HIGH RESOLUTION DIGITAL TERRAIN MODELS OF THE BOTTOM OF LAKE FERTÖ (AUSTRIA, HUNGARY) - A HUNGARIAN-AUSTRIAN JOINT PROJECT FOR CREATING CROSS-BORDER DATA BASES FOR ECOSYSTEMS RESEARCH

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ABSTRACT

Digital terrain models (DTMs) of bottoms of lakes depend on selected methods of data collection and data treatment. As research on limnetic ecosystems needs exact informations of the topography of the regions under investigation DTMs are most efficient tools for providing suitable data bases for interdisciplinary cooperation. Applying DTMs to hydrological and limno-ecological tasks opens a wide range of possibilities of multithematic modelling and simulation of ecosystems behaviour in function of variations of water levels, water currents and patterns of human impact. Building up powerful data bases for holistic research has to connect DTM layers with multitemporal remotely sensed informations of landuse and landcover. Very high resolution mapping of vegetation structure, physiognomy and vitality is guaranteed by colour infrared (CIR) aerial photography and by space photography. Digital data of the topography of the terrain and of landcover extracted from DTM and multisensor images are therefore the basic parts of an operationalized GIS for monitoring and modelling of limnetic ecosystems.

RÉSUMÉ

Models numériques du terrain (MNT) sont de la haute importance pour créer des bases des informations spatiales sur les écosystémes des lacs. Le terrain d'interet étant pas accessible, les methodes d'évaluer les differences du niveau du fond de lac doivent étre spécial. La hydrologie et la limnologie sont besoin des informations numériques sur le terrain en haute résolution. Le traitement thématique des MNTs permets de modeler et simuler la condition des écosystémes en fonction des variations de niveau d'eau, des courants et des activités de l'homme. L'intégration de l'interprétation des photographies aériennes en couleur infrarouge (CIR) et des photographies spatiales en haute résolution donne des informations sur la structure, la taxinomie et la vitalité de la vegetation lacustre en fonction du niveau et de la structure du fond du lac. Un systéme d'information géographique sur les écosystémes des lacs doit donc etre fondée sur deux colonnes - l'une le MNT, l'autre la télédétection.

KURZFASSUNG

Digitale Geländemodelle (DGMe) von Seeböden liefern wichtige Informationen im Rahmen von Forschungen zur Limno-Ökologie. Die spezielle Aufgabe, in größtenteils unzugänglichen Gebieten Meßpunkte abzusetzen, erfordert spezielle Methoden der Datenerfassung und -verarbeitung. Forschungen zur Hydrologie und Ökologie der Seen können die digitale Datenbasis eines hochauflösenden Geländemodells vor allem zur Dokumentation, Modellierung und Simulation von Dynamismen der Sedimentation, von Sedimentmächtigkeiten, Wasserstandsschwankungen und resultierenden Analysen des Wasserhaushaltes nutzen. Die Verknüpfung der DGMe mit multitemporalen Kartierungen der Vegetationsstrukturen, -gemeinschaften und des Vitalitätszustandes einschließlich der Muster von Landnutzung auf Basis hoch auflösender Farb-Infrarot-Luftbilder (CIR) und Weltraumphotographien ermöglicht die komparative Analyse von Parametern der Vegetation (Schilf), der Wasserflächen und des Seeuntergrundes.

1. INTRODUCTION

High resolution digital terrain models (DTMs) are important modules of environmental information systems (Petrie et Kennie, 1990, Goodchild et al., 1993, Michener et al., 1994, Mather, 1995). DTMs of bottoms of lakes can support multithematic investigations especially in the fields of hydrology, limnology and vegetation sciences. Mapping submersed and littoral vegetation is optimized by the interpretation of high resolution remotely sensed data. CIR-aerial photography, space photography and satellite imagery of the earth observation programs of Spot and Landsat are worthful tools for landcover and landuse mapping. Integrating digital imagery with digital terrain models is part of a GIS-approach to strengthen efforts in research on the ecology of lakes.

Lake Fertö and the Hanság, a relic of a lowland moor east of the lake, are part of the Austrian-Hungarian border region southeast from Vienna. The former epicontinental sea of the Pliocene was desalinated and brackish water sediments were deposited to layers of up to 4km thickness. After a period of uplifting and processes of deposition and deflation during the ice age the region of the lake subsided about 10000 to 15000 BP, the bottom of the lake was deepened and filled with water. The eastern parts of the depression were drained and thus transformed to a lowland moor (Löffler, 1979, Tollmann, 1985).

Since 1921 the region is divided by the Hungarian-Austrian border. About 90km² of the lake and its reed belt belong to the Hungarian, 230km² to the Austrian territory (Csaplovics, 1984).

Environmental problems increased when traditional extensive grazing of the puszta (grasslands) was displaced by single-crop farming. In Austria the economic potential of wine-growing and tourism was exaggerated to a great extent during the last decennia. Though sewage purification plants have been installed all around the lake over-fertilization of fields and vineyards as well as waste water spills from camping sites still deteriorate the water quality of the lake. The lake itself is overused by crowds of summer tourists. Uncontrolled harvesting and burning of reed endanger breeding habitats of rare migratory birds. The Hungarian border region is lately open to public. Therefore large areas of the southern parts of the lake and of the grasslands remained relatively undisturbed.
Recently Austrian and Hungarian authorities established a national park following the criteria of the International Union of Conservation of the Nature (IUCN). The Hungarian-Austrian Fertö Tó National Park consists of about 72km² of primary zone areas and of about 60km² of secondary zone areas.

2.DIGITAL TERRAIN MODELS OF LAKE FERTÖ

Since the early eighties needs for creating, maintaining and applying a geographical information system of the lake and its surroundings forced research in various fields of remote sensing and GIS, like multitemporal high resolution photo-interpretation and digital image analysis, multithematic inventory and integration of environmental data pools into GISs, analysis of high resolution space photography, and production of digital orthophotos (Csaplovics, 1982, Csaplovics, 1987, Csaplovics, 1993).

Soon limnologists, hydrobiologists, ecologists and others claimed urgent need for high resolution digital terrain data of the bottom of the lake. Research on structure and vitality of the reed belt, on dynamics of sedimentation in off-shore and reed-water-interaction zones needed digital terrain models containing informations on the variations of water depths respectively sediment layer thicknesses. Creating tools for monitoring and simulating the ecological situation of the lake and its surroundings was the focus of interdisciplinary work.

From 1985 to 1988 work for the compilation of the digital terrain model of the Austrian part was carried out. Based on the methodology of trigonometric height measurement flexible interaction between master- and remote stations allowed the coordinate determination of grid-like arranged points describing the bottom topography of the lake. Calculation of refraction and correction of the measurements minimized mean height errors to lower than +/-2.5cm for a horizontal distance of 3km. By treating data with the SCOP-DTM-software (Stuttgart Contourline Program, Kraus 1993) digital terrain models of the sediment surface and the ground surface of the bottom of the lake have been calculated. Contour line maps of both surfaces - limited by the contour line 116.50m - have been derived. Extensive silting up in the reed belt could be documented. Profiles, calculations of sediment volumes and selected perspective views of the bottom surface are further results of the analysis of the Austrian DTM data (Csaplovics, 1989).

In 1990 a joint research program supported by the Austrian Ministry of Research and the Hungarian Academy of Sciences raised the opportunity to complete the digital data pools by integrating the Hungarian part of the lake. Austrian and Hungarian scientists adapted the methodology of data collection and data treatment to the Hungarian situation (Csaplovics et al., 1993).

Problems of coordinate transformation caused by different reference ellipsoids and different sea level reference points had to be solved (Bácsatyai, 1995).

Parallel to field missions in Hungary the existing DTM files of the Austrian terrain models had to be prepared for integration of the Hungarian data. In 1995 the final digital terrain models of Lake Fertö have been created. These models consist of data sets of both the sediment surface and the ground surface of more than 350km² of the bottom of the lake, the reed belt and the terrain of surrounding areas limited by the contour line 116.50m. More than 10000 points per terrain model have been calculated by using the facilities of the SCOP-software As the terrain is very flat, contour line intervals of 10cm meet the requirements of limnologists. On the other hand methodological, technological and organizational constraints had to be overwhelmed to reach these accuracies in praxi. Profiles, perspectives of selected sceneries, thematic maps showing variations of dry areas in function of simulated seasonal and/or annual variations of water levels are further thematic components of the DTM-package (figure 1).
Combination of these data with thematic overlays, e.g. maps of breeding places of protected rare birds, enlarge the efficiency of interdisciplinary applications of the DTMs to a great extent. Diagrams of areas and volumes of the water body of the lake in function of varying water levels meet the needs of hydrologists for exact modelling of the lake. Intersection of the digital terrain data of sediment and ground surfaces allows the computation of a difference model and the calculation of volumina respectively isolines of thickness of sediment layers (figure 2).

3. DTM, REMOTE SENSING AND GIS

The representative variety of basic and applied products stands for the powerful facilities of the DTM Lake Fertö. They all have recently been produced and analysed (Csaplovics et al. 1996). Aerial CIR-photo-interpretation of the Austrian and Hungarian reed belt add valuable informations concerning lateral extension of reed areas both in an actual and multitemporal sense (Csaplovics 1984, Csaplovics 1989, Márkus 1986).

The contour line maps of Lake Fertö integrate these informations and thus give the opportunity to study the relation between water-reed-borderlines and sedimentation (uplanding) with the highest vertical accuracy possible (contour line interval 10cm). Data of the DTMs are available and ready for operational application by the interdisciplinary user community.

Further activities will focus on the synthesis of reed classification based on aerial CIR-photography and the DTM. Besides having solved a selective problem of data collection for calculating DTMs consisting of more than 10000 points located in inaccessible water and reed areas of the lake, the DTM Lake Fertö represents a powerful application of research on operationalization of DTM-software for creating topographic as well as multithematic information systems of regions of outstanding ecological value. For the first time scientists of Austria and Hungary cooperated in producing cross-border contour line maps of the bottom of the lake and its reed belt and in building up the core modul of the Geographic Information System of the Austrian-Hungarian Fertö Tó National Park. Based on these postive experiences the DTM Fertö Tó will be the platform for forthcoming projects like the cross-border interpretation of the ecological structure of the reed belt (180km^2) by combined methods of aerial CIR- and high resolution space photo-interpretation as well as by correlated field work. Actual dynamics of sediment deposition can only partly be discussed when comparing the results of the recent program with nivellement surveys of the lake made during a period of very low water in the early sixties and with inaccurate measurements by sounding dating back to the beginning of the century. Therefore the homogenous digital terrain models of Lake Fertö will be basic data pools for evaluating comparative time series of topo-chronological change detection concerning sediment layer thicknesses and/or extension of dried out areas. Thus the basic modul of the Geographic Information System Fertö Tó will consist of a fully operational digital 4D-model consisting of topo-chronological spatial and multithematic informations.

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REFERENCES

Bácsatyai, L., 1985. Umwandlung der Budapester stereographischen Koordinaten in österreichische Gauß-Krüger-Koordinaten. Vermessung und Geoinformation 83(4), pp.227-233.

Csaplovics, E., 1982. Interpretation von Farbinfrarotbildern. Geowissenschaftliche Mitteilungen 23, TU Wien.

Csaplovics, E., 1984. A practical application of CIR-image interpretation - the classification of the reed belt of Lake Neusiedl (Austria). In: International Archives of Photogrammetry and Remote Sensing, Rio de Janeiro, Brazil, Vol.XXV, Part A7, pp.143-153.

Csaplovics, E., 1987. Fernerkundung am Neusiedler See. Geowissenschaften in unserer Zeit 5, pp.129-136.

Csaplovics, E., 1989. Die geodätische Aufnahme des Bodens des Neusiedler Sees. Wissenschaftliche Arbeiten aus dem Burgenland 84, Burgenländisches Landesmuseum, Eisenstadt, Österreich.

Csaplovics, E., 1993. Remote sensing of the Fertö Tó National Park (Austria, Hungary) - perspectives of integrating multi-temporal environmental monitoring and GIS. Proceedings of the 12th EARSeL Symposium, Eger, Hungary, pp.13-19.

Csaplovics, E., Senftner, G., 1991. Multitemporale Luftbildinterpretation zur Landnutzungsanalyse im Naturraum Neusiedler See - Seewinkel. Zeitschrift für Photogrammetrie und Fernerkundung 59, pp.60-63.

Csaplovics, E., Kanonier, J., Bodi, A., 1993. Geodätische Aufnahme und Bildung eines digitalen Modelles des Bodens des Neusiedler Sees - Verlandungstendenzen des Sees. Biologische Forschungsstation Burgenland, BFB-Bericht 79:51-52.

Csaplovics, E., Kanonier, J., Sindhuber, A., 1994. High-resolution KFA-photography for integration with geo-information systems - a case study of Fertö Tó National Park (Austria, Hungary). Proceedings of the 13th EARSeL-Symposium, Dundee, Scotland, pp.181-188.

Csaplovics, E., Bácsatyai, L., Márkus, I., Sindhuber, A. 1996. Digitale Geländemodelle des Neusiedler See-Beckens. Wissenschaftliche Arbeiten aus dem Burgenland, Burgenländisches Landesmuseum, Eisenstadt, Österreich (in preparation).

Goodchild, M.F., Parks, B.O., Steyaert, L.T. (eds.) 1993. Environmental Modeling with GIS. Oxford University Press, Oxford.

Kraus, K., 1993. Photogrammetry. Vol.1, Dümmler, Bonn.

Márkus, I., 1986. Die Fernerkundung im Dienste der umweltbiologischen Untersuchung des Neusiedler See-Biosphärenreservates mittelsPhotointerpretation. Bericht der Biologischen Forschungsstation 58, Illmitz, Österreich, pp.87-95.

Mather, P., (ed.) 1995. Terra 2 - Understanding the Terrestrial Environment. Wiley, Chichester, New York.

Michener, W.K., Brunt, J.W., Stafford S.G. (eds.) 1994. Environmental Information Management and Analysis. Taylor and Francis, London.

Petrie, G., Kennie, T.J.M. (eds.) 1990. Terrain Modelling in Surveying and Civil Engineering. McGraw-Hill, New York.

Vizgazdálkotasi Tudományos Kutato Központ (ed.) 1981. Fertö Tó. Vizrajzi Atlasz Sorozat 24, Budapest.

Figure 1. Digital model of sediment thickness of the bottom of Lake Fertő, scale ≈ 1:180000.

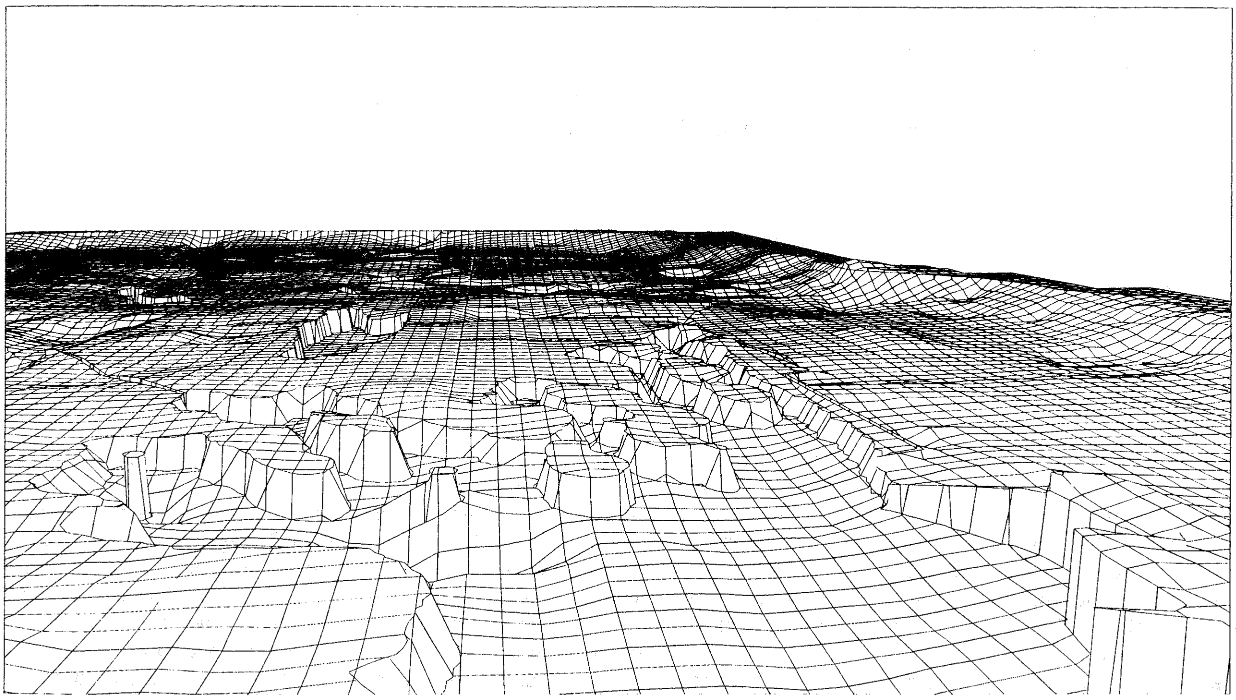

Figure 2. Perspective view of the south-western part of the sediment surface of the bottom of Lake Fertö.