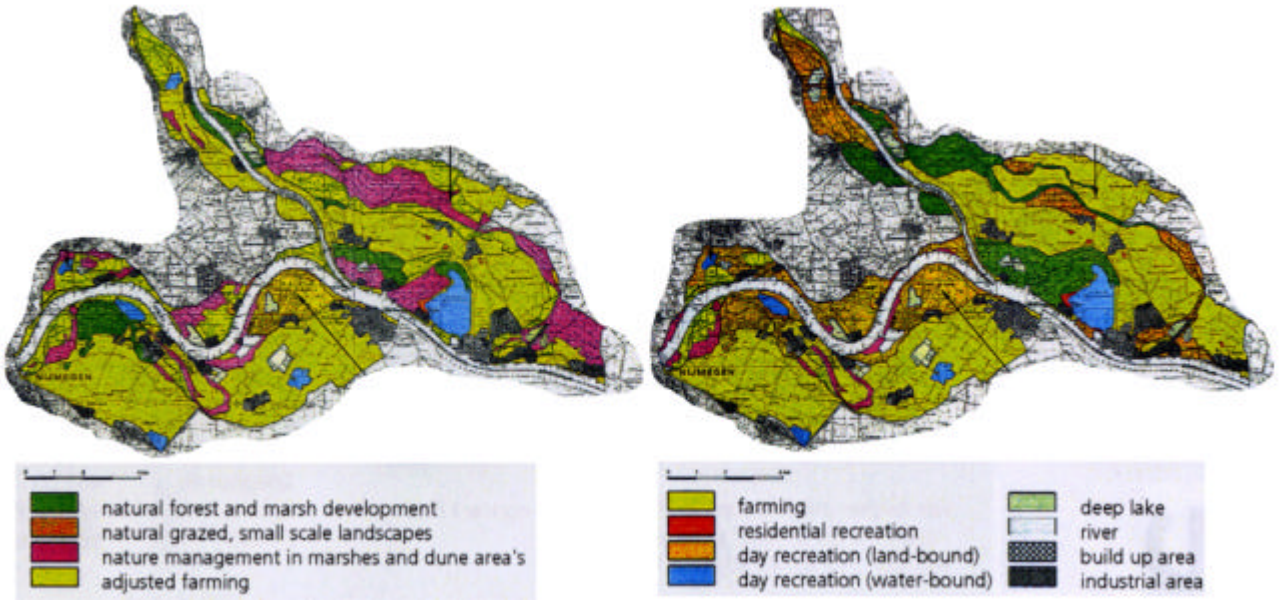

Fig. 1 -Two plan alternatives for the Gelderse Poort: Macrogradients (left) aims for high biodiversity, maximum variation in management,and both integration and zoning of land use; River Dynamics (right) is based on the natural dynamics of the river, little or no management, and separation of

Nature, management and farming

The Gelderse Poort is an important area for nature. It covers 20 000 hectares at the entrance to the Rhine delta on the Dutch-German border. In the near future 30 per cent of the natural habitat in the area will need to be restored. Three design concepts have been drawn up by SC-DLO, based on an integration of the various land uses in the area and derived from ecological principles. Two have been worked up into plan alternatives, 'Macrogradients' and 'River Dynamics', from which a number of scenarios were generated.

Macrogradients aims at an increase in biodiversity through specific management practices, changes to farming practices and spatial integration of the various land uses in the area. River Dynamics aims to create a more natural landscape by reducing human interference as much as possible and by separating the various land uses. A control situation, derived from the autonomous development of the area in its present state, served as a reference for comparing both scenarios. The LEDESS knowledge-based model was used to evaluate the ecological impacts of the scenarios by simulating the development of the vegetation and animal populations. The vegetation dynamics here depend on the abiotic conditions, the nature target types selected andthe management regime. The suitability of the habitats for the animals depends on the spatial variation in abiotic conditions and vegetation types.

New landscapes

Implementation of the Macrogradients alternative will

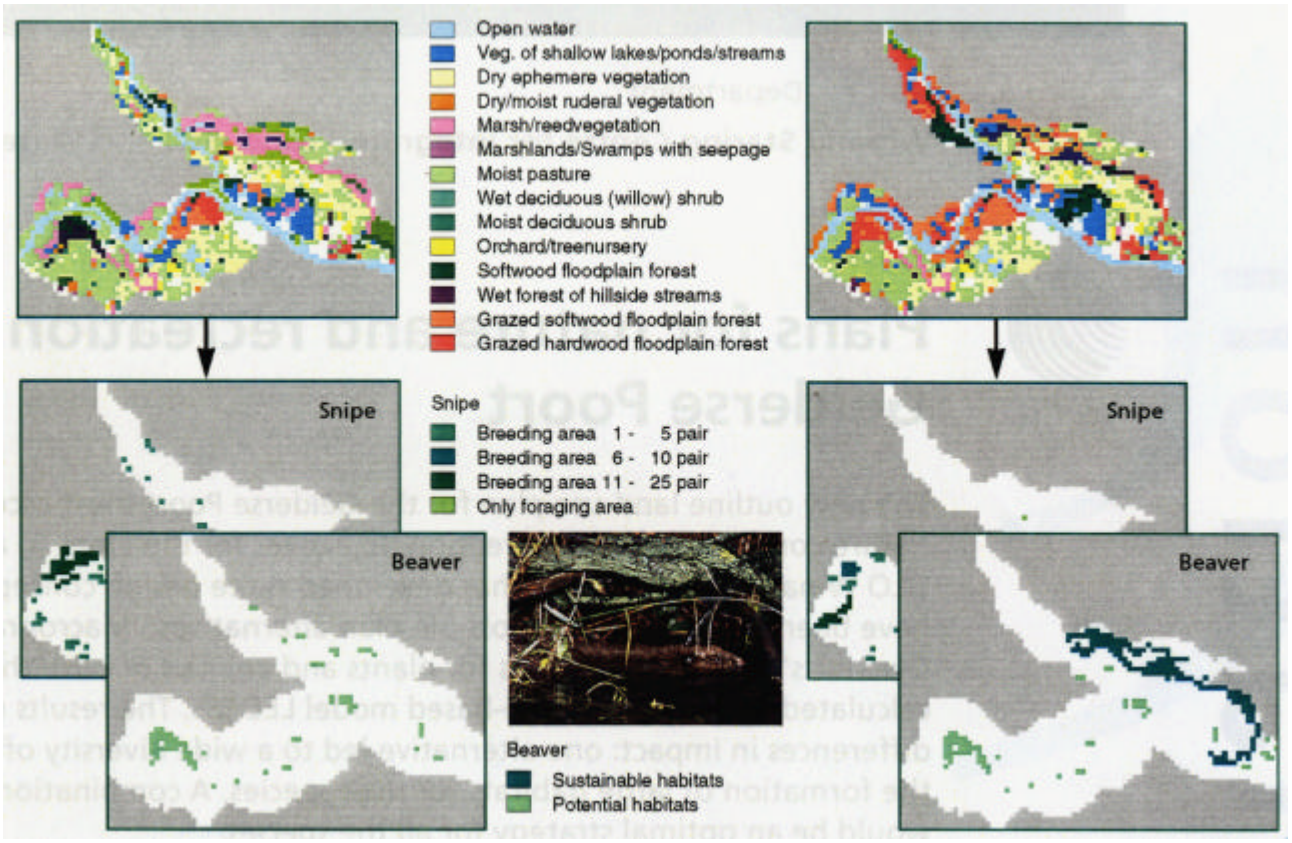

Fig. 2 - Ecological results for the vegetation cover after 30 years in the Macrcogradients and River Dynamics alternatives, and the potential and sustainable habitats for snipe and beaver derived from these results.

maintain the current openness of the landscape. This is of benefit for the natural history and geological value of the area.
The recreational value of the area is also based on the historical interest of the landscape, and so farming can continue while taking on a landscape management role. This scenario provides the greatest diversity of both plants and animals. The management costs are high.
Implementation of the River Dynamics landscape in which the recreational interest is focused on the experience of nature.
Ecologically, the emphasis is on naturalness.
This leads to habitat improvements, particularly for the plants and animals most associated with the river, and low management costs.

The best plan
Both plan alternatives are improvements on the reference situation. Which alternative will prove to be most appropriate depends on the targets set: either high biodiversity while maintaining the historical and cultural aspects of the landscape, or rehabilitation of the natural river ecosystem. A combination of plan alternatives will provide an optimal strategy for all the plant and animal species in the area.

LANDSCAPE DYNAMICS CONSEQUENT TO FIELD ABANDONMENT AND EFFECTS ON SOME BIRD SPECIES IN ABRUZZO REGION (ITALY)

Silvia Scozzafava - A. De Sanctis

Conservation policies have since long recognized the need to mantain ecological links between protected areas, to ensure long-term achievement of their aim, both towards animal and plant species. Yet this new approach poses a problem: how to plan and manage the territory for this purpose. It's not simply a matter of expanding environmental protection areas, and in the end this isn't always possible, neither desirable. The restrictions connected to the management of a protected area often cause hard conflicts; moreover, as a protected area expands, it becomes more and more difficult to manage it.
On the contrary, traditional ways of natural resources exploitation and land management, as extensive pastures and cultivations, create landscapes that are in themselves pervious to many species, constitute a first choice habitat to many others, even of conservation value, and last, do not give rise to strog clashes of interests. Nevetheless, traditional farming systems are now at risk of extinction, due to agriculture intensification and marginal areas abandonement; this can mean a great loss of biodiversity in areas which are normally not subject to specific conservation laws.
Agriculture abandonement in marginal areas is a widely spread phenomenon in Eurpoe, and particularly in Abruzzo, where the socio-economical conditions in the postwar period

have led to a massive emigration from mountain and rural villages towards industrialized towns or foreign countries. So in rural and mountain areas, in a 40-years period, we get to the abandonement of large areas and to a quick vegetation recolonization process, not yet completed, but well visible by a simple comparison of aerial images. It is exactly on these dynamics, and on their possible effects on birdlife, that we focused our attention. The effects of this transformation on animal species which are linked to rural environment, in fact, have not yet been throughly studied, especially as regards Italy and in general Southern Europe. Anyhow, there are numerous signs that many animal species don't take advantage from these modifications; especially the ones linked to a varied agricultural landscape do not find enough resources in the new environment, and disappear. Many of these have undergone such a steep decline as to lead the European Community to include them in the annexes of the Birds Directive (409/79); this is the case of the Ortolan Bunting (*Emberiza hortulana*), of the Red-backed Shrike *(Lanius collurio*), of the Tawny Pipit (*Anthus campestris*).
The importance of rural environment for the conservation of natural environment has been recently recognized by the European Community with the issue of the Regulation 2078/92, now replaced by the 1257/99; these Regulations comprise a set of measures called "agro-environmental", aimed at the improvement of rural areas form an environmental poit of view, through economic incentives as a compensation for crop loss. Lately, agro-environmental policies have become an integral part of the Common Agricultural Policy (CAP), and are also coordinated with the prescriptions of the "Birds" and "Habitat" Directives. Yet an evaluation of the achieved results is not always easy; some measures need certainly a careful planning, for example the twenty-year set- aside: there is the risk of even enhancing the decline of traditional farming systems, which are economically weaker. The methodology hereby illustrated, as we will see, can be applied to rural environment surveys, in a rapid, cheap and meaningful way, aimed at a careful planning of agroenvironmental measures and at the protection of traditional farming systems, as well as for nature conservation, following the holistic approach fostered in the Commission VI Work Document on Evaluation of Agro-environmental Schemes, in 1998.

Methods

The study area, the "Rocche Plateaus" in L'Aquila's Province, is a series of three karstic plains at an altitude higher than 1300 m a.s.l.. They are covered mainly by meadows, with some arable land in the marginal parts of the plains, sown mostly with cereals and fodder.
We chose to work with aerial photographs, using two sets of images, one dating back to 1954, the other to 1994, to study any changes occurred in landscape structure in this forty year's time, a period in which there has been the highest emigration, as well as industrialization and agriculture mechanization; these events led to a steep decline in farming and forestry activities, which formerly affected deeply Abruzzo landscape features, and whose disappearence is having almost as incisive effects.
The agricultural economy in this area exploited as a main resource the rich meadows in the central parts of the plains, which every spring get flooded by snow melting, producing great amounts of fodder, and giving rise to a widespread cattle raising. Besides this, also cereals, legumes and potatoes were cultivated in those sectors of land less subject to flooding. The plots were small, and surrounded by hedges. Nowadays hedges have almost disappeared, because mowing and other field works are mechanized; the permanence of hedges is often due to field abandonement; the hedges themselves are then starting points for shrub recolonization, that in the areas still subject to grazing doesn't go beyond the bushy stage.
On the mountain sides surrounding the plains, in the steepest parts, we find now wood and shrubs, despite the fact that in 1954 there were still many cultivated or recently abandoned plots, all surrounded by hedges. So, of course, land abandonement started first on steeper and more distant areas; on the other side, where agricultural activities didn't cease, modern practices and techniques were adopted which involved hedge removal.
Our next step was trying to see which were the consequences of such deep transformations on some animal species, choosing some that could work as environmental indicators for landscape structure change.
This choice was driven by some fundamental remarks. The bird fauna was chosen, for being the one, among all, which is mostly affected by vegetation structure and land use, rather than by floristic composition (D'Oleire-Oltmans *et al.*, 1994). Among birds, the passerines are the most linked to a territory in the breeding period, and consequently their distribution is apparently affected by habitat alterations at a landscape scale. To this can be added that passerines are easily sighted in reproductive period, due to continuous nesting and territory defense activities.
Lastly, among all passerine species, the most linked to the traditional rural landscape have been chosen, that are experiencing a severe decline due to its loss. The three selected species have slightly different habitat preferences: the Corn Bunting can adapt to a variety of situations, even in quite open habitats, while Red-backed Shrike and Yellowhammer need a more structured and varied habitat (Cramp, Perrins, 1993). These species are easily recognized even by unexperienced observers, and consequently very suitable for quick environmental surveys, aimed at planning tasks. The three species' distribution has been surveyed in the field in reproductive period (May-July), using fixed hearing/sighting points. 110 "plots" of 100 m in diameter were chosen; in each of them each species was noted as absent or present. The survey was carried on two times for each plot, at a month distance.
The first problem we had to face was the lack of historical data about the distribution of these species at a landscape scale. We used a statistical model to try to overcome this, and anyway to highlight the possible effects of lanscape change.
First of all, we took a set of environmental and landscape data on 1994 aerial photographs; the chosen variables are known as important in determining birds' nesting site choices:

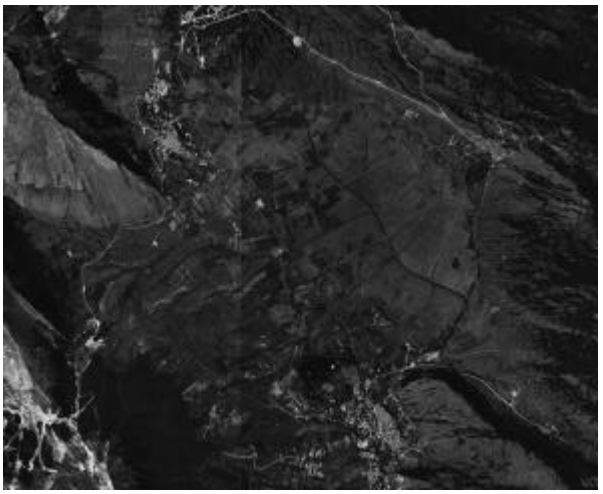

Fig. 1 - 1994 aerial photograph of "Rocche Plateau"

exposure, orographic complexity, distance from nearest building, distance from nearest road, field border length, hedge length, dry-stone wall length, number of isolated trees, number of isolated bushes, untilled land percentage (estimated in circle sectors), distance from woodland border.
Then we elaborated three logistic regression models, one for each bird species, to link its presence/absence in reproductive period to environmental variables values in the plot area. Testing the efficiency of the model on our data led us to exclude the Corn Bunting from analysis, as the correlation was not significant. We put in the two remaining models' independent variables the 1954 values, obtained by aerial photographs interpretation, to perform a simulation of the two birds' distribution in the past.
We expected the simulation to give us a wider distribution of these species in 1954, due to much greater hedge length in large areas of the plains. Nevertheless, the results were surprising: the models gave a much reduced distribution in 1954 with respect to the present, for both species.
The reason of this could be found in the variables that resulted the most important in the models. We realized that the model gave to the "isolated bushes" variable a greater weight than to "hedge length" or "untilled land"; and, most of all, that changes occurred in those environmental variables had involved not only simply the values, but also their intercorrelations, which even switched sign. This "mathematical details" not only can distort a model's output, but have also a definite meaning in terms of landscape structure. In 1954 there were few isolated bushes: all the fields were cultivated, or only just abandoned. From aerial photos we can see that there were also large bushy areas, but only on the steeper slopes, in areas that, being now covered with wood, were not included in the study. On the other hand, in 1994 many fields in marginal areas were completely invaded by bushes, with values that changed from 0 in 1954 even to many tens. This great change had a heavy effect on the model. We can however wonder why lack of bushes in 1954 was not counterbalanced by hedge abundance; here, too, further analysis could give an explanation. We highlighted how at present hedge length is strongly and positively correlated to the number of isolated bushes, while in 1954 this correlation was exactly opposite in sign. Of course the model output was biased by this variation, and the hedge abundance couldn't mathematically make up for lack of bushes.

Fig. 2 – Rocche Plateau and Rocca di Cambio

Conclusions

Sometimes lack of data leads researchers, Public Boards or Local Governments to use environmental models which were elaborated in very different contexts, or even in other countries; it is now clear how this can be dangerous in terms of scientific reliability of the results. It is very important for mathematical models used in environmental study, planning and management to be elaborated directly on the spot, as a simple variation in the variables' correlations can completely change the model output. Furthermore, every result must always be critically reviewed for correct interpretation, and for adjustments if necessary.
Mathematical analysis, together with interpretation of aerial photographs, has well highlighted which dynamics are in progress in the Rocche Plateaus, owing to mechanization on the one hand, and to abandonement on the other hand. In particular the dynamics following land abandonement are rather complex, as they affect mainly those fields which are unsuitable for mechanized cultural practices, and in which consequently hedges were not removed: this accounts for change in correlations between variables linked to abandonement vs variables linked to traditional agriculture. At first, bush recolonization in abandoned fields increases the vegetation structure complexity in areas that were already well structured, but finally it knocks down complexity through transformation of fields in shrubland and secondary woodland.
This method proved itself efficient in distinguishing environmental features which are most important to two passerine species; as for Corn Bunting, it is advisable to expand the study area to more large and heterogeneous areas, to include all environmental conditions, both favourable and not for this species' needs. This method can thus be used in studies concerning every passerine species which is territorial in its reproductive period, and so dependent from local environmental condition for breeding success.
A comparison of environmental features over long time scales, using aerial photographs interpretation, can also point out and quantify any variation occurred recently in landscape variables and in their correlations, allowing an effective planning of interventions, in case these tendencies should lead to an excessive simplification of landscape structure, with negative consequences on many endangered or protected species.
The probabilistic model used to detect long term trends in some bird species' distribution, on the contrary, didn't prove itself very reliable at first. Nevetheless, it can be easily adjusted in order to overcome the problems we faced: for example, other plots can be included in the study, chosen in areas formerly open or bushy but now recolonized by wood, so as to take into account all the effects of land abandonement, including the most extreme; or else, the model can be applied only to areas that didn't change land use from 1954 to 1994, to highlight only the consequences of changes in agricultural practices.
The characteristics of this methodology, according to us, make it very suitable for agro-environmental planning in mountain and protected areas, given the crucial role that agriculture has in creating and preserving habitat which are both rich in species and permeable to many others; implementation of Regulation 1257/99, that has replaced 2078/92 and 2080/92, could so support other birdlife protection measures, according to the "Bird Directive" 409/79. Most of the territory now included in protected areas was, in fact, agricultural, but not highly productive, and so it was not concerned by strong antropic pressure such as to clash with conservation. But at the same time its low agronomic value makes it at high risk of abandonement and finally of biodiversity reduction and landscape change, with both ecological and cultural damage and, eventually, impoverishment of touristic attractions. With regard to this, implementation of agri-environmental measures could be better planned in relation to actual environmental needs. At present, the drafting of EU Regulation Regional Implementation Plans by Local Authorities and Park Boards is not preceded by careful analyses of local environmental features and species habitat needs to ensure they are really helped by such measures. In some cases, some of the adopted

measures (set-aside, afforestation, hedge plantation) are exceedingly generalized, in many cases taken directly from very different environmental contexts. Moreover, the scale at which the measures are planned and implemented is too large and it doesn't allow a site by site differentiation on the basis of local conditions and needs.
Last but not least, other notable advantages of this mehodology are its cheapness (the bird survey can be carried out easily by a single observer, as well as aerial photographs interpretation; no particular or expensive equipment is needed), quickness (field work must be concentrated in 1-2 months), immediate deduction of data which are useful for planning conservation strategies, at least for some bird species.

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IN U.S.A., PROTECTED AREAS PLANNING BECOMES MORE COMPLEX

Massimo Sargolini

In Italy, but also in the great part of Europe, protected areas planning concerns territories characterized by the presence of natural and cultural resources and with a great population density. This means that Italian Parks have a lot of cultural resources but also problems connected to historical human presence. For this reason, the improvement of life quality becomes one of the aims to pursue. The four main aims enounced in lot of parks are: 1) natural resources conservation; 2) artistic, architectonical, historical and cultural resources conservation; 3) public fruition of the resources; 4) local socio-economic growth. In order to elaborate a plan in italian protected areas, with a lot of natural and cultural resources, we have to create a work group composed by: naturalists, economists, geologists, sociologists and architects. It's necessary mixing disciplines proper to social sciences world with disciplines proper to the physics and natural sciences world , because we have close mutual relations between man and environment.
Since the first years of the 70's, in different international documents, the protection and conservation of resources have been jointly considered to the action of changing by man work:
- in 1973, in "Man and Biosphere" by Unesco are examined the interrelations between man and hearth;
- in 1980, in "World Conservation Strategy" by IUCN, in cooperation with Fao, Unesco and WWF, conservation is considered like a biosphere management able to warrant a rational and durable economic growth for coming generations;
- in 1987, in "Our common future" by World Commission for the Environment and Development, are examined the main themes concerning interdependence and connections existing between economic development and environment;
- in 1991, in "Caring for the earth. A strategy for sustainable living", by IUCN/UNEP/WWF, we hypotesise a development model able to warrant to human being a real improvement of quality life preserving in the meantime vitality and biological diversity of hearth.
Recent international documents (Action Plan of Caracas, 1992; Montreal meeting, 1996) have ratified necessity to integrate protected areas in the larger structure of planning.
Protected areas planner in Italy run across costant situations of interference between anthropics components and natural components. It's clear that the environmental protection needs territorial planning. Researchers, administrators and planners, sustain that a real conservation can't exist without planning.
In Italy the park plan regulates:
- general organization of territory;
- pedestrian accessibility and footpaths;
- services for public fruition (camping, bed and breakfast, refreshment-areas, museums, information centers, ...);
- fauna and flora.
The park plan shares the territory in four zones:
- integral reserves;
- general reserves;
- protection areas;
- economic and social promotion areas.
The introduction of the "zoning" in urbanism subject, as so far tested, is not productive. This rigorous subdivision of territory uses could prevent the vivifying connections between elements and their ambit of relation. In Italy, the criticism of "zoning" started in 1970 with Giacomini and Romani, who have privileged the examination of system. The new aims are: to regulate connection between elements instead of regulating single elements; to regulate problems instead of graduating preservation of environment; to request a connection between environment planning and territorial planning.
In Europe the experiences are different:
- Norway integrated park planning in general planning;
- Great Britain introduced connections between park planning and general planning, In several english parks there is a reference to different kinds of landscape: uplands, waterways, open waters, coasts and estuaries, forests and conifers, agricultural landscapes, other landscapes;

Fig. 1 – Grand Canyon National Park

- France introduced the" Programmes d'Amenagement " that shares territory in two zones : central zone and peripheric zone; and a further subdivision keeps in consideration the functions: agricoltural areas, secondary and tertiary activities areas, "accuil" and recreation areas,
- Spain introduced the "Planes Rectores de uso y gestion" that shares the territory in four zones: reserves, limited use, public use and special use;
- Denmark integrated park planning in the general planning.
- Germany introduced park plans that provide for the following zones: rigorous conservation areas, transition areas, recreation areas.
We always imagined that overseas situation is different.

Thinking of the american parks, we can imagine big ecosystems (sea, rivers, marshes, glaciers, coasts, lowlands, mountains, deserts, forests, plants, flowers and animals), protected by uncontrolled man work, so humanity will take a general benefit. In deed, historical parks planes, edited by the National Park Service, focus only on naturalistic management, conservation of natural resources and public enjoyment. In the most of famous and historical parks, we only find naturalistic elements without man interference:

-Acadia National Park, created in 1919, placed in Maine, here is possible to admire nature in artic environment, natural survival and untouched views. In this park we find only some motel or camping, or few luxury residences;

-Arches National Park, created in 1971, placed in south part of Utah, typical for the red rock pinnacles, modelled by water and wind. It's a desert zone that gives hospitality only to a considerable variety of wild animals;

-Badlands National Park, created in 1978, placed in South Dakota. In this park we find a vast expanse of lowlands and undulating hills, including an eroded high ground with a lunar aspect. Here we can find vast meadow, herds of buffalos and indian huts;

-Denali National Park, created in 1917, placed in Alaska. In this park there are: glaciers, forests, tundre and blue lakes; and we can find only some lodge and camping;

-Grand Canyon National Park, created in 1919, placed in the north Arizona, around Colorado river. In this park we can find some lodge and camping;

-Grand Teton National Park, created in 1929, placed in the State of Yoming. In this park we have mountains, lacustrine mirrors and Snake River, and we can find only some tourist reception centre;

- Great Smoky Mountains Park, created in 1934, placed in North Carolina. In this park we have forests, valleys and mountains. Time ago in its interior were present wood manifacturing companies, later they ceased their activity beacause some magnates bought those lands. In the end, those lands were donated to the Government. Actually, we can find some lodge and some tourist reception centre;

- Mount Rainer National Park, created in 1899, placed in Washington State. In this park we have an extinct volcano covered by big glaciers. We can find only some tourist recption centre;

- Yellowstone National Park, created in 1872, placed in the heart of the Rocky Mountains (Wyoming, Montana, Idhao). Here we can find several tourist reception centres;

- Yosemite National Park, created in 1892, placed in Sierra Nevada (California, Nevada). Here we can find several tourist reception centres;

- Zion National Park, created in 1919, placed in the south-west of Utah. In this park we have: narrow gorges and vertically rock-faces, table-lands and rocky peaks. We can find only some lodge.

In the last few years, we notice with evidence, that not all the american protected territories could be assimilable to the stereotypes above-mentioned. In the North-East of U.S.A. we can see portions of territory identifiable like heritage areas: Blackstone River Valley National Heritage Corridor; Delaware and Lehigh Navigation Canal National Heritage Corridor; Essex National Heritage Area; Hudson River Valley National Heritage Area; National Coal Heritage Area; "Path of Progress"; Quinebaug and Shetucket Rivers Valley National Heritage Corridor; Shenandoah Valley Battlefields National Historic District; Steel Industry American Heritage Area/ "Rivers of Steel"; Lackawanna Heritage Valley; Wheeling National Heritage Area. In a heritage area, the interaction of physical features, natural processes, cultural traditions and economic and social forces have created distinctive patterns of human settlement that have shaped the landscape over time. In some area of the east Mississipi-Missouri (Chesapeake Bay,...), there is a strong concentration of problems due to the presence of natural resources (fauna habitat, river vegetation, wooded areas,...), cultural landscape and intense human activities (residential, agricultural, industrial, commercial) at the same time (see 4a, 4b, 4c). This fact causes significant interferences and conflictual relationships. For this case, near enough to typical European situations, some NGO (non Governative Organizations) founded the "Chesapeake bay critical area commission" that in cooperation with the U.S. Environmental Protection Agency representing the Federal Government, the District of Columbia, the State of Maryland, the Commonwealths of Pennsylvania and Virginia faces problems concerning protection and ecosystemic balance of that area. This event is very important because testify a determinant attendance of the NGO. NGO helps Government to be interested in administration and protection not only of high importance natural areas but also of areas compromised by human action. For the first time, the action planner of Government intervenes with resolution out of National Parks and National Monuments and it manages territories that aren't Government's property.

For planning these areas it's necessary to search complex cases. These cases introduce new valuational disciplines, most of them proper to economic and social sciences. The activities, that interfere with the present ecosystems, are productive and residential activities. So, protected areas planning in USA becomes more complex: we haven't only monothematic plans (typical for historical parks) which consider natural resources and fruition systems for visitors, but also plans with composite problems, in which every valuation and decision need to be considered by the experts of the different disciplines. The "Chesapeake bay critical area commission" consists of a solid work group composed by architects, engineers, economists, and naturally botanists, geologists, ecologists and naturalists. The american Guidelines, already tested by National Park Service, will help american planner to draw up as zones with different vocation (natural zones, historical zones, zones for development, special uses zones). The american Guidelines are better to solve new american planning problems than italian "zoning".

THE EVALUATION OF ENVIRONMENTAL FRAGMENTATION USING GIS TECHNIQUES

Donato Di Ludovico, Bernardino Romano

The types of territorial environmental fragmentation caused by infrastructures and urban areas were studied in a research programme financed by the Italian Ministry of Higher Education and Scientific and Technological Research (MURST) as part of the PLANECO project (Planning in Ecological Networks).

Understanding how barriers effect natural environmental continuity is essential if planning instruments are to prevent or at least mitigate the continual break up of the Italian and European ecomosaic.

The physical characterization of fragmentation was established by studying the type and size of barriers and the presence of urban structures with a prevalently linear development. Fragmentation due to infrastructures was defined by the kilometres of road structures compared to the unit of territory under consideration (protected areas, administration zones, landscape units). The index of fragmentation caused by linear development, on the other hand, is proportional to the maximum length of the settlement under consideration and the theoretical radius of its total area which is taken to be perfectly circular (Romano, 2000).
On the basis of the above, analyses were carried out using a GIS application which elaborates the data in the Planeco-SIT. The elements used to define the settlement are linear in the case of infrastructures and areal in the case of urbanised areas. For geographical analyses the following information is therefore available: the position of the geometric entity with respect to a global reference system, UTM, its dimensions (length or area) and its category.
The areas chosen as a point of reference for the evaluation of the fragmentation are the Environmental Units, regions in which the homogeneity is determined by their geo-lithological, physiographical connotations, land use and climatic characters. This differentiation leads to: area = poligonal geometric entity crossed by an infrastructural reticle and affected to differing extents by urban extensions.
At this point, the georeferred data allow the creation of models capable of estimating fragmentation or the level of occlusion, caused by all types of road (infrastructural fragmentation) and by industrial and civil urbanization (urban fragmentation).
The instruments used needed to be flexible as well as powerful in order to be able to implement the models and to be able to handle such an enormous quantity of data (the area of study was central Italy). The GIS software employed, Esri's Arcview, allows for the handling of different levels of data and the development of applications in an Avenue environment. In addition a further control panel was inserted, the function of which is explained below (see figure 1).

Fig. 1

Original themes (roads and urbanised areas) and the calculation of indices (the models proposed are based on the calculation of the indices) can be studied by opening the following applications, from left to right:
clean
clip theme on theme
clip theme on theme for partial areas
explode
IFI
approximate
local UFI
territorial UFI

The first group of buttons allows the manipulation of the themes that come up. The clean button eliminates any mistakes which occur when zooming in with the video and creates a new 'clean' theme.
The Clip theme on theme generates a new theme in which the original has been 'cut' (the graphic element) along the external borders identified by a second theme of polygons (for example environmental units).
The Clip theme on theme for partial areas generates like the previous Clip a new theme in which the original has been 'cut' (the graphic element) along all of the borders identified by a second theme of polygons (for example environmental units).
The explode function corrects mistakes that are not actually visible but which occur with multipart polygons or polylines i.e. graphic elements made up of more than one part that are treated by the software as if they were one.

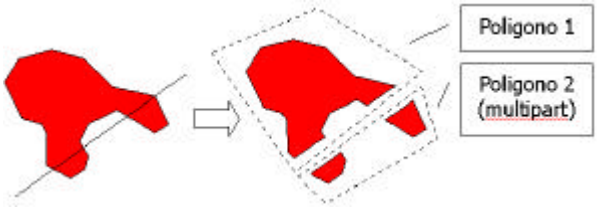

Fig. 2

Infrastructural Fragmentation Index (IFI)
The IFI (Infrastructural Fragmentation Index), as the name itself indicates, concerns the fragmentation generated by roadways. As has already been mentioned, road infrastructures are described geographically by broken lines (polylines) which are distributed in a reticulated fashion over the territory. They can be classified quite easily by referring to the database linked to every geometric element in which a field denominated 'category' is created. The classes of infrastructure considered are linked to their importance and to their physical conformation (first or secondary roads, motorways, railways and infrastructures in tunnels).
The calculation of the IFI is based on the following elements:

$$IFI = \Sigma(L_i * p_i)\ \mathbf{N/A}*F$$

Where:
L_i = length of infrastructures within the considered environmental unit;
p_i = the environmental occlusion weight assigned to each category of infrastructure:
p = 100% for highway and national railway;
p = 70% for roads with high traffic flow;
p = 30% for local and rural roads.
N = number of parts in which the considered environmental unit is divided by the infrastructures;
A = surface calculated per environmental units
F = perimeter calculated per environmental units

The surface An corresponds to that of the Environmental Unit in which infrastructures previously cut with the clip function are present.
Thus the value of the index of fragmentation due to infrastructures is automatically obtained for each environmental unit. By dividing the IFI values into ranges it is possible to classify environmental units and obtain a configuration that allows us to identify which units are most fragmented by the presence of infrastructures.
Note that is possible to assign varying weights to roadways

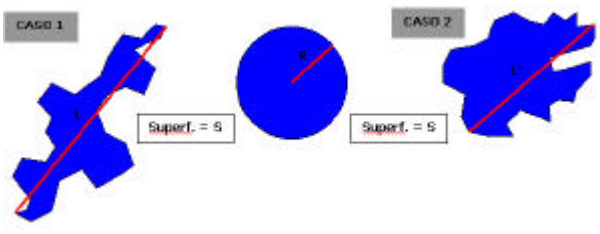

Fig. 3

allowing structures such as tunnels or rural roadways, for example, to be classified as completely permeable.

Linear urban fragmentation index

Fragmentation caused by concentrated or scattered linear urbanisation can be evaluated using the UFI (Urban Fragmentation Index).
In contrast to the IFI, the local UFI has to be calculated using the same inhabited area (Level 4 of the CORINE map) and the territorial UFI of the environmental unit.
This distinction is necessary as the single inhabited areas are initially approximated to lines.
Figure 3 shows two different urban area conformations, the first linear and the other concentrated. Approximating the two polygons to lines, then L>L'. Assuming that the surface S of the inhabited area is equal to the circumference and given that, minus factor π, S can be expressed as:

$$S = R^2 \Rightarrow R = \sqrt{S}$$

the local UFI will be equal to:

case 1 ➔ $UFI_{loc} = L * \sqrt{S}$
case 2 ➔ $UFI'_{loc} = L' * \sqrt{S}$
then: $UFI_{loc} > UFI'_{loc}$

Consequently, linear urban structures cause more fragmentation than concentrated ones.
Approximating areas to lines can be done by pressing the the approximate button (fig.1 third from the right) which also calculates the surface of urban areas and memorizes them in a database column on the new theme which the same function creates. The UFI indices, calculated for each urban agglomerate, are then summarized in a further index with reference to environmental units rather than the single areas the index of fragmentation caused by territorial urbanisation which shows how the local UFI affects the territory to which it refers.
The Index of Fragmentation due to territorial Urbanisation can be defined:

$$UFI_{tot(i)} = \sum_{j=1}^{n} UFI_{loc(j)} \qquad UFI_{terr(i)} = \frac{UFI_{tot(i)}}{S_i}$$

where: i = environmental unit i-esima
j = approximate line j-esima
n = total number of lines within the environmental unit i-esima

In practice, the UFI_{terr} is obtained by first summing the values of the UFI_{loc} for the agglomerates within the environmental unit and then normalising this value for the area of the unit itself. As with the IFI, each unit is associated to an index of fragmentation caused by urbanisation and consequently they can be classified by dividing the indices into ranges.

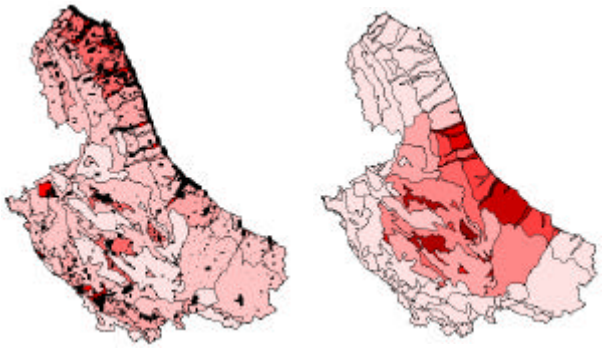

Fig. 4

Figure 4 shows the graphs that result from the classification of the units using the IFI and the UFI. A first glance shows that the areas classified, in both cases with a darker shade, share the same geographical collocation.
This is the case of typical factors in an urban setting where the main road structures (especially primary roadways) structue the urban setting in a linear form.
However dark areas are obvious concentrated along the coast, areas of economical importance, and in places of sustained industrial and/or industrial development.
The lightly shaded polygons on the other hand are associated with rather low indices and frequently correspond to mountainous areas or foothills.
A summary can be obtained quite simply by overlaying the previous graphs.

The autors of this issue

Bert W. Harms
Alterra,Green World Research Institute
P.O. Box, 47 – 6700 AC Wageningen
The Netherlands
w.b.harms@alterra.wag-ur.nl

Silvia Scozzafava
University of Stirling
Stirling, Scotland, FK9 4LA
silvia.scozzafava@stir.ac.uk

Massimo Sargolini
University of Camerino
msargol@tin.it

Donato Di Ludovico

Bernardino Romano
University of L'Aquila
Monteluco di Roio – 67100 L'Aquila – Italy
romano@dau.ing.univaq.it

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romano@dau.ing.univaq.it, gp114@cus.cam.ac.uk, guccione@anpa.it

DAU
Department leader
Giulio Tamburini

Editor of this issue
Bernardino Romano

Translations
Tania Bastow

Photos by B. Romano