A LINK BETWEEN MULTISPECTRAL REMOTE SENSING, IMAGE PROCESSING AND ECOLOGICAL ANALYSIS OF LANDSCAPE ELEMENTS

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Abstract – For the purpose of combining the concepts of multispectral remote sensing, image processing and landscape ecology overflights over an area near the city of Nürnberg (FRG) have been made. To account for the small scales under consideration in landscape ecology (extensions of ecotopes and ecotones of minimal a few 10cm) the Daedalus AADS 1268 airborne scanner has been used providing high spatial resolution (70cm at flight hight 300m) and 11 spectral channels. In addition, high resolution aerial photographs and data of ecological evaluations of the experimental area are available.

By edge detection on the vegetation index image several ecotones (of different stands of wood) could be seperated. The fractal dimensions of two edges of an oak stand are computed. The fractal dimension of a man made wood edge is lower than the fractal dimension of an edge of the same stand but resulting obviously from a storm damage, making the latter more valuable in a landscape-ecological sense.

INTRODUCTION

The influence of man on the environment is large and increases rapidly. This development calls for forming human activities in a way which ensures the viability and sustainability of landscapes. Methods of 'ecological stock-taking' of the landscape are needed to produce data-bases for such measures. This can not only be done by means of ground truth measurements due to the big areas to be considered. Here contributions from remote sensing techniques and computerized (and as a long-term goal automized) image processing are presented. With this study we try to merge methods of *multispectral airborne remote sensing*, *image processing* and *landscape ecology* for the above mentioned purposes.

The most important and meaningful scale in landscape ecology is the dimension of the *topes* (also *patches*). A tope is defined as a *spatial* region with *homogeneous* content and function [4] (i.e. ecotope). Accordingly, the concept of the transition zones between ecotopes, the *ecotones*, plays also an very important role in landscape ecology. Besides the control of diffusion processes of energy and matter, ecotones also influence the transport by turbulence, the transport of information and the locomotion of individuals. In addition, ecotones can be the only habitat for certain species. Thus, the density of ecotones, as representants for gradients in a landscape, can be an indicator for viability [2].

To consider that, we put emphasis on the investigation of ecotones. Extensions of ecotopes and ecotones in landscapes generally reach from the 10cm to the 10m domain. However, until recently commercial satellite remote sensing has only provided spatial resolutions down to 10m (panchromatic, i.e. SPOT) or 20m (three spectral channels). The use of airborne photography, as a means of high spatial resolution, is restricted to at most three spectral channels. We concentrate therefore on using a digital multispectral airborne remote sensing instrument providing a spatial resolution of a few 10cm with 11 spectral channels.

MEASUREMENTS

According to the multidisciplinary character of this study the data set consists of two parts:

1) Multispectral images of the landscape were taken with a *Daedalus AADS 1268* airborne scanner, operated by the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR). It was installed downlooking in a *DO 228* aircraft. The scanner measures the radiance in ten channels covering the solar spectrum (total range 0.42 – 2.35μm with bandwidths between 30 and 270nm) and in one channel placed in the thermal infrared (10.5μm with a bandwidth of 4.5μm). Until now, three overflight campaigns have been performed near the city of Nürnberg (FRG) (Aug. 21. 1991, Apr. 22.1992 and Oct. 18. 1994) with flight altitudes $300m$ $900m$ and $1800m$, the first one resulting in a ground pixel size (= spatial resolution) of $0.7m$. The swath

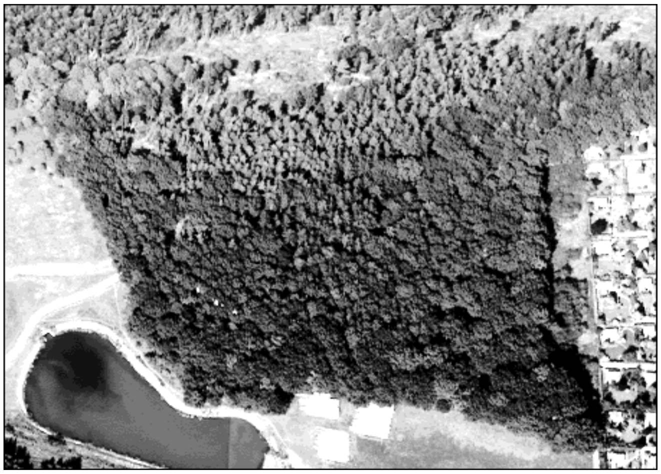


Fig. 1: Image of the *Daedalus AADS 1268* airborne scanner, taken Aug. 21. 1991. A detail of the landscape south of the airport of Nürnberg (FRG) is shown in channel Daedalus 3 ($0.52-0.60\mu m = TM$ channel 2, contrast enhanced). A small lake can be seen adjacent to a forest stand.

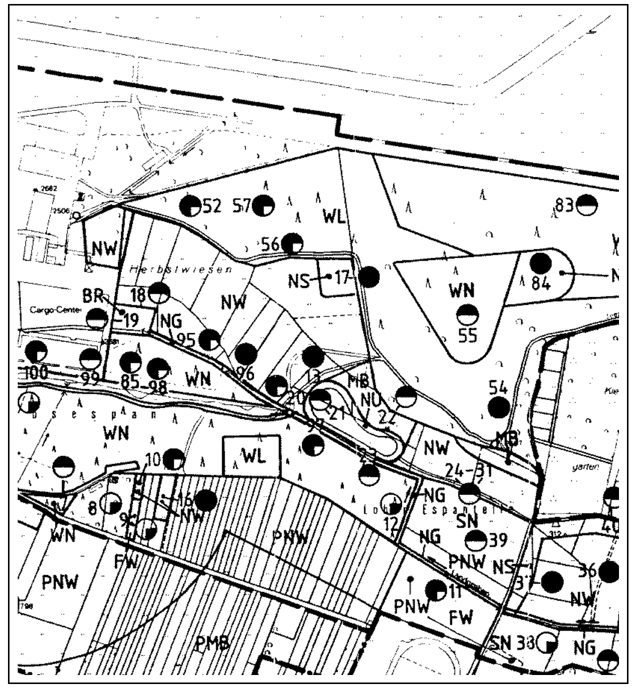


Fig. 2: A map showing a valuation of the ecological status of the area south to the airport of Nürnberg (detail of the entire map). The image of Fig. 1 can be located in this map. The circles reproduce the total *ecological value* of single landscape elements [7]. The scale reaches from '1: very good' (filled circles) to '5: very bad' (non filled circles).

is $\pm 42.3°$. In this work, dedicated to vegetation, we will concentrate on data of the Aug. 1991 campaign. Since our study points to the scales of the $tope$-dimension [4] we have selected an image with the highest spatial resolution available, i.e. we use the $300m$ flight hight images. Fig. 1 illustrates channel 3 ($0.52-0.60\mu$m) of the image under consideration. It shows a forest stand of approx. 300x300m^2 extension.

2) For city planning purposes the Gartenbauamt of Nürnberg had performed ecological evaluations in an area south of the airport of Nürnberg [7]. The investigation was made in Aug. - Sep. 1993. An example of its results is reproduced in Fig. 2. The landscape elements are valuated based on ground thruth observations of the vegetation. These data are used to form the ecological data base.

ANALYSIS AND RESULTS

Fig. 3a shows the calculation of the vegetation index V_I of the image in Fig. 1. V_I was calculated by taking the ratio of Daedalus channels 7 ($0.76-0.90\mu m$) and 3 ($0.52-0.60\mu m$). One connection between scanner-data and the ecological evaluation can be seen at first glance: The high ecological value, indicated by the filled cirlce number 54 in Fig. 2 ('a wood stand of old oaks'), corresponds here to high V_I values found in the Daedalus image.

To detect the edges of Fig. 3a pixels indicating a transition of V_I through a fixed value were selected (by first thresholding the V_I shown in Fig. 3a and then applying a Laplace-filter for edge detection of the thresholded image [3]). From all ecotones found in that manner, only the largest two were chosen by *region growing* as a means of *pixel aggregation* [1]. They are shown in Fig. 3b. A measure of their 'density' on the landscape's surface, and thus their ecological value, is the fractal dimension D [9]. For the computation of D the number of windows N of different extension r/a are counted which are neccesary to cover the ecotone. Here the lenghts r and a are measured in 'pixel' units and a is the extension of the entire image. r reaches from $r=1$pixel to a ($r/a=1$). D is defined as the slope of the function ln(N) vs. ln(r/a).

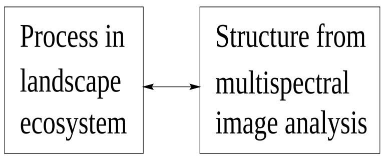
$$D = -\frac{\ln(N)}{\ln(\frac{r}{a})}$$

It yields fractal dimensions of 1.258 for the northern curve (transition oak to spruce) and 1.039 for the southern wood-edge. It is assumed, that the northern transition stems from a storm damage [8] while the southern edge is man made. Thus, it follows that the northern ecotone has a higher ecological value than the other which corresponds to the ratio of the fractal dimensions.

DISCUSSION AND OUTLOOK

The study presented here is an attempt to merge the methods of different disciplines, multispectral airborne remote sensing, image processing and landcsape ecology to derive indicators for the viability of landscapes. It is shown, that the detection of edges in a vegetation index image allows to extract ecotones of an landscape-element (ecotope). The computation of the fractal dimension of the edges is a means to differentiate between edges of different ecological value.

In the future it has to be clarified, which other quantities of multispectral image analysis (i.e. texture measures, fourier transformation, other descriptors of landscape elements) can be linked with which indices of landscape ecology:



In addition, to consider the current development of new sensing instruments as the airborne scanners DAIS, ROSIS (DLR), MIVIS or the spaceborne MERIS on ESA's ENVISAT, which will have up to about 100 spectral channels and work as imaging spectrometers, emphasis on the definition of *multispectral* remote sensing and image processing algorithms has to be put. Due to the large landscape areas to be managed, and thus data amounts to be expected, the long-term goal has to be the automation of the processing.

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a b

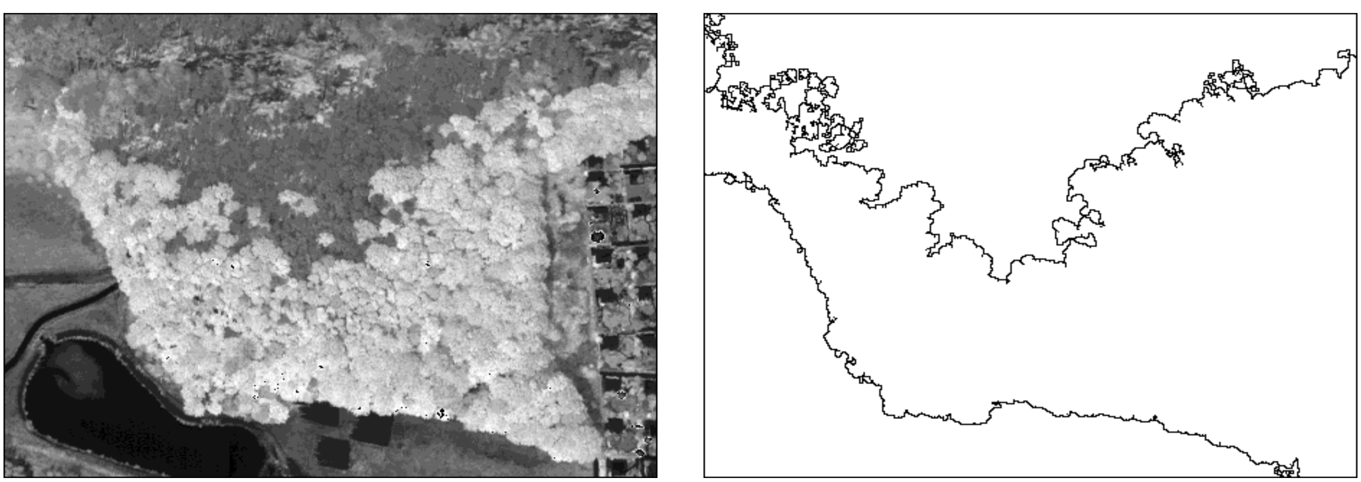

Fig. 3: a) The vegetation index V_I of the image in Fig. 1, calculated from the ratio of Daedalus channels 7 ($0.76 - 0.90\mu m$) and 3 ($0.52 - 0.60\mu m$). Now, different tree species can be seperated within the forest stand. b) Transitions of V_I over a threshhold (= ecotones) are indicated in black.