EnviroInfo 2002 (Wien)
Environmental Communication in the Information Society - Proceedings of the 16th Conference
 ISBN: 3-9500036-7-3

Landscape Structure Model

Roland Grillmayer[1]

Abstract

To report on the state of the nature environment as requested for example by the sustainable development strategy of the European Union, information on the landscape and the underlying processes forming the landscape is needed. In principle we can differentiate two basic approaches to analyse the processes forming the landscape. These processes can be measured directly using measurements of energy- and nutrient flows. However, information on the processes can be derived indirectly using the landscape structure as main information source. The basic idea is, that the landscape structure, i.e., what we see today, was produced by flows yesterday, so there is a linkage between structure and processes (FORMAN, 1995). In this paper we give a review about the theory of landscape ecology, define the term "landscape structure" and discuss the processes occurring in the landscape.

1. Introduction

The term landscape ecology was introduced by the German biogeographer Carl Troll (TROLL, 1939). Subsequently, several definitions of landscape ecology were published. The main aspects of them can be formulated as the study of (1) *spatial relationships among landscape elements, or ecosystems*, (2) *the flow of energy, material nutrients, and species among the elements, and* (3) *the ecological dynamics of landscape mosaics trough time.*

The main object of landscape ecology is the landscape. According to (FORMAN (et al.), 1986) a landscape can be defined as *a heterogeneous land area composed of a cluster of interacting ecosystems (landscape elements) that is repeated in similar form throughout.* The term Ecosystems is defined as *a relatively homogeneous area of organisms interacting with their environment. This can be applied at any scale* (FORMAN, 1995).

Having regard to the main concepts of landscape ecology will lead to a more integrative design and planning. It helps to reduce the landscape fragmentation and deg-

[1] Institute of Surveying, Remote Sensing and Land Information, University of Agricultural Sciences Vienna (BOKU), Peter Jordan Str. 82, A-1190 Wien,
e-mail: grillmayer@boku.ac.at, http://ivfl.boku.ac.at

radation so evident around use (TURNER (et al.), 2001). Landscape ecology has rapidly emerged in the past decade to become usable and important to practicing land-use planners and landscape architects (DARMSTAD (et al.), 1996). The development of new data structures (graph theory, (STEINWENDNER, 2002)) on the on hand and the use of remote sensing image analysis (SCHNEIDER, 2002) on the other hand enables to integrate the theory of landscape ecology into future planning processes which will play a fundamental role for future land development.

According to the landscape structure different ecological functions of the landscape are provided. To describe the linkage between landscape structure and ecological functions we use the concept of patch – matrix – corridor.

2. Model concept of patch – matrix - corridor

The concept of patch – matrix – corridor was originally introduced by (FORMAN(et al.), 1986) and is a means to describe and to analyse the landscape processes.

The concept is based on the analysis of the spatial arrangement of landscape elements. In other words, the structural pattern of patches, corridors and the matrix is used as major determinate of functional flows and movements in and through the landscape. The changes in landscape pattern is used as an indication for process changes over time.

The basic unit of a landscape is the landscape element. A landscape element is a "homogenous surface area that differs from its surroundings in nature or appearance"(TURNER(et al.), 2001) or "the smallest possible land unit that is a holistic unit which forms a patch or corridor (FORMAN(et al.), 1986). Whether an observed area is homogenous or not, depends on the scale of observation. Using remote sensing images we define homogeneity in relation to the pixel size. Details smaller than pixel size are not considered for the assessment of homogeneity. So the minimum size of observed patches are a few pixels.

Depending on the shape of a landscape element we call a compact element a *patch* and an elongated element a *corridor*.

The mosaic of the predominating patch type or background cover is defined as the matrix.

For better understanding the following images show a landscape area in the east of Vienna where the landscape elements are classified in patch, matrix and corridor.

The matrix is the most extensive and connected landscape element type and plays therefore a dominant role in the functioning of the landscape. In the example, the matrix is composed of mainly agricultural fields shown in the image in gray color. In this matrix forest-, meadows-, settlement patches are scattered. These scattered patches can be categorized into four patch classes with different ecological relevance. The black patches in the image are "Introduced Patches". Typical introduced

patches are settlements. The other three patch types (see also Fig. 1, other Patch types) are “Remnant Patches”, “Disturbance Patches” and “Environmental Resource” patches. In our example the national park “Donauauen” represents on the on hand an environmental resource landscape and on the other hand a “Strip Corridor”, that are corridors which are wide enough to contain an interior environment. Disturbance of a small area in a matrix produces a “Disturbance Patch”. For example mud slides, windstorms, floodings but also human activities like logging in forest cause disturbance patches. The fourth and last patch type is the “Remnant Patch”. *A remnant patch is caused by widespread disturbance surrounding small area, the inverse of the mechanism for the disturbance patch* (FORMAN(et al.), 1986). In the area of interest relict forest- and lea patches are identified as Remnant Patches.

Rivers, hedgerows, motorways, railways, and all other elongated infrastructure facilities can be identified as corridors. Corridors can be differentiated in three different types, each of them with different ecological functions. The Danube is a “Stream Corridor”, controlling the water and mineral nutrient runoff. Motorways, railways and all other elongated infrastructure facilities are so called “Line Corridors”, which play an important role in the context of landscape fragmentation. Hedgerows are also “Line Corridors” playing an important role in the connectivity of cultivated landscapes. The third type are “Strip Corridors” like the national park Donau Auen. These Corridors are wider bands, with a central interior environment that contains an abundance of interior species.

The main idea is to derive indirectly information about the processes that occur in the landscape by analyzing the landscape structure. To classify the landscape into these types of landscape elements and the aggregations of elements to the matrix build the basis for further analysis of processes and functions.

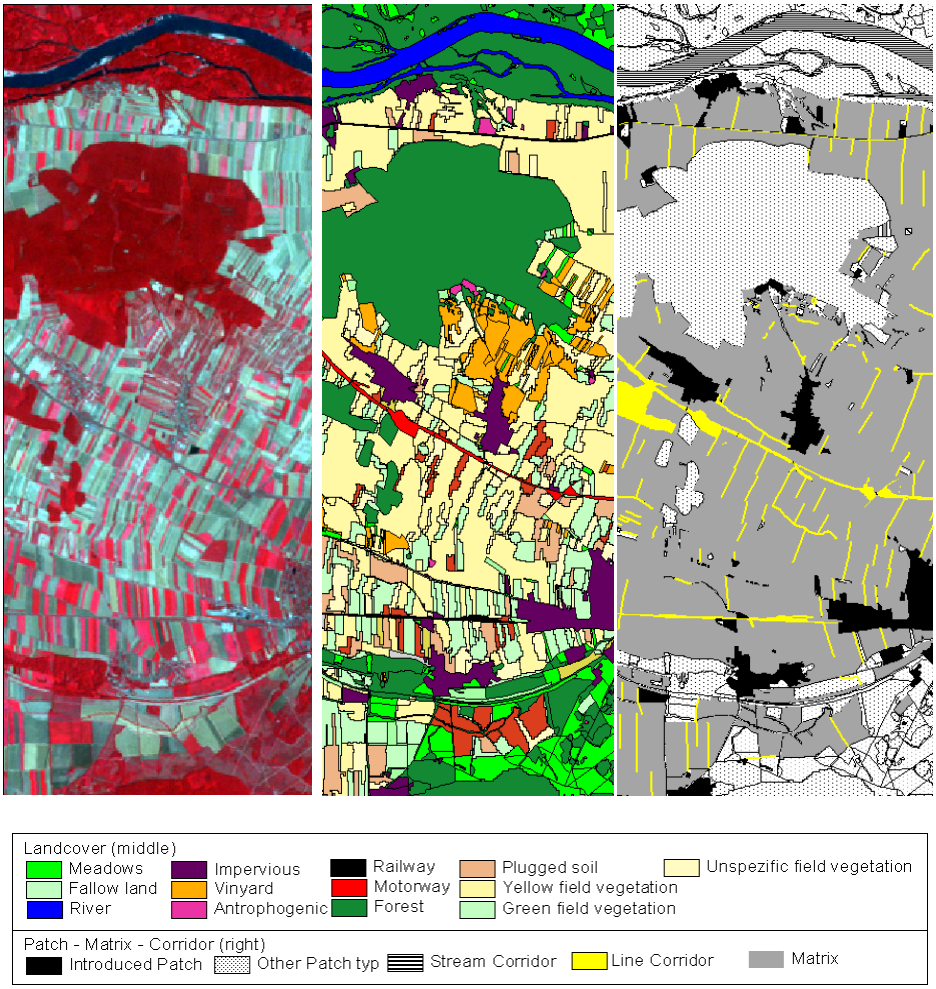

Fig. 1. Left: Landsat TM – CIR image
Middle: Results of landcover classification
Right: Results of Patch – Matrix – Corridor classification

3. Landscape Hierarchy

The relation between remote sensing data, landscape elements and landscape unit is documented in Figure 2. The remote sensing image is composed by picture elements (pixels) and are the lowest level in the landscape hierarchy. The landscape elements represent the second level. The image analysis process leading landscape elements is called segmentation and is in detail discussed in (SCHNEIDER, 2002;

STEINWENDNER, 2002). The landscape elements are aggregated to (meta segmentation) to the landscape units, the highest level.

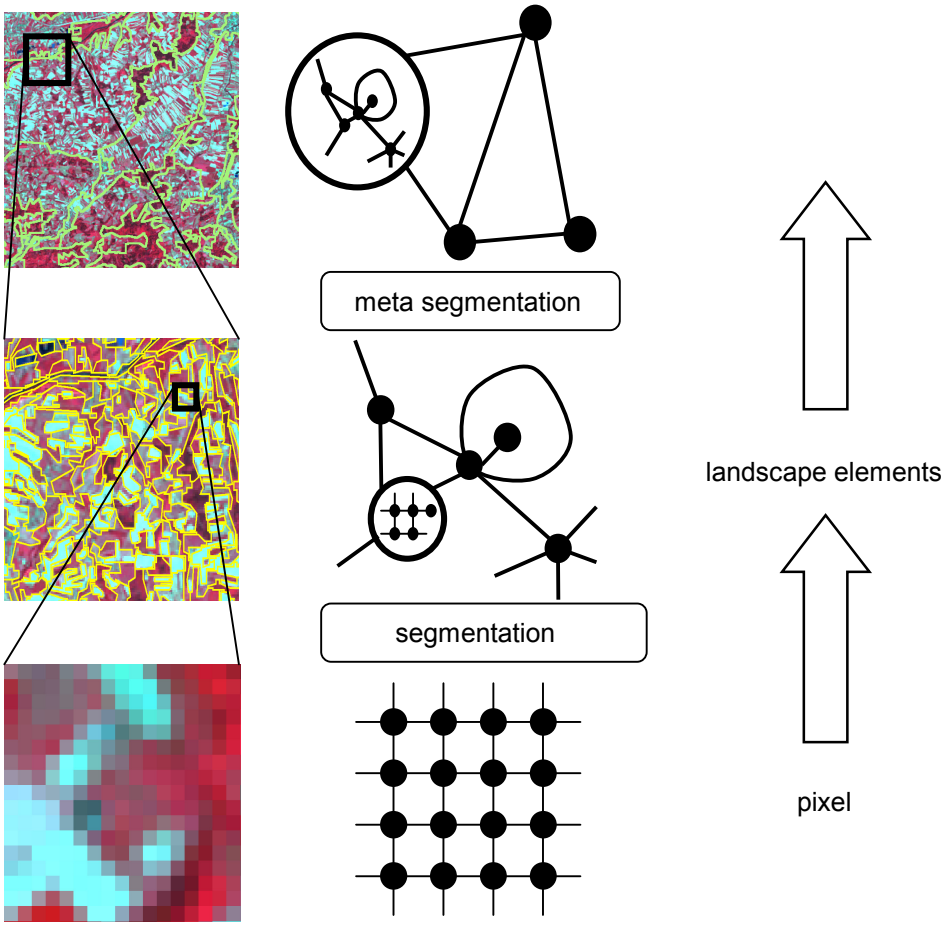

Fig. 2. Remote sensing data, landscape element and landscape unit and image processing steps

4. An example for a landscape function

The following example describes the corridor function of a landscape unit taking the red deer movements as an example of the area under investigation displayed in figure 1.

What are the important structural facts influencing the red deer movement? Is it possible to detect migration routes only study the landscape structure?

First we have to determine the source/target resource patch. In our case the national park Donau Auen and the Leitha Auen are the target/source landscape units. These landscapes are separated by an intensively used agricultural area. To identify possible migration routes, the matrix affecting the animal movement plays a key role. Matrices can be differentiated in subclasses of suitability (high, less, low) depending on the landscape element composition. One of the key facts in our example are the landcover and the average size of fields. For example fields without cover have a higher resistance than covered fields or fields containing food are more attractive than fields without. The size of fields are also an exclusion fact in migration activities. The larger a field the less the probability of being crossed. Also the connectivity of the matrix influence the migration rate.

What are the important corridor types influencing the migration? As seen in figure 1 two types of line corridors exist. These corridors are hedgerows, bordering the cultivated fields, and motor-, railways, and other infrastructure facilities. In our case most of the hedgerows are planted, only a few are regenerated or remnant and play an important role for wildlife migration. The hedgerows connect the isolated forest patches and enable thus the migration through these isolated patches. The position and orientation of these line corridors are of importance (among others), e.g. for migration it is more useful if the hedgerows are orientated in the mean direction of the animal movement. Line corridors like motor- and railways have a negative impact on wildlife migration and act as a barrier in the landscape. In the worst case the hole landscape is separated and the generic flow is restricted. Especially the orientation, the width and the frequency of traffic determine the barrier effect.

Forest patches foster the migration rate and play the key role for red deer migration in this area. These patches serve as stepping stones in the agricultural matrix. They are used as resting places and are important for navigation of wildlife animals. The major attributes of these patches are the orientation, patch shape and patch size. Larger patches are less disturbed by neighbouring disturbances. Patch shape and orientation relative to the moving direction of the wildlife animals affect the movement rate. Introduced patches such as settlements and other anthropogenic introduced patches act as barriers and lead to a perturbance of the animals.

5. Conclusion

In this work, a landscape structure model is described. Remote sensing data and image analysis methods allow to automatically extract landscape elements being the atoms a landscape consists of. The derived landscape structure allows conclusions about the processes forming and taking place in a landscape. This information is an important prerequisite to be able to report on the state of the nature environment as

requested for example by the sustainable development strategy of the European Union.

Acknowledgement

This work has been funded by the Austrian Science Foundation (FWF), project "Hierarchies of plane graphs for the acquisition, analysis und visualization of geographical information", grant number Grant-Nr. P14662-INF. This project is conducted with the collaboration of the Institute of Pattern Recognition and Image Processing and the Department of algorithms and data structures of the Institute of Computer Graphics, Technical University Vienna.

Bibliography

Darmstad, W.E., Olson, J.D. and Forman, R.T.T., (1996): Landscape Ecology Principles in Landscape Architecture and Landscape Planning. Island Press, Washington.

Forman, R. and Godron, M., (1986): Landscape Ecology. John Wiley & Sons Ltd., New York, 620 pp.

Forman, R.T.T., (1995): Land Mosaics, The ecology of landscapes and regions. Cambridge University Press, Cambridge, 632 pp.

Schneider, W., (2002): Knowledge Based Methods of Analysis of Remotely Sensed Images for Landscape Ecology, this publication.

Steinwendner, J., (2002): Graph theoretic issues in remote sensing and landscape ecology, this publication.

Troll, K., (1939): Luftbildplan und ökologische Bodenforschung. Zeitschrift der Gesellschaft für Erdkunde zu Berlin Nr. 7-8: pp. 241-298.

Turner, M.G., Gardner, R.H. and O´Neill, R.V., (2001): Landscape ecology in theory and practice. Springer - Verlag, New York, 401 pp.