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APPLICATION OF REMOTELY SENSED DATA FOR THE ASSESSMENT OF LANDSCAPE ECOLOGY

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ABSTRACT

For an agricultural region near Ingolstadt, Central Europe, multispectral image data was analysed with regard to its use for investigations of landscape ecology. The present situation demands an analysis of human impact on the environment. The use of remote sensing information can be a meaningful step towards a balanced management of natural resources.

Results obtained prove that remote sensing data can deliver actual and sufficiently precise information about larger areas of land use, thermal and site conditions relevant for landscape ecology assessment.

KEYWORDS

Remote sensing, landscape ecology, planning, multispectral scanner data, land use, classification, thermal mapping, site conditions.

1. INTRODUCTION

Today our living space can be regarded as a complex ecosystem, steered out of its natural equilibrium. On one hand an ecological system is an autonomous functional and structural unit with productivity and stability as pecific attributes. On the other hand it belongs to a superimposed organisational level, the landscape (Ref. 3).

A natural ecological system is held stable or in shifting equilibrium by an endogeneous automatic control mechanism dependent on available energy and material input.

Man-made arable land, forest and settlements can only be kept functioning by intensive human control and additional insertion of energy and material. Natural control and human intervention cause the instability of this ecosystem. Its effects are often described in terms of loads and disturbances.

The agricultural production may serve as an example. High productivity is the aim of cultivating a single plant species. Fields of these species are part of an ecosystem, but natural control is still effective. Other plants, so called weeds, will be concurrent with them. Animals feed on the plants and will be considered as parasites. Plant diseases tend to spread in monocultures. Man tries to counteract these factors by the use of biozides, and thereby disturbs the continuous automatic control process in the local district and the surrounding scene again.

This situation demands an investigation of human influence on the environment. It is necessary to evaluate the type and amount of the human impact and the efficiency of the natural ecological system. An effective approach for the assessment of landscape ecology can be the first step to the protection of our environment as well as a balanced management of natural recources (Ref. 8).

2. OBJECTIVE

To clarify the possible role of remote sensing in this field the DFVLR participated in a study performed by the Technical University of Munich, Institute for Landscape Ecology (Refs. 9, 7). A preliminary model for the assessment of landscape ecology for a Central European region should be prepared. The study was supported by the German Federal Agency for Environment Protection and the Bavarian Ministry for Regional Development and Environment Protection. For computer aided analyses and image processing the Digital Interactive Image Analysis System (DIBIAS) of DFVLR was used (Ref. 11).

3. DATA ACQUISITION

In the Ingolstadt region (60 km north of Munich) the area Freinhausen 2 was selected. It is a fine structured Tertiary region with dominant agricultural use. From this area 11-channel multispectral scanner data was gathered at noon on May 16, 1979. The plane was flying in N-S direction at an altitude of 1500 m above ground. At the same time ground truth measurements were performed in that area.

Due to the average field size of 0.5 ha the size 4 m x 4 m was chosen for the image elements. The reflected solar energy of the earth's surface was measured in spectral channels 1 - 10, the emitted radiance was recorded on channel 11, see channel allocation of 7 selected channels in table 1.

As a consequence of limited spectral and spatial resolution presently available satellite imagery could not be used (Refs. 4, 6, 7).

spectral channel	center wave-length nm	band-pass nm	
2	465	50	visible region
3	515	50	
5	600	40	
6	640	40	
8	720	40	near IR
10	1015	90	
11	10500	5000	TIR

Table 1: Allocation of the selected spectral channels of the Bendix multispectral scanner.

4. PHENOLOGY

The adaption of the flight date to the regional situation is decisive for the separation of agricultural species.

Image data of a flight in the middle of May will not allow the separation of different species of cereals. In spring early soil covering cultures as winter cereals can be separated from summer cereals or meadows as a function of their state of growth. It will be difficult to differentiate between corn, potatoes, beets and fodder corn as well as hops and asparagus.

A flight date middle to end of July offers the possibility for separation of cereals, potatoes, beets and special cultures. Precise differentiation between pasture, meadow and agricultural land will be possible in the second half of September. In addition potatoes, beets and corn can be separated (Ref. 1).

5. ANALYSIS OF SCANNER IMAGE DATA

5.1 Visual Interpretation

A visual comparison of information content was made between the land use mapping on ground, IR-false color photos from the metric camera and false color composites from spectral channels 2,3,6; 3,6,10 and 3,10,11.

On the IR false color photo 14 classes could be recognized, on false color composites 9 classes. They are correlated in table 2.

IR-photos land use	FCC land use
corn, potatoes, beets, fodder crop	bare soil
hops	hops
asparagus	asparagus
winter wheat	winter wheat
summer cereals	summer cereals
meadow, clover, sown grassland	meadow, pasture
forest	forest
sand pit	sand

Table 2: Correlation of land use classes from IR-false color film and scanner false color composites (FCC), data acquisition May 16, 1979

The visual interpretation of IR-photos showed a better result as a consequence of the three-dimensional image and the higher geometric resolution, which yields additional textural and structural features (Ref. 10).

5.2 Spectral Analysis of Training Areas

Seven spectral channels out of eleven were selected. The final choice of classes and corresponding training areas was made with the help of detailed spectral analyses. As a first step the mean values of spectral radiances for representative training areas were plotted, see figure 1. The separability of classes and preliminary choice of the most significant spectral channels for their identification was investigated (Ref. 12).

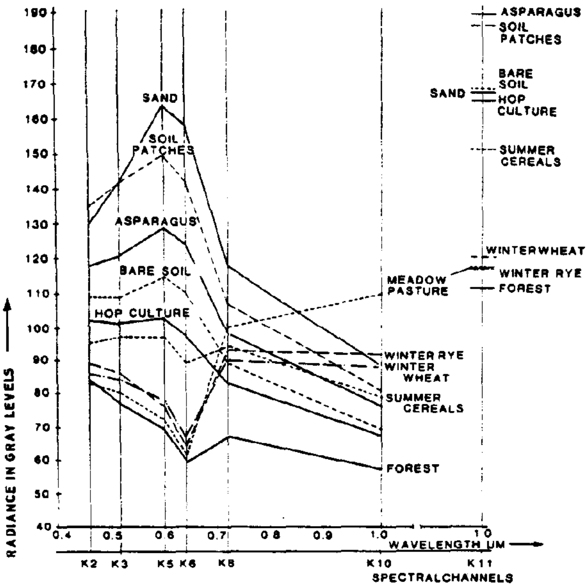

Figure 1: Mean values of spectral radiances from training areas in Freinhausen 2

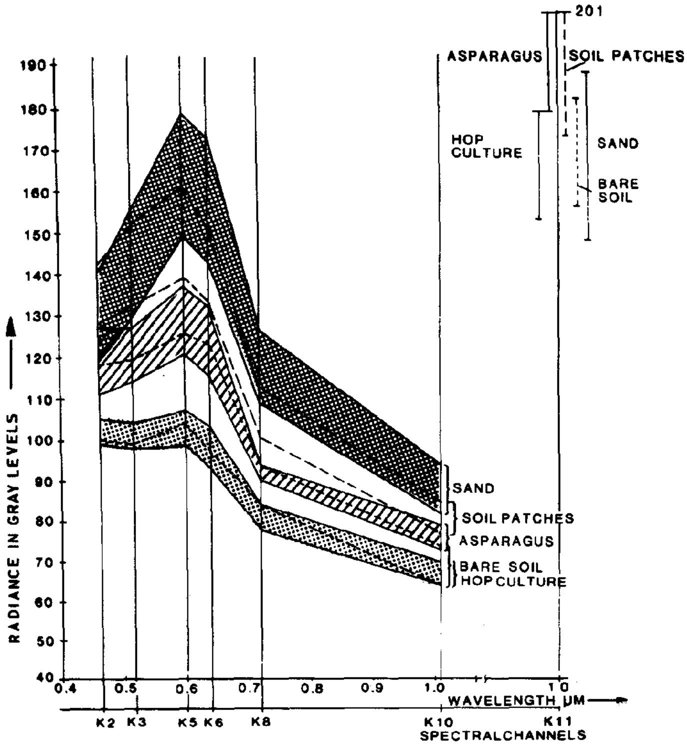

Figure 2: $\pm 2\sigma$ bandwidth of spectral radiances from soil training areas in Freinhausen 2

As a second step the $\pm 2\sigma$ bandwidth of spectral radiances for soil and vegetation training areas were plotted assuming the normal distribution of class histograms, then 95,5 per cent of the statistical mass is contained within this range, sufficient for further studies, see figures 2 and 3.

The quality of training areas: the course, the bandwidth and the overlapping with adjacent spectral radiances are meaningful indicators for the proper selection of classes, their separability, favorable spectral channels for computer aided classifications and the choice of further processing algorithms (Refs. 5, 2).

For equally weighted classes and simultaneous classification of all classes the spectral channels 3, 5 and 10 were selected.

Spectral analysis and an additional cluster analysis of training areas as a third step proved that the subclasses, winter rye and winter wheat, soil patches and bare soil, have to be integrated into the main classes winter cereals and bare soil respectively after classification (Ref. 7).

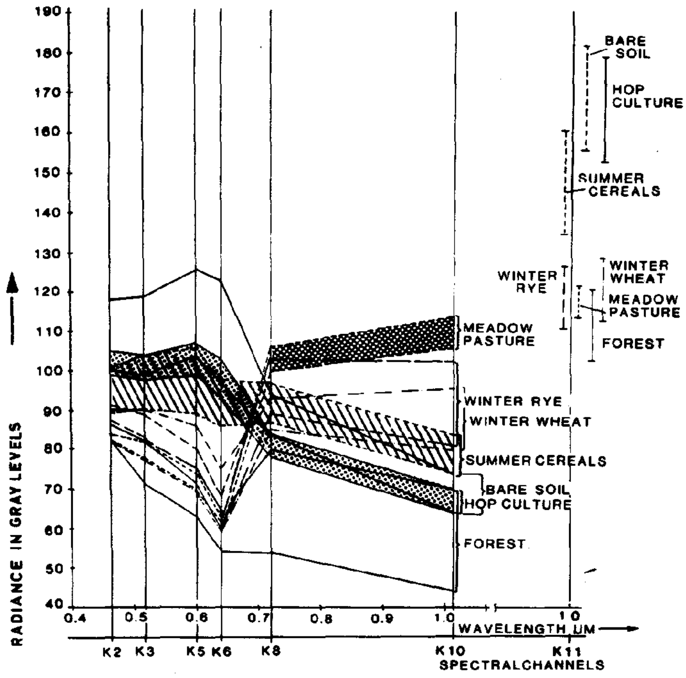

Figure 3: $\pm 2\sigma$ bandwidth of spectral radiances from training areas for vegetation in Freinhausen 2

6. LAND USE CLASSIFICATION

The result of supervised classification, applying the maximum likelihood algorithm, is displayed in figure 7. A generalization operator was applied.

The generalization operator compares the adjacent eight image elements of each classified pixel. The center pixel will be attributed to the dominating class. This operator promotes the creation of larger areas of homogeneous land use. This procedure simulates the process of conventional land use mapping.

From the ecological point of view there are two objectives for classification. One aim is the presentation of homogeneous land use or vegetation cover. It could be achieved applying the above mentioned operator.

The second goal is the detection of natural habitat or site conditions as a function of soil, humidity, sun exposure and other main parameters.

These parameters produce variations in vegetation growth, plant species and soil color and, as a consequence, differences in spectral radiances. Variations in spectral radiances within the same type of land use may cause it to be attributed to different classes.

These deviations are indicators for the local site conditions and the ecological situation of the landscape. For their interpretation the classification results without postprocessing were used. During interpretation possible errors from mixed signatures also have to be considered. They occur mainly on the boundary of land use areas with strongly different spectral signatures.

Finally eight classes of land use were separated. The classes for selected surface features are sand (light blue), bare soil (middle brown), asparagus (magenta), hops (dark brown), summer cereals (yellow), winter cereals (middle green), meadow-pasture (dark green), forest (blue), and not classified (black). The color code for figure 7b is in round brackets.

At the 95 percent confidence level the following classification accuracies were obtained: sand 95 percent, bare soil 80 percent, asparagus 81 percent, hops 94 percent, summer cereals 91 percent, winter cereals 99 percent, meadow-pasture 58 percent and forest 99 percent.

The classification result for meadow-pasture looks rather poor. It can be explained by the phenology in the area, where this class comprises meadow, clover and sown grass. Sown grass hat not yet completely covered the soil, the number of species is rather small and the row structure is still visible. At the flight date these fields seemed more similar to winter wheat than to meadows or pasture.

7. THERMAL MAPPING

For an analysis of landscape ecology the local climatic conditions are important indicators for human influence on the climate.

From the scanner data of spectral channel 11 the surface temperature can be calculated. For these investigations the earth's surface could be considered as "black body".

In Freinhausen 2 the measured temperature region from + 18°C to + 35°C was divided into 9 levels. The mean temperature of the lowest level is + 19°C, the highest + 34°C, see figure 7a.

The spectral information gathered by channel 11 of the scanner corresponds to the combined effect of the object's spectral properties in its natural environment. Changes in site conditions such as kind of soil, moisture, climate and morphology will generate a mosaic of spectral signatures.

The general comparison of surface temperatures and type of land use reveals a clear relation between temperature and kind of vegetation cover. This relation can be explained by inherent evaporation capacity. It is illustrated in figures 7c, 7d.

The land use class soil, composed of bare soil, asparagus and hops, shows relatively high temperatures + 27°C to + 34°C. Summer cereal fields rest in the medium temperature region. Low temperatures + 20°C to + 25°C are attributed to winter cereals with high vegetation cover, while meadow-pasture covers the temperature band from + 19°C to + 23°C. The lowest temperatures + 18°C to + 21°C are in forested areas.
Thermal mapping therefore renders possible the separation of areas covered with dense vegetation from those with lower coverage and bare soils. Within zones of identical land use temperature variations are mainly caused by site conditions, in this case mainly by sun exposure, soil and moisture. The influence of sun exposure on surface temperature of winter cereals and of bare soil is demonstrated in figure 4. It is thereby confirmed that the highest temperatures occur on southern slopes at noon.

In larger zones (1), figure 5, the dominance of sun exposure over other influencing parameters is indicated, compare with figure 7a. The soil is sandy and fairly dry, a favourable provision for higher temperature. But here at a N-NE exposure low temperatures were measured.

Other examples (2) show high temperatures of dry soil at south. The influence of sun exposure and soil is less for vegetation covered (cereals) areas (3) .

Temperature variations caused by soil and moisture were investigated at several sites (4), see figures 6, 7a. The soil map of Freinhausen offered general indications.

Further small size variations could be explained only by ground truth of vegetation, soil, moisture and topography.

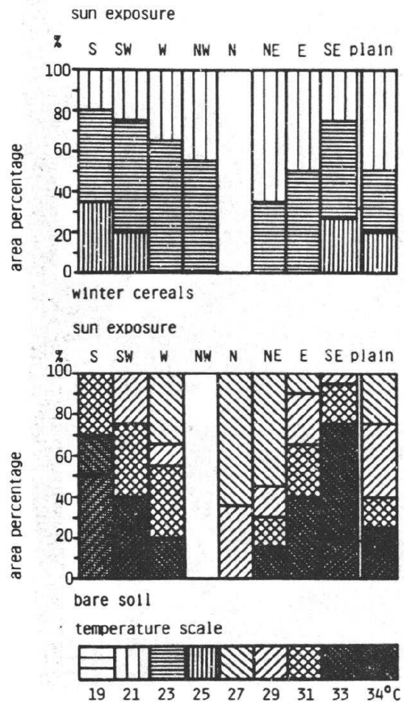

Figure 4: Correlation of surface temperature and sun exposure for winter cereals and bare soil at May 16, 1979, 12 o'clock local time, slope 5 - 10 percent.

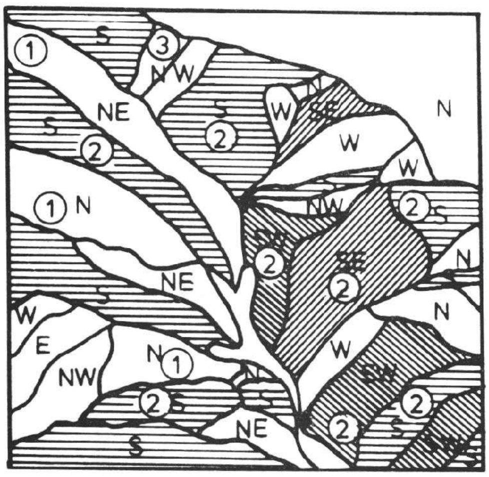

Figure 5: Sun exposure of Freinhausen 2

Figure 6: Soil map of Freinhausen 2

- Colluvium, fairly fresh
- silty loess-loam, fresh
- Gravely-loamy sand
- Gravely sand

8. CONCLUSION

For landscape planning problems such as demands upon land use, structural change, burden upon natural resources, supply and disposal have to be solved.

For a surface covering analysis a data base is necessary of the area of investigation. It has to include data sets on soil texture, slope, vegetation type or land use.

With the help of remote sensing actual information upon larger areas can be obtained and processed within a short time. This data is available in digital form and standard format, thereby facilitating and accelerating its processing and evaluation. Geometric rectification and referencing to a common geodetic coordinate system enables data exchange with data banks or information systems. Combinations with other data or multitemporal investigations offer the possibility of monitoring time sensitive processes or features (diurnal temperature variations, seasonal vegetation and land use change, flooding).

In the framework of this study image processing of single date airborne multispectral scanner data from Freinhausen 2 was performed. On the DIBIAS system (Ref. 11) contrast enhanced false color composites for visual interpretation were produced and supervised land use classification as well as thermal mapping carried out. The results were correlated with each other and with sun exposure and soil type.

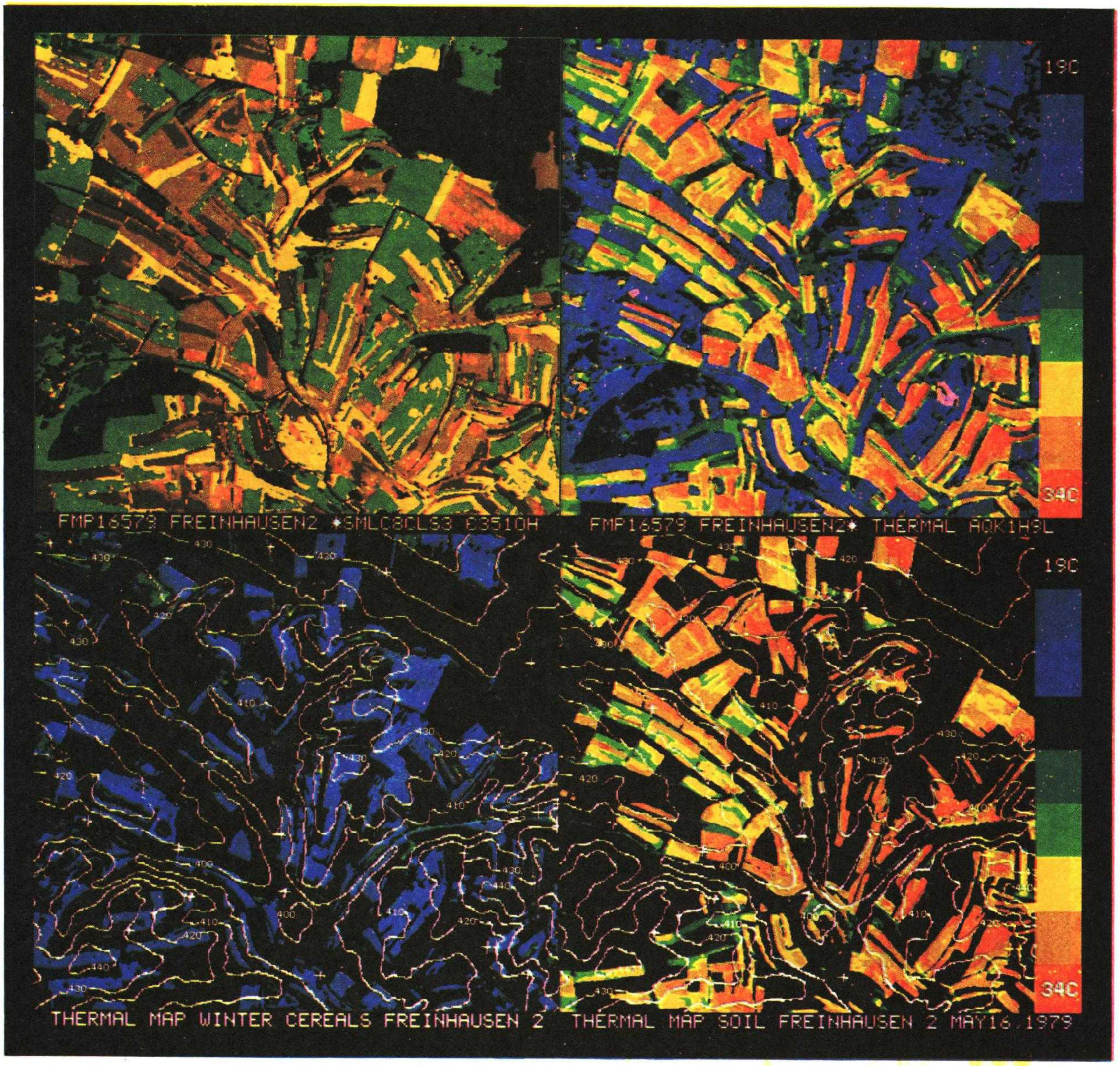

Figure 7: Four color coded thematic maps of Freinhausen 2, length of one side of each image 2050 m.

b	a
c	d

a) Thermal map, temperature region + 18°C to + 35°C is divided into 9 levels as indicated on the right side.

b) Result of supervised classification, a generalization operator was applied. The eight classes of selected land use are: sand (light blue), bare soil (middle brown), asparagus (magenta), hops (dark brown), summer cereals (yellow), winter cereals (middle green), meadow-pasture (dark green), forest (blue), not classified (black).

c) Thermal map of winter cereals with contour lines.

d) Thermal map of soil with contour lines.

Results obtained prove that remote sensing can deliver actual and precise information about larger areas of land use, thermal and site conditions relevant for landscape ecology assessment. This information can be transferred to a data bank or an information system, or can be supplemented from them for further processing.

In this way remote sensing can contribute to decision making for the protection and a well balanced management of our living place.

For the present decade improved satellite sensors with respect to spatial resolution, allocation of spectral bands including additional spectral channels in the near infrared, and extended dynamic range can be expected to deliver valuable information required for detailed ecological studies and environmental monitoring.

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