Renaturalization of Parts of the National Park Neusiedler See-Seewinkel/Fertö-Hansag by the Aid of Laser Scanning

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Abstract The Neusiedler See is situated at the lowest point of the Small Hungarian Plain, in a basin without outlet, at about 113 metres above sea level and with a surface area of about 320 km^2. East of the lake extends the Seewinkel plain with an area of about 450 km^2. For the National Park the meadowlands, created through use for traditional haymaking, the remaining pastureland and the unique, frequently evaporating saltwater pans with their varying salinity levels are areas of particular interest. In the 20th century the water management in the Seewinkel (artificial draining, over-exploitation of groundwater) caused severe damage to the natural hydrological cycle and the aquatic ecosystems, and from 1900 to nowadays the water surface area was reduced by 75%. In the future, the environment Seewinkel needs to be managed in landscape units, based on integrative hydrological, physico-chemical, biological and socio-economic assessments. One aspect could be the renaturalization of parts of this landscape.
Potential wetlands in the National Park Neusiedler See-Seewinkel/Fertö-Hansag can be detected by the aid of different sources. Historical maps are one possibility to reconstruct earlier positions of wetlands. Existing maps for this purpose are the land register from 1856 or different topographic maps as a product of the survey emerged in the 18th and 19th century. A more up to date and a very accurate method for locating potential wetlands is the new technology of airborne laser scanning to generate digital terrain models. Due to the very high point density of laser scanner data, even very shallow natural depressions can be determined. A short introduction of the technical background of this way of data acquisition is presented. Furthermore the issue of the derivation of digital terrain models from laser scanner data is addressed. Finally the combination of the digital model and orthophotos and land register is effectuated. Such a fusion of data is performed in a geographic information system (GIS).

1. Introduction and purpose

The Neusiedler See is situated at the lowest point of the Small Hungarian Plain, in a basin without outlet, at about 113 metres above sea level and with a surface area of about 320 km^2. East of the lake extends the Seewinkel plain with an area of about 450 km^2. For the National Park the meadowlands, created through use for traditional haymaking, the remaining pastureland and the unique, frequently evaporating saltwater pans with their varying salinity levels are of particular interest. These biotopes are internationally famous and important for their many nesting or migrating wader species, not to forget the many orchid species, salt tolerant plants, dragonfly and butterfly species, grasshoppers, beetles, and spiders.
However, from the beginning of the 20th century wide spread artificial draining took place which did withdraw the surface waters from that area very effectively and also lowered the water table in waterlogged soils. Long-term extraction of groundwater for irrigation exceeded long-term recharge rates leading to regional groundwater over-exploitation.

Of the originally more than 100 Seewinkel pans, also called „Lacken“, the majority have been destroyed by draining or changing their salinity by connecting them with the groundwater or pumping groundwater into these lakes during summer months when they are usually dry.

More than 100 pans can be recorded for the year 1900, and nowadays only 36 are still existing of which 20 can be called healthy ecosystems. The water surface area was reduced by 75%.

In parallel to the draining the agricultural area and the intensity of the management has been increased. Frequently wineyards directly border upon the water bodies. As a consequence, the nutrient content of the water of the pans increased.

Obviously sociopolitical and socioeconomic motives and decisions led to this development. A cost-benefit analysis for drained systems and intensive agriculture versus loss of conservation, aestetic and recreational values never was performed, the latter even generally disregarded. We need a catchment based management of water, which means controlled extraction of groundwater and inhibition or reduction of the outflow of surface waters from the area.

In the future, the environment Seewinkel needs to be managed in landscape units, based on integrative hydrological, physico-chemical, biological and socioeconomic assessments.

For such an approach we need new research like

- multidisciplinary data collection, including monitoring on past and present system state, behaviour and functioning;
- exploration of methods to organize, display, and illustrate the interrelationships of the data collected, e.g. National Park-GIS, computer simulations;
- exploration of methods of transdisciplinary synthesis of varied data, e.g. multipurpose, integrative targets and indicators.

2. Different sources for monitoring on past and present state of wetlands

Landcover changes can be detected by documenting the historic and the actual state of landcover. In the following the issue of monitoring will be restricted to the most important element of landscape in the National Park Neusiedler See-Seewinkel/Fertö-Hansag , the wetlands.

As historic sources the following documents are available:

- The topographic map of the first land survey, also named after its principal Joseph II, issued about 1780, is multicoloured and has a scale of 1:28.800.
- During the 19th century the second and the third land survey were implemented by order of emperor Franz I. The topographic map of the third land survey from 1870 (scale 1:25.000) is still existing and particularly valuable for recovering these system states in the context of renaturalization.
- Finally, there are the maps of the land register of 1856, at the very large scale of 1:2.800.

These historic maps enable a topo-chronological analysis of the past state of landcover, especially the state of wetlands and pans. Figure 3 and 4 show obvious changes of shape and extension of the pans.

As modern documents of landcover the following have been provided: For use in the project two different series of colour infrared orthophotos are available: one from 1998 with a resolution of 0.25 m and another series from summer 1999, flown at a time near the laser scanning flight (see later), with a resolution of 0.4 m.

Historic maps and digital orthophotos provide rather insufficient information about the terrain heights, hence a high-quality digital terrain model has been generated by the new technology of laser scanning that will be explained in more detail below.

3. Airborne Laser Scanning

Laser scanning represents a new technology for the highly automated generation of digital terrain models and surface models (e.g. Petzold, 1999). In the following section the major components of a laser scanning system, the technical background and the method of measuring will be described. The particular parameters of the laser scanner flight for the area of interest are topic of the second chapter, while the third section focuses on georeferencing aspects.

3.1. Description of the Laser Scanning system

An Airborne Laser Scanner system basically consists of two components, an active scanning device, i.e. a laser rangefinder (LRF) and a positioning unit with GPS-receiver and Inertial Navigation System (INS). The laser scanner transmits high-energy light pulses towards the ground where they are reflected back to a light sensor in the scanner. The running time of the emitted beam on its way to the ground and back is measured. The scanner delivers distances between the sensor and the reflecting point on the surface. The direction of the beam can be derived from the instantaneous (interior) angle of the scanning system and the aircraft's (exterior) angle, given by the INS. The position of the aircraft and the origin of the laser sensor is determined by the GPS-receiving unit. (Fig. 1) (Wehr & Lohr, 1999).

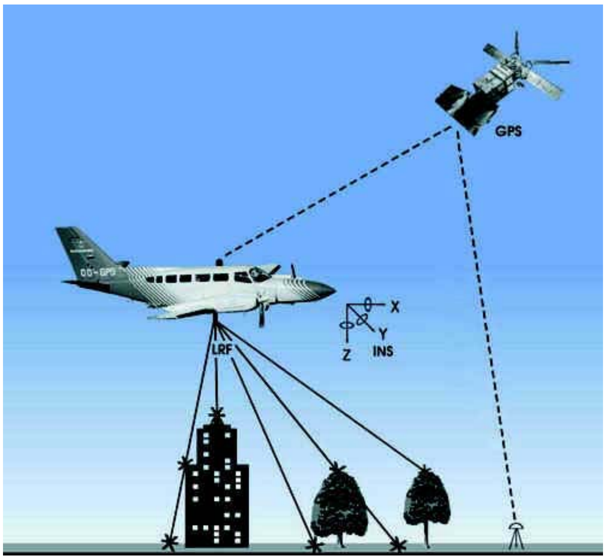

Fig. 1 Principle of Airborne Laser Scanning
[source: http://www.eurosense.com]

3.2. Parameter of the flight and scanning

The German company TopoSys provided the laser scanner data for this project. The flight was carried out in August 1999. The scanned area extends about 4 km in east-west direction and about 6 km in north-south direction and is situated east of the Neusiedler See and north of the village Illmitz (Fig. 2.)
The width of a flight strip is a function of the scan angle and the flying height. With about 960 m above ground one strip is about 230 m wide, resulting in 28 slightly overlapping strips for covering the area of interest. The sidelap is approximately 50 m. The scanning process generates parallel profiles of laser points orthogonal to the flight direction with a spacing of 1.9 m in our case and a very high point density in the flight direction, i.e. 11 cm

in this project. The high density of 9 ground points per m² results in a total amount of more than 200 million laser points.

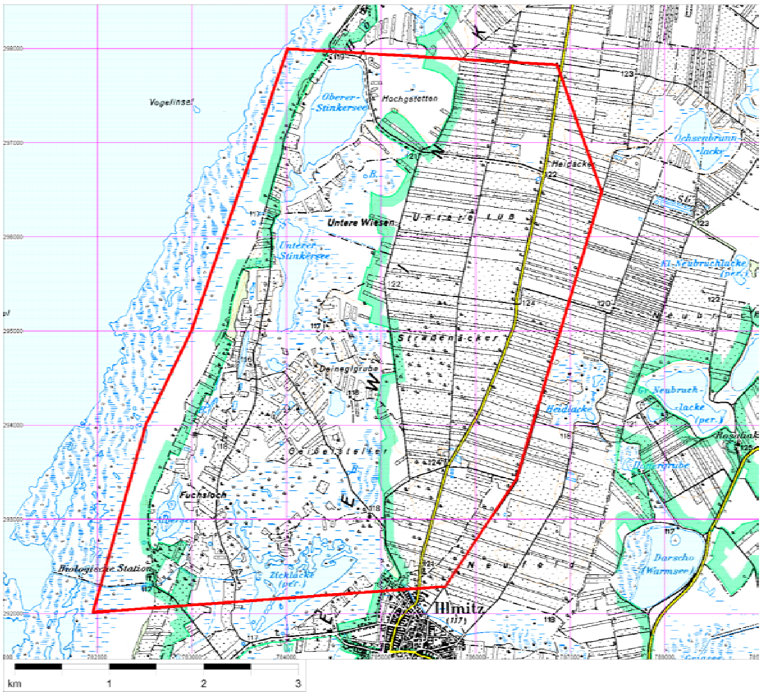

Fig. 2 Area of interest near the Neusiedler See plotted on the Austrian topographic map, original scale 1:50.000. [source: Austrian Federal Office of Meteorology and Surveying, publishing rights requested]

3.3. Georeferencing

After the flight the recorded positioning data have to be analysed in a post processing step. Then, for each laser point the 3D co-ordinates can be calculated, first as polar co-ordinates, finally as XYZ co-ordinates of a global (reference) system.[1]

Surfaces derived from laser scanning data may show Z-discrepancies in overlapping regions of adjacent flight strips. Their magnitude in the current project was a few decimetres, big enough to seriously impair the quality of results where shallow water levels are crucial parameters.

The deformations probably originated in orientation deficiencies of the GPS or INS system. Photogrammetric block adjustment provides an appropriate tool for minimizing discrepancies of that kind. Each individual laser scanning strip serve as "model" for the adjustment where additional parameters in form of polynomials are applied to model systematic GPS or INS errors. For connecting the strips to one uniform block tie information is needed. The conventional photogrammetric way of observing well-defined tie points in overlapping areas cannot

[1] As global co-ordinate system the European Terrestrial Reference System 1989 (ETRS 89) was chosen. In the course of a Phare project for the Hungarian part of the Neusiedler See data (topographic maps, orthophotos, land register, etc.) were transformed to the same European co-ordinate system. In this manner a Nationalpark GIS can be used for analysis and planning across national borders. The responsible person for the Phare project was Dr. Márkus. The transformation of the Hungarian data to the ETRS 89 was performed by Dr. Bácsatyai and DI Király. They are all members of the University of West Hungary. The appropriate preparatory work for the georeferencing in the Austrian part was performed by DI Titz (Department of Advanced Geodesy, Vienna University of Technology), Dr. Erker (Austrian Federal Office of Meteorology and Surveying) and DI Mandelburger (Institute of Photogrammetry and Remote Sensing, Vienna University of Technology).

be pursued in the case of laser scanning data which are, according to the acquisition principle, irregular samples of elevation information. A work-around is possible by defining small surface patches in areas where tie information is required. With the help of those patches homologous points can be determined. Control points, i.e. points with known XYZ co-ordinates, allow the transformation of the entire block into the global (reference) co-ordinate system. It can be carried out in one adjustment step together with fitting the strips to each other.

If the correction of the above mentioned height discrepancies were neglected, the result, i.e. the digital terrain model, would slightly be shifted in the affected regions. In the current project the height differences of the homologous patches were ± 9.4 cm before adjustment and ± 3.6 cm after adjustment (95% probability). The method of adjustment is described in more detail in (Kager & Kraus, 2001), while the results will be discussed in (Horvath, 2001).

4. Analysis of the Laser Scanning Data together with the other sources

4.1. Detection of pans

After the adjustment of the laser scanning strips a digital terrain model is calculated. The method is described in (Kraus & Pfeifer, 1998). A visualization of this high-resolution terrain model (grid width 1 m) as contour lines gives a first overview of interesting areas with natural shallow depressions.

A problem occurs in densely vegetated areas (reed, crop). Since the laser beam cannot penetrate through dense vegetation to the terrain, the derived elevation model does not represent the bare ground. Appropriate filtering of the data as a first processing step offers a possibility to avoid the problem.

The procedure for finding areas for possible renaturalization commences in areas with existing „Lacken" where natural depressions are sought for. By using historic maps (like those depicted in Fig.3 and Fig.4) positions of former „Lacken" and former extents of still existing pans may be detected. The visualisation of the DTM by colour coding of the terrain height (Fig.5) can be excellent help. We recommend to start with blue colour for elevations up to the water level of a „Lacke" and continue with green, yellow and brown tones for elevations above. By raising the virtual water level areas in the surroundings of the investigated region may be flooded where in reality water does not exist any more. The current state can be found in the orthophotos. Figure 6 shows the situation in summer 1999, when the water surface area may be smaller than in other seasons. Those virtually flooded areas indicate potential „Lacken" to be investigated for possible renaturalization.

In Figure 5 the heights up to the level of 116.9 m are coloured blue globally for the shown area extending 6 km in north-south direction. Because of the different height levels of the pans, the water level of the southern pans already overflow at this particular level, while some smaller pans in the north are not yet filled with water. By selecting smaller areas (e.g. area in Fig. 7) for interpretation and analysis, more accurate results in the sensitive height evaluation can be achieved.

Fig. 3 Parts of the topographic map of the first land survey, 1780, original scale 1:28.800. [source: BIXa S27 Col IV Sect3, Austrian State Archives, publishing rights requested]

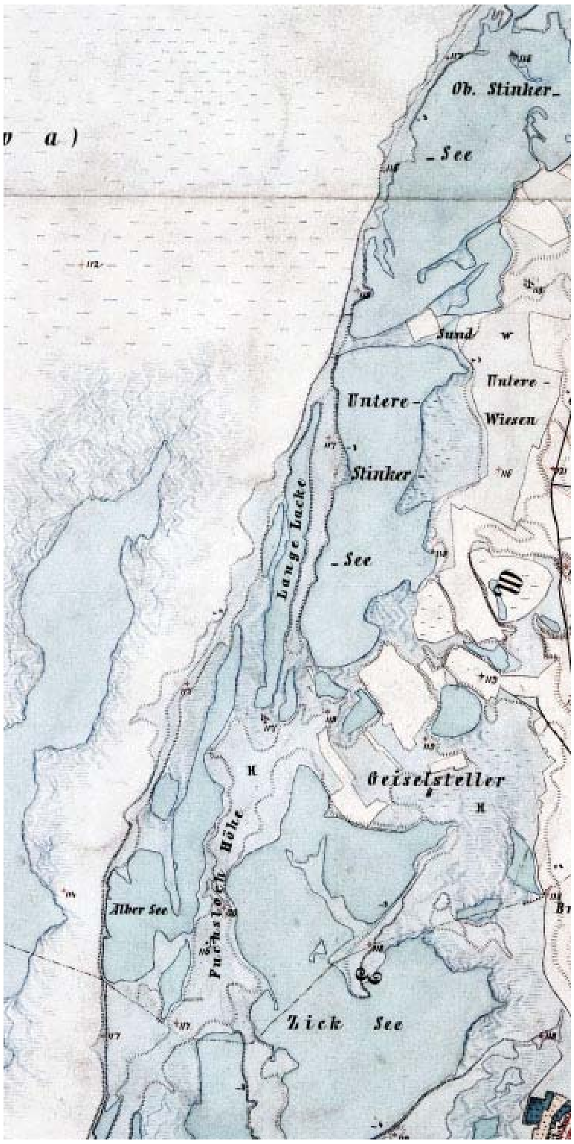

Fig. 4 Parts of the topographic map of the third land survey, 1870, original scale 1:25.000. [source: 4857/4, Austrian Federal Office of Meteorology and Surveying, publishing rights requested]

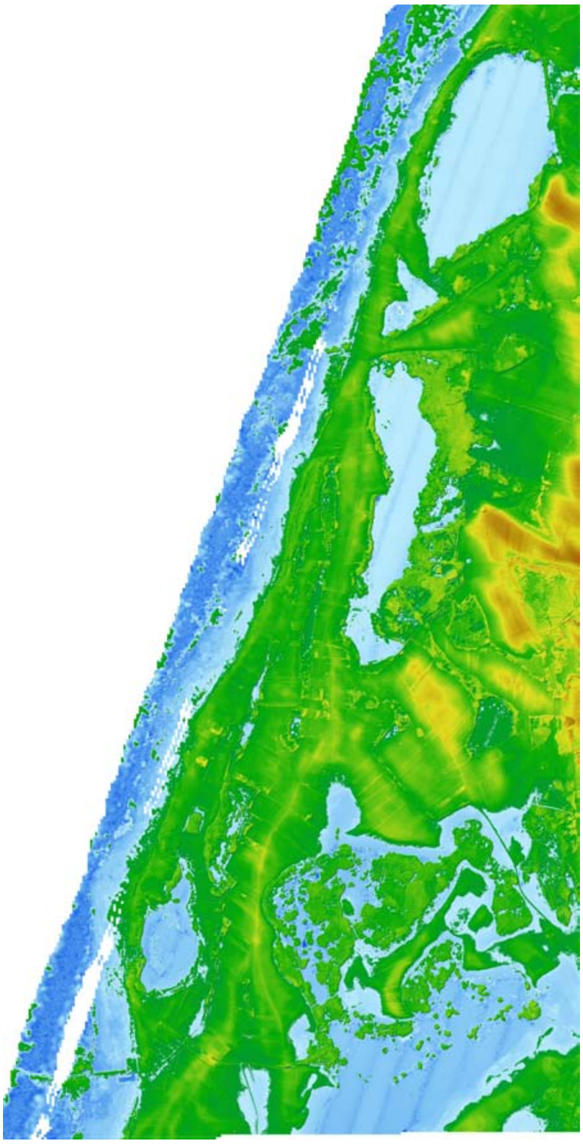

Fig. 5 Coloured height coding of the terrain model - blue tone up to 116,9 m, 1:40.000.

Fig. 6. Colour infrared orthophoto, summer 1999, 1:40.000. [source: Biologische Station Illmitz]

In the following two typical examples of areas of interest for renaturalization are presented. The extent of the very narrow, but long pan called "Lange Lacke" west of "Unterer Stinkersee" has dramatically changed in the last century. The former length of the pan as documented by the third land survey of 1870 was some 1750 m, while today, as one can see in the orthophoto (Fig.6), the pan's size has decreased to 500 m. The orginal pan has significantly changed its shape and is now split up in one larger and a few smaller parts. With the help of the DTM the present location and the elevation properties in the area of "Lange Lacke" can be investigated in more detail.

The second example focuses on a small pan near "Zicklacke" west of the village Illmitz. In contrast to the "Lange Lacke", which still exists although with much smaller extents, this pan has vanished completely. In the map of the third land survey of 1870 its size is about 0.2 km². The coloured height coding shows the current situation in location and elevation. By raising the virtual water level up to 116.9 m a simulated water surface appears in the region of the former pan (Fig. 7). The orthophoto of summer 1999 may serve as proof for the derived state of the pan. One can see the surroundings of the empty pan with two drainage canals running across (Fig. 8).

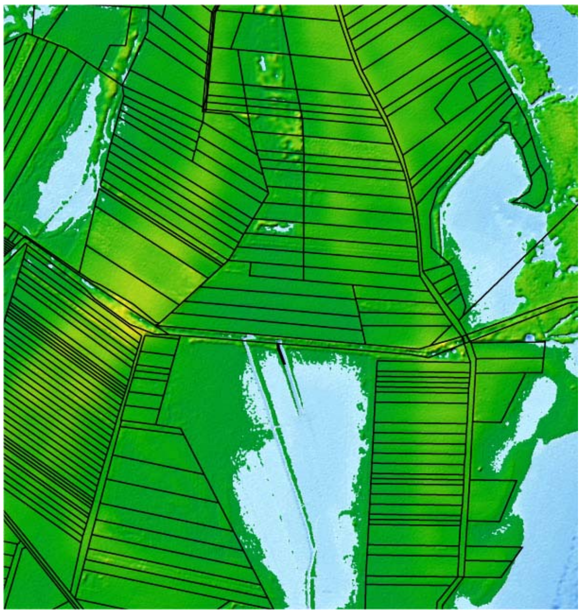

Fig. 7. Coloured height coding of the terrain model of the area of the small pan (lower side in the middle) in the west of Zicklacke combined with the land register, blue tone up to 116,9 m, 0.8 x 0.8 km. [source - digital land register: Amt der Burgenländischen Landesregierung]

Fig. 8. Part of the colour infrared orthophoto summer 1999, area of the small pan (lower side in the middle) in the west of Zicklacke, [source: Biologische Station Illmitz]

4.2. Further applications of the digital terrain model

An important application of the coloured height coded terrain model are **water level scenarios**. With the terrain model it is possible to visualise any water level to recognize thereby flooded areas. This is very important for planning and management issues in the national park region, because endangering for agricultural use and for the security of men due to higher water level can spatially be much better assessed. Figure 5 shows the Zicklacke (in lower part of picture) with a very high water level as it is the case in spring after good rain and snow in winter.

Further application possibilities of the digital terrain model are **calculation of profiles, depths, volumina and surface areas.**

Beside the visualisation of the terrain model as colour height coding an important potential of the terrain model is the possibility of laying vertical cuts through the terrain and analysing the course of the terrain in elevation along a cut line. Fig. 9 shows such a profile through the little pan beside the Zicklacke; the course of the cut line belonging to is marked in Fig. 10. In the profile one can see, that the pan continuously slopes in the eastern part (right in the profile), then forms a little plateau and after the jump at the drainage canal stays at this little higher level.

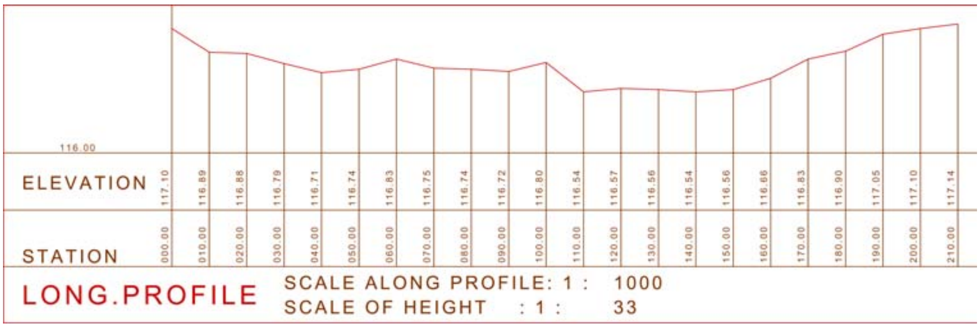

Fig. 9. Profile through the little pan west of the Zicklacke along the cut line shown in fig. 10

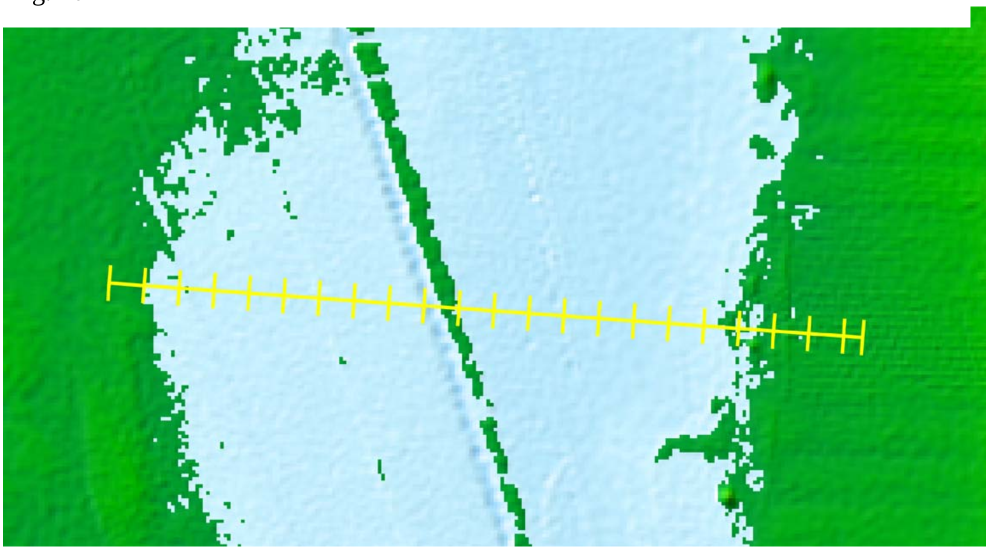

Fig. 10. Position of the profile shown in fig. 11 through the little pan west of the Zicklacke

Furthermore it is possible to calculate the distance between a certain reference plane, e.g. a certain water level, and the terrain model for any point. In this way the depth of a potential Lacke can be determined.

By use of such a reference plane and a limiting polygon – e.g. the course of a certain contour line – it is also possible to calculate the volume of the enclosed solid. In this case it can be a water volume. This value can be interesting for considerations of artificial flooding. In this calculation also the flat area – e.g. the water surface area – and the surface area of the terrain enclosed in the limiting polygon is determined. These values are useful for an estimation of additional evaporation etc.

In the example of this little pan beside the *Zicklacke* a plane with the height of 117 m and the contour line of 117 m have been chosen as reference plane and as limiting polygon respectively (Fig. 11). Based on these assumptions, following parameters were calculated: the volume of the virtual water body like in a flooding up to 117 m, the emerging (flat) water surface as well as the surface of the terrain inside the limiting polygon (in absence of water). Results:

Volume	14511.42 m³
„Water surface“	58219.42 m²
Terrain surface	58391.75 m²

One can see that the terrain surface is only little bigger than the flat water surface because of the small depth.

Fig. 11. The little pan west of the Zicklacke with a virtual water level of 117 m; contour line 117 m in black; calculation of volume, area and surface

4.3. Combination of digital terrain model, orthophotos and digital land register

Important questions that sooner or later arise in the course of the renaturalization project are the following:

- Which parcels may be involved in areas of potential renaturalization?
- What is the current landuse in that areas?

These questions have to be answered as soon as the decision has been made to renaturalize and/or to integrate an area into the National Park, because negotiations with the owners have to be initiated, where matters of closing cultivation, of turning into fallow land, of lease or purchase by the National Park's administration and other legal subjects have to be discussed and worked out.

An ideal basis for answering technical and legal questions, not only during the decision making process, is a Geo-Information System (GIS) that allows management and analysis of a great variety of data. The integration of DTM, orthophotos and digital land register in a GIS may be just one basic, though very important process. By linking the results of the technical investigations (with the help of DTM and orthophotos) to legal information (digital land register), for instance, a detailed list can easily be created that contains the parcels and their respective owners. Data fusion by GIS analysis has always been an invaluable help for decision makers.

5. Concluding remarks

The project is a first step in establishing a National Park information system. The spatial fundament is built up by basic data sets such as a very accurate DTM of high resolution derived from laser scanning data; digital colour infrared orthophotos; and vector data of the digital land register. Already at the present state of the art it has ideal data viewing capabilities and allows the efficient and effective visual examination of solutions. An information system of that sort has to be open to many other data sets leading to a multidisciplinary management and analysis tool. It should become a powerful tool to assist in multiple criteria spatial decision making and conflict resolution (scientific, political), as well as for monitoring the past and present state and future developments of the valuable but vulnerable ecosystem of the National Park Neusiedler See - Seewinkel / Fertö-Hansag.

Acknowledgements

We would like to express our thanks to the partner of the INTERREG IIC project “National Park Information Systems (NPIS) in the Central European Space – Homogenization and Operationalization of GIS-Concepts for Monitoring and Planning by Means of Geomatics (GIS, Laser Scanning, Remote Sensing) and Field Work” in Dresden (head: Prof. Csaplovics) and to the provincial government of Burgenland for providing the digital orthophotos and the digital land register.

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