DEVELOPMENT OF A GEOGRAPHICAL INFORMATION SYSTEM TO EXPLAIN THE MECHANISMS OF FOREST DISEASE AND ITS VARIATIONS

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ABSTRACT

Within the forest damage research project "Aufbau eines Geographischen Informationssystems zur Ermittlung von Waldschäden und deren Veränderung" ("Development of a geographic information system for investigation and monitoring of forest decline") multiple layers of ecosystematic characteristics were combined with datasets containing information about the spatial distribution of forest damage. Methods for the integration of CIR-based data and results are discussed.

ZUSAMMENFASSUNG

Im Rahmen des Forschungsvorhabens "Aufbau eines Geographischen Informationssystems zur Ermittlung von Waldschäden und deren Veränderung" wurde eine Vielzahl von flächenhaft vorliegenden Eigenschaften des betrachteten Landökosystems mit Daten über die räumliche Ausprägung von Waldschäden kombiniert. Methoden der Eingliederung von Daten, die aus Infrarotluftbildern abgeleitet wurden sowie Ergebnisse der Untersuchung werden vorgestellt.

INTRODUCTION

Forest damage and tree species data of three different scales formed the basis of the forest damage research project "Aufbau eines Geographischen Informationssystems zur Ermittlung von Waldschäden und deren Veränderung" ("Development of a geographic information system for investigation and monitoring of forest decline")[1]:

- A grid with a size of 4km * 4km contains data of the "terrestrische Waldschadensinventur 1985" (terrestrial forest damage inventory) of the area of Baden-Württemberg (FRG).
- In the southern part of the Black Forest a grid with a size of 1km * 1km contains data of forest damage derived from aerial colour infrared (CIR) photographs.
- In addition, datasets exist of two small areas (Schluchsee and Kälbelescheuer) in the southern part of the Black Forest with a grid size of about 25m * 25m. These data were derived from aerial CIR photographs, too.

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[1] The investigation was sponsored by the "Projekt Europäisches Forschungszentrum für Maßnahmen zur Luftreinhaltung" which is located at the Kernforschungszentrum Karlsruhe (FRG).

RASTER-BASED GIS IN LANDSCAPE ECOLOGY

For most applications it is desirable to use a GIS which can combine both image and raster data, but up to now it is valid what WILKINSON et al. (1986) pointed out: "Integrated Geographic Information Systems (IGIS) are GIS which accomodate the input of data in either format and are able to manipulate and display that data. ..., an ideal IGIS should be able to store, manipulate and display both raster and vector data, without losing the beneficial characteristics of either structure." (p. 1-1). The authors remark furthermore, that IGIS "do not yet seem to be fully developed" (p. 1-3). For that reason it has to be decided what type of GIS is to be used.

Research in the field of forest damage is done in two different fields. First, a detailed analysis of (probably) all tree influencing aspects is to be done. With this method hypotheses for the reasons of increasing forest damage can be derived. Mostly these theories can not be proved, because only individuals are regarded. Thus, as a second approach, it is necessary to verify these hypotheses in great areas with a great number of individuals. Therefore, this approach is part of landscape ecology.

It is a common practice - because there are financial, technical and personal limits - that interrelations in an ecosystem are analyzed on data of a single or only a few measuring points. That is why they are in a strict sense only valid at these points. So this method is to be characterized as point-oriented or topological. In contrast, datasets in a GIS may be spatial datasets like remote sensing data or interpolated data, where the interpolation may use several other datasets, as is only possible in a GIS. As a consequence we can say that a GIS facilitates working with chorological methods, as it was first suggested and done by NEEF.

It is to be emphasized that both methods are needed. A strict analysis of interrelations is founded on a great number of different measurements, which can be done only at some points. Based on the derived knowledge spatial datasets could be generated by the aid of a model. These datasets may be used to verify the model by regarding additional point measurements. On the other hand, it is possible to extract those data which are important for a specific question, by a statistical analysis. With this information those factors that are to be measured in (point-oriented) surveys were derived.

Research in landscape ecology has up to now been almost exclusively topological. Ecosystems were "divided" into various "homogeneous" parts. In the last few years a trend to analyze the "inhomogeneous" aspects in environment (KLUG & LANG, 1983; NAVEH & LIEBERMAN 1984); i.e. research in landscape ecology is changing and is done much more often from a chorological than of a topologic point of view.

Raster-datasets demonstrate a corresponding transition. Each pixel is a measurement on a small area, or at a "point". The combination of neighbouring points or pixels allows therefore a transition from the topological to the chorological dimensi-

For determination of ground coordinates X_i, Y_i, Z_i of the sample points three methods were developed and valued:

- projective transformation,
- transformation by image coordinates and terrain height,
- interpolation in an irregular grid.

These methods are described in detail in BEHR & SAURER (1988). Thus, only the method which leads to the best results is shortly described.

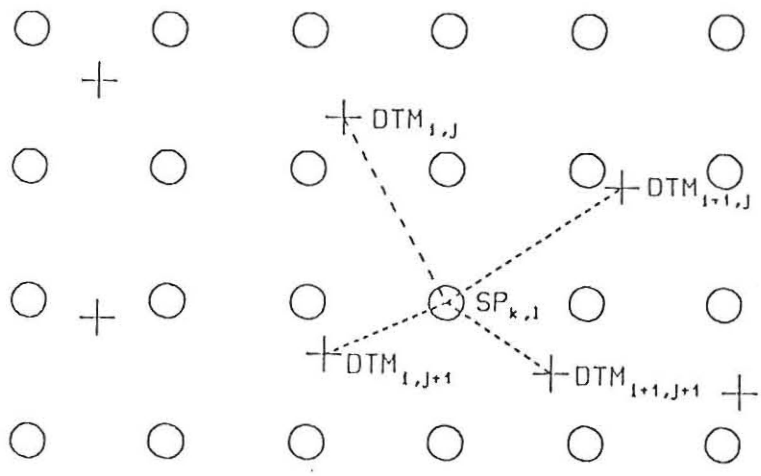

Fig. 2 Interpolation in a distorted grid. DTM points, which are represented by crosses, are projected in the image plane. Sample points are drawn as circles. The ground coordinates of sample points $SP_{k,l}$ can be calculated by interpolation between the four neighbouring DTM points.

Interpolation in a distorted grid

In contrast to WALDHÄUSL, ENTHOFER & KAGER (1986), who are searching the point of intersection of the optical ray with a digital terrain model (DTM), we chose an indirect method. First, all grid points of the DTM are projected in the image plane, according to the parameters of absolute orientation of the camera, which can be received by intersection in space - a photogrammetric process which will not be described in this paper. As a result, we got two grids in (non-geocoded) image coordinates (fig. 2), i.e. a regular one, representing the sample points, and a distorted one, showing the location of the DTM grid points in image coordinates. With these two grids we were able to interpolate X, Y and Z coordinates of a sample point from the neighbouring DTM points.

Proceeding

After interpreting the CIR photographs the data of each interpretation film are entered manually in a data file according to their location in the sample grid. Each sample is related by coordinates to this data matrix. From CIR photographs the following topics as examples for natural and cultural effects on the ecosystem:

- water-supply
- settlements and traffic.

In both cases neighbouring effects were regarded. Therefore, corridors along or around specific entities of the landscape were generated. Within these corridors the distribution of the trees on the four classes of forest damage was examined.

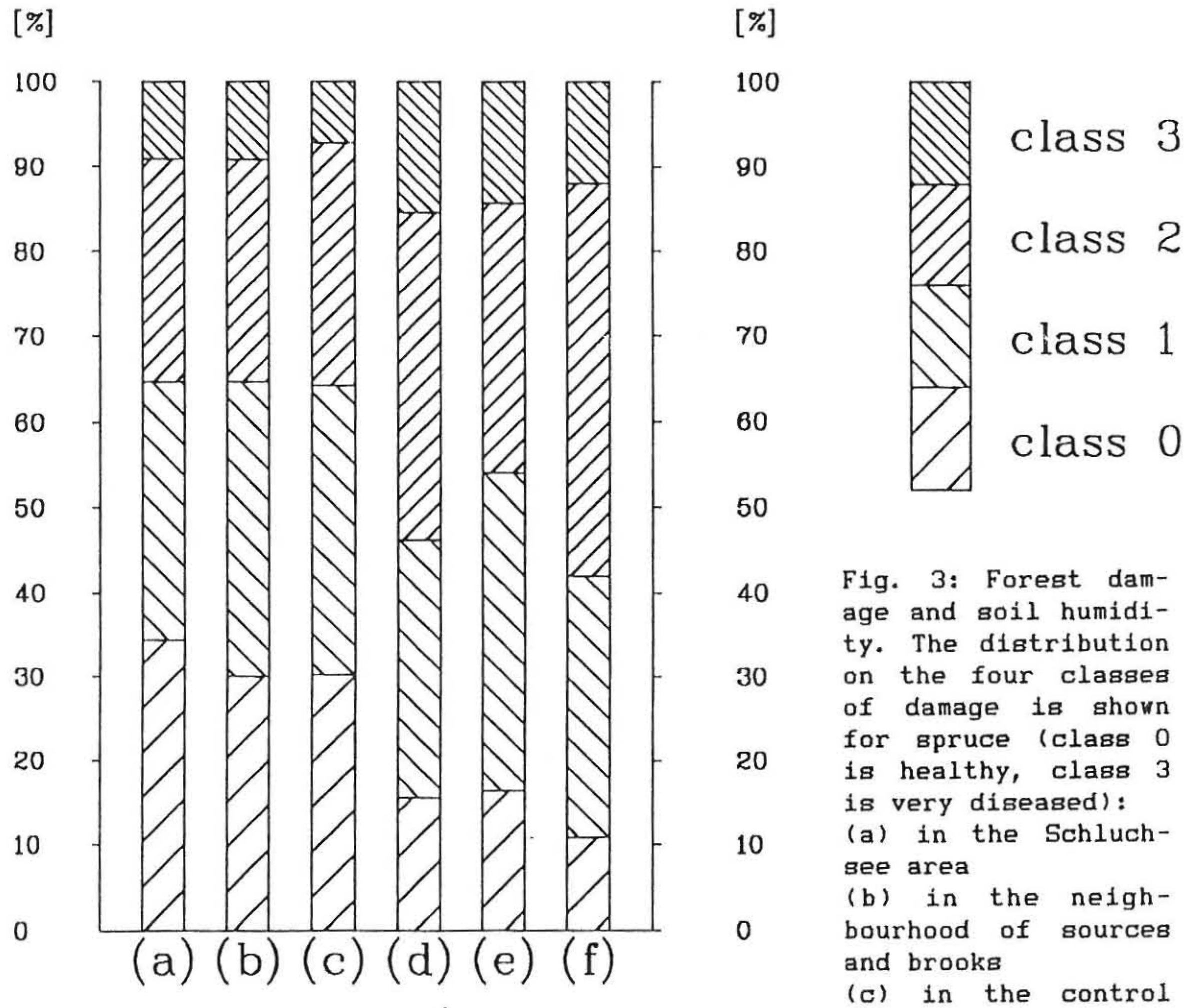

Fig. 3: Forest damage and soil humidity. The distribution on the four classes of damage is shown for spruce (class 0 is healthy, class 3 is very diseased):
(a) in the Schluchsee area
(b) in the neighbourhood of sources and brooks
(c) in the control area
(d) of age-classes old timber and old forest in the Schluchsee area
(e) of age-classes old timber and old forest in the neighbourhood of sources and brooks and
(f) of age-classes old timber and old forest in the control area.
It is obvious that - in comparison with other sites - in the neighbourhood of sources and brooks old trees are in a significantly better condition.

In figure 3 the results of this evaluation are given. It is striking that there is only an effect on old trees (only spruces are regarded) of the age-classes old timber and old forest. As a consequence we can extend the position of BOSCH, who states that dryness is in extended areas a subordinate factor in forest damages, to smaller regions. Dryness leads to a significant rise of forest damage for old trees only.

Settlements and traffic

As already mentioned above, we could not integrate a dataset with the spatial variation of air pollution. As compensation we did a neighbouring analysis of settlements and traffic lines as regional sources of air pollution. A graphic representation of the results is given in figure 4. With the aid of data of a traffic census we classified the roads as main (fig. 4 (c)) or subordinated roads (fig. 4 (b)). For a traffic line which is nearly parallel (distance 100-400m) to a main road we calculated the distribution of trees on the four classes of forest damage, too (fig. 4(d)). As a result we can point out that there is an increasing amount of forest damage in the area along the main roads, which may be caused by air pollution and/or water pollution (salt, hydrocarbonates).

In the case of settlements we regarded three corridors of size 125m to 500 m. The results show a strong correlation of distance from settlements and forest damage. This may be a consequence from air pollution by heating and traffic as well as from disturbing effects on the ecosystem e.g. by pedestrians, water pollution and other effects.

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