DTM and GIS as Part of an Evaluation Methodology for the Vegetation Development Related to the International Garden Exhibition (IGA 2003) in Rostock

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Abstract

In 2003 the city of Rostock will host the International Garden Exhibition, IGA. The exhibition area lies in the north-western part of the city. The potential impacts of the planned rearrangement of the whole IGA area on the vegetation were investigated using geographic information systems (GIS) and Digital Terrain Models (DTM). Because of its vicinity to the Baltic sea and the River Warnow IGA 2003 may be seen as a garden exhibition between land and water. Therefore the restoration of brackish water reed in the marine-terrestrial transition zone is of major importance.

1. The IGA 2003 Area

In 2003 the city of Rostock will host the International Garden Exhibition, IGA. The exhibition area lies in the north-western part of the city in the lowlands of the Unterwarnow, a river passing Rostock on its way to the Baltic Sea. During the preparation phase for the IGA a landscape and urban design contest was held in 1997 and has lead to the current state of pre-planning. The rearrangement of the whole area for the establishment of this international event will lead to tremendous changes in the current landscape. The possible consequences of this rearrangement for the vegetation should be investigated using geographic information systems (GIS) and Digital Terrain Models (DTM). Given the IGA concept of a garden exhibition between land and water, the recultivation of brackish water reed in the marine-land transition zone seems to be very important and is therefore studied in more detail.

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The area investigated has a total size of 100 ha. A major part of it is occupied by the estuary of the Schmarler Bach, a conservation area (see figure 1). The colonisation of this area began in the early 13th century and it was later used for agricultural purposes. Drainage ditches were created to establish arable land beside the lower estuary areas of the small rivers. Aerial photographs taken after the Second World War show that the whole area was divided into small parcels without major natural vegetation. Close to that area large settlement activities took place in the times of the former German Democratic Republic, but the IGA site was excluded because soil and water conditions here were not conducive to settlement. Smaller rivers were regulated to provide protection against high tides. At the end of the 1970s, extensive parts of the site were filled with coarse sand, which reduced the marshland. Then, succession led to the establishment of different plant communities, apparently without any human interaction. Today the site is characterized by reed vegetation, woody areas along the former field structure and by fallow land with herbaceous vegetation.

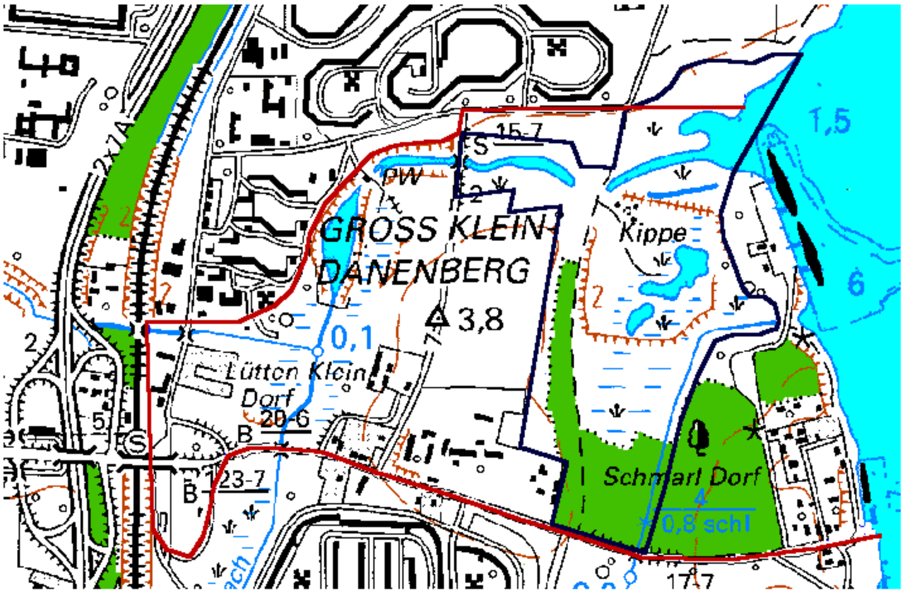

Figure 1:
The IGA 2003 site

The area investigated belongs to the moraine landscape typical of this region. Most parts are in the flat or undulating with heights between 0 to 5 m above sea level. The last glacial period strongly affected the area geologically, leaving numerous fairly typical microforms, so-called kettle holes. In the lowlands along the rivers Schmarler Bach, Klosterbach and Dragunsgraben peat soils with more than 1m peat height are dominant. With the ascent towards the border of the estuaries they build up the fringe area to the mineral soils (Humusgley). The area investigated is influenced by the tributaries of the River Warnow, e.g. the Schmarler Bach and the Klostergraben. At the Baltic Sea, the water table often rises considerably following major storms. Brackish water then floods the estuaries beside the River Warnow and its tributaries. This allows reed vegetation of brackish water, an ecologically valuable type of vegetation, to grow especially in areas without built structures and human interactions, mainly along the Schmarler Bach.

2. Vegetation Mapping as an Inventory of the IGA Site

The different vegetation types were mapped during the 1999 vegetation period. For this purpose the occurrence of plant species, both in its qualitative and quantitative aspects, was sampled and species combined to produce vegetation types based on the degree of floristic similarity. During the vegetation mapping the terrain was explored and homogeneous vegetation types were captured in a work map based on a orthophoto mosaic from 5 aerial images. The very high level of detail of the aerial imagery permitted a working scale of 1:2500. 77 test sites of size 25 square metres each were distributed over the whole site. The vegetation acquisition was evaluated in tables to produce vegetation types with similar floristic characteristics. The main plants associations identified were reed, ruderal, trees and brackish water reed (Zschunke, 2000) and detailed maps were created with ArcView GIS. A biotope type map exists on a scale of 1:5000 , differentiating between water, swamp and shore, agricultural land use, forestry and woodland as well as settlements, infra-structure and landscapes. This permitted comparison of the more detailed mapping of the vegetation types with the biotope types. An evaluation strategy was developed for nature conservation. Impacts of the planning on the vegetation were documented by maps with the evaluated vegetation types and by impact maps.

Special attention was given to the distribution of brackish water reed within the planning area of IGA 2003 (Theussig, 2000). The planning scheme for the site considers the fact that certain parts of the rivers are again connected to the natural water regime of the lower Warnow. So parts of exhibition areas may again be flooded by brackish water, which in turn may lead to the re-establishment of brackish water reed. Detailed investigations and mappings of the vegetation were carried out to derive a stochastic model for the height and disturbance intensity with a view to predicting the future situation.

3. Geoinformatics Methodology

3.1 Vegetation and Biotope Type Mapping, Evaluation and Impacts of the Planning

The extensive vegetation mapping and the mapping of the brackish water reed were transferred to Arc View GIS and set in a common reference frame. A digital orthophoto on the scale of 1:2500 was used as a geodetic reference system. The orthophoto was very useful for vegetation type mapping. A topographic map, scale 1:10,000, was also used. The detailed digital terrain model was taken to investigate the correlation of site factors with the occurrence of brackish water reed. The genesis of the area was examined by means of historical aerial imagery. The pre-state planning was also transferred to the GIS and future usage and the future terrain derived from this.

The evaluation method of the vegetation type mapping was implemented in ArcView GIS. This method, developed primarily for vegetation mapping, was used for both the vegetation types and the biotope types. As evaluation criteria we used, among others, the degree of naturalness, rareness and endangerment, of reversibility, of diversity and individuality. Target visions were developed which were later transferred to a scale in five graduations from very high to very low. The individual evaluations for each criterion were aggregated to a final result. The method was embedded in the tabular structures of ArcView GIS to produce evaluation maps.

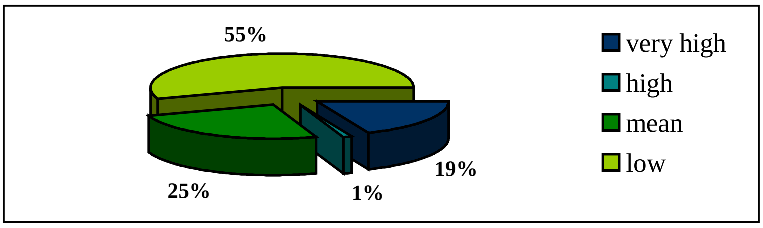

Figure 2:
Breakdown by area of vegetation associations of common valence

Lower valued vegetation types are dominant in the area investigated (55%, 36,0 ha, Fig. 2). These are plant associations which represent initial successive stages in the formerly agricultural parts of the terrain. To assess the impact of the IGA plans the maps with the evaluated vegetation types were overlaid with the plans. This permitted differences between current and future situations to be shown precisely in statistical and spatial contexts. In total 32.5 ha were judged to be influenced by the planning scheme, which is half of the IGA site of relevance to nature conservation. This terrain has mainly vegetation of lower ecological value. Sensitive areas are treated carefully by the planning scheme for the IGA site. The restoration of the smaller rivers in particular will lead to an improvement in ecological quality, which is described in more detail in the next chapter.

3.2 Prediction of Brackish Water Reed Distribution

Extensive investigations and mapping were performed at the IGA site, including the hydrological littoral, the soil and its salt content. The subdivision of the littorals was derived from hydrologic measurements. Interest centres on the part between 45cm below and 45cm above sea level. The salt content of the flood water and the soil were established by means of electrical conductivity measurements, gravimetric determination, and ion sensitive electrodes. The following results were: flood water and soil water is meso- to oligohaline (2 to 10 PSU), the salinity shows wide variability and the salt content in the soil decreases towards the terrestrial soils. Furthermore, a soil map covering the whole area was transferred to the GIS ArcView and soil samples were taken.

Detailed vegetation mapping was performed along 7 transects with a total length of around 200m. The transects were levelled in height within a range of 1-2m. The plant species occurrences, the height above sea level and the anthropogenic disturbances were sampled along this gradient. Gradient analysis was used as a method to investigate the causal relations between spatial distribution of environmental factors and the arrangement and combination of the plant associations. Thus, the impact of the environmental factors height and disturbance on brackish water reed were established by means of logistic regression procedures. The question was whether there is a significant correlation between the occurrence of the plant species and the measured environmental factors of height above sea level and disturbance. The regression was assumed to be a uni-modal Gaussian-logit-surface. A suitable approach is a logistic bivariate regression. The model in general consists of the polynomial:

$$
\begin{aligned}
g(x,z) &= \log it(P(x,z) \\
&= \log\left(\tfrac{P(x,z)}{1-P(x,z)}\right) \\
&= I + (Koeff_H * x) + (Koeff_S * z) + (Koeff_{HH} * x^2) + \\
&\quad (Koeff_{SS} + z^2) + (Koeff_{HS} * xz)
\end{aligned}
$$

The computations were carried out with PROC LOGISTIC from SAS Statistics Software, which computes “Maximum Likelihood” estimations for constant (“intercept”), regression parameters and error estimations. The regression equation for a logit function, where x is equal the height and z is equal the disturbance, needs to be transformed to P(x) – the probability of occurrence:

$$P(x,z) = \frac{e^{I+(Koeff_H * x)+...}}{1+e^{I+(Koeff_H * x)+...}}$$

This equation was programmed in Arc View and combined with the height model. Thus the probability of occurrences of individual vegetation types could be presented as a function of the terrain height on the IGA site. The spatial distribution of the vegetation units was determined based on the maximum probability in relation to the height above sea level $P(x)_{max}$. Testing the statistical significance improved the given statements. The significant models for different plant associations were graphed. The height classes and the disturbance intensity are displayed on the horizontal axis, whereas the probability of occurrence is displayed on the vertical axis (Fig. 3).

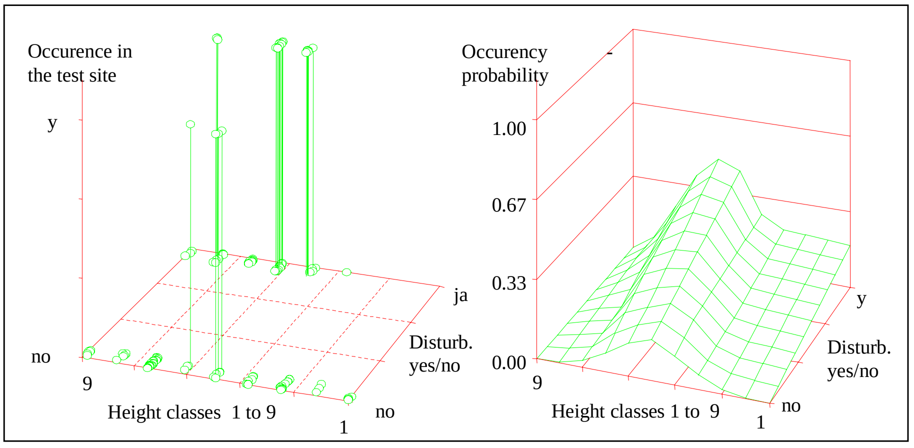

Figure 3:
Graphs showing input data and results of the statistical analysis for *Aster tripolium* vegetation type (needle diagram of the raw data and estimated occurrence in regression surface based on the logit function).

The model illustrates that this vegetation type has a somewhat higher likelihood of disturbed areas and a marked preference for lower heights near sea level.

After that statistical modelling a terrain model was calculated for the current situation as well as for the future situation. This was based on surveying data, contour lines, watersheds, and embankments. The data was then combined in a TIN structure followed by a grid conversion. A grid was preferred to do the following computations in the raster modus, embedding the statistical model with ArcView Spatial Analyst. The height range from -45cm to +45cm was reclassified in height classes 1 to 9. The probability of occurrence of the individual plant societies in future was thus forecasted spatially and visualised cartographically.

4. Results

The impacts of IGA planning were modelled and estimated very well using GIS and DTM. The restoration of the smaller rivers and the opening towards the Warnow could possibly lead to a two-fold increase in brackish water reed occurrence. Current IGA planning impacts on around 50% of the IGA site, mainly areas with vegetation of lower value.

Nevertheless the results of these investigations depend to a considerable degree on the amount of work one is willing to devote to vegetation mapping. It was shown that the information content of the vegetation type mapping is superior to that of the existing biotope type mapping. Thus for instance 14% of the impacted area is covered with vegetation types of higher conservation value, a fact which was obliterated by the less discriminate biotope mapping.

All in all, the planned rearrangement of the whole area and its use for an international garden exhibition results in positive nature protection effects. The method applied may be used in a similar way for other planning scenarios, too.

References

Theussig, D. (2000): Aktuelle und prognostizierte Verbreitung von Brackwasser-röhricht im Planungsgebiet der IGA 2003 (unpublished degree paper at the Department of Land Cultivation and Environmental Protection, Rostock University)

Zschunke, S. (2000): Die GIS-gestützte Bewertung der Vegetation in der Niederung zwischen den Rostocker Stadtgebieten Schmarl und Groß Klein für die Planung der IGA 2003 (unpublished degree paper at the Department of Land Cultivation and Environmental Protection, Rostock University)