The use of SPOT and CIR aerial photography for urban planning

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1. Abstract

Environmental factors influencing the air, water, soil and biosphere of a city are mainly due to the structure of the urban areas and the land use. In order to map and characterize this process an environmental description of the spatial structure of a city and its land use is required. In this sense the use of SPOT multispectral data is evaluated in combination with high altitude photography and thematic maps. Color transformations are used to differentiate between sealed and vegetation areas together with hierarchical classification methods for the city of Hannover in the north of Germany.

2. Introduction

Remote sensing as a tool for regional planning has been applied frequently in the past using satellite imagery like Landsat MSS or Thematic Mapper. Interpretation of this imagery yielded thematic maps of small or medium scales. In addition traditional methods of photointerpretation of large scale aerial photography have been applied in the field of urban planning (Schneider 1984).

This has been done normally by the use of manual interpretation of color infrared aerial photography at scales ranging from 1 : 4.000 to 1 : 25.000. In the city of Hannover the interpretation of CIR - photography of a scale of 1 : 4.000 resulted in the production of a thematic map showing biotopes with 17 major classes being further divided into 126 subgroups at a scale of 1 : 10.000 with a resolution of better than 50 cm. As an example part of this map is shown as a black and white reproduction in figure 1. These maps are updated at regular intervals with actual CIR - photography.

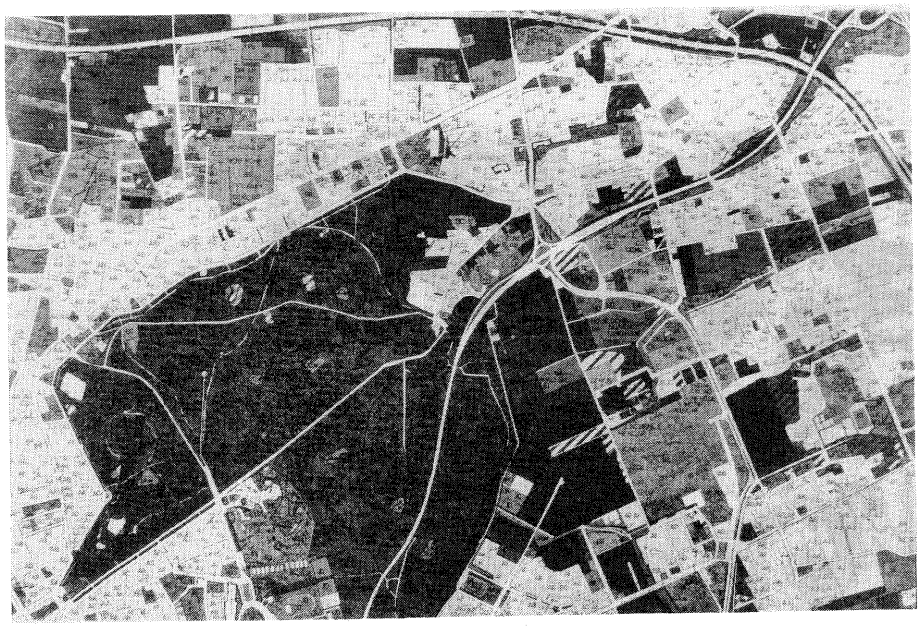


Figure 1: Black and white reproduction of part of a map of the biotopes of the city of Hannover

Although this high resolution cannot be achieved by digital interpretation of satellite image, it can be expected that the major classes may be separated by hith resolution satellite images like SPOT. In addition it would be desirable if SPOT could provide a tool for monitoring major changes within the principle classes.

3. Separating vegetation from sealed areas

The quality of a city and its environment is influenced to a great extent by the amount and degree of sealed and vegetated areas. The recreation value of a city may be qualified by the ratio of buildings, streets and other sealed areas to the existence of lakes, meadows, forest areas and gardens. In order to differentiate these two groups of landuse, SPOT multi-spectral data in combination with aerial photography have been used. For this purpose SPOT data taken at 6-17-1986 have been co-registered to a high altitude aerial photography from December 1983. The aerial photography at a scale 1 : 120.000 has been digitized to a pixel size of 5 m. Using the IHS (intensity - hue - saturation) transformation the three bands of SPOT have been transformed to the IHS - color space and retransformed to the RGB - color - space by replacing the intensity channel with the aerial

photography. Figure 2 shows all those areas having no color, i.e. the sealed areas.

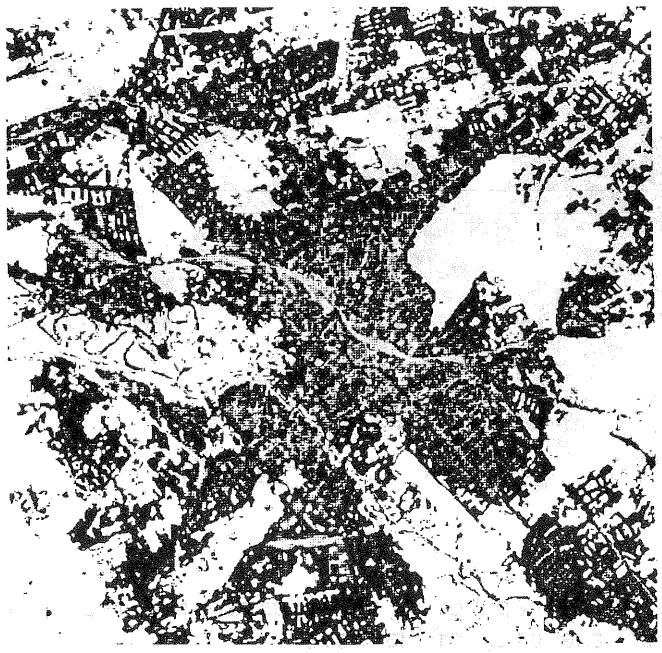


Figure 2: Non vegetated areas extracted from SPOT multispectral data

In addition a thresholding of the infrared channel allows for the seperation of sealed and vegetation areas.
In order to sperate transportation lines within this area a line detecting operation (CONTEXT VISION 1987) was applied. This operator computes for every neighbourhood an estimate of the line energy, e.g. the strength of the line structure, as well as the orientation of the line. The amount of the estimated line energy is inversely weighted with the amount of edge energy within the neighbourhood. This weighting function can be controlled by a threshold which specifies the number of times the line energy must exceed the edge energy to produce an output. The result of this operation is shown in figure 3.

4. Hierarchical classification

Multispectral classification as a tool for segmenting image information is frequently used for the production of thematic maps. This classification very often results in broad classes of land use like those mentioned earlier. In order to differentiate more subclasses within the major land use classes a hierarchical method like the following has been used.

Figure 3: Linear structures extracted from SPOT XS3

Figure 4 illustrates this procedure. In a first step a supervised classification according to the maximum likelihood method is used to generate the major classes. Figure 5 shows as a result 8 classes superimposed by

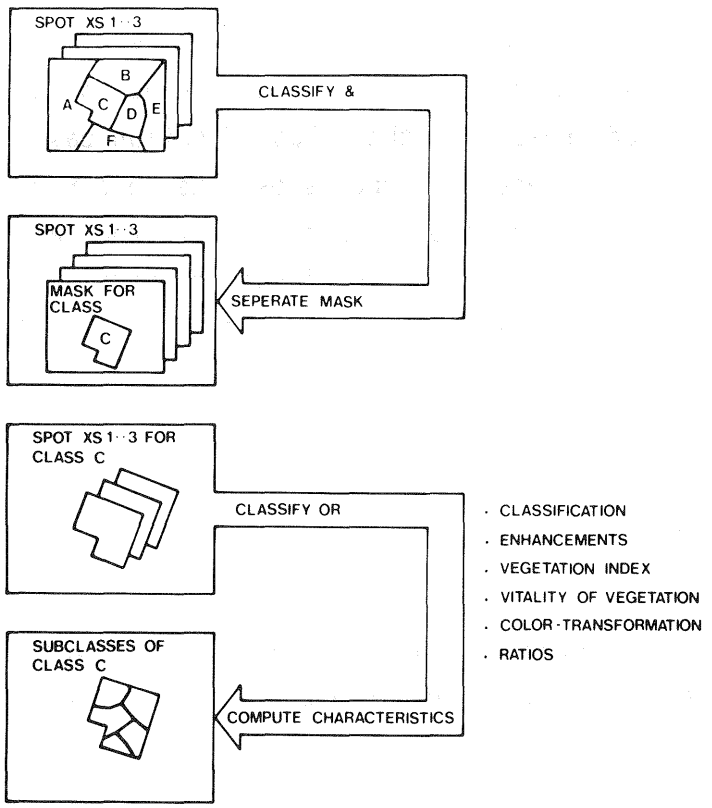


Figure 4: Flow chart of hierarchical processing

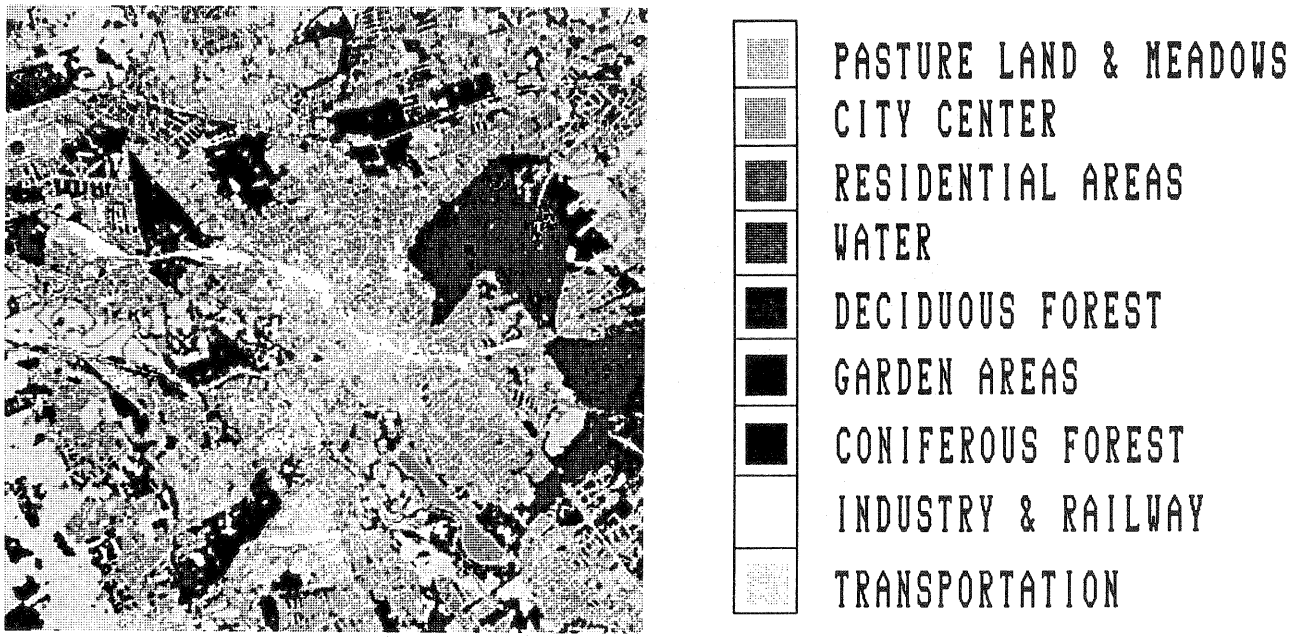


Figure 5: Result of maximum likelihood classification of SPOT multi-spectral data showing 8 major landuse classes over the city of Hannover

the transportation areas. In a second step each class served a mask for extracting the original image information out of the three spectral bands of SPOT. Within these masked areas a further classification based on ground truth may be applied to generate subclasses. The reason for not classifying the total image in one step is mainly due to the fact that this would result in a large number of false classified pixels outside the masked areas. This is true especially if instead of a classification some other kind of transormation is like simple coloring or level slicing is used.

Figure 6 shows this simple application of level slicing the infrared channel within the major class of deciduous forest resulting in three subclasses.

Other transformations like pseudo coloring the vegetation index or ratios may be applied in the same way by using different lookup tables.

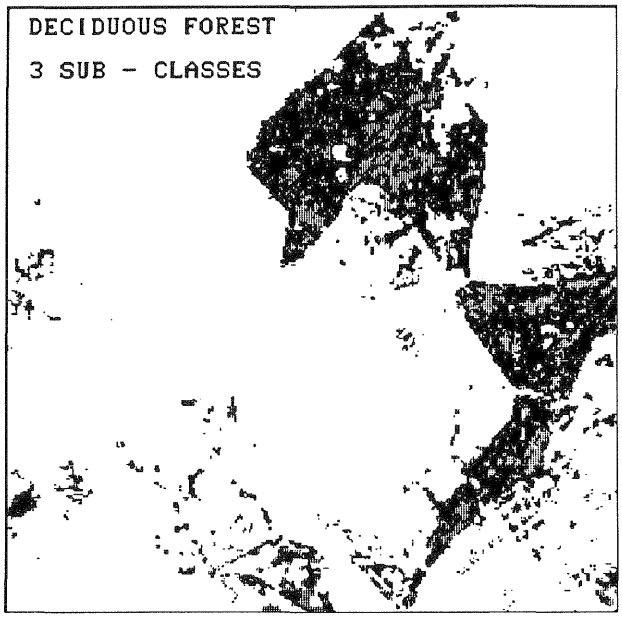


Figure 6: Sub-classes of deciduous forest obtained by slicing SPOT XS3

A further possibility would be to use the masked areas as an aid for performing manual interpretation of existing aerial photography. Monitoring the change in shape of the major classes could be a tool for the rapid detection of land use changes of these major categories.

5. Results

The classification of the SPOT scene of Hannover resulted in 8 major land use classes for the area of the city of Hannover. For agricultural areas it could be shown that additional 15 classes of land use are possible to differentiate (Michaelis 1987). The accuracy of the classification of the urban area can be estimated by the interpretation of the confusion matrix shown in table 1.

As expected the classes of 'residential areas' and 'city center' show the largest amount of misclassified pixels. Out of the 'residential areas' 9 % have been classified as 'garden areas' and 23 % as 'city center'. This is mainly due to the inhomogenity in the definition of this class, because very often 'residential areas' are a mixture of gardens and buildings also being part of the other classes and hence homogeneous training areas are difficult to define. The same holds for the class of 'city center' where 11 % have been classified as 'residen-

Table 1: Confusion matrix

	PREDICTED CLASS							
TRUE CLASS	1	2	3	4	5	6	7	8
1	92.99	1.02	3.28	2.26	0.45	0.00	0.00	0.00
2	1.44	91.27	1.14	0.30	0.00	0.00	0.00	5.85
3	2.71	0.52	90.45	6.28	0.00	0.00	0.02	0.02
4	1.79	0.10	8.90	61.84	23.45	3.67	0.24	0.00
5	0.19	0.00	0.00	11.35	74.17	14.00	0.28	0.00
6	0.06	0.00	0.34	3.42	14.25	79.52	2.41	0.00
7	0.17	0.04	1.51	4.36	1.68	6.16	86.09	0.00
8	0.00	9.42	0.00	0.48	0.00	0.00	0.00	90.10

Pixels per training area

885 5705 4827 4908 1057 1782 2387 414

Number of classified pixels per class

52681 23157 52485 80482 32879 10616 6179 3663

Average of fractions of correctly classified pixels

83.30

1 = pasture land & meadows
2 = deciduous forest
3 = garden areas
4 = residential areas
5 = city center
6 = industry & railways
7 = water
8 = coniferous forest

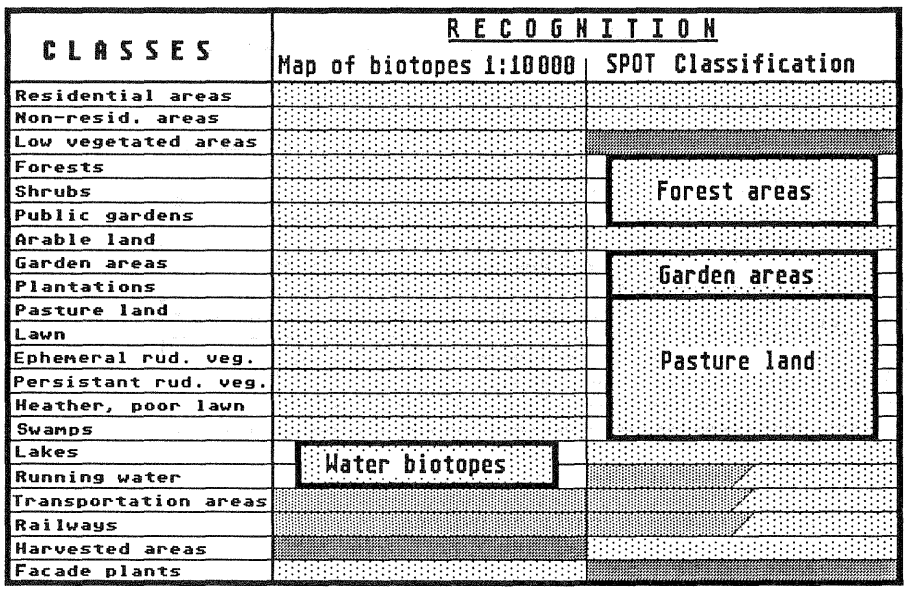
tial areas' and 14 % as 'industry & railways'. However, the average fraction of correctly classified pixels of 83.3 % shows that the classification of SPOT multispectral data can be a very useful tool for monitoring land use changes of major land categories in the field or urban planning.

As could be shown the application of hierarchical methods after separating the major classes can give more information about structures within these classes. As an example, for the class of 'deciduous forest' it was not possible to differentiate between various species of trees because the type of forest in Hannover is of mixed woods, but good correlation to the age of the stand and the density of the treetops was observed and verified

by ground truth. This forms a good potential for the conduction of forest inventories even in an urban environment.

Table 2 shows a comparisan of the SPOT classification and the map of the biotopes 1 : 10.000 over the area of Hannover (Birkner 1988). The class 'recognizable only in parts, improvement ...' means that the use of statistical texture measures promises an essantial improvement.

Table 2: Comparison of SPOT multispectral classification with a map of the biotopes at a scale of 1 : 10.000



well recognizable

recognizable only in parts

not recognizable

recognizable only in parts, improvement expected

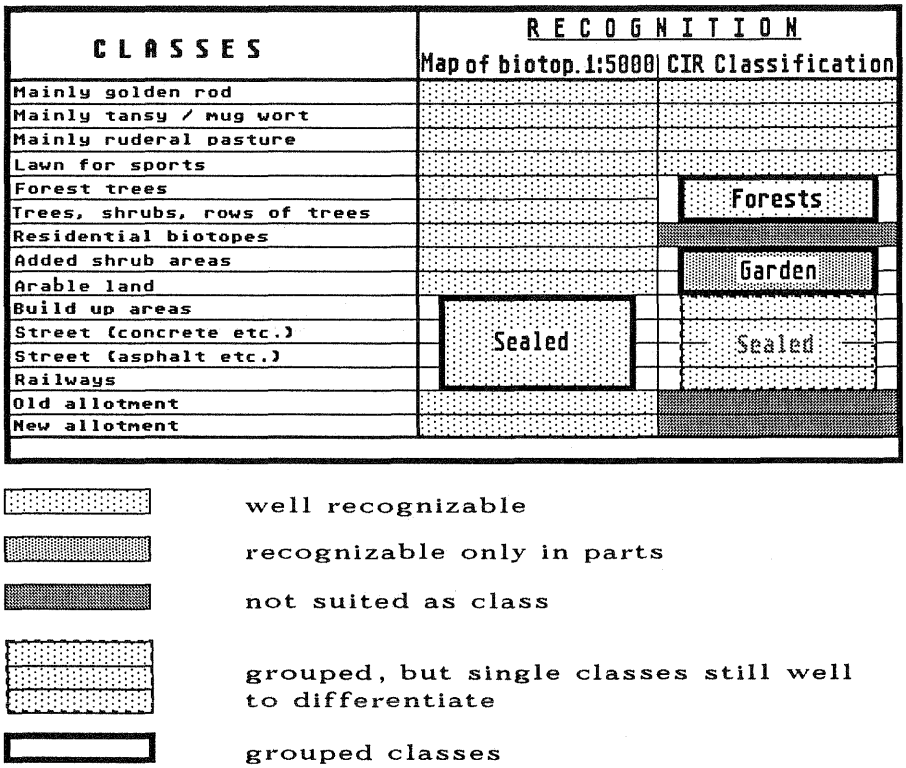
grouped classes

Because of the necessary grouping of landuse types for the classification with respect to the map, the information contents of the classification is of course smaller compared to the map. This is true especially for the reduction of six types of meadows to one class of 'pasture land'

The use of multitemporal data will certainly improve this fact because different phases of vitality of vegetation could be differentiated, while the use of texture or structure information is thought of being limited by the low spatial resolution of the data.

In comparison to table 2, table 3 shows the situation in the case of classification of a CIR-photography at a scale of 1 : 6.000.

Table 3: Comparison of multispectral classification of CIR aerial photography at a scale of 1 : 6.000 with a map of the biotopes of the area of Hannover at a scale of 1 : 5 .000



Three classes of the map of the biotopes are because of their inhomogenety not useful for automatic classification even after feature extraction. The results in general are comparable to the map of the biotopes as could be shown by BIRKNER. This fact in combination of taking the results of SPOT classification as an indicator for the presence of a major class leads to an economic way of producing maps of the biotopes of a city, which are an essential tool for planners and policy makers.

6. References

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