ACTA CLIMATOLOGICA ET CHOROLOGICA
Universitatis Szegediensis, Tom. 38-39, 2005, 163-169.

AN INVESTIGATION OF THE GROWTH TYPES OF VEGETATION IN THE BÜKK MOUNTAINS BY THE COMPARISON OF DIGITAL SURFACE MODELS

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Összefoglalás – A karsztok hasznosításának leggyakoribb hazai formája az erdőgazdálkodás. A fák növekedési ütemének ismerete kiemelten fontos az erdészeti hasznosítás számára, valamint jól használható a terület monitoringjához is. Vizsgálatainkban digitális felületmodelleket használtunk, melyet – a Bükki Nemzeti Park 100 km^2-es mintaterületéről 1965 és 2004. években készült légifelvételek alapján – digitális fotogrammetriai (SOCET SET) munkaállomásokon készítettünk. A digitális felületmodellek erdős területen tartalmazzák a famagasságokat is, így a felületmodell és a terepfelszín magasságának különbségeiből famagasság térképek készíthetők. A felületmodellek magasságkülönbségei a növekedésmenetek üteméről ad átfogó képet.

Summary – The most common form of land use in Hungarian karsts is woodland. The rate of tree growth in the forest is of utmost importance for forest management but it is also useful for monitoring purposes. In this study we review the possible uses of digital surface models (DSM) derived from aerial imagery in investigating tree growth rates. Two digital surface models were created of a 100 km^2 study area in the Bükk Mountains, Hungary by using aerial imagery from the years 1965 and 2004. Tree growth maps were created by extracting the areas' digital elevation models from these surface models. Our results suggest that these digital maps could replace field measurements in the future.

Key words: digital surface model, aerial images, tree growth, Bükk National Park

INTRODUCTION

The most common form of land use in Hungarian karsts is woodland. An integrated forest management taking into account considerations of environmental protection as well could insure the conservation of karsts in a near-natural state (*Keveiné Bárány*, 2004). Before World War II, the forests of the Bükk Mountains were owned by the state. While earlier the forests were mainly cut down to increase the area suitable for grazing, after the war deforestation followed due to a highly increased claim for wood production. The exploitation of forests also had an impact on their age composition. The foundation of the Bükk National Park in 1977 meant a turning point in the history of the area's forests, introducing the concept of sustainable management (*Keveiné Bárány*, 2003). In an earlier investigation we compared time-series of aerial photos in order to follow changes in the area. The species composition of the stands was defined by the supervised classification of Landsat satellite imagery (*Zboray and Keveiné Bárány*, 2002).

Most of the forests in the study area consist of European beech (*Fagus sylvatica*) which is usually cut down at the age of 120-130. *Bondor* (1986) summarized the relations of tree age and height in so-called yield tables. The main aim of the foresters' researches was to describe tree growth and changes in its rate. According to their results, the main differences in growth within a species can be shown in the case of young trees, because between the ages of 0-20 several factors can hinder growth. In this study we examine a 100-km^2 area of the Bükk Mountains (*Fig. 1*).

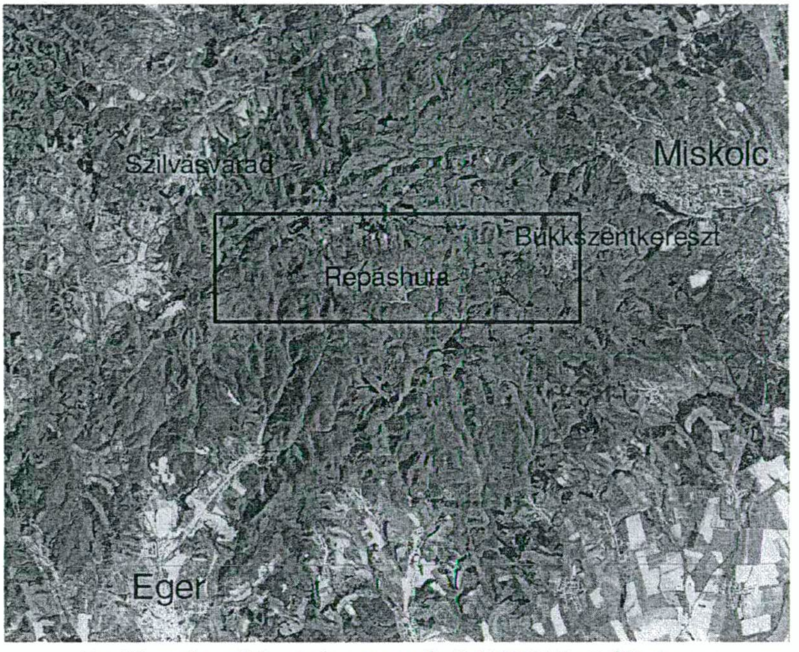

Fig.1 Location of the study area on the LANDSAT satellite image
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We reviewed the recent and archival aerial photos available of the area, provided by the Ministry of Defense Mapping Company. The aim of our investigation was to define tree heights and tree growth rates by means of photogrammetry and the visual analysis of the aerial photos in order to get information on the state and changes of the forest cover.

METHODS

Up to now defining tree height was only possible by field measurements. In the case of trees with a considerable height errors of several meters were common. *Bán* (1996) attempted to measure tree height in aerial photos. He took photos of the study area with and without canopy cover and then measured the height above sea level of the trees' apices and their root collars by photogrammetrical methods. He calculated the height from the difference of the two. The drawback of his method is the small number of measured elements, which means that the use of this method in the case of large areas is rather time-consuming.

Measuring tree height is also possible on spatial models created from satellite imagery. On the basis of LANDSAT and SPOT data *Donoghue et al.* (2004) found a root mean square error (RMSE) of 1.5 meters compared to field measurements. The most modern height measurements are conducted with lasers but the high expenses strongly hinder their use in Hungary.

In geographic information systems digital surface models created with digital photogrammetric workstations (SOCET SET) are spreading (*Fig. 2*).

Fig. 2 Digital elevation model (left) and the digital surface model (right) of part of the investigation area

As opposed to a digital elevation model, a digital surface model includes the height of natural and artificial objects on the surface as well as the elevation. The creation of a digital surface model is – as part of the photogrammetric workflow – automatic. A further advantage is that by processing archival photos we can gain information of the area from decades before. On the hypsometric image of the surface model – compared with the elevation model – the sites of clear-cuttings and logging by the roads can be clearly seen. For data processing and presentation we used the image-processing software ERDAS IMAGINE, as before.

Aerial imagery of the area was taken by the military cartographers in the years 1956, 1965, 1975, 1987-88, related to the revision of earlier maps. The most recent photos were taken in 2004 with a scale of 1:30,000. In order to compare with these we chose the photos taken in 1965 with a similar scale (1:32,000) which are of excellent quality – a crucial point in processing. Orthophotos created from the photos taken in 2004 and some ground control points measured by GPS served as the basis of the photogrammetric processing. Reliability is well shown by the root mean square error (RMSE) of the aerial triangulation, that is the following: X:0.433, Y:0.510, Z:0.460 (m), the total RMSE is 0.671 m. (In the case of a lot of measurements this is the theoretical average difference between the surface model and the real heights. In practice there can be 1-1.5 meters differences between model height and real height.) In the case of the photos from 2004: X:0.094, Y:0.089, Z:0.091 (m). The total RMSE is 0.146 m.

The creation of the surface model is only possible in the overlapping areas of the orientated and calibrated photos. This happens by the software looking for identical points in the model area; it measures the height then restarts in a previously defined distance (in this case it was 10 m). Thus the surface model is a set of automatically measured height data which, in a forested area, also contains heights measured in the canopy. If there is a DEM available of the area the difference of the two provides information on tree height while comparing digital surface models from two different years shows us the changes in tree height and the spatial distribution of these changes.

DISCUSSION AND RESULTS

By subtracting the elevation model from the surface model we got digital tree height maps (*Fig. 3*). The areas of the settlements founded in places of earlier clear-cuttings are clearly visible (Répáshuta in the middle and Bükkszentkereszt on the right, with an approximately zero height difference). Even without quantifying the change it is clear that the height (and so the age) of the area's forests generally increased due to the foundation of the national park and the following sustainable management.

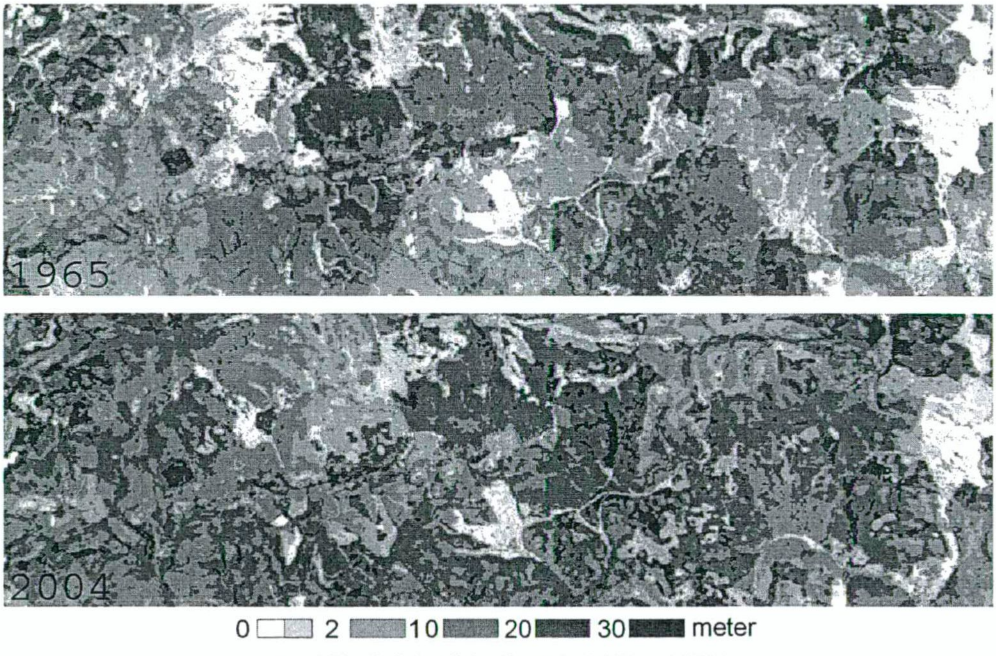

Fig. 3 The height of the forest in 1965 and 2004

On the basis of the tree height maps we drew the frequency distribution of the heights (*Fig. 4*). This shows a 7% increase in the proportion of forested areas. Maximum tree heights correspond to the maximum values shown in the yield tables for beech (40 meters in the case of a 120 year-old beech tree). By analysing the chart we can state that while in 1965 two dominant groups could be distinguished (an older with trees of 15-20 m height and a younger with 5-10 m high trees); in 2004 these two maximums are united in one, with twice the value. The explanation for this is probably that after the huge clear-cuttings related to the world war, fast-growing beech types were planted that reached the heights of earlier planted stands by 2004.

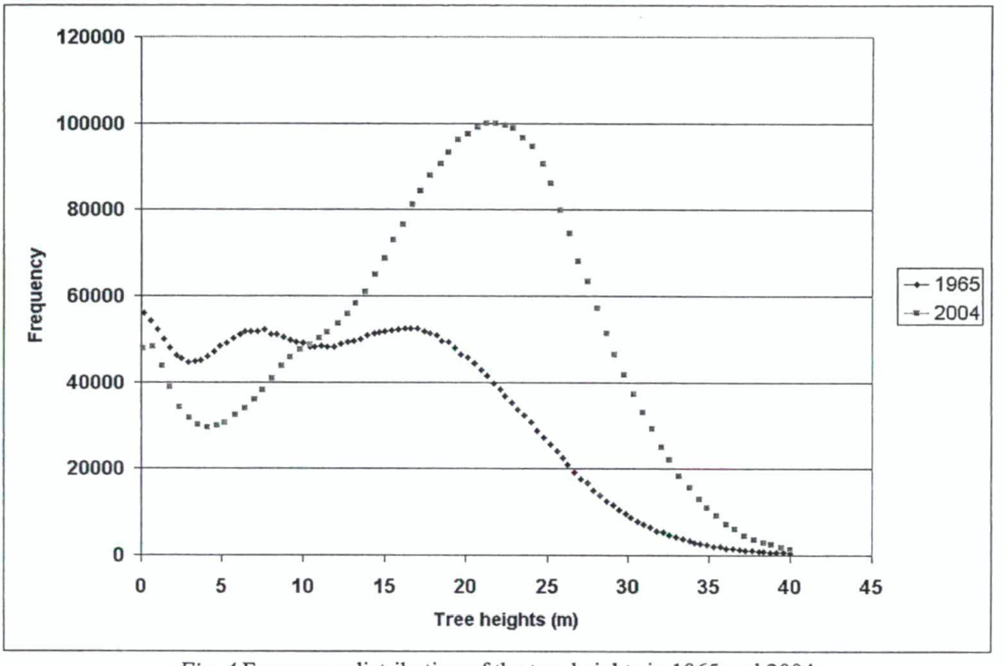

Fig. 4 Frequency distribution of the tree heights in 1965 and 2004

The height difference between the surface models serves with information on tree growth (in the case of negative values it shows traces of logging). The data show that logging occurred on 22% (20.40 km^2) of the study area (*Fig. 5*).

The changes in growth rates are the consequences of the following factors' interaction:

1. Tree species (90% of the area's forests consist of European beech – *Fagus sylvatica*)
2. The age of the forest (the growth of young trees is faster than that of old ones so the year of plantation is an essential information)
3. The characteristics of the production site (basically defined by the climate, soil and elevation) which can vary within a short distance

Thus the knowledge of the first two (e.g. species and age) along with a knowledge of the species-specific growth rates can help us to predict site characteristics. In the case of forests that consist of trees of the same age and species we can even distinguish different types of production sites. *Keveiné Bárány et al.* (2003) analysed production site data from the Aggtelek National Park area and proved that some of the local forests do not suit the ecological characteristics of the land.

In addition to the creation of the digital surface models we also prepared the orthophoto mosaic of the study area out of the aerial images. This enables us to carry out a quick visual analysis of the changes that occurred in the area between 1965 and 2004. The most recent photos suggest that the various non-native coniferous species are gradually retreating (*Fig. 6*). Stands consisting of such species are not regenerated while a natural reforestation by native species is also evident.

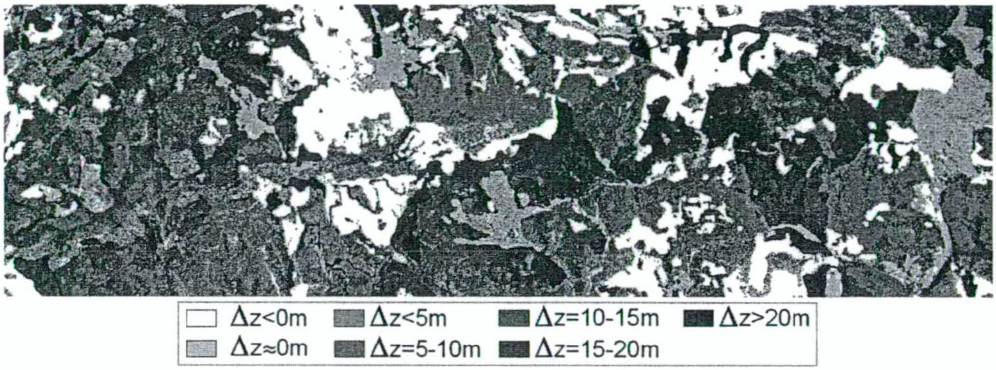

Fig. 5 Changes in tree heights (logging Δz<0, constant Δz≈0, increase Δz>0) 1965-2004

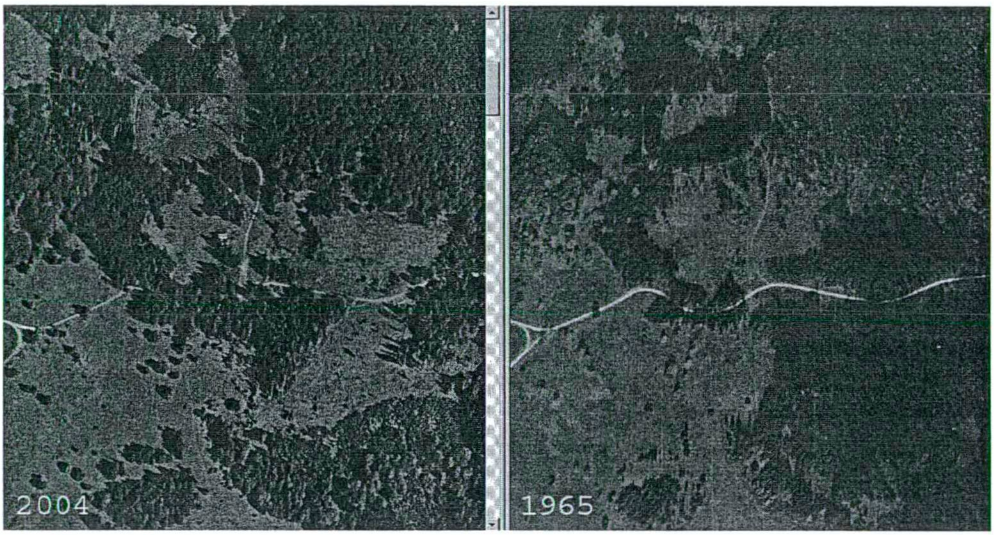

Fig. 6 Orthophotos of a small part of the investigation area (Nagy-mező), in 2004 and 1965

CONCLUSION

1. Tree height maps created from digital surface models can be effectively used in the field of forest management as a complementary method for field measurement and analysis carried out by manual instruments.
2. To define differences in tree growth rates the influence of local factors should be further investigated and, in case of regular bias, local functions should be explored.

3. Knowledge of the differences of tree growth in different production sites provides a unique opportunity to extend optimisation investigations in karstlands.
4. On the basis of the orthophoto series and the maps showing tree height changes we can conclude an increase in the proportion of forests, and the gradual disappearance of degraded vegetation patches of the karst area.

Acknowledgement – This research was supported by the grant of the Hungarian Scientific Research Fund (OTKA T/048356). We wish to give special thanks to F. Szmorad (Aggtelek National Park) for his help with the yield tables and related information, L. Buga (leader of Ministry of Defence Mapping Company, Budapest, Hungary) for the access to archives of aerial photos, F. Siristye (leader of Photogrammetry Section, Ministry of Defence Mapping Company, Budapest, Hungary) for his help and knowledge in the photogrammetry (SOCET SET) workflow.

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