Using GIS for Visibility Assessment of a Wind Farm in Perenye, Hungary

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1 Introduction

Perenye Wind Farm is planned to be built in West-Hungary, close to the Austrian border. The plans included 11 wind turbines situated in an arable area near the village of Perenye and neighbouring settlements, to the south of the scenic Kőszegi Mountain and the so-called Írottkő Nature Park. The visibility assessment of the wind farm was commissioned in 2009 by the West Transdanubian Authority for Environmental Protection.

Windmills and wind turbines are not traditional landmarks of the Hungarian landscape. Significant number of wind farms appeared in the last few years, mostly in the windy western arable countryside. The plateau, where the Perenye Wind Farm is planned to be located, is surrounded by forested hills and mountains, scenic hiking routes and lookout points. It is an exceptional landscape in the scenic protection zone of the country where the most developed and most popular hiking route, the Blue Trail, starts from. These circumstances made it necessary to carry out a complex visibility assessment integrating many visual aspects, in order to forecast possible changes in the scenery induced by the planned wind farm.

The aim of the assessment was thus to forecast what effects the wind park will have on the appearance of the landscape. Therefore, the visibility assessment had to contain a study of the main routes and viewpoints of the area from which the changes of the scenery to be caused by the wind farm become apparent. Further the possible ways of minimising the visual effects of the wind farm through landscape design methods had to be considered and recommendations had to be given for new roadside plantings as well as for the ideal colouring and assessment driven displacement alternatives of the turbines. This paper introduces how a set of GIS tools can be used in the final steps of the planning process of a wind farm in frame of a visibility assessment.

2 Background

The visibility or visual impact assessment studies of wind farms are published in great number either with GIS software (MÖLLER, 2006; RISSER, 2007; AYDIN ET AL., 2010) or with CAD tools (HURTADO ET AL., 2004). It is a wide-spread method to use GIS tools to make a comparison between selected sites regarding the feasibility of wind energy development (PANTALEO ET AL., 2005; MÖLLER, 2006) and optimized site selection for wind farms (AYDIN ET AL., 2010). The wind power resource, the accessibility of the wind farm by roads and other infrastructure, the reliability of the electrical transmission system, the investment costs, the energy prices, the profitability, the available subsidies, the
property rights, the land ownership, the land structure, the ecological and environmental aspects are all essential and decisive aspects of planning and locating wind farms. The visibility of the turbines and the assessment of their aesthetic impact are key social issues in most of the cases.

Visibility and visual impact assessments mostly deal with the following variables:

- total area of the farm (TORRES SIBILLE ET AL., 2009; PANTALEO ET AL., 2005; MEYERHOFF ET AL., 2010)
- density of turbines (MÖLLER, B. 2009; MÖLLER, 2006)
- road length or travelling time affected by the view of turbines (RODRIGUES ET AL., 2009; SWOFFORD & SLATTERY, 2010)
- colouring of turbines (BISHOP & MILLER, 2007; TORRES SIBILLE ET AL., 2009)
- change of the background attributes (TORRES SIBILLE ET AL., 2009; OZIMEK ET AL., 2009)
- area or houses affected by the view of the turbines (TSOUTSOS ET AL., 2009)
- populated area affected by the view of the turbines (TSOUTSOS ET AL., 2009) or distribution of population (MÖLLER, 2006)
- number of wind farms (LADENBURG & DUBGAARD, 2007)
- rotor diameter (PANTALEO ET AL., 2005)
- continuity (TORRES SIBILLE ET AL., 2009) – meaning the “number of turns in the silhouette”
- contrast (BISHOP & MILLER, 2007; OZIMEK ET AL., 2009)
- lightness (BISHOP & MILLER, 2007)
- climate (TORRES SIBILLE ET AL., 2009)
- movement – moving or stationary blades (BISHOP & MILLER, 2007)
- observers height (RODRIGUES ET AL., 2009)
- weather, or atmospheric conditions (TORRES SIBILLE ET AL., 2009)
- open view to the turbines (TSOUTSOS ET AL., 2009)
- forest cover (MÖLLER 2006; RODRIGUES ET AL., 2009)
- built environment (MÖLLER, 2006)

In some researches visibility indices (HURTADO ET AL., 2004; BISHOP & MILLER, 2007) also termed aesthetic impact indicators (TORRES SIBILLE ET AL., 2009) are calculated from some of the variables listed above. These indices can provide a type of visibility assessment and can be expressed on maps. To analyse visual impact a simple and reasonable solution is to
overlay visibility and population maps (MÖLLER, 2006). Most of these maps, based on cumulative layers, contain an elevation model and software generated viewsheds. The more variables (see the list above) are included and are represented by layers, the more complex the result of the assessment is. This method of cumulative viewsheds forms the GIS-based decision support system (RAMÍREZ-ROSADO ET AL., 2008).

Such a system is sentenced to be universal, and adaptable to any regions, but it needs to be re-calibrated in every project to fit the actual plan, setting, landscape, situation and timing. In case of Perenye Wind Farm the GIS-based decision support system was commissioned in the very final steps of the planning process. The formerly prepared environmental impact assessment (EIA) had to be extended by a visibility assessment of the planned turbine settings. The West Transdanubian Authority for Environmental Protection found that visibility aspects are missing from the EIA. The need for quick results and effective solutions for minimising visual impacts of the turbines a GIS based decision-support tool was created based on the method of cumulative viewshed layer generation.

3 Method

When the Environmental Authority commissioned the visibility assessment the location of the planned turbines was already defined on the level of land parcels. The method of the visibility assessment had to limit itself to this situation. The planned turbines in Perenye needed either approval of their originally defined location, or recommendation for displacement. Additionally wood plantations for view protection and a colouring plan had to be suggested (Fig. 1).

![Diagram of visibility assessment](image)

**Fig. 1:** The concept of the visibility assessment of Perenye Wind Farm
The viewpoints defined by the Environmental Authority consisted of the traces of the two major roads running close to the site, and a well-known look-out point of the Köszegi Mountain called Szent Vid Chapel. People usually perceive the landscape when they are travelling, hiking or visiting lookout points out of populated places. That is one more reason to include viewpoints, hiking routes, railways or roads as well where the impact of turbine visibility can be more significant. The official guidelines for the development of wind energy plants and the national standard of aesthetic assessment of landscapes (MSz 20372) was not advising satisfactory visibility assessment methods for wind farm displacement purposes, thus we decided to broaden the scope of the visibility assessment according to international practice.

A decision-support system was set up based on the cumulative viewshed generation method. ERDAS Imagine and ArcGIS software were used as tools in the decision-support system. Viewsheds were generated by the Virtual GIS Module of ERDAS Imagine as it offered more options for the analysis of different height-ranges of turbines than ArcGIS. For this purpose the best available digital elevation model of 5 m spatial resolution from the Institute of Geodesy, Cartography and Remote Sensing was used.

Fig. 2: Visualised layers in the decision support system (vertically distorted model)
This data represented the theoretical earth surface without land cover height. High resolution satellite images of Google Earth were visually interpreted and digitized to create forest cover layer. In Perenye and the surrounding landscape the forests are dominated by extraneous, evergreen pine trees (Pinus nigra, Pinus sylvestris). Most of the forest patches are plantations, and are about the same age and bear approximately the height of 15m. We decided to include the forest land cover in visibility assessment and generate viewsheds for the land surface covered by 15m average forest height.

Turbine visibility was analysed for three different height-ranges (see Fig. 3.). Single, grouped and multiple visibility of turbines was assessed in detail. The system could visualise whether a piece of land is saved from the view of turbines because of the elevation, the forest cover, or the viewshed of the forest nearby. The road network the hiking routes and the look-out point were assessed and visualized depending on what length of the column and how many of the turbines were visible from them.

The layers of wind turbines (location and physical parameters), settlement areas, municipality borders, plot map of land ownership, location of lookout points, major roads, railways, hiking trails and all viewshed layers were integrated to ArcGIS 9. This software provided a simple overview of the viewsheds and the multiple layers could be visualised. These all viewsheds, layers and software composed the decision-support system.

Fig. 3: Multiple visibility of towers
The assessment was carried out by creating numerous visibility maps as follows:

- Visible landscape from look-out points
- Overall visibility of the wind farm
- Visibility of each turbine for various heights (from 5m, 75m, and 140m)
- Visibility from roads, railways, trails
- Visibility with proposed aforestation or wood plantings
- Visibility gain in case of turbine displacement (new setting)

4 Results

The results of visibility assessment were summarized in more than 40 maps. The view from the popular tourist attraction, Szent Vid Chapel look-out point, was assessed to be affected by all the turbines. There is no option to minimize this visual influence as the turbines are right in the middle of the main scenery. And the look-out point provides a bird-eye’s view of them. The most complex interpretation of wind farm visibility results is shown by Figure 3. It presents a wide scale of turbine visibility from the case when the top of few turbines are visible to the situation when all turbines are fully visible.

The GIS-based decision-support method made it possible to establish recommendations based on purely visual aspects. The original wind farm plan was revised and different alternatives were identified with new locations of the turbines within the same parcel each. The displacement of turbines was only possible inside of the respective parcels. At this last phase of the planning process there was no option to recommend turbine displacement on other pieces of land. The displacement of turbines was only possible inside of the respective parcels. At this last phase of the planning process there was no option to recommend turbine displacement on other pieces of land. At this last phase of the planning process there was no option to recommend turbine displacement on other pieces of land. At this last phase of the planning process there was no option to recommend turbine displacement on other pieces of land. At this last phase of the planning process there was no option to recommend turbine displacement on other pieces of land. The lowest elevation alternative inside the originally planned parcel was analysed in case of each turbine, but only in four cases did this alternative provide real visibility gain (Fig. 4.) The turbine Nr. 5L, which is a lowest elevation alternative, offers more than 5% less visibility of the total area than version 5P, which was the original setting of this wind turbine. This 5% appears to affect the scenery in two neighbouring villages Lukácsháza and Gyöngyös falu significantly.

The results of the digital visibility assessment were turned into two main groups of proposals. The replacement of four wind turbines was proposed in order to decrease the area affected by the visibility of the turbines. By placing them to lower elevation alternatives more than 5 km² was saved from their view. Woods of mingling evergreen and deciduous trees were recommended for planting for scenic purposes along the visually most affected sections of major roads.

The views resulting from our proposals were illustrated by photo-realistic visualisation. Different colouring possibilities demonstrated the foreseeable visual effects. The authority has accepted the assessment and the Perenye Wind Farm is going to be built with the proposed additional plantations and appropriate measures. The applied methodology of viewshed generation offered a quick solution for a plan oriented visibility assessment, and produced concrete results, which enabled us to propose easily realizable and effective recommendations for decision-makers.
5 Discussion

Although the present application of a decision support system was satisfactory in case of Perenye Wind Farm visibility assessment in many cases the use of GIS tools is supplemented by other means of inquiry, such as questionnaires and interviews, in order to involve more people in projects and reach more complex results. The above mentioned methods can support visual impact oriented research efficiently (BISHOP & MILLER, 2007; ELTHAM ET AL., 2008; TSOUTSOS ET AL., 2009; GEE, 201; SWOFFORD & SLATTERY, 2010) to assess the significance of visibility. These occasionally include visualisations, various scenarios of different settings of turbines, interactive planning rooms (ZEHNER, 2009) with simulations in order to facilitate participatory planning. This tools can be recommended for all the investors to estimate the possible reaction of the inhabitants towards the planned investment in advance. There are several projects where the attitudes towards the wind
farms interest level of locals, activists (Bishop & Miller, 2007) instinct to NIMBY (Swofford & Slattery, 2010) (Eltham et al., 2008) willingness to pay for change turbine setting local turbine history (Bishop & Miller, 2007) and relation to peoples identity can be surveyed. There are researches which analyse the visibility results by age, (Eltham et al., 2008) (Ladenburg & Dubgaard, 2007) gender, geographic regions, income, education, view to farm (Ladenburg & Dubgaard, 2007) etc. These subjective variables can reveal a more complex situation, refine the significance of visibility and give a detailed view of visual impact. All these tools are highly recommended for municipalities and investors.

6 Conclusions and Outlook

As a result of our work, the Environmental Authority accepted the plans of the wind farm on the condition that all assessment driven instructions for landscape protection have to be realized by the investor. The GIS-based visibility assessment worked well in case of Perenye Wind Farm. The applied method in Perenye based on cumulative viewsheds and other layered information can satisfy “last minute” turbine displacement and scenery protection requirements. The various methods of generating viewshed based maps in ERDAS Imagine and the options in ArcGIS to visualise results were proper tools for the assessment. These two software perfectly supplement each other. Roads and pathways affected by wind turbine visibility could be assessed and visualised with them. The visibility gain method based on turbine displacement was sufficient to minimize the visual effects of turbine visibility. Nevertheless the use of visibility assessment as a final step of locating turbines could lead to controversies regarding energy efficiency. A turbine displacement to the lowest elevation alternative could mean that the wind resource capacity will be used less efficiently. It is highly recommended to include the visibility assessment already in the first site selection procedures. If the wind farm location and turbine setting is selected as a result of a complex site assessment process, including visibility aspects both authority and locals would be more satisfied that their interests were taken into account. Thus visibility aspects could be interpreted as an important component of site selection, turbine setting and scenery protection plan.

References


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