SZENT ISTVÁN UNIVERSITY

VEGETATION RECONSTRUCTION STUDY BASED ON PANCHROMATIC PHOTOS AND IMAGE SEGMENTATION ON THE EXAMPLE OF THE MIRES OF THE GREAT HUNGARIAN PLAIN

THE MAIN POINTS OF THE THESIS

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1. The antecedens and the aims of the work

Over the past few decades, the wide spread and the rapid development of remote sensing and GIS opened new opportunities to many disciplines including vegetation mapping. Nowadays in the botanical researches, investigating the past still plays a big role. There is a need for researches which are taking the spatial and temporal dynamics of vegetation into consideration, and to accomplish that, aerial photos provide one of the best support, and thus there is a chance for long-term investigations. The previously widespread used, primarily hand-made vegetation maps were gradually replaced by digital maps drawn by manual techniques (manual digitalisation) during the botanical researches. The aerial photographs until the 1980's only served as a complement in field work that is primarily for the landmark identification, due to the poor quality and low-resolution images, the analog techniques and the difficult accessibility. One of the fundamental problems of the traditional vegetation mapping is the subjective (human) factor. The digital methods try to reduce that very factor as much as possible. However, those methods are useless without the botanist's few years of field experience and experience in manual mapping. It is therefore necessary to develop methods which could provide more accurate and more objective maps and for that the ratio of these factors should be optimized.

Since the discovery of the mires of Bereg-plain in the fifties, continuous research began only in the mid-1990's. For that very reason, one cannot rely on the bibliography during the reconstruction of vegetation history that includes the missing period too. Since the aerial photos from the fifties are available, there is a need for a method which can effectively provide information of the vegetation and solves the limitations of the manual methods. Aside from the quality aspects it allows the quantitative analysis as well. On this basis the aims of my research were:

(1) to develop a new methodology based on aerial photos that can be used in vegetation mapping,
(2) and to test the method on two mires of Bereg-plain (Nyíres-tó, Navad-patak).

In connection with the aim of the method development I also wanted to find answers of the following questions:

1. Could the accuracy of the vegetation mapping be increased by the new method?
2. What’s the relation between the thematic resolution and the scale of segmentation?
3. How can the method be used in cases where the manual interpretation cannot be done or difficult to carry out?
4. How can the method be applied for reconstructing the former states of the vegetation based on archival images and considering the actual vegetation?
5. How can the method be applied for investigation of stability and changeableness?

2. Material and methods

2.1. The study area

The study area is the paludificated beds of Nyíres-tó and Navad-patak located on the Bereg-plain (NE Hungary). Previously in the area *Sphagnum* dominated associations were present in 5 mires which are Nyíres-tó, Báb-tava, Navad-patak, Zsid-tó and Bence-tó. Today they are extinct from Navad-patak and Bence-tó. The mires belong to the administrative area of Hortobágy National Park, and they lie near to Csaroda and Beregdaróc. Nyíres-tó and Báb-tava gets artificial water supply since 1986, Navad-patak and Zsid-tó since 1994 and Bence-tó since 1999.

2.2. The methods used

I used black and white aerial photos taken in 1956, 1966, 1975, 1988, 1997 and 2002. The scale of the negatives were usually 1:30 000 but the photos could be enlarged to the scale of 1:5000 while still remaining usable.

I digitalized the aerial photos with a Canon CanoScan 9000F type scanner, then I did the georeferencing with the ERDAS Imagine 8.4 software.

The image interpretation process reviewed in this thesis is the image segmentation. During the segmentation the aerial photo is partitioned into homogeneous image objects called segments. A fundamental difference compared to conventional classification processes is that the objects are not defined only by their shape and spectral property but it also takes adjacent, higher class and lower class objects into consideration. The segmentation was done with the Definiens eCognition Software.

When creating the segments, the primary factor is the heterogeneity which is shown by an abstract term called scale parameter. This is determined by both the shape and color of the object. In case of the panchromatic photos, the distribution of these factors was 50-50%.

For accuracy assessment I used color aerial photos of 0.5m resolution taken in 2005, provided by FÖMI. I compared the manually digitalized maps with the ones made with segmentation. The comparison was made with raster grid files using ArcView MapCalculator.

The segmented maps were also made with the help of ArcView. Associations with textural similarity (associations dominated by *Glyceria-Carex-Typha-Sparganium* or the willow and birch carrs) were not distinct enough so I used higher coenotaxon for their mutual visualization. In the case of Navad-patak due to the lack of references and vegetation map, I used higher coenotaxons again.

I also analyzed the changes with taking botanical aspects into consideration. The comparison was done with raster maps, with the help of MapCalculator in this case too. Using successive pairs of vegetation maps I selected from the total possible changes those, which don’t take place in the nature and considered them to be the errors of the segmentation.

During the stability analysis, I wanted to separate areas that remained more or less unchanged during the near 50 years interval and to find if there was any difference in the stability of the two examined mires. This was done with raster maps too. I marked the changes between the two phases with +1, 0 and -1 (mire developing, non-changed, degradation process), then I made the stability map by summing these maps. After that I made the simplified analysis with using only "changed" and "non-changed" categories. On the stability map made from this I created three categories based on the number of changes: stable (0-1 changes), moderately changeable (2-3 changes) and changeable (4-5 changes).

I separated the shadows occurring on the aerial photos manually. The identification was done based on the spots surrounding the shadowy spot.

For the reconstruction I also used the precipitation data regarding the area.

3. Results

3.1. Methodological results

In this thesis I developed a vegetation reconstruction method based on panchromatic images and image segmentation. The steps for the analysis are the following:

1. Actual aerial photo
    a. determination of scale parameter
    b. image segmentation
2. Selection of the segmented image's polygons
3. Upload segments with vegetation content
4. Merging of polygons, post correction

The steps are repeated after the first archive aerial photo as well. In this case the determination of the vegetation content is based on the current field knowledge, archive field data, and on the data of the reconstructed maps. In the latter case the vegetation is determined by the following factors:

1. The plant association of the next period
2. The environmental data between the two dates (meteorology, hydrology)
3. Succession pattern (association origin, options)
4. (Visual separation)

In case of the comparison of the manually digitized and segmented photo the delineations of the associations on the digitized map are much more coarse and simple because the free-handed digitalization does not move from pixel to pixel but the borderline is pulled along a lot more pixels. The difference between the two maps is about 15,241 m^2, which compared to the total area is 21,39%. However, according to MOLNÁR et al. (1998) there can be a 50% difference in maps drawn of the same area by different people. It is important to highlight that true colored image is well-suited for manual digitization. In case of a black and white photo it is much more difficult especially with older the photos, so segmentation is much more justified for them.

3.1. Botanical results

I made five historical vegetation maps of Nyíres-tó and six of Navad-patak with the help of the reconstruction method. The example of the Nyíres-tó pointed out that the map reconstructed by the method shows a similar picture to the earlier drawn vegetation map based on field experience. The main difference is the separation of associations with similar texture due to the absence of field data thus a higher coenotaxon should be used for the segmented map.

I divided the mire-development into three phases based on the analysis of the vegetation maps:

1. Natural state: In the first phase the environmental conditions of the raised bog associations were still satisfying, although in case of the Navad-patak the disruptive effects were very significant (pig farm). The end of the phase at Nyíres-tó can be put around in the mid-sixties. In case of the Navad-patak the end of the phase was the burning in 1967, when the raised bog associations finally disappeared from the area.
2. Degradation period: Due to gradual drying, forestification processes became stronger, so the extension of the willow carr has increased significantly in both mires. The degradation phase of Nyíres-tó lasted until the artifical water supply

in 1986. At Navad-patak the same period also lasted until the artifical water supply in 1994.

3. Regeneration period: Due to the limitations and interventions, the vegetation of Nyíres-tó quickly regenerated, the extension of raised bog associations increased, also as a result of the destruction of willow carr and birches, the tree cover has significantly reduced. In case of the Navad-patak due to the drastic rise in water level the remaining *Sphagnum* species disappeared from the mire, but at the same time floating mire-formation processes started in the inner, deeper parts of the mire.

With the help of botanical validation I found that the error per image pairs dose not exceed 10%. If the error was applied to the whole study, I found out that the rate of the pixels where botanical error was detectable two or three times in a row, barely reaches 5% of the area, thus the error in the maps does not accumulated.

The stability significantly differs in case of the two mires. Nearly 50% of the area of Nyíres-tó can be considered as stable, the rate of the moderately changeable area is 43%. However, at the highly changeable areas the mire-formation processes dominated, the predominance of the degradation processes was only significant at the mire's east lagg-zone. In case of the Navad-patak the rate of the stable area was only 26%, while the rate of moderately changeable area was 65%. In this case mire degradation processes dominated more, primarily at the lagg zone and along the borders. Mire-development was dominant at the east and west, deeper areas. At the same time the analysis showed that only the two type of stability analysis together give accurate results.

3.3. New scientific results

Methodological results:

1. I developed a vegetation mapping method based on digital image segmentation, which can be used better than manual digitalization which is:
   A. Much less subjective
   B. Gives a much more accurate result in regards of vegetation delineation and patch sizes
   C. Post correction may be carried out anytime
   D. Gives the option for quick and accurate repetitions, thus capable of to follow quick changes
   E. Provides the possibility of accurate qualitative and quantitative analysis in spatial- and time-scale
   F. The error of a map can be calculated mathematically.

2. I developed a validation system to support the vegetation changes and to detect the error of segmentation.
3. I pointed out that the information obtained from panchromatic images is reliable for the vegetation mapping using digital image processing, however, field work is still necessary, its role in the reconstruction work is primary.
4. I concluded that the scale parameter can not be standardized if panchromatic photos were used, and the decisive factor is the depth of the particular color (grayscale), in contrary to the shape of the objects.
5. Using this method I reconstructed the past 50 years' vegetation of the two mires of Bereg-plain, Nyíres-tó and Navad-patak, and I showed the changes

on a series of historical vegetation maps. I divided the development of the mires into three stages, as the natural state, the degradation period and the recovery period.

6. With digital vegetation maps I calculated the exact area of the associations and determined their dimensional change on a time-scale.
7. During the stability analysis I classified the pixels into stable, moderately changeable and changeable categories, depending on how many times their value (association) has changed during the examined period. I concluded that the rate of the changeable areas in Nyíres-tó do not even reach 10% and the rate of the stable areas is around 50%, while in case of Navad-patak the changeable areas are of the same ratio but the rate of the stable areas is only about 20%. It is provable by the method that the vegetation of Nyíres-tó in the examined period was more stable than that of Navad-patak.

Specific botanical results:

8. The following plant communities/areas can be considered most stable over the past 50 years in Nyíres-tó: the inner *Carici elongatae–Alnetum,* its surrounding *Calamagrosti–Salici cinereae,* the middle part of *Eriophoro vaginati–Sphagnetum,* the *Fraxino pannonicae–Ulmetum* at the edge of the mire, and *Phragmitetea australis* (mainly *Glycerietum maximae*) at the northern part of the mire.
9. The following plant communities/areas can be considered most changeable over the past 50 years in Nyíres-tó: mainly *Phragmitetea australis* situated in the lagg-zone (primarily *Glycerietum maximae* and *Caricetum ripariae*).
10. The following plant communities/areas can be considered most stable over the past 50 years in Navad-patak: the *Carici elongatae–Alnetum* association, the *Calamagrosti–Salici cinereae* surrounding it, the willow dominated floating mire associations, and the older populations of the *Populetum tremulae*.
11. The following plant communities/areas can be considered most changeable over the past 50 years in Navad-patak: mainly the *Phragmitetea australis* situated in the lagg-zone (primarily *Glycerietum maximae* and *Caricetum ripariae*), the northern part of the mire (here tall-sedge, weed associations, willow carr, and thicket follow each other), and the area which is next to the track that once crossed the mire (tall-sedge, weed association, green canary grass, reed sweet grass and willow carr).

4. Conclusions and propositions

The main advantage of the method is that the segmentation can be repeated any time, the parameters of it can be changed again and again. The segmentation is much faster than the manual digitalization it is only determined by the size of the aerial photo. The extension of the image does not affect the result, this way the segmentation dose not require a separate file conversion which makes the method even faster and simpler. The segmentation can process equally panchromatic, color or even multispectral images. My work confirmed that the previously undervalued panchromatic images are well-suited in vegetation reconstruction while at the same time it is much cheaper then the modern multispectral images. The resulting segments can be changed later, the upload with vegetation content can be quickly done with the needed field experience. The quickly altering ecosystems and the suddenly occurring natural and anthropogenic changes can be easily tracked. After entering the result in the GIS the images of particular dates can be compared easily. It is easy to calculate the areas of the segments, and also their change in a time-scale. This way the qualitative comparison is possible along with the quantitative analysis. With the help of the validation process described by me, it is easy to calculate the error of the segmentation.

In addition one of greatest advantage of the segmentation-based vegetation reconstruction is that it reduces the subjectivity of the mapping, since the delineation of the cut-off patches dose not depend on the interpreter, thus the mapping is based on a more objective way.

The method has several advantages in addition to constraints to be reckoned with. The scale parameter cannot be standardized, it has to be set with every single photo, the mapping of the individual decision can, moreover, must predominate here. Another disadvantage of the method is handling the shadows. Digital separation method has not yet been developed, so manual adjustment is needed. However, small patches can only be isolated if they are highly separated from their environment. Separating the vegetation types with similar textural parameters causes further difficulties (e.g. reed, sedge, reed-mace) for which a photo with an infrared band is needed. Last but not least, the segmenting softwares are quite expensive, as well as the multi-and hyperspectral images which give more accurate results.

The case studies presented in the thesis showed the criteria of an investigation based on panchromatic images at an association scale. During the investigation, generally it is more appropriate to work with a smaller scale parameter value, because this way we get sufficiently numerous patches, which should provide a basis for mapping the delineation and designation. The goal is to minimize the freehand drawings on the maps. Subsequent merging of two patches is more accurate than drawing additional borderlines manually. The application of the method in landscape scale did not yet happen, partly this could be a future direction of the research. In regards of the scale parameter here one can work with a lower value (fewer segments). Certain categories of land cover, biotopes are more detached from each other both in texture and color than a selected habitat’s dissimilar associations. This way in the course of separating grasslands, forests, thickets, agricultural areas segmentation would probably yield a better result.

The reconstruction of the vegetation at Navad-patak and Nyíres-tó shows the sensitivity and vulnerability of the mires. Evidently the most important limiting environmental factor is the available quantity of water. In case of both mires the increasing water shortage and the increasing drought led to degradation and the transformation of the species structure. In addition the nature protection interventions have reached a positive effect, since after the restoration of water balance the natural processes have become stronger in both mires. It means that the future of the mires depends on the nature conservation treatments, of which the primary task is to uphold a controlled and permanent water level.

My results can be primarily used in the course of botanical mapping, and can assist in monitoring studies as well. The described method also opens up new possibilities in succession-research. However, the application of the method at landscape scale provides a new direction not only in the botanical studies, but also for zoological studies and for landscape ecology. All these contribute to a more precise planning and realization of nature protection intervention.

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