Interreg III B

Alpine Windharvest

ALPINE WINDHARVEST

Development of information base regarding potentials and the necessary technical, legal and socio-economic conditions for expanding wind energy in the Alpine Space*

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GIS Analysis Methodology

Workbook and Results

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ALPINE WINDHARVEST

…is an interdisciplinary research project funded by the EU Interreg IIIB "Alpine Space Programme" (Project No. A/I-2/3.1/5) and by national and regional co-financing bodies of the project partners. The project started in May 2002 and will end at the end of April 2005.

Background of the project:

Wind power became a leading renewable energy technology in flat terrain, especially near shore. While the alpine space also promises some excellent wind locations, much of the knowledge and experience accumulated about wind power so far cannot simply be transferred to the alpine setting.

The lack of experience concerns all levels of government confronted with problems of siting, spatial planning, nature protection/environmental impact analyses, road and electric grid requirements, appropriate tariff regulation etc. The project aims at remedying these deficiencies.

This lack of experience also regards entrepreneurs, investors and even producers of equipment given the special climatic and geological conditions. This increases economic risks, inhibits site exploration and planning activities even for attractive locations. The small number of existing projects in the alpine space impedes standard procedures.

Lack of experience also affects the acceptance of wind power by nature protection organisations and local residents. There is much need for additional knowledge and information; standard models for the resolution/mediation of conflicts will be useful.

For this reason, it is essential to pool the limited experience with wind power in the alpine space for synergy effects, cross-fertilisation and greater efficiency in developing data sets, methods, approaches and solutions for public and private actors, particularly since many of the underlying phenomena are trans-national while most research so far was primarily national (e.g. meteorology).

A common approach will facilitate a harmonised European approach to the problems under consideration, particularly with regard to government policy.

Main activities:

Develop knowledge basis for deploying wind energy:

a) Methods and instruments for identifying wind energy potential in complex terrain more efficiently (meteorologists, geographers, digital relief analyses and actual wind measurements; includes pilot measurements on specific locations).

b) Deal with problems peculiar to wind turbines in alpine conditions (blade icing; access - need for special mounting equipment); standardise technologies, estimates of access requirements (roads and grid). Common approaches for entire alpine space will create bigger market for improvements and induce responses from equipment manufacturers.

c) Analyse ecological impact of turbines in different alpine settings on fauna and flora according to altitude, soil/rock and meteorological conditions; establish check list of factors for whole alpine space. Develop strategies to minimise impact. Improve information for local/ regional authorities.

d) Analyse and compare legal, social, political and economic framework conditions for deployment of wind power in alpine space and their impact on its competitiveness. Formulate regulatory proposals.

e) Prepare methods of resolving conflicts between wind power and other interests (environmental organisations, local residents, hunting). Improve visualisations (more difficult in alpine terrain), standardise participation in administrative procedures and mediation. Facilitate work of local and regional authorities.

f) Measure potential contribution of this energy source to regional development, particularly when joined with hydro storage and electricity generation from biomass.

Alpine Windharvest Report Series:

The Alpine Windharvest Report Series is published by the Alpine Windharvest partnership network in order to disseminate the results of the project to the interested public and to experts in the field. Reports are edited by the responsible project partner(s) who commissioned and approved the report according to our internal division of labour. Reports can be downloaded from our homepage. Printed versions can be directly ordered from the project coordinator by e-mail: dieter.pesendorfer@sbg.ac.at.

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GIS Analysis Methodology

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Abstract

One objective of work package 7 of the Interreg III b project "Alpine Windharvest" was to establish a methodology for regional Geographical Information System (GIS) analyses to identify promising sites for wind energy.

In Switzerland, a comprehensive study to identify preferable sites for wind energy was performed in 2002–2004. The GIS methodology employed in the framework of that study was adapted as a generally applicable GIS analysis methodology for identification of suitable sites for wind power in the current study.

The methodology consists of three main steps: First, identify the limiting factors for wind power production within the considered region. For each factor, determine distinct exclusion criteria (thresholds or classes) that indicate which sites are not suitable for wind power production. Second, compile a GIS layer for each of the limiting factors. Each of these intermediate layers indicates unsuitable sites for wind power production according to the corresponding criteria. Finally, aggregate the layers into a result layer. Any sites not indicated as unsuitable in any of the intermediate layers is considered as suitable for wind power production in the result layer.

The analysis can be tuned in order to give a more "optimistic" or a more "pessimistic" result, according to the general characteristics of the test area and depending on the knowledge about the situation that is available beforehand.

The GIS analysis methodology was implemented in 4 test areas in Austria, Italy, Slovenia and Switzerland. The results are documented in separate reports and on the internet at http://stratus.meteotest.ch/windharvest as interactive maps.

It was found that the established methodology is efficient. It is quite easy to implement, and the results are significant. The identified areas generally corresponded very well with the sites known to be suitable beforehand, while unsuitable sites were eliminated.

In the case studies, criteria were defined to the best knowledge of the mandated institute. For more concise results, which could for example be used as the basis for a comprehensive regional or national wind power concept, the criteria for suitable/unsuitable sites will usually have to be defined in a socio-political process.

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1. Introduction

1.1. Framework and objectives

One of the objectives of work package 7 of the Interreg III b project "Alpine Windharvest" was to establish a methodology for regional Geographical Information System (GIS) analyses to identify promising sites for wind energy. The methodology should be efficient and significant and easy to adapt to any area within the Alpine Space (or elsewhere).

1.2. Related projects

Similar projects were executed by ***METEOTEST*** in 1996[1] and 2004[2]. The methods have since been refined, especially using the latest GIS versions and new tools, but always following the same methodical base line.

In the current study, the GIS methodology employed in the framework of the 2004 study was adapted as a basis.

1.3. General procedure

The GIS analysis is performed in three basic steps (fig. 1):

1. Identify the limiting factors for wind power production within the considered region. For each factor, determine distinct exclusion criteria (thresholds or classes) that indicate which sites are not suitable for wind power production.

2. Compile a GIS layer for each of the limiting factors. Each of these intermediate layers indicates unsuitable sites for wind power production according to the corresponding criteria.

3. Aggregate the layers into a result layer. Any sites not indicated as unsuitable in any of the intermediate layers is considered as suitable for wind power production in the result layer.

Subsequently, if desirable, the identified suitable sites can be classified.

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[1] Oekoskop, ***METEOTEST***, ENCO, 1996: Windkraft und Landschaftschutz

[2] BFE, BUWAL, ARE, 2004: Konzept Windenergie Schweiz – Methode der Modellierung geeigneter Windpark-Standorte

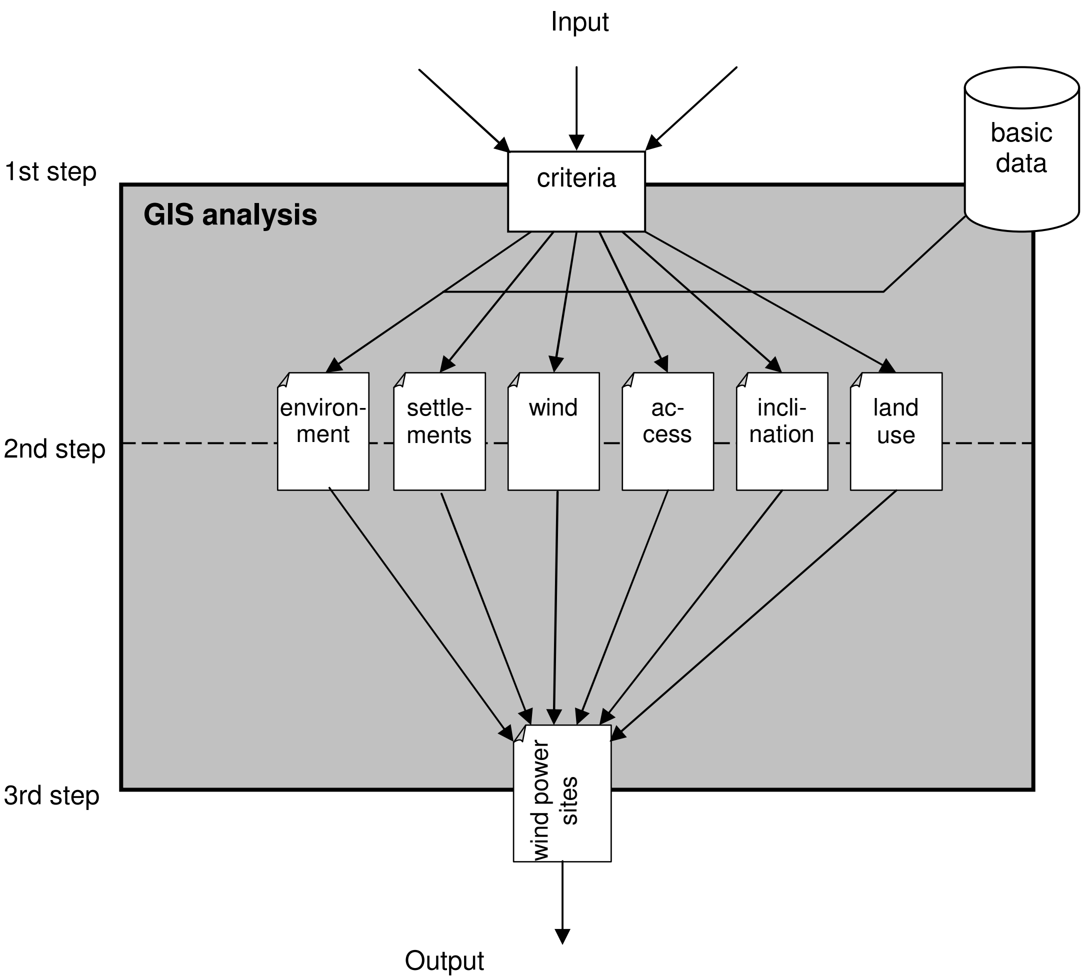

Fig. 1: General GIS analysis procedure.

1.4. Software framework

The modeling steps in all the projects mentioned in this report were developed and tested using the ArcGIS® suite by ESRI®[3]. All the same, the same principles can be applied in any GIS that fulfills the methodic requirements.

ESRI partner++

[3] ArcGIS and ESRI are registered trademarks by Environmental Systems Research Institute, Redlands, CA, USA

2. General GIS model concept

2.1. Decision support system

The features of the methodology we propose here are those of a Decision Support System (DSS)[4]. Such models are built by combining a set of input data according to a predefined set of rules, with the purpose to answer only the question: Where are the most suitable sites for wind power projects?

A GIS analysis model is typically run only once since the input data remain unvaried over a long period. Only a change in the criteria settings or the availability of new, important input data may justify a new model run.

The proposed methodology is not suitable for specific site planning. It is intended for screening of larger regions for suitable sites. Sites identified by the methodology will have to be further evaluated (e.g. on-site wind measurements).

2.2. Types of criteria

The question of finding the best places for wind power projects that has to be answered by the model implies aspects that possess two types of criteria:

Categorical criteria:
Areas where it is physically (or legally) impossible to install a wind turbine, to be excluded by the model. Typical examples are settlement areas or protected areas.

Gradual criteria:
Usually applying the logics of economy, areas considered unattractive for wind power projects. The main problem here is to define the thresholds of attractivity/suitability. Examples are wind resources or access.

2.3. Optimistic vs. pessimistic: model tuning

Especially with the gradual criteria, model results can be adjusted, not to say, manipulated, in order to obtain more or less areas considered suitable. Lowering the thresholds of suitability will increase the size of such areas, raising them will reduce or even eliminate promising sites.

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[4] Definition according to wikipedia.org: "interactive computer-based systems that help decision makers utilize data and models to solve unstructured problems", on the opposite of OLTP: On-line transaction processing systems.

Knowing about the danger that lies in this fact, we impose three rules for handling the gradual criteria:

- Decide consciously whether to build an "optimistic" model with low thresholds, or a "pessimistic" model with stronger restrictions.
- Suitability thresholds have to be within the limits of common sense.
- Scenarios and choices of suitability thresholds have to be disclosed to the readers of the model results.

The first decision depends on how much knowledge about the suitability for wind power exploitation already exists for the area to be examined:

For new areas without any known previous research, or for areas with relatively bad conditions for wind energy, we suggest applying an "optimistic" model with comparatively low thresholds. The results will then be an inventory of all areas even moderately suitable, with a high certainty that no parts are wrongly discarded that might possibly be interesting.

For areas where it is already known that wind power projects might be possible, we propose to build a more "pessimistic" model with higher restrictions. The model result will then show the most interesting parts, the "hot spots", where it is most promising to attempt wind power projects.

At any rate, model output is always and only valid "assuming that…", meaning that the results only reflect the conditions that came with the input data, and the criteria that were applied to them. Careful documentation of data and criteria is therefore a crucial issue when building and publishing decision support system models.

2.4. General requirements

Models built according to the proposed GIS methodology fulfill the following requirements:

- They identify suitable sites for wind energy installations.
- They can be applied for any region.
- They work with a set of simple mathematical and analytical operations.

However, the proposed models depend on adequate, accurate and reliable input data that cover every relevant aspect of the issue and are available for the entire test area perimeter.

3. Data specifications

3.1. Required and recommended input data

No model can be set up without suitable data covering the area to be examined. In the following list, only the wind speed layer is strictly speaking indispensable for modeling wind power sites, because wind is the one physical prerequisite for wind power production. All other layers will enhance the precision of the model results.

The list can be extended; any other data is welcome as long as they show a feature that might be relevant for setting up a wind power project. Data with only marginal importance to the subject may be discarded. The set of input data has to be adapted for the country or region where the test area is situated.

- Wind resources at hub height, e.g. mean annual wind velocity at 70 m a.g.l., probably from modeling output
- DTM/Slope
- Forests
- Settlement areas
- Access information (roads)
- Landscape protection areas
- Wildlife protection areas
- Zones of wind power promotion or inhibition issued from land use planning
- Electricity grid
- Soil stability
- Military prohibited areas
- Topographical background map (for displaying results)

3.2. Data preprocessing

Before including it in the model and combining it with other data, each input layer has to be prepared in order to fit in the concept. The following aspects have to be observed:

- Raster vs. Vector
  Technically, GIS analysis can be done using raster or vector data. As soon as data layers are combined, one of the two formats must be chosen. For the Windharvest analyses we chose the raster approach, because most data were available in raster format.

- Projection
  Input data will be overlaid and combined, so all data have to be converted to the same projection system.

- Extent/area coverage
  The project extent has to be defined at a very early stage of the modeling process. Any data used in the GIS model must cover or overlap the entire test area, otherwise the results would not be of equal reliability in the whole area.

- Raster data: cell size, origin
  Each raster data set has the basic properties of data origin and cell size.

  Cell size should be chosen depending on the information density in the basic input data, e.g. cell sizes for raster data, or target scale dimension of vector data. Cell sizes of 50 to 250 m can be considered appropriate for the topic to be examined.

  The origin of raster data sets that are newly created for the current analysis should be defined in a way that the test area borders run along cell edges. If a data set is to be used for the model that doesn't fit into this box, there will be an offset to all other data. Depending on cell size, value ranges, and information density, the contents may have to be interpolated to fit into the project extent.

- Data classification
  Of course, for each input data layer the value ranges and meanings have to be known. For data with nominal value scales (e.g. land use classes) the effect of each class on a possible wind power project has to be defined (suitable or not suitable).

4. GIS analysis

4.1. Criteria definition

For each data layer, a set of rules has to be defined under which the installation of a wind power plant would be possible or not. According to the data type in the layer, a range or a set of values are declared suitable/unsuitable, resulting in a binary classification (1 = suitable, 0 = unsuitable).

For certain types of land use such as inhabited areas, a distance to wind power installations has to be respected. Thus, not only the inhabited areas themselves, but also a buffer zone around them will be considered unsuitable. The width of the buffer will depend on the type of installation and has to be defined along with all other criteria.

Table 1 contains aspects that are typically decisive and possible definitions of corresponding criteria. The list is not conclusive. Exactly which aspects and criteria are to be considered for a certain area depends on the area's characteristics, the scope of the analysis as well as data availability.

Tab. 1: Examples of aspects and criteria determining suitability for wind power.

aspect	**possible suitability criteria**
wind resources	threshold value of e.g. 5 m/s for mean wind speed
land use	exclusion of certain categories e.g. lakes, swamps, forests due to building restrictions and constraints
settlements	exclusion of settled areas including a buffer of e.g. 500 m due to acoustic and optical immissions
protected areas	exclusion of areas with constraints for wind power plants such as nature parks, military areas etc., possibly with buffer
access	exclusion of areas that are impossible or uneconomic to reach (e.g. by calculating cost distance from existing roads)
slope	exclusion of certain steepness. Possibility of combination with access criterion.
electricity grid	exclusion of areas too far away from suitable grid connection (e.g. by calculating cost distance)

4.2. Data analysis

The first step in data analysis is then to aggregate and extract from each input data layer the suitable areas according to the criteria, resulting in one intermediate layer for each criterion, typically with values of 0 for suitable areas, and 1 for restricted areas.

The suitable areas are those that fulfill the criteria in each input layer. They are obtained as the result of an overlay of all the intermediate criteria layers. When adding the layers up, which is one possibility of overlaying, the suitable areas are those with a value of 0 in the output summary layer.

4.3. Criteria adjustment

Depending on the decision whether to build an "optimistic" or a "pessimistic" model (see chapter 2.3), the picture of the resulting suitable areas may more or less satisfy the expectations.

For an optimistic scenario that looks for an inventory of possibly interesting areas, the result is useful if, as a rough indication, the part of suitable areas is between 20 and 50% of the test area.

For a pessimistic scenario, where the most interesting spots are looked for, the amount of suitable areas should typically be no more than 15% of the test area.

If the portions of suitable areas are beyond these ranges, the criteria applied to the input layers can be adjusted – always following the three rules mentioned in chapter 2.3. The model will then be re-run and should eventually lead to a consistent picture.

Of course it may happen that no areas at all can be considered suitable, or that very large portions of the test area really have very good conditions. In either case the contribution of the GIS model to the decision making of a possible investor in wind power projects will not be very important.

5. Case Studies

The GIS analysis methodology was implemented in four test areas in Austria, Italy, Slovenia and Switzerland. The results are documented in separate reports[5] and on the internet at http://stratus.meteotest.ch/windharvest as interactive maps.

5.1. Franches Montagnes, Switzerland

An area of 30 x 30 km was analyzed in the Franches Montagnes in Switzerland by *METEOTEST*, Bern. Relatively strict criteria were applied in order to find only the most suitable sites for wind energy projects. At Mt. Crosin, the identified sites match the turbine locations of an existing wind park nicely.

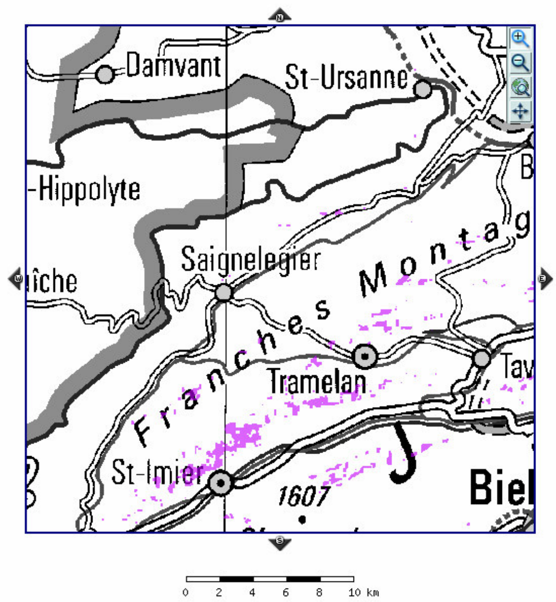

Fig. 2: GIS analysis result for Franches Montagnes, Switzerland. The preferred areas for wind power projects are shown in purple.

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[5] Ehrenreich et. al, 2005: GIS analyses 'Aineck' and 'Brenner', Austria and Italy. Alpine Windharvest report No. 7-4.
Dällenbach et. al, 2005: GIS analysis 'Franches Montagnes', Switzerland. Alpine Windharvest report No. 7-5.
Podobnikar et. al, 2005: GIS analysis 'Menina planina', Slovenia. Alpine Windharvest report No. 7-6.

5.2. Aineck, Salzburg, Austria

An area of 30 x 30 km was analyzed near Aineck, Salzburg, Austria by ecowatt, Graz. Several interesting sites for wind park projects were identified. Known wind energy projects lie within the identified preferred areas.

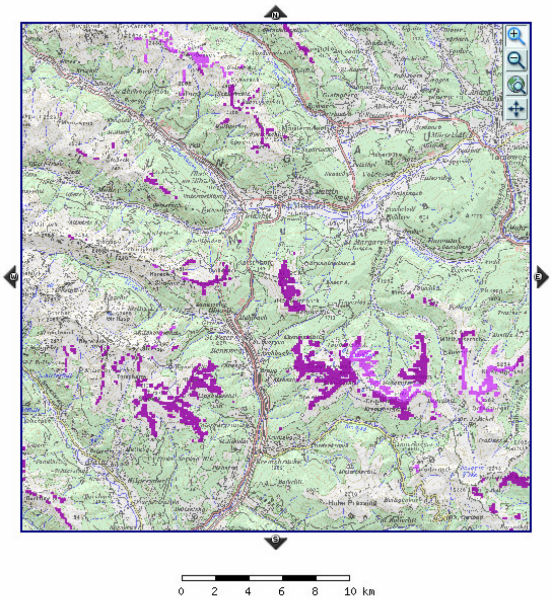

Fig. 3: GIS analysis result for Aineck, Austria. The preferred areas for wind power projects are shown in purple. Light purple areas are within landscape protection zones.

5.3. Brenner, North and South Tyrol, Austria and Italy

An area of 30 x 30 km was analyzed at the Brenner Pass, Austria and Italy by ecowatt, Graz. Sites for wind park projects are mainly restricted to high ridges that are perpendicular to the main wind directions north and south. Known wind energy projects lie within the identified preferred areas.

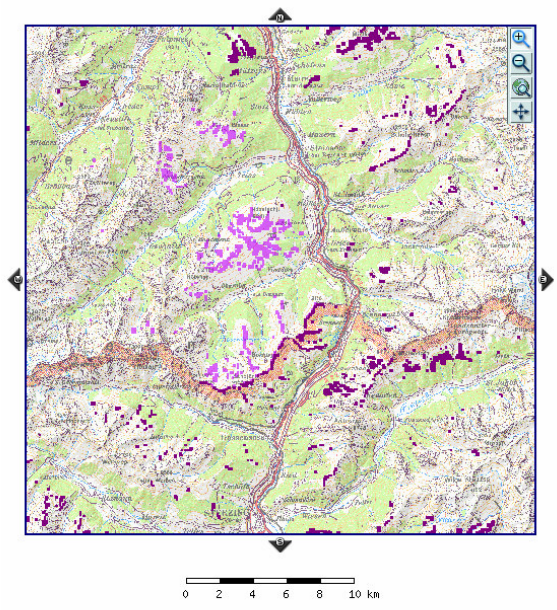

Fig. 4: GIS analysis result for Brenner, Austria and Italy. The preferred areas for wind power projects are shown in purple. Light purple areas are within landscape protection zones.

5.4. Menina planina, Slovenia

The investigated area in Slovenia has not priorly been studied extensively for wind energy. It was known that the wind resources are rather sparse. Additionally, the wind resource data is rather insecure in this region due to the lack of sufficient measurements. Therefore, "optimistical" criteria were defined (e.g. threshold for mean wind speed at 4.5 m/s) in order to identify all sites potentially suitable for wind energy.

An area of 30 x 30 km was analyzed by the Scientific Research Centre of the Slovenian Academy for Sciences and Arts. With a few exceptions, potential sites were only found on the Menina planina mountain. Even here, sites are relatively sparse, mainly due to forests and housing areas, which were excluded.

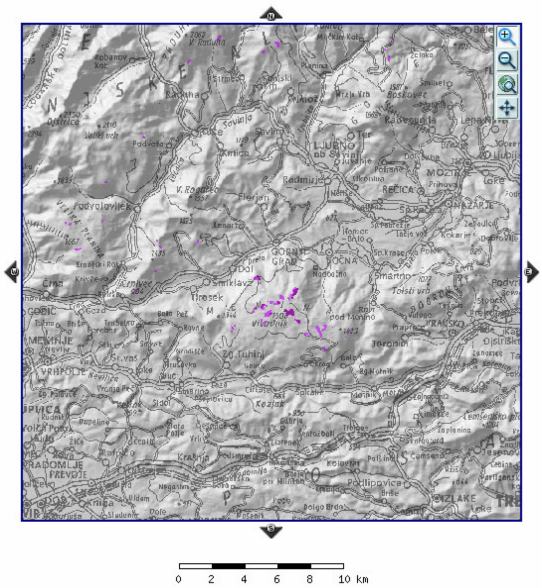

Fig. 5: GIS analysis result for Menina planina, Slovenia. The preferred areas for wind power projects are shown in purple. Light purple areas have mean wind speeds of 4.5 m/s or higher, dark purple areas have mean wind speeds of 5.0 m/s or higher.

6. Conclusions and Outlook

In former studies in Switzerland as well as in the case studies performed in the framework of "Alpine Windharvest" it was found that the established methodology is efficient. It is quite easy to implement, and the results are significant. The identified areas generally corresponded very well with the sites known to be suitable beforehand, while unsuitable sites were eliminated.

For all case studies, an area of only 30 x 30 km was examined. If the necessary input data is available, the area of analysis can easily be extended to include bigger regions or even whole countries.

In Slovenia, interesting new results were obtained with the GIS analysis. We hope that this approach will be extended to the whole country in Slovenia. Currently, a detailed wind map for Slovenia is being produced by the Meteorological Institute of Slovenia. This might be an ideal data basis for the wind resource aspect of the analysis.

In the case studies, criteria where defined to the best knowledge of the mandated institute. For more concise results, which could for example be used as the basis for a comprehensive regional or national wind power concept, the criteria for suitable/unsuitable sites will usually have to be defined in a socio-political process.

The proposed methodology is not suitable for specific site planning. It is intended for screening of larger regions for suitable sites. Sites identified by the methodology will have to be further evaluated (e.g. on-site wind measurements).