



## **Site Assessment Report**

### ***GIS aided Evaluation of Fourteen Sites for potential Wind Measurements in Nine Regions of Tunisia***

Client:

**Deutsche Gesellschaft für Internationale  
Zusammenarbeit (GIZ) GmbH**

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65760 Eschborn  
Germany  
**(short: GIZ)**

Contractor:

**German ProfEC GmbH**

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49744 Geeste  
Germany  
**(short: German ProfEC)**

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## 1 BACKGROUND

Tunisia is a partner country for German development cooperation. GIZ has been working on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) in Tunisia since 1975. Since 1999, GIZ has maintained an office in Tunis.

Since 1990, the country has generated average growth of approximately 5% of its GDP per annum. Development has largely taken place in the agricultural sector. As it accounts for a large number of jobs and is a major supplier to the food industry, the sector is of great significance in economic and socio-political terms. However, the contribution to GDP made by industry (textiles, leather, food, electrical engineering) and the service sector has increased disproportionately in recent years and has overtaken that of agriculture. Due to its economic growth and political stability, Tunisia is one of the most important partners in the Barcelona Process and for the European Neighbourhood Policy.

Yet these positive development indicators are accompanied by problematic trends. The country's economic and demographic development, rapid urbanisation, resource-intensive industrialisation and the expansion of irrigated agriculture have placed a considerable burden on the environment and have heavily depleted natural resources, a situation that is set to worsen with climate change.

The Tunisian Government is trying to counteract these trends through the implementation of reform and development plans. Its aims are to lower unemployment and to improve the competitiveness of domestic industry, as well as to protect and sparingly use natural resources and adapt to climate change.

German development cooperation supports Tunisia's reform and development plans for the priority areas economic development and environmental protection.

As part of GIZ's work in Tunisia, special emphasis is placed on supporting the Tunisian Government in its efforts to encourage sustainable development in the country by among other:

- promoting economic development, especially through the strengthening of industrial innovation processes and entrepreneurship;
- implementing the country's environmental policies, agendas for sustainable development and resource use and implementing the international Climate Change Convention.

Economic and social developments are causing constant increases in consumption of energy in Tunisia. But supplying energy at present is cost-intensive and pollutes both the environment and the climate. The heavy dependence on fossil energy, most of which has to be imported, is proving increasingly detrimental to the national budget and economy. The significant potential Tunisia has for renewable energy and energy efficiency is insufficiently exploited.

For that purpose the program "*Promotion of Renewable Energy and Energy Efficiency*" (ER-EE) was launched by the German Federal Ministry for Economic Cooperation and Development (BMZ) for the period from 2003 – 2013. The lead executing agency is: Agence Nationale pour la Maîtrise de l'Énergie (**ANME**) des Ministère de l'Industrie, de l'Énergie et de la Petite et Moyenne Entreprise (**MIEPME**).

The overall objective is to make much greater use of regenerative energies and energy efficiency. Energy saving approaches are used when consuming energy.

The project approach is to provide organisational and technical advice to the National Agency for Energy Management of the Ministry for Industry, Energy and SMEs. Priority areas are the development and use of promotional instruments for renewable energy forms and energy efficiency. The project also advises other public institutions, private enterprises and other energy consumers, informing them about ways to use innovative energy technologies.

Training measures are given to companies working in the fields of energy and energy efficiency. Pilot projects demonstrate the technical and economic feasibility of using renewable energy and increasing energy efficiency. In the scope of public-private partnerships, the project supports European and Tunisian enterprises with the transfer of sustainable energy technologies.

Among other activities, the Tunisian Ministry of Industry and Technology (MIT) has decided to launch a program to promote the self-production and consumption of electricity from wind power by companies that are accounted as large electricity consumers, so called "EGCElec" (Entreprises Grosses Consommatrices d'Electricité).

The National Agency for Energy Management (ANME) was responsible for preparing the conditions for implementing this program and to provide support and assistance to such EGCElec-companies interested in such project.

ANME in turn is supported by the German Technical Cooperation (GIZ) under the project ER-EE. The project aims to assist the ANME in promoting renewable energy and energy efficiency in Tunisia. Under this project, GIZ is committed to assist the EGCElec's within the implementation of wind energy projects for generating the own electricity needs.

In the year 2007 measurement masts have been installed near to the location of several EGCElec.

Based on the collected data, feasibility studies for potential wind energy projects shall be prepared, in order to analyze the possibilities for auto-production of electricity through EGCElec based on wind energy.

## 2 INTRODUCTION

German ProfEC GmbH was contracted to perform the following works:

- ✓ Elaboration and establishment of a GIS Tool to support ANME in the steering and planning of the future national wind energy development and to perform efficient site selection processes;
- ✓ Qualified site assessment and bancable reporting with recommendations about the most promising sites to be chosen for further wind measurements.

Contract: 81136452

Project: 09.2455.5-001.00 "*Promotion of Renewable Energy and Energy Efficiency*"

Period: July 2011 – October 2011

The GIS tool has been implemented and training has been given to ANME and GIZ staff on the utilization of the tool. A how-to manual to use the tool has been discussed and transferred to ANME and GIZ staff as part of the training.

Based on the GIS Tool the site assessment mission to nine regions in Tunisia has been prepared. Numerous wind measurements have been performed in Tunisia already in the past and any new wind measurement mast installed by GIZ / ANME should preferably be located at a site that makes most sense. In that context the Tool was created and used:

- to avoid a new measurement at / close to a site that already was subject of a qualified measurement campaign in the past, or
- to select the most promising wind sites, thereby incorporating the wind re-source, terrain complexity, infrastructure conditions and exclusive zones right away.

The GIS Tool elaborated therefore combines a set of relevant information needed, in order to perform a most optimized and result-oriented site selection for wind measurement campaign and later wind farm planning. The following data and information have been digitized and incorporated into the GIS Tool:

- Topographical and digital maps for the entire country as far as available;
- Orography and roughness information for the entire country based on satellite data<sup>1</sup>;
- The existing wind atlas of Tunisia<sup>2</sup> and any other available wind data (GIZ measurement campaigns, Helimax measurement campaigns, CENER measurement campaigns), thereby highlighting each spot where a wind measurement was taken in such way that by aid of the GIS Tool easily the main wind resource and performance parameters can be accessed at the computer. ANME will need to provide full and free access to the wind atlas in order to incorporate it into the GIS Tool;

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<sup>1</sup> Source: SRTM (orography) and Sattelite data (roughness)

<sup>2</sup> Source: CENER/ ANME

## Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

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- The current and future-planned course and characteristics of the national inter-connected electricity system and sub-stations;
- Any existing information on land use plans, exclusive zones (e.g. soil usage, environmentally protected areas, bird track routes)<sup>3</sup>, or military areas that might prohibit the installation of either measurement masts or wind turbines later on;
- Main transport roads and infrastructure (Settlements and cities, National road network, Electrical substations)<sup>4</sup>;
- Long-term meteorological stations;
- Satellite images from Landsat 5 (high speed internet connection required).

For further information with regards to the GIS embedded wind energy development steering tool, it is referred to the manual “GIS Steering Tool”, October 2011.

The GIS Tool was studied and applied together with ANME and GIZ staff. As a result a set of pre-selected sites to be visited during in nine different regions of Tunisia had been derived and a site visit schedule has been elaborated and followed.

All sites visited were pre-selected previously using the GIS Tool developed by German ProfEC as part of the contract objectives. Introduction to ANME and GIZ took place during the 3 day during an in-house workshop and during a 1-day field training. During the first two days of the training the usage of the Tool and auxiliary software has been practiced. Subsequently a case study assignment has been performed and a typical site visit was performed for practicing. At day 3 of the in-hose workshop, the sites for site visit were selected together with staff from ANME.

The visit to the individual sites was performed by a wind energy expert of German ProfEC from 20<sup>th</sup> of September 2011 – 29<sup>th</sup> of September 2011. Together with staff from ANME fourteen sites have been visited and the site characteristics have been recorded, documented and verified. Subsequently the data gathered at each individual site have been analyzed and all insights together are presented within the following of this Site Assessment Report.

The report in hand is the Site Assessment Report and provides an evaluation of fourteen visited sites in the nine regions of Tunisia as to recommend at which sites wind measurements should be performed in the foregoing years.

The report’s objective is to describe the visited and evaluated sites according to their suitability for wind energy utilization, thereby considering a wind farm design with at least 50 MW installed capacity.

A ranking has been performed and the most suitable sites are depicted and recommended to GIZ and ANME, being subject to further analyses and potential wind measurement campaigns.

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<sup>3</sup> *Source:* Google Earth, protected planet, ANME

<sup>4</sup> *Source:* ANME, Open Street Map, STEG

### 3 EVALUATED WIND MEASUREMENT SITES

The purpose of the site assessment was to elaborate an overview and to derive recommendations about which sites are most suitable for potential wind farm planning activities, thereby respecting the existing infrastructure, wind resource databases and a minimum space for 50 MW installed capacity at each site.

The following map gives an overview on the visited sites pre-selected by aid of the GIS steering Tool:

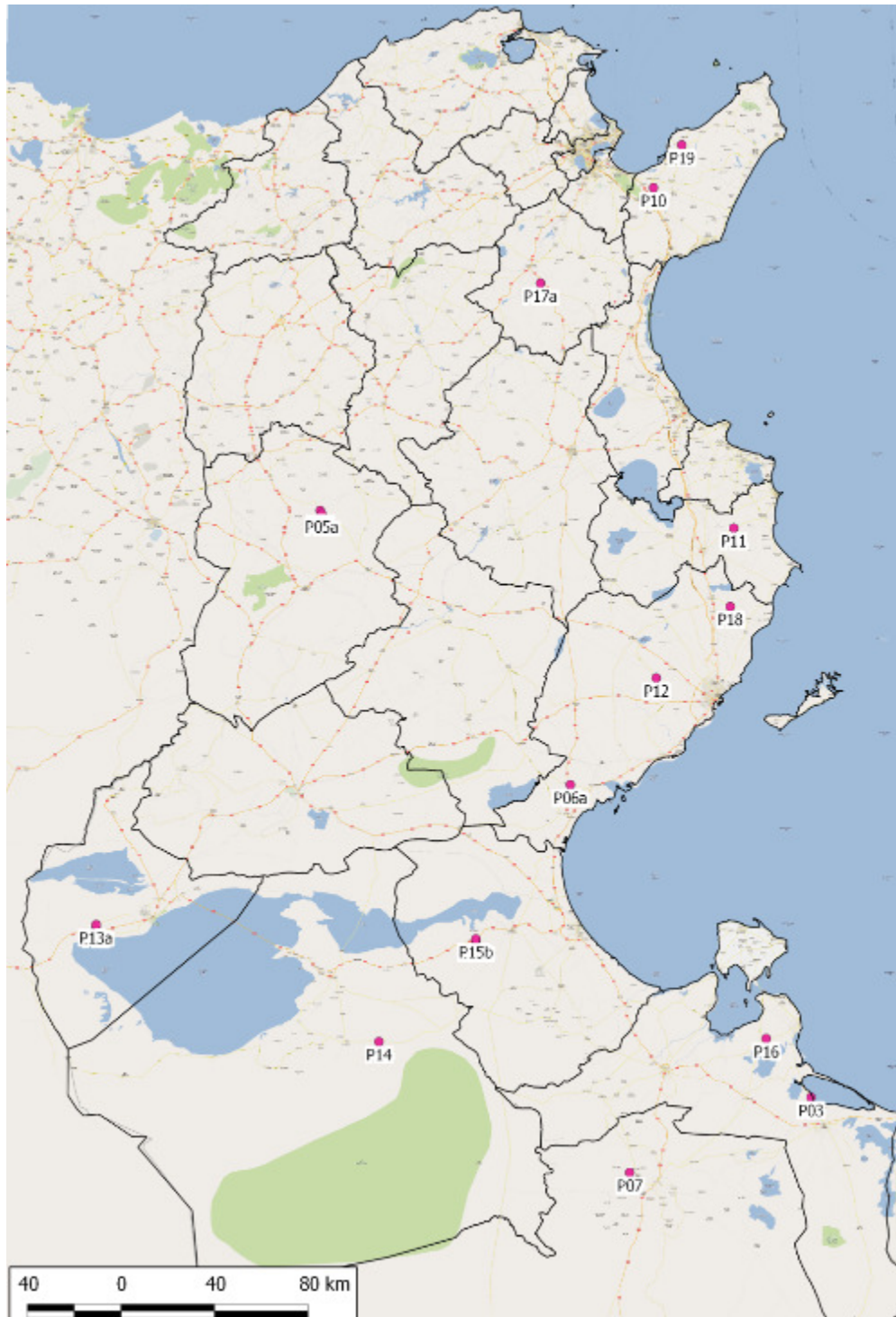


Figure 1: Visited sites during the site assessment mission



## Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

In total fourteen sites have been visited and analysed, but only eleven are evaluated in detail within this report. The sites P11, P12 and P18 were surrounded by dense olive plantations and neither are suitable for wind farm development activities nor for wind resource measurements.

The following table gives an overview on the planned site visits<sup>5</sup>:

Name	Date	Comment
P01	22/09/2011	Visited for training purpose, not suitable for 50 MW, not documented in this report
P02	27/09/2011	Not visited due to inaccessibility (no road, no infrastructure)
P03/ P03a	27/09/2011	-
P05/ P05a	25/09/2011	-
P06a	28/09/2011	-
P07	27/09/2011	-
P08	25/09/2011	-
P09	25/09/2011	-
P10	29/09/2011	-
P11	29/09/2011	Not suitable for 50 MW scenario due to dense olive plantations
P12	28/09/2011	Not suitable for 50 MW scenario due to dense olive plantations
P13/ P13a	26/09/2011	-
P14	27/09/2011	-
P15/ P15a/ P15b	28/09/2011	-
P16	27/09/2011	-
P17a	25/09/2011	-
P18	29/09/2011	Not suitable for 50 MW scenario due to dense olive plantations
P19	29/09/2011	Selected ad-hoc during the site visits

One criterion to pre-select sites was that no wind measurement masts have been operating in the past at the visited measurement sites or within a distance of at least 10 km. The sites in addition were pre-selected for a site visit mission and analysis based on the promising infrastructure, the topography and the wind resource assumptions given in the national Tunisian Wind Atlas.

The following filters have been applied to the GIS Tool for the pre-selection process:

Parameter	Selection criteria
Wind resource acc. to the Tunisian Wind Atlas at 100 m	<i>Mean Wind Speed &gt; 6 m/s</i>

<sup>5</sup> Enumeration P04 never assigned to any site, thus missing.

Performed measurement campaigns	<i>Minimum distance to another measurement site of &gt; 10 km</i>
Terrain expansion as well as openness, complexity and surface roughness	<i>Terrain slope <b>less than 5%</b></i>
Available space	<i>Space to set up a wind farm of <b>about 50 MW</b></i>
Grid connection	<i><b>Maximum distance</b> to next electrical high-voltage substation: <b>50 km</b></i>
Access	<i><b>Maximum distance of 500 m</b> to an asphalt road (applies for recommended Met Mast location)</i>

The individual sites are described in the next.

### 3.1 Sites in the area of Zaghouan

During the site assessment one site in the Region of Zaghouan has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Zaghouan	36° 23' 17"	10° 10' 05"	~ 200

Table 1: Coordinates of city Zaghouan

The next map depicts the area of the site visited near Zaghouan:

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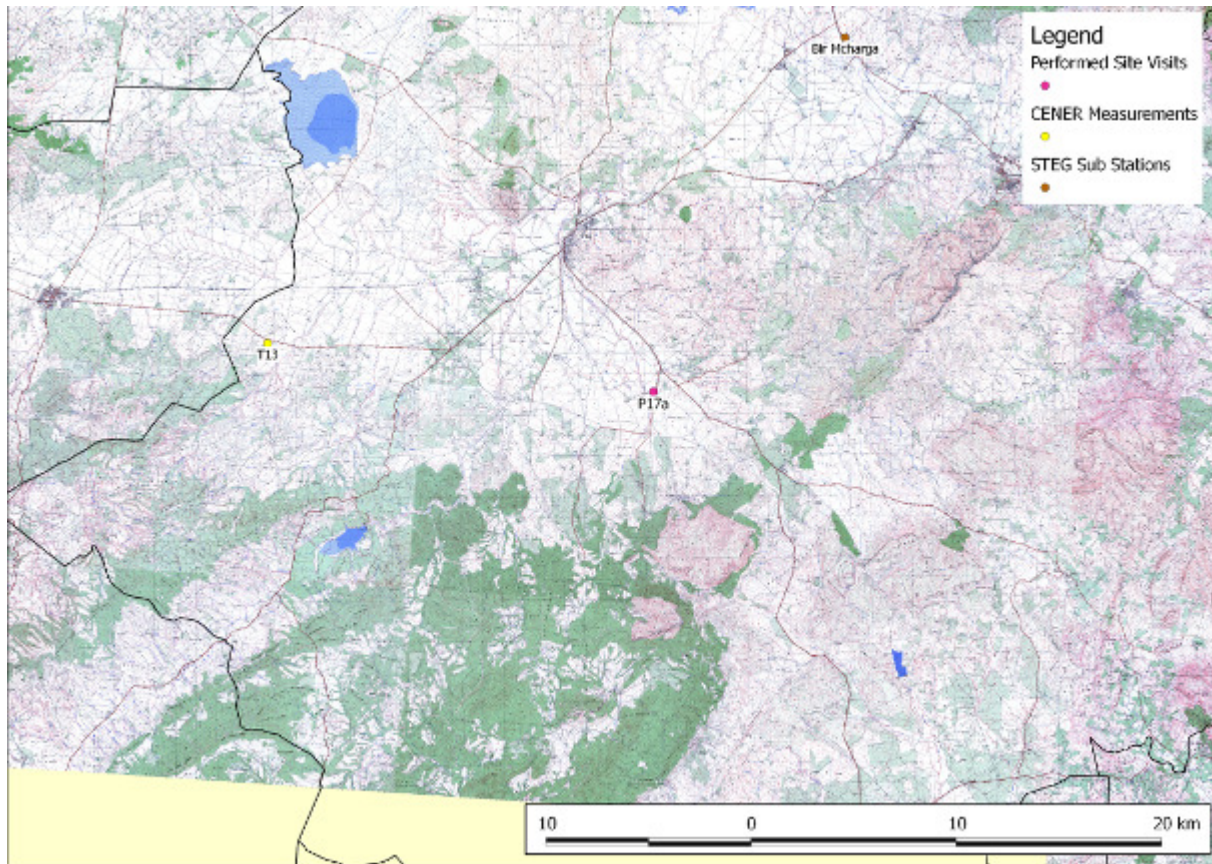


Figure 2: Map showing the positions of the visited site **P17a** in the area Zaghouan. The purple point is indicating the visited site **P17a**.

Name of the site	Ain Belkhir (EL FAHS) - <b>P17a</b>
Date	25/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 9° 56' 59.6"
	Y / Latitude: 36° 18' 31.9"
	Z / h.a.s.l.: ~ 218 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.60
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.30
Area	Uniform flat area with low roughness. Partially grass or crop covered. Agriculturally used land. Rarely some trees of up to 4 m height.
Complexity of terrain	Smooth, plain terrain with height differences of up to 10 m. There are gentle rise at a distance of 5km in north to

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	<p>north-east direction (340° - 80°) and at 10km distance in south to south-west direction (180° - 240°). Mountains with a height difference of up to 400m rise at a distance of 10km in east direction (90° - 105°) and at a distance of 7km in south-east direction (140° - 180°).</p>
Surface roughness	<p>In the surroundings crops (wheat) are planted in all directions.</p> <p>In north direction at a distance of about 3km some individual freestanding trees with a height up to 10m are growing. In north-eastern direction in a distance of 500m some freestanding trees are growing and in a distance of 1.5km there is an olive farm with trees up to 3m height.</p> <p>The eastern sector is interrupted by some individual freestanding trees with a height of up to 5m. In a distance of 10km in the mountains (see above) a forest is growing with trees up to 10m. In south-east direction the crop is interrupted in a distance of more than 5km by some freestanding trees with a height of up to 5m.</p> <p>In southern direction there is an olive farm with olive trees up to 5m in a distance of 3km.</p> <p>All sectors not described above are of uniform agricultural use with individual farmers' houses, surrounded by some trees in a distance of 500m .</p>
Extension of proposed area	<p>In north-east direction there is an olive farm at a distance of 1.5km.</p> <p>The whole south-west, west and north-west sectors are completely free up to a distance of 10km. In west there is a small farm in a distance of round about 500m.</p> <p>South of the site in a distance of 3km there is another olive farm.</p> <p>All other sectors not mentioned above is free up to a distance of at least 10km only interrupted by some individual freestanding trees.</p> <p>Given the free available space clockwise in north-west to south-east direction and in south-west direction the area is considered suitable for a 50 MW scenario.</p>
Information on ground and soil conditions (for wind turbine foundations)	<p>Agricultural land. It can be expected that in deeper soil layers there are solid rocks.</p>
Infrastructure	<p>Main asphalted road in about 200 m to the north-east.</p>

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Voltage level [kV]	In about 200 m distance, parallel to the asphalt road there is a 30 kV grid. The nearest HV sub.station is Bir Mcharga in a distance of 20 km.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	<p>NABEUL (~72 km E-N-E) X: 10° 42' 0.0" E Y: 36° 28' 1.2" N Z: ~9 m</p> <p>KAIROUAN (~73 km S) X: 10° 06' 00.0" E Y: 35° 40' 01.2" N Z: ~64 m</p> <p>SILIANA (~59 km S-W) X: 9° 22' 01.2" E Y: 36° 04' 01.2" N Z: ~446 m</p> <p>BEJA (~83 km N-W) X: 9° 10' 58.8" E Y: 36° 43' 58.8" N Z: ~159 m</p>

Table 2: Site characteristics of point P17a in the area of Zaghouan

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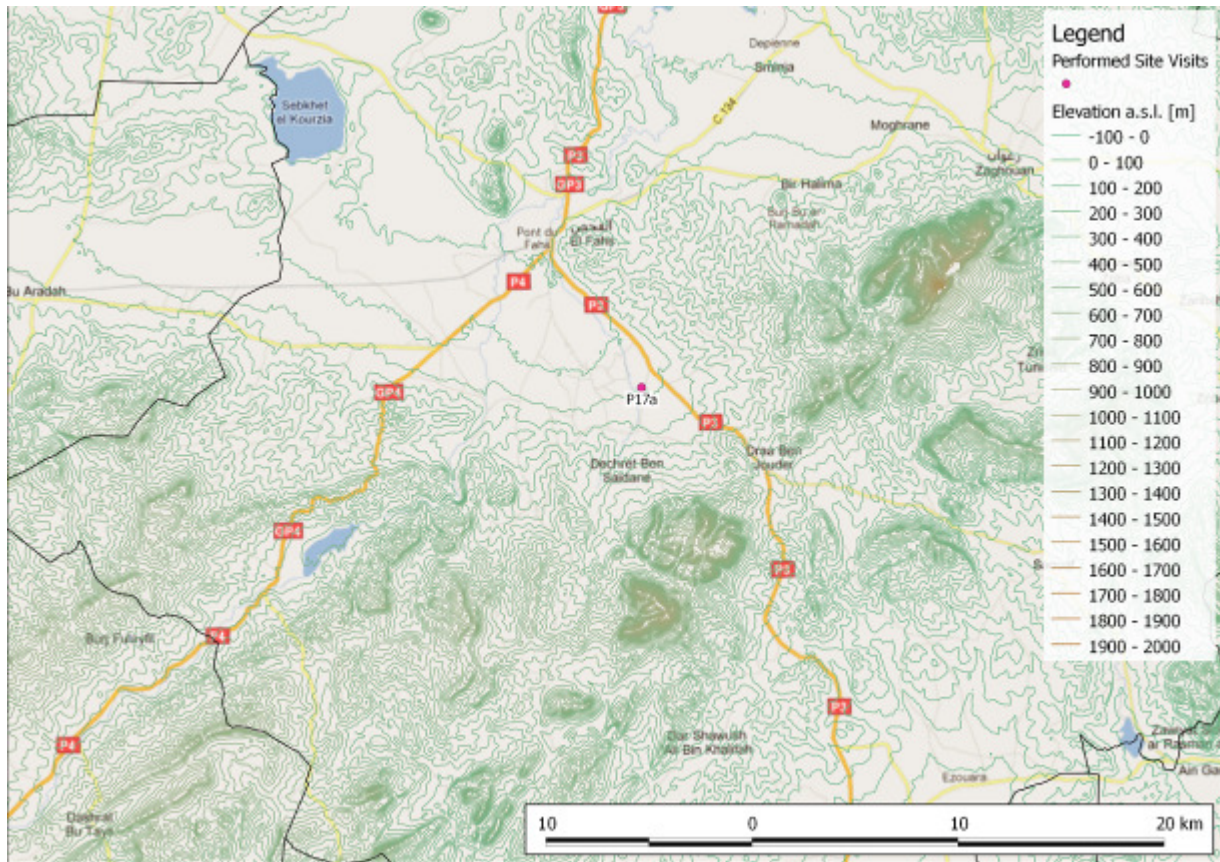


Figure 3: Orographic map showing the terrain complexity at point P17a

### Site Panorama Photographs





Figure 4: Panoramic view as seen at the point P17a

### 3.2 Sites in the area of Kasserine

During the site assessment one site in the Region of Kasserine have been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Kasserine	35° 10' 18"	08° 49' 44"	~ 662

Table 3: Coordinates of city Kasserine

The next map depicts points visited in the area of the site visited near Kasserine:



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

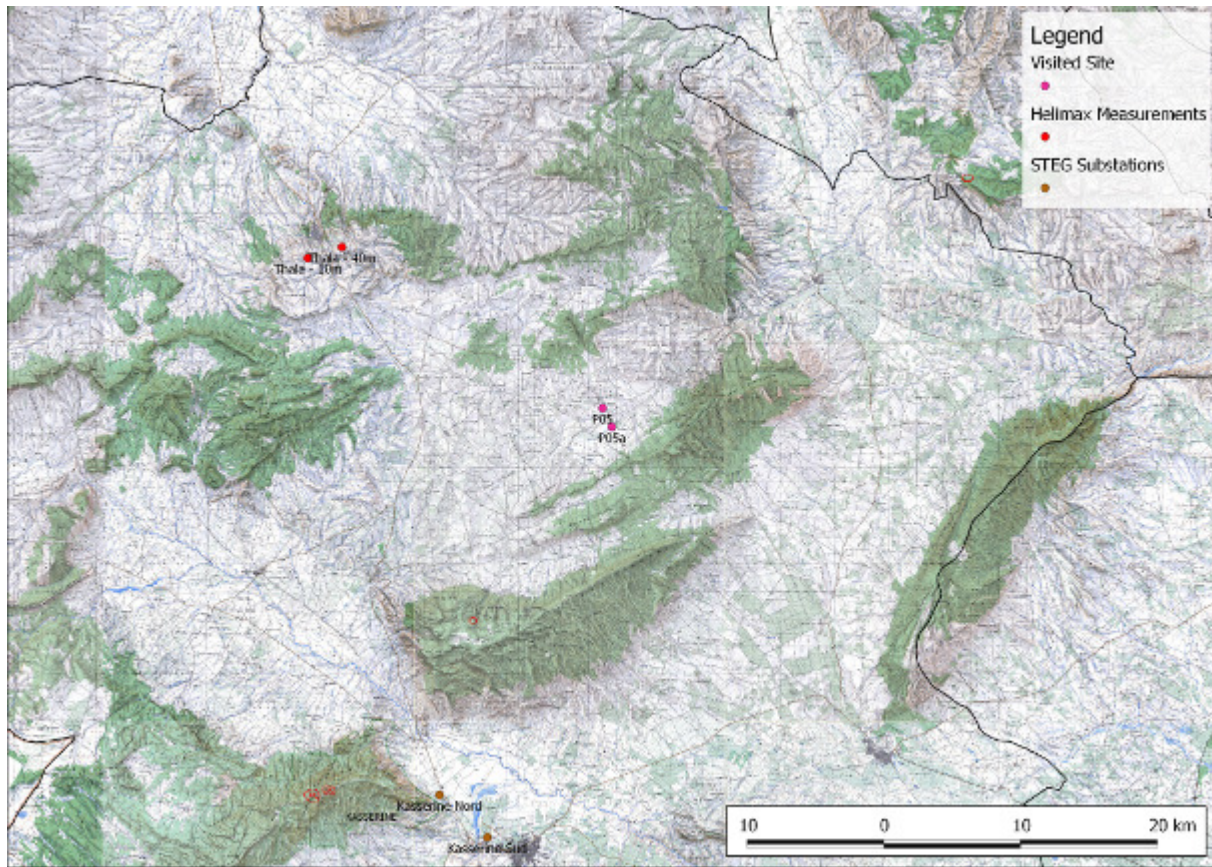


Figure 5: Map showing the positions of visited points **P05** and **P05a** in the area Kasserine

The purple points are indicating visited points **P05** and **P05a** at the site.

Name of the site	Route de Sbela (ESSKIRA) - <b>P05a</b>
Date	25/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 8° 54' 32.5"
	Y / Latitude: 35° 26' 43.6"
	Z / h.a.s.l.: ~ 888 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.87
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.66
Area	Uniform flat area with low roughness. Crop and grass covered. Agricultural used land. Rarely some trees and bushes of up to 3 m height.
Complexity of terrain	Smooth, plain terrain with height differences of up to 30 m.

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	Mountains with a height difference of 400 m with respect to the site are present in all directions at a distance of 6 km to 15 km
Surface roughness	<p>In the surroundings crops are planted in all directions.</p> <p>In north direction there is are crops and in a distance of 2 km some trees with a height up to 3 m.</p> <p>The whole north-eastern and eastern sector is covered by scattered, freestanding houses, beginning in a distance of 500 m and extending up to a distance of 5 km.</p> <p>In the south-eastern and southern direction a in a distance of 2.5 km a forest with trees up to 4 m is found.</p> <p>The south-western and western sector is interrupted by a scattered individual freestanding houses, beginning in a distance of 2 km approx.</p>
Extension of proposed area	<p>Beside the village in northern direction and the freestanding houses in the east and the west the area is free of obstacles.</p> <p>The available area is limited by a crest in southern direction in a distance of 10 km which has a height difference of up to 400 m with respect to the visited site. The second considerable limitation is a crest in eastern direction in a distance of 5 km.</p> <p>Considering especially the free space up to 5 km in eastern direction, up to 10 km in southern and south-western direction and the free space in western and northern direction the area is considered suitable for a 50 MW scenario.</p>
Information on ground and soil conditions (for wind turbine foundations)	Agricultural land. Solid rocks have been seen in a depth of 2 m.
Infrastructure	Main asphalted road in about 100 m to the north-east.
Voltage level [kV]	<p>In about 400 m distance in south-west direction there is a 1 kV power line for the village. 30 kV grid lines has been seen in a distance of 24 km in south-west and in 36 km in northern direction.</p> <p>Two STEG HV sub-stations (Kasserine Nord and Kasserine Sud) are in a distance of 35 km in southern direction.</p>
Access to sites	Very good.
Transport and Installation	Unproblematic

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Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	SILIANA (~80 km N-E) X: 9° 22' 1.2" E Y: 36° 04' 1.2" N Z: ~446 m
	SIDI BOUZID (~72 km S-E) X: 9° 28' 58.8" E Y: 35° 00' 00.0" N Z: ~376 m
	KASSERINE (~53 km S-W) X: 8° 27' 00.0" E Y: 35° 09' 00.0" N Z: ~1127 m
	LE KEF (~79 km N-W) X: 8° 42' 00.0" E Y: 36° 07' 58.8" N Z: ~494 m

Table 4: Site characteristics of point P05a in the area of Kasserine

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

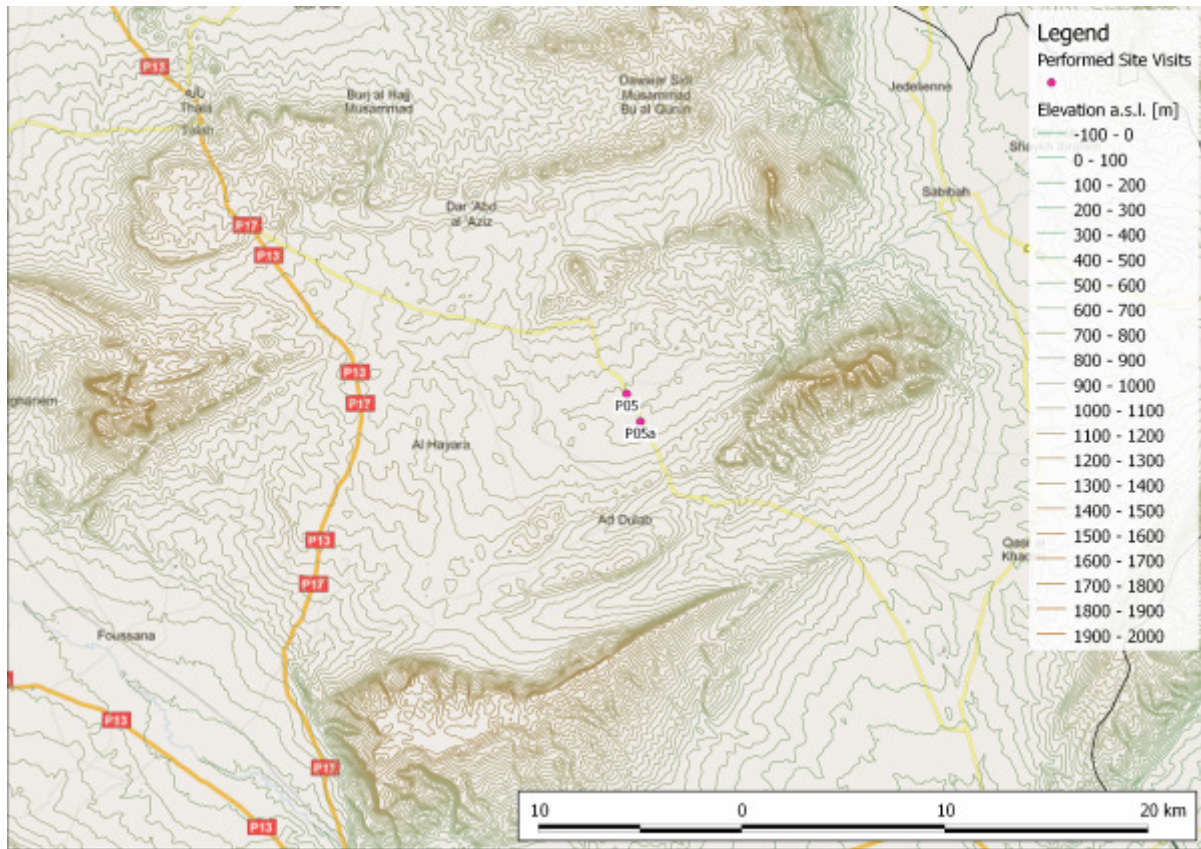


Figure 6: Orographic map showing the terrain complexity at point P05 and P05a



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Figure 7: Panoramic view as seen at point P05a

Additional photos were taken in a distance of 1.5 km north-west of the photo-point P05a. The coordinates as well as the panorama photos are given in the following:

Name of the site	Route de Sbela (ESSKIRA) - <b>P05</b>	
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude:	8° 54' 05.5"
	Y / Latitude:	35° 27' 27.9"
	Z / h.a.s.l.:	~ 886 m



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Figure 8: Panoramic view as seen at point P05

### 3.3 Sites in the area of Tozeur

During the site assessment one site in the Region of Kasserine has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Tozeur	33° 55' 27"	08° 07' 52"	~ 45

Table 5: Coordinates of city Tozeur

The next map<sup>6</sup> depicts the points visited in the area of the site visited near Tozeur:

<sup>6</sup> Topographical map was not available for the area, hence a street map was used instead.



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Figure 9: Map showing the positions of visited points 13 and 13a in the area Tozeur. The purple points are indicating visited points **P13** and **P13a** at the site.

Name of the site	Nafta - <b>P13a</b>
Date	26/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 7° 52' 04.4"
	Y / Latitude: 33° 53' 43.0"
	Z / h.a.s.l.: ~ 84 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.42
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.24
Area	Uniform flat area with very low roughness. Sand covered, interrupted by bushes smaller than 1 m.
Complexity of terrain	Smooth, plain terrain with some dunes with heights up to 2 m.

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	Slightly decreasing terrain in the south at a distance of 3 km with a drop of 50 m approx.
Surface roughness	<p>The surroundings are governed by desert or semi-desert with individual bushes up to 1 m height.</p> <p>In north-east direction lies a plantation of palms in a distance of 8 km.</p> <p>In the south lies the village of Nafta in a distance of 1 km, extending from 130° to 205° and covering together with the oasis in the south an area of 5 km depth.</p> <p>Also in the south there is a plantation in a distance of 800 m.</p>
Extension of proposed area	<p>Beside the village and the oasis in the south the whole area in the sector extending from the west (250°) to east (90°) is free of major obstacles and limitations up to a distance of 20 km, thus making the area suitable for a 50 MW scenario.</p> <p>South of the village and the oasis lies a “chot” (dry salty plane area, that can fill up with water), which shall be avoided as the wind farm site.</p>
Information on ground and soil conditions (for wind turbine foundations)	Sand, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 1 km to the south-east. Minor access roads, suitable for 4x4-Trucks up to the site.
Voltage level [kV]	30 kV grid line as well as a STEG HV sub-station can be found in a distance of 17 km.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	<p>TOZEUR (~22 km E)</p> <p>X: 8° 06' 00.0" E</p> <p>Y: 33° 55' 01.2" N</p> <p>Z: ~97 m</p>

Table 6: Site characteristics of point P13a in the area of Tozeur

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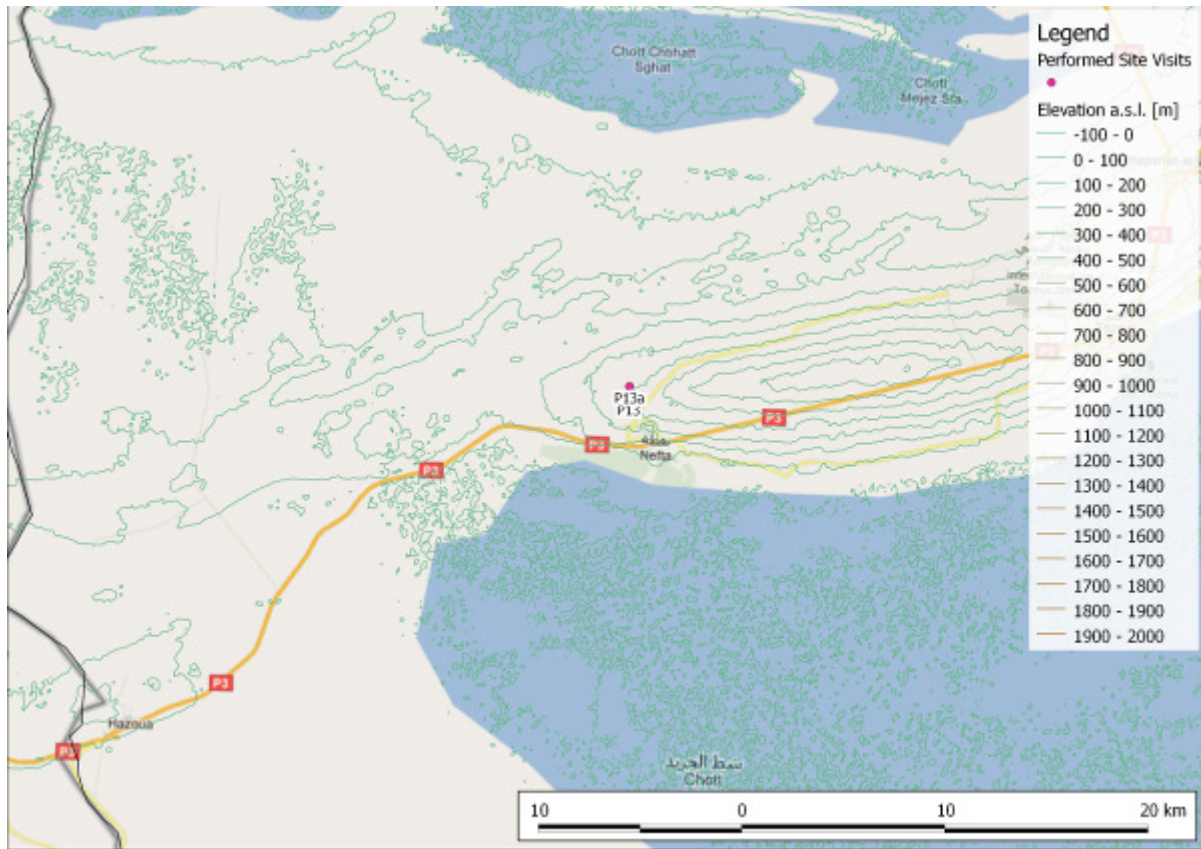


Figure 10: Orographic map showing the terrain complexity at points P13 and P13a



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 11: Panoramic view as seen at the measurement point P13a

Additional photos were taken in a distance of 600 m south of the photo-point P13a. The coordinates as well as the panorama photos are given in the following:

Name of the site	Nafta – <b>P13</b>
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 7° 52' 02.4"
	Y / Latitude: 33° 53' 23.8"
	Z / h.a.s.l.: ~ 78 m



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia





### 3.4 Site in the area of Kebili

During the site assessment one site in the Region of Kebili has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Kebili	33° 42' 07"	08° 58' 26"	~ 49

Table 7: Coordinates of city Kebili

The next map depicts the area of the site visited near Kebili:

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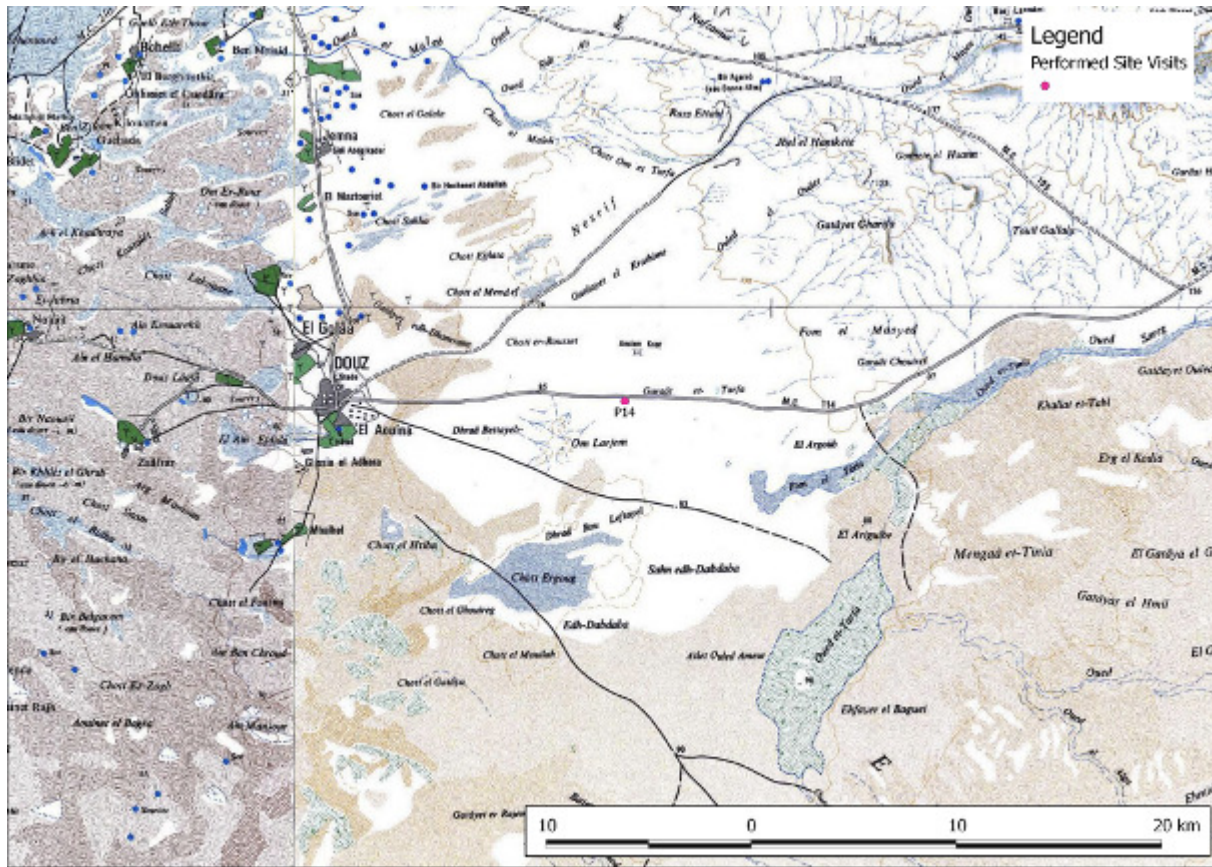


Figure 12: Map showing the positions of visited site P14 in the area Kebili  
 The purple point is indicating visited site **P14**.

Name of the site	Douz - <b>P14</b>
Date	27/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 9° 10' 27.4"
	Y / Latitude: 33° 27' 37.8"
	Z / h.a.s.l.: ~ 84 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.92
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.73
Area	Uniform flat area with very low roughness. Sand covered, interrupted by bushes smaller than 1 m.



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Complexity of terrain	Plain terrain.
Surface roughness	In the surroundings are governed by desert or semi-desert with bushes up to 1 m height.
Extension of proposed area	Beside the village of Douz in a distance of 12 km in western direction the area is free of major obstacles, thus making the area suitable for a 50 MW scenario.
Information on ground and soil conditions (for wind turbine foundations)	Sand, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 100 m to the north.
Voltage level [kV]	A STEG HV sub-station (Kebili) lies 30 km north-west of the site. Major grid lines have not been detected.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	GABES (~98 km E) X: 10° 06' 00.0" E Y: 33° 52' 58.8" N Z: ~7 m

Table 8: Site characteristics of point P14 in the area of Kebili

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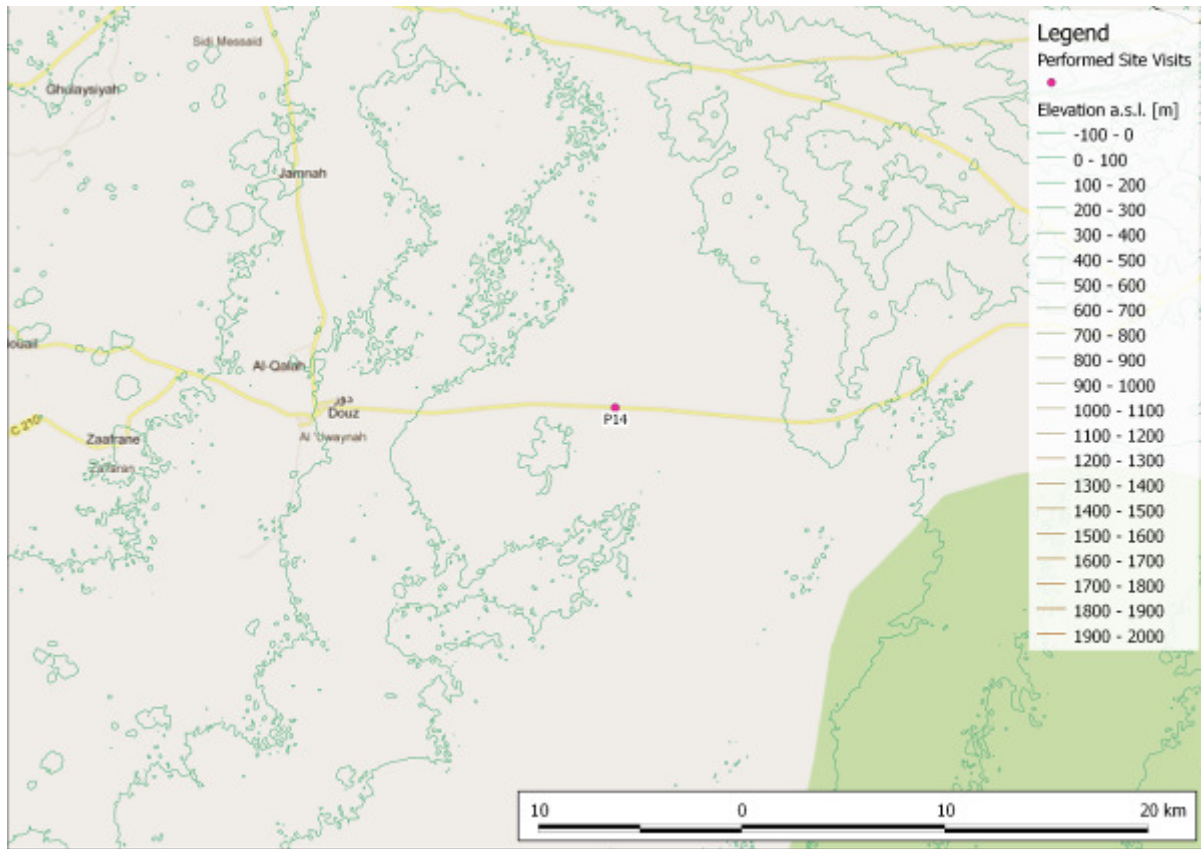


Figure 13: Orographic map showing the terrain complexity at point P14



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 14: Panoramic view as seen at the point P14

3.5 Sites in the area of Medenine

During the site assessment two sites in the Region of Medenine have been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Medenine	33° 20' 56"	10° 29' 41"	~ 92

Table 9: Coordinates of city Medenine

The next map depicts the area of the sites visited near Medenine:



Figure 15: Map showing the positions of visited sites P03 and P16  
 The purple points are indicating the visited sites **P03** and **P16**.

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Name of the site	En-Nbahna- <b>P16</b>
Date	27/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 10° 57' 19.3"
	Y / Latitude: 33° 27' 25.1"
	Z / h.a.s.l.: ~ -2 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.76
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.48
Area	Uniform flat area with low roughness (semi-desert with small bushes up to 1 m) near to the visited site, higher roughness in the surroundings due to olive farms.
Complexity of terrain	Plain terrain.
Surface roughness	<p>The close surroundings are governed by desert or semi-desert with individual bushes up to 1 m height. Further away the surroundings are governed by dense olive plantations which cover the whole area.</p> <p>The distances to these plantations are:</p> <p>North (315° - 45°): 500 m  East (45° - 135°): 500 m  South (135° - 225°): 600 m (135° - 180°)  1.5 km (180° - 215°)  West (225° - 315°): 2.5 km</p> <p>Beside this a waste deposit with a height of 6 m lies in southern direction in a distance of 300 m. The nearest village is 2 km away in western direction.</p>
Extension of proposed area	<p>The far surroundings (see surface roughness) are characterized by olive plantations in all directions, thus limiting the suitable area for a 50 MW scenario.</p> <p>Technically suitable for at least 50 MW it depends on the legal framework to build wind farms within olive farms.</p>

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Information on ground and soil conditions (for wind turbine foundations)	Cultivated land, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 100 m to the south-east.
Voltage level [kV]	A STEG HV sub-station (Zarziz) lies 5 km east of the site. Major grid line passes in a distance of 2 km south of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	<p>GABES (~92 km N-W) X: 10° 06' 00.0" E Y: 33° 52' 58.8" N Z: ~7 m</p> <p>JERBA (~49 km N-N-W) X: 10° 46' 01.2" E Y: 33° 52' 01.2" N Z: ~2 m</p> <p>MEDENINE (~46 km W) X: 10° 28' 58.8000" E Y: 33° 21' 0.0000" N Z: ~96 m</p> <p>TATAOUINE (~76 km S-W) X: 10° 27' 00.0" E Y: 32° 55' 01.2" N Z: ~299 m</p>

Table 10: Site characteristics of point P16 in the area of Medenine

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 16: Orographic map showing the terrain complexity at point P16



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia





Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 17: Panoramic view as seen at the point P16

Name of the site	Garâat el Oued - <b>P03</b>
Date	27/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 11° 09' 21.0"
	Y / Latitude: 33° 13' 57.4"
	Z / h.a.s.l.: ~ -1 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.99
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.64
Area	Uniform flat area with low roughness (semi-desert with small bushes up to 1 m) near to the visited site. Seashore at a distance of 1 km north-east of the site and olive farms in a distance of 3 km southwards.
Complexity of terrain	Plain terrain with elevations up to 1.5 m.
Surface roughness	The surroundings are governed by desert or semi-desert with individual bushes up to 1 m height. Seashore lies at a distance of 1 km north-east. Olive trees as well as the city of El Masrá are growing in a distance of 3 km southwards.
Extension of proposed area	The surroundings westwards and northwards are free of major obstacles and roughness changes. In these direction the suitable area extends up to at least 7 km. Southwards the proposed area is limited by olive farms and the city of El Masrá in a distance of 3 km. Considering the available space in western, northern and southern direction the area is considered as suitable for a 50 MW scenario.
Information on ground and soil conditions (for wind turbine foundations)	Compact sand, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 150 m to the east.

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Voltage level [kV]	A STEG HV sub-station (Zarziz) lies 30 km north-west of the site. Major grid line passes in a distance of 5 km south of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned
Nearby meteorological station	<p>JERBA (~79 km N-W) X: 10° 46' 01.2" E Y: 33° 52' 01.2" N Z: ~2 m</p> <p>MEDENINE (~64 km W) X: 10° 28' 58.8" E Y: 33° 21' 00.0" N Z: ~96 m</p> <p>TATAOUINE (~75 km W) X: 10° 27' 00.0" E Y: 32° 55' 01.2" N Z: ~299 m</p>

Table 11: Site characteristics of point P03 in the area of Medenine

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 18: Orographic map showing the terrain complexity at point P03



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 19: Panoramic view as seen at point P03

3.6 Sites in the area of Tataouine

During the site assessment one site in the Region of Tataouine has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Tataouine	32° 55' 33"	10° 26' 48"	~ 254

Table 12: Coordinates of city Tataouine

The next map depicts the area of the site visited near Tataouine:

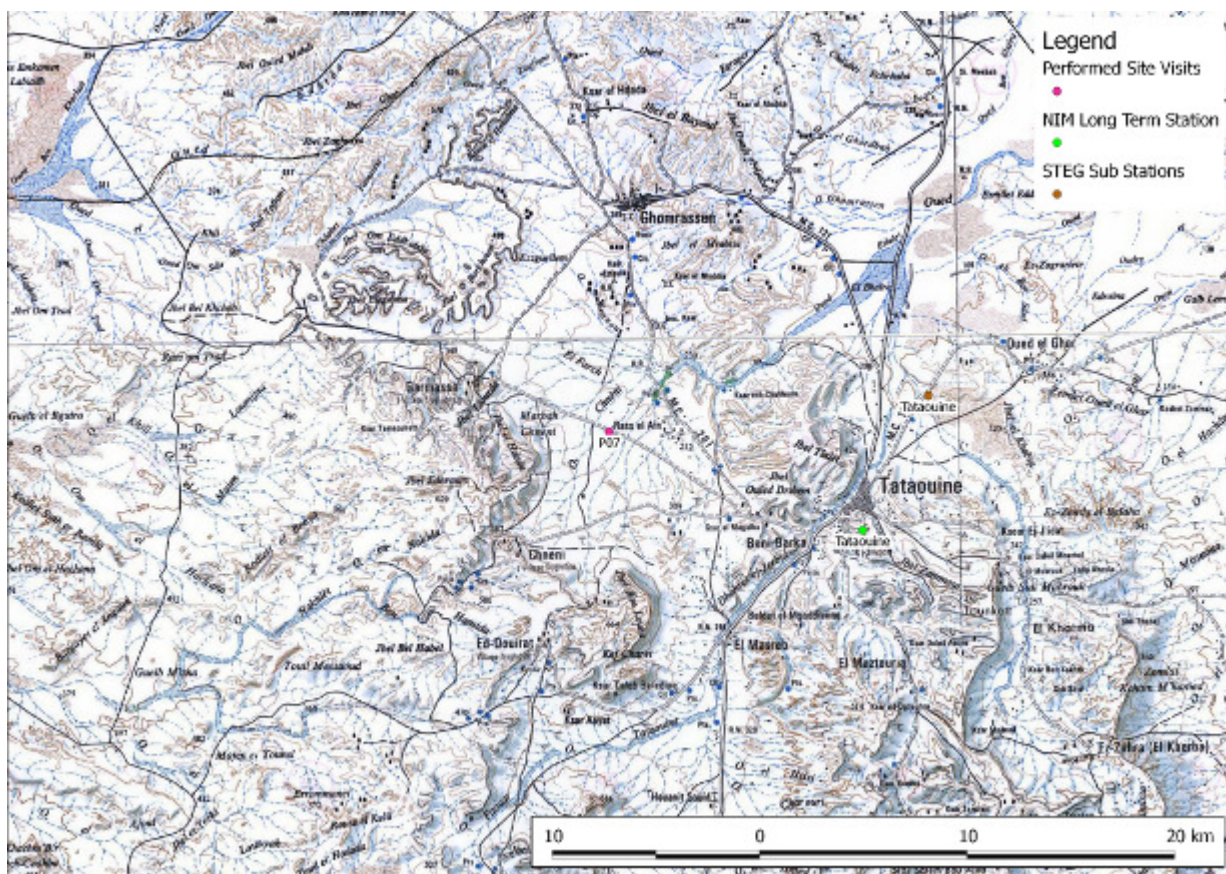


Figure 20: Map showing the position of the visited site P07 in the area Tataouine  
The purple point is indicating the visited site **P07**.

Name of the site	Guermasa - <b>P07</b>
Date	27/09/11

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 10° 19' 11.9"
	Y / Latitude: 32° 57' 40.5"
	Z / h.a.s.l.: ~ 296 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.69
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.16
Area	Uniform flat area with low roughness. Soil covered with sand and small stones.
Complexity of terrain	<p>Plain terrain. Surrounded by mountains at a distance of at least 5 km with a height difference with respect to the visited site of up to 300 m.</p> <p>In a distance of at least 10 km there is a crest in east direction with a height difference with respect to the visited site of 100 m. The crest is perpendicular to the line of sight extending from north to south.</p> <p>In a distance of 5 km there is a crest in west direction with a height difference of 300m with respect to the visited site. The crest is perpendicular to the line of sight extending from north to south.</p>
Surface roughness	<p>The surroundings are governed by desert or semi-desert with individual freestanding trees in all directions with a height of up to 3 m.</p> <p>In northern direction there is an olive farm in a distance of 1.5 km as well as a village in a distance of 12 km. In north-east direction there is a small forest in a distance of about 8 km as well as a village.</p> <p>In east direction olive farms start at a distance of 1.5 km and a village in a distance of 3 km.</p> <p>South of the site there is a small farmers house with some surrounding trees in a distance of 1 km. South-west there is another village in a distance of 9 km.</p>

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Extension of proposed area	<p>Beside the surrounding villages and olive farms the area is free of major obstacles.</p> <p>Main limitations are given by the steep crests in the east and the west so the suitable area extends in east-west direction round about 10 km, while in north-south direction the area extends 20 km, thus making it suitable for a 50 MW scenario.</p>
Information on ground and soil conditions (for wind turbine foundations)	Sand and stones, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 50 m to the north-east.
Voltage level [kV]	A STEG HV sub-station (Tataouine) lies 15 km east of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned or private.
Nearby meteorological station	<p>MEDENINE (~46 km N) X: 10° 28' 58.8" E Y: 33° 21' 00.0" N Z: ~96 m</p> <p>TATAOUINE (~13 km W-S-W) X: 10° 27' 00.0" E Y: 32° 55' 01.2" N Z: ~299 m</p> <p>REMADA (~72 km S) X: 10° 24' 00.0" E Y: 32° 19' 01.2" N Z: ~294 m</p>

Table 13: Site characteristics of point P07 in the area of Tataouine

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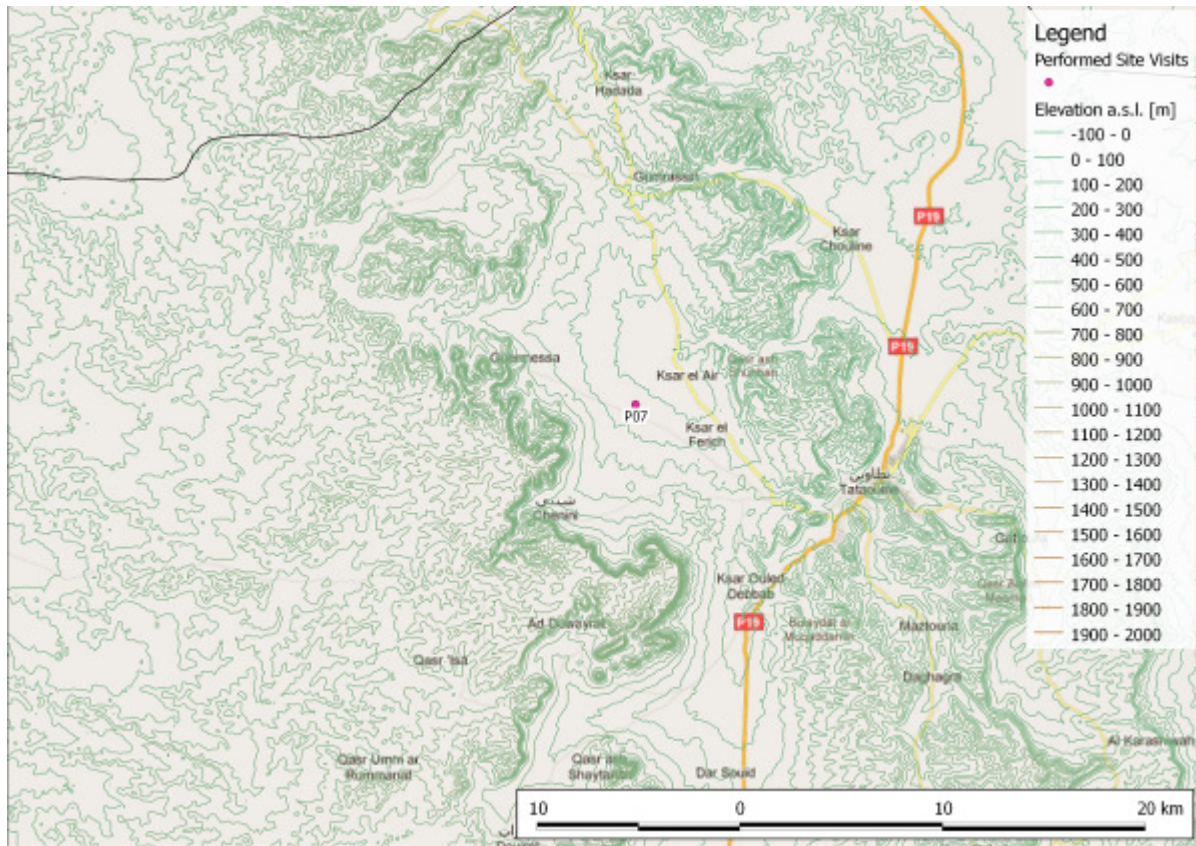


Figure 21: Orographic map showing the terrain complexity at point P07

**Site Panorama Photographs**





Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 22: Panoramic view as seen at point P07

3.7 Sites in the area of Gabes

During the site assessment one site in the Region of Gabes has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Gabes	32° 53' 36"	10° 06' 10"	~ 6

Table 14: Coordinates of city Gabes

The next map depicts the area of the sites visited near Gabes:

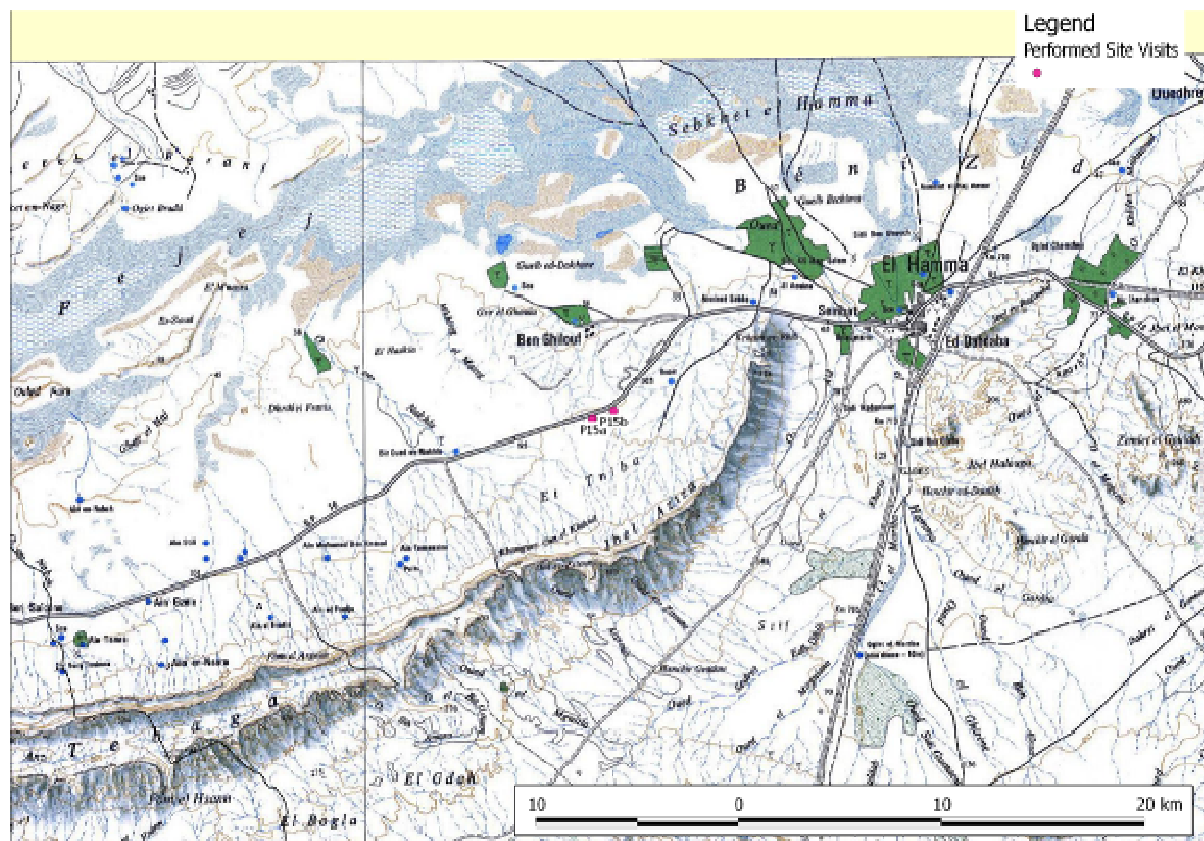


Figure 23: Map showing the positions of visited sites P15a and P15b in the area Gabes. The purple points are indicating the visited sites **P15**, **P15a** and **P15b**.

Name of the site	Beniri Luv - <b>P15b</b>
Date	28/09/11

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 09° 37' 21.5"
	Y / Latitude: 33° 50' 43.1"
	Z / h.a.s.l.: ~ 92 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.90
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.87
Area	Uniform flat area with low roughness. Soil covered with sand and small stones.
Complexity of terrain	<p>Plain terrain. Surrounded by mountains at a distance of at least 6 km with a height difference with respect to the visited site of up to 300 m.</p> <p>In a distance of at least 6 km there is a crest in south direction perpendicular to the line of sight with an elevation of 200 m with respect to the visited site. The crest is extending from north-east to south-west.</p>
Surface roughness	<p>The surroundings are governed by desert or semi-desert condition with few individual freestanding bushes in all directions with a height of up to 1 m.</p> <p>North of the site in a distance of 5 km there is a dry salt plain (chot).</p> <p>In western direction there is a greenhouse in a distance of 1 km and a second one in a distance of 1.5 km.</p> <p>South-west of the sight in a distance of 1.5 km there is a small farm with some houses and olive plantations.</p>
Extension of proposed area	<p>The area is in general free of major obstacles.</p> <p>The available space extends in east, south-east, south and south-west direction up to a distance of at least 6 km. Thus making the area in general suitable for a 50 MW scenario.</p> <p>Westwards in a distance of 2 km there is a huge military area which probably can be not used for wind farms.</p>
Information on ground and soil conditions (for wind turbine foundations)	Sand and stones, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 150 m to the north-west.

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Voltage level [kV]	Several STEG HV sub-stations (all near to Gabes) lie 45 km east of the site. A 30kV grid line passes in a distance of 1.5 km south of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	Private.
Nearby meteorological station	<p>GAFSA (~98 km N-W)  X: 8° 49' 01.2" E  Y: 34° 25' 01.2" N  Z: ~313 m</p> <p>GABES (~44 km E)  X: 10° 06' 00.0" E  Y: 33° 52' 58.8" N  Z: ~7 m</p> <p>MEDENINE (~97 km S-E)  X: 10° 28' 58.8" E  Y: 33° 21' 00.0" N  Z: ~96 m</p>

Table 15: Site characteristics of point P15b in the area of Gabes

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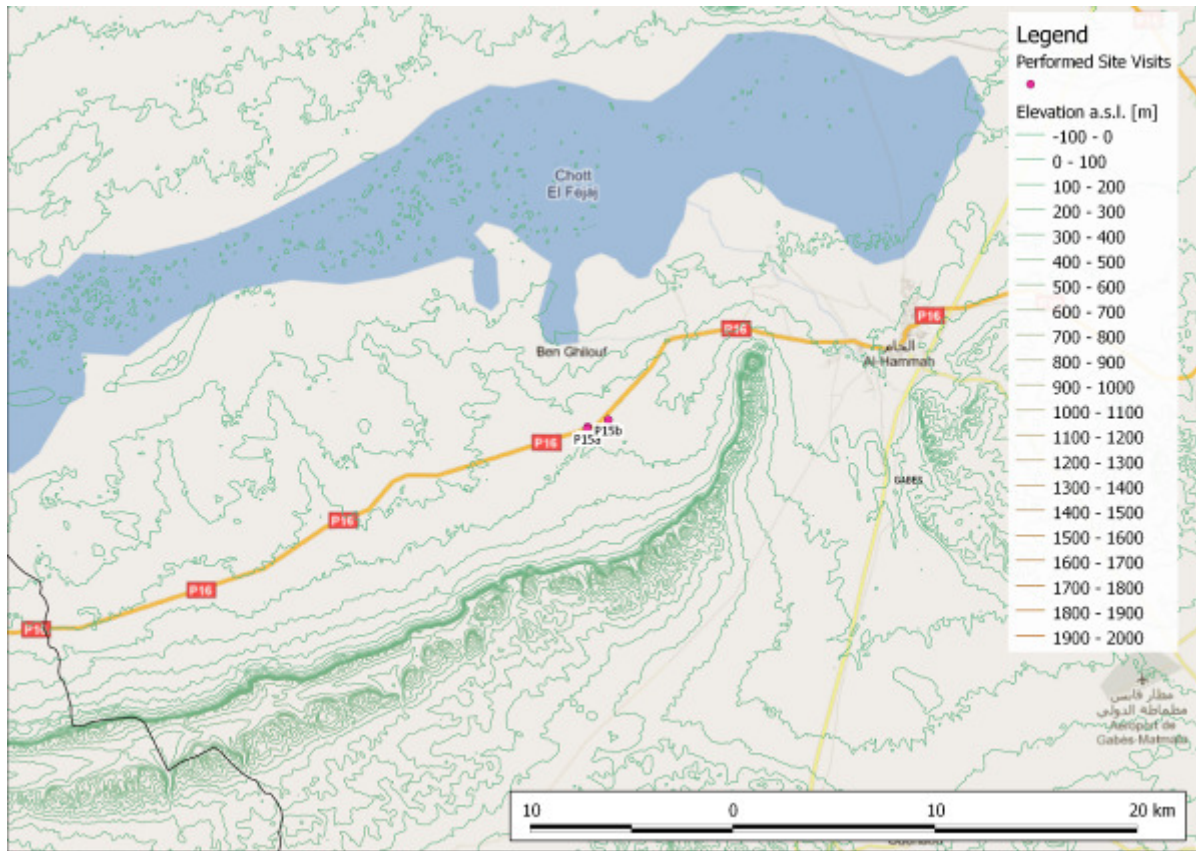


Figure 24: Orographic map showing the terrain complexity at point P15b



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



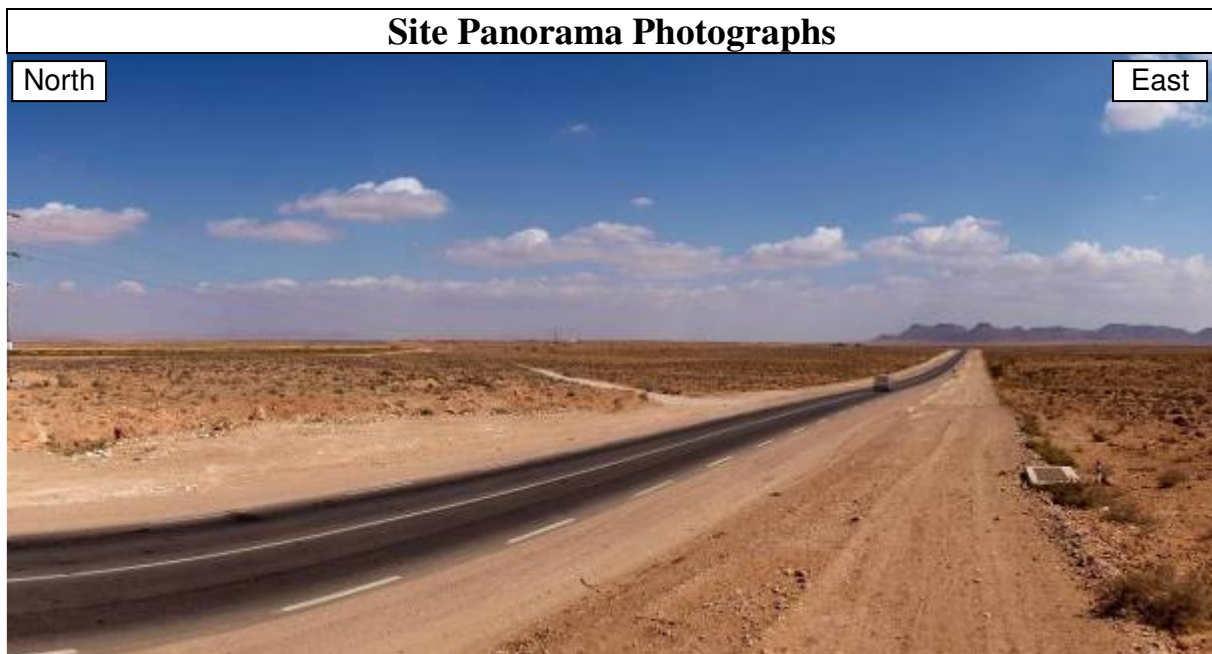
Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 25: Panoramic view as seen at the point P15b

Additional photos were taken in a distance of 1.0 km north-east of the photo-point P15b. The coordinates as well as the panorama photos are given in the following:

Name of the site	Beniri Luv – <b>P15</b>	
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude:	9° 37' 22.3"
	Y / Latitude:	33° 50' 31.7"
	Z / h.a.s.l.:	~ 92 m



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia





Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



At point P15a no photos were taken as the distance between P15 and P15a was only 75 m.

### 3.8 Sites in the area of Sfax

During the site assessment one site in the Region of Sfax has been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Sfax	34° 44' 43"	10° 45' 41"	~ 4

Table 16: Coordinates of city Sfax

The next map<sup>7</sup> depicts the area of the site visited near Sfax:



Figure 26: Map showing the positions of visited site in the area Sfax

The purple point is indicating the visited site **P06a**:

Name of the site	Ahmed Nouiguez - <b>P06a</b>
Date	28/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 10° 04' 00.4"
	Y / Latitude: 34° 25' 19.4"

<sup>7</sup> Topographical map was not available for the site, hence a street map was used as background map.

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

	Z / h.a.s.l.: ~ 29 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.13
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	5.93
Area	Flat, structured area with higher roughness.
Complexity of terrain	Plain terrain with a slight rise in north-west direction at a distance of 10 km. Height difference with respect to the visited site of up to 100 m.
Surface roughness	<p>The close surroundings are governed by semi-desert soil and agricultural land characteristics interrupted by some individual trees in eastern direction. The further surroundings are governed by olive farms and villages.</p> <p>In northern direction there are olive farms at a distance of 4 km (0° - 70°) and 10 km (350° - 90°) as well as some houses in a distance of 400 m.</p> <p>In the east there are two major villages at a distance of 1 km and 6 km.</p> <p>In the west there are 3 villages in a distance of 5 km as well as the future highway from Tunis to Gabes at a distance of 500 m. In the same direction there are olive plantations in a distance of 800m and 8 km.</p>
Extension of proposed area	<p>The area is full of considerable obstacles. The roughness is, compared to the other sites visited during the mission, very structured</p> <p>The available free area extends about 4 km to the north, 1.5 km to the east, 3 km to the south and 1 km to the west, making the area not suitable for a 50 MW scenario. The available area might be larger if it is possible to build wind farms within olive farms. Then the area extends some 10 km in northern direction,</p> <p>This available area is an estimation and could not be evaluated on site due to olive farms in the surroundings and villages in the whole area.</p>
Information on ground and soil conditions (for wind turbine foundations)	Sand and stones, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 100 m to the north-east.

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Voltage level [kV]	A STEG HV sub-station (Skhira) lies 11 km south of the site. A 90kV grid line passes in a distance of 8 km east of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	State owned.
Nearby meteorological station	<p>SIDI BOUZID (~83 km N-W)  X: 9° 28' 58.8" E  Y: 35° 00' 00.0" N  Z: ~376 m</p> <p>SFAX (~65 km N-E)  X: 10° 40' 58.8" E  Y: 34° 43' 01.2" N  Z: ~21 m</p> <p>GABES (~60 km S)  X: 10° 06' 00.0" E  Y: 33° 52' 58.8" N  Z: ~7 m</p> <p>JERBA (~89 km S-E)  X: 10° 46' 01.2" E  Y: 33° 52' 01.2" N  Z: ~2 m</p>

Table 17: Site characteristics of point P06a in the area of Sfax

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 27: Orographic map showing the terrain complexity at point P06a

**Site Panorama Photographs**



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia



Figure 28: Panoramic view as seen at the point P06a

3.9 Sites in the area of Nabeul

During the site assessment two sites in the Region of Nabeul have been visited.

Area	N (Geo WGS 84)	E (Geo WGS 84)	Height above sea level [m]
Nabeul	36° 27' 15"	10° 44' 05"	~ 11

Table 18: Coordinates of city Nabeul

The next map depicts the area of the sites visited near Nabeul:

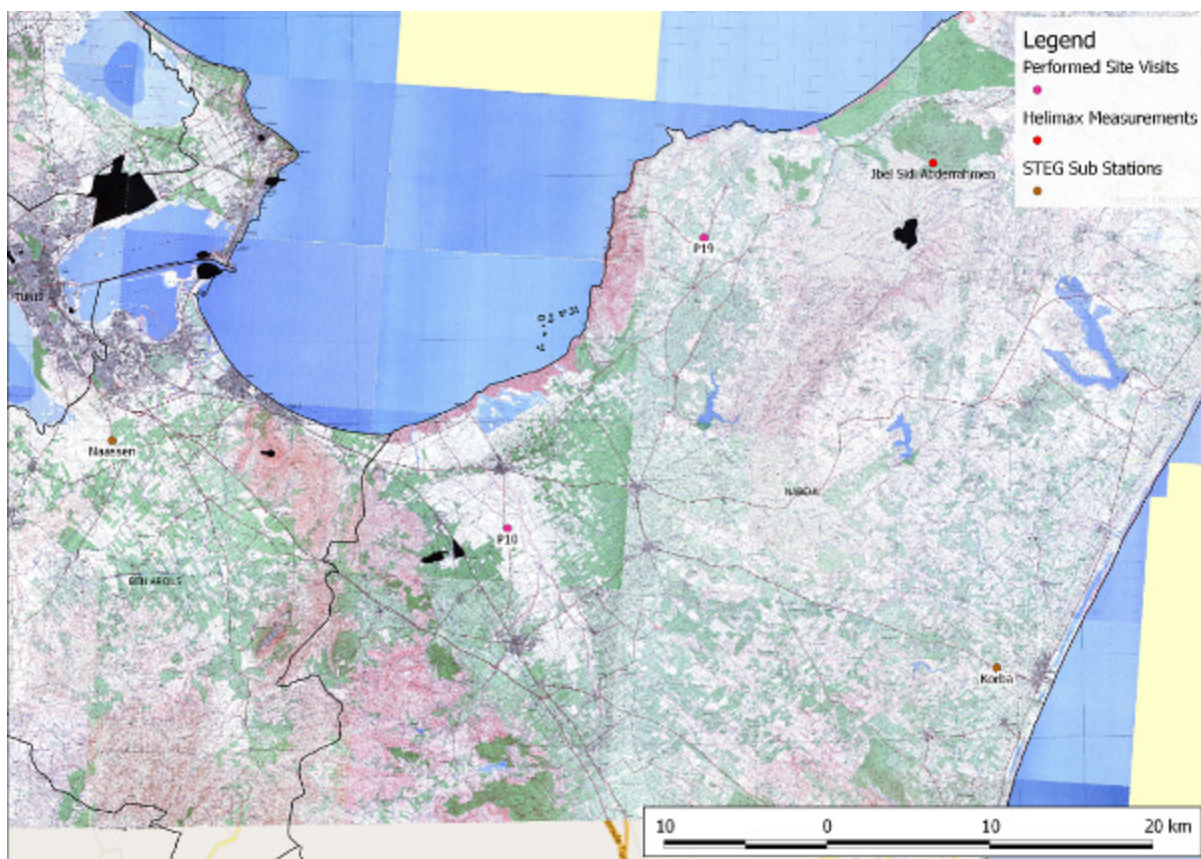


Figure 29: Map showing the positions of visited sites P10 and P19 in the area Nabeul  
The purple points are indicating visited sites **P10** and **P19**:

Name of the site	Soliman - <b>P10</b>
Date	29/09/11

Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 10° 29' 40.7"
	Y / Latitude: 36° 39' 44.2"
	Z / h.a.s.l.: ~ 28 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.69
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.44
Area	Flat, structured area with higher roughness.
Complexity of terrain	Plain terrain with mountains rising in the west in a distance of 10 km. Height difference with respect to the visited site of up to 250 m. Other mountains lie in a distance of more than 20 km in north and north-east direction.
Surface roughness	<p>The close surroundings are governed by agricultural land characteristics. The further surroundings are governed by plantations and villages.</p> <p>In northern direction there is a building with a height of 8 m at a distance of 400 m. The village of Soliman is 6 km far away.</p> <p>In the east a small forest with trees up to 5 m is growing at a distance of 1.5 km.</p> <p>In the south in a distance of 1.5 km a new sub station was erected.</p> <p>The whole area is surrounded by trees (olives and oranges) in a distance of 6 km.</p>
Extension of proposed area	<p>The area is has some obstacles. The suitable area is sited within a radius of 6 km around the visited site, except to the west, where a 90kV line is passing in a distance of 2 km and considerable distance has to be maintained.</p> <p>The available area is considered as suitable for a 50 MW scenario as there is free available space in all directions except westwards. Considering the possibility to build a wind farm within olive farms there might be a possibility to fit more than 50 MW.</p>
Information on ground and soil conditions (for wind turbine foundations)	Agricultural used land, rocks might be expected at some depth.



Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

Infrastructure	Main asphalted road in about 200 m to the west.
Voltage level [kV]	A new STEG HV sub-station (name unknown) lies 1.5 km south of the site. A 90kV grid line passes in a distance of 2 km west of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	Private.
Nearby meteorological station	<p>NABEUL (~32 km S-E) X: 10° 42' 0.0" E Y: 36° 28' 1.2" N Z: ~78 m</p> <p>KELIBIA (~57 km E) X: 11° 04' 58.8" E Y: 36° 51' 00.0" N Z: ~17 m</p> <p>BIZERTE (~90 km N-W) X: 9° 48' 00.0" E Y: 37° 15' 00.0" N Z: ~7 m</p>

Table 19: Site characteristics of point P10

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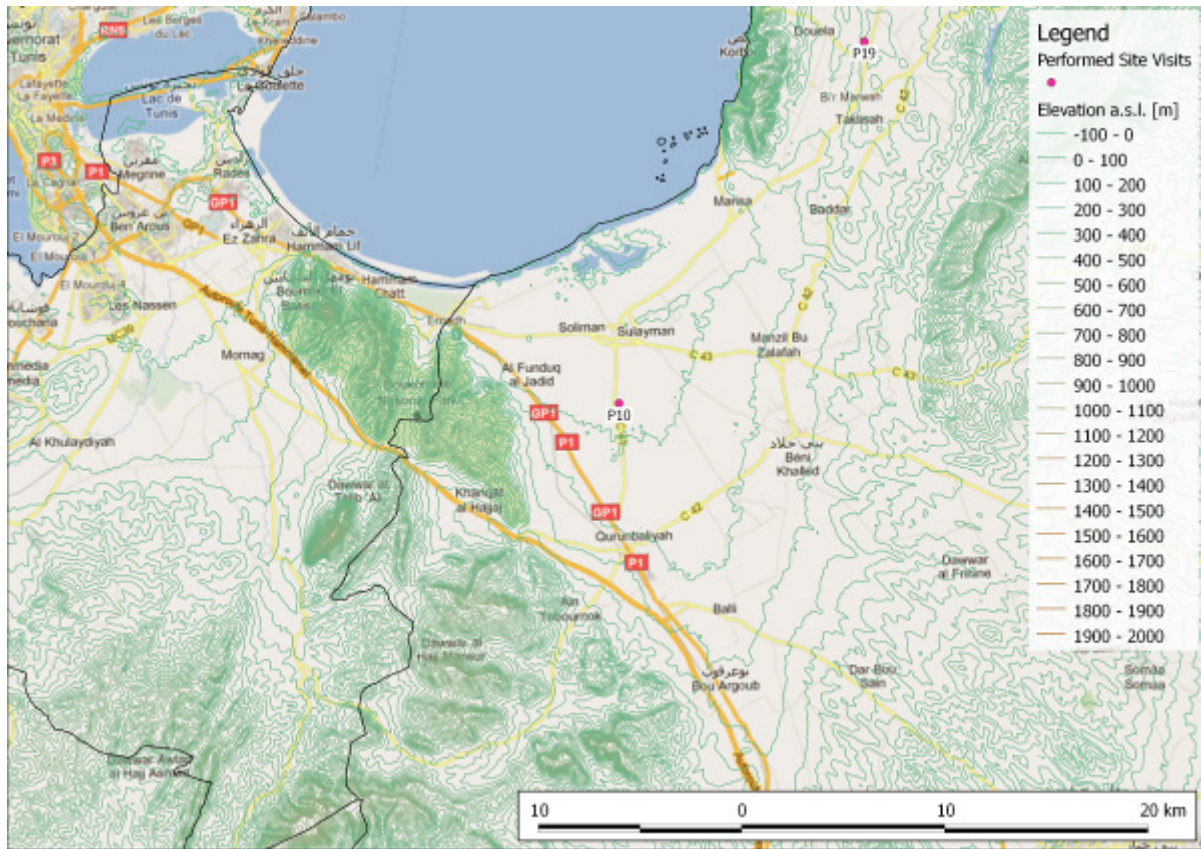


Figure 30: Orographic map showing the terrain complexity at point P10



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Figure 31: Panoramic view as seen at the point P10

Name of the site	Douala - <b>P19</b>
Date	29/09/11
Inspected by	Mathias Hölzer, German ProfEC GmbH
Coordinates of photo point at proposed wind farm site (GEO WGS 84)	X / Longitude: 10° 37' 58.8"
	Y / Latitude: 36° 49' 15.3"
	Z / h.a.s.l.: ~ 116 m
Average wind speed at 100 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.78
Average wind speed at 80 m h.a.g.l. (acc. to Tunisian Wind Atlas) [m/s]	6.70
Area	Agricultural used land, interrupted by a few freestanding trees.
Complexity of terrain	Smooth hills in all directions with a height difference up to 70 m with respect to the visited site. Mountain in a distance of 3 km in western direction with a height difference of 100 m with respect to the visited site.
Surface roughness	The close surroundings are governed by agricultural land, interrupted by individual trees up to 4 m. In northern direction there is an olive farm and a village in a distance of 400 m. In eastern direction there are olive as well as almond plantations in a distance of 500 m. In the south a olive plantation as well as a village is in a distance of 600 m. In western direction at a distance of 5 km there is a village.

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Extension of proposed area	The area has some obstacles. The extension of the suitable area is limited as there are several villages in the surroundings. Depending on the legal framework regarding the minimum distances to houses and villages a 50 MW scenario might fit into the area.
Information on ground and soil conditions (for wind turbine foundations)	Agricultural used land, rocks might be expected at some depth.
Infrastructure	Main asphalted road in about 300 m to the east.
Voltage level [kV]	Two STEG HV sub-station (Menzel Tetmine and Korba) lie 30 km east respectively south-east of the site.
Access to sites	Very good.
Transport and Installation	Unproblematic
Narrow thoroughfares or road and bridge load-bearing	No concern.
Land property	Private.
Nearby meteorological station	<p>NABEUL (~42 km S) X: 10° 42' 0.0" E Y: 36° 28' 1.2" N Z: ~78 m</p> <p>KELIBIA (~40 km E) X: 11° 04' 58.8" E Y: 36° 51' 00.0" N Z: ~17 m</p> <p>BIZERTE (~88 km N-W) X: 9° 48' 00.0" E Y: 37° 15' 00.0" N Z: ~7 m</p>

Table 20: Site characteristics of point P19

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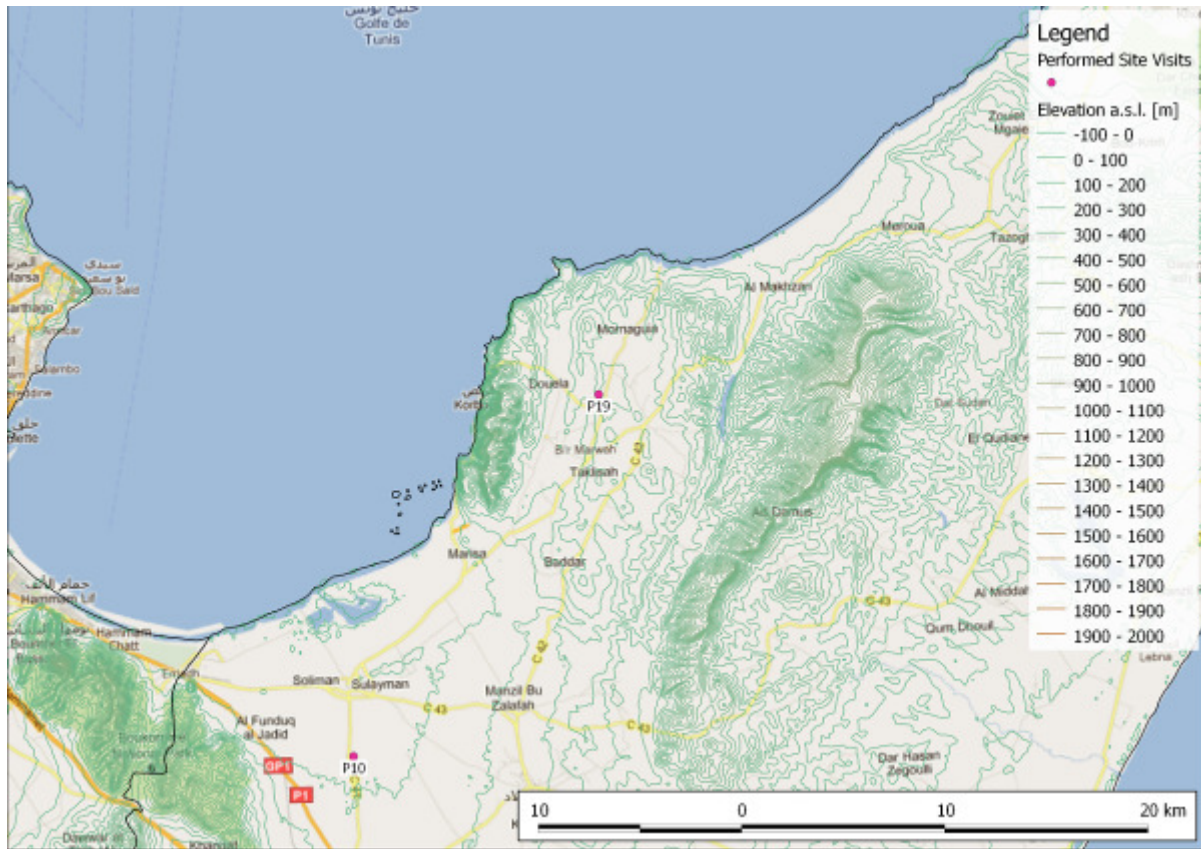


Figure 32: Orographic map showing the terrain complexity at point P19



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Evaluation of Fourteen Sites for Wind Measurements in Nine Regions of Tunisia

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Figure 33: Panoramic view as seen at the point P19



#### 4 Summary

The sites have been ranked evaluating the following characteristics for each site:

- Available wind resource according to the Tunisian Wind Atlas
- terrain expansion as well as openness, complexity and surface roughness
- available space to consider a 50 MW wind farm as the minimum scenario
- available and nearby infrastructure for
  - o Access (all good)
  - o Grid connection

Issue \ Site	P17a	P05a	P13a	P14	P16	P03	P07	P15b	P06a	P10	P19
<b>Wind resource<sup>8</sup> [m/s] at 100m</b>	6.6	6.87	6.42	6.92	6.76	6.99	6.69	6.9	6.13	6.69	6.78
<b>Wind resource [m/s] at 80m</b>	6.3	6.66	6.24	6.73	6.48	6.64	6.61	6.87	5.93	6.44	6.7
<b>Complexity of the site</b>	Smooth, plain terrain with minor height differences up to 10 m.  Mountains are rising in the surroundings in a distance of more than 5 km.	Smooth, plain terrain with minor height differences up to 30 m.  Mountains are rising in the surroundings in a distance of more than 6 km.	Smooth, plain terrain with minor height differences up to 2 m (dunes).  Drop of 50 m in south direction in a distance of 3 km.	Smooth, plain.	Smooth, plain.	Smooth, plain, with height differences up to 1.5 m.	Plain terrain. Mountains in a distance of at least 5 km.	Plain terrain. Mountains in a distance of at least 5 km.	Plain terrain. Slight rise in north-west direction at a distance of 10 km.	Plain terrain. Mountains in a distance of at least 10 km.	Smooth hills in all directions. Mountains in a distance of 3 km.

<sup>8</sup> Acc. to the Tunisian Wind Atlas

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Issue \ Site	P17a	P05a	P13a	P14	P16	P03	P07	P15b	P06a	P10	P19
<b>Complexity of roughness</b>	<p>Uniform roughness (agricultural land with some freestanding trees and bushes).</p> <p>Some roughness changes in north-east, east, south east and south direction in a distance of more than 3 km (olive farms and villages).</p>	<p>Uniform roughness (agricultural land with some freestanding trees and bushes). Freestanding houses are present in all directions.</p> <p>Major roughness change in south east and south direction in a distance of more than 2.5 km (dense forest).</p>	<p>Uniform roughness (sand, desert). Freestanding houses are present in east, south and west direction. Village of Nafta and oasis in south direction at a distance of 1 km.</p>	<p>Uniform roughness (sand, desert, small bushes up to 1 m).</p>	<p>Uniform roughness (agricultural land, sand, small bushes up to 1 m)</p> <p>Olive farms in the surroundings at a distance of at least 500 m.</p>	<p>Uniform roughness (agricultural land, sand, small bushes up to 1 m)</p> <p>Seashore in a distance of 1 km north-east.</p> <p>Olive farms and the city of El Masrá southwards in a distance of 3 km.</p>	<p>Uniform roughness (agricultural land, sand, freestanding trees up to 3 m).</p> <p>Major roughness changes in north and east direction by olive farms in a distance of 1.5 km. Villages in several directions with a distance of 3km to 12 km.</p>	<p>Uniform roughness (agricultural land, sand, freestanding bushes up to 1 m).</p>	<p>Uniform roughness (agricultural land, sand, freestanding trees up to 4 m in the east).</p> <p>The further surroundings are governed by olive farms and villages in distances of ranging from 800 m up to 8 km.</p>	<p>Uniform roughness (agricultural land, freestanding trees up to 5 m).</p> <p>The further surroundings are governed by plantations (olives and oranges) and villages. In a distance of 6 km.</p>	<p>Uniform roughness (agricultural land, freestanding trees up to 4 m).</p> <p>Olive and crop plantations in distances of 400 m and more in all directions.</p>

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<p><b>Available Space and terrain extension</b></p>	<p><b>Very good</b>, suitable for 50 MW and more.  The whole south-west, west and north-west sectors are completely free up to a distance of 10km.  Rest of the sectors with some olive farms and other obstacles.</p>	<p><b>Very good</b>, suitable for 50 MW and more.  Beside the village in northern direction and the freestanding houses in the east and the west the area is free of obstacles.  The south-east direction is limited by a crest perpendicular to the line of sight a distance of 10 km from south-west to north east.</p>	<p><b>Very good</b>, suitable for 50 MW and more.  North-west, north and north-east sector is free of obstacles, roughness changes and orographic limitations up to 20 km.  South is limited by a mostly dried salt lake.</p>	<p><b>Very good</b>, suitable for 50 MW and more  All sectors free of obstacles and major limitations</p>	<p><b>Moderate</b>, might be suitable for 50 MW, depending on the possibility to build wind turbines into existing olive farms.  The presence of several olive farms will limit the available space In all directions.</p>	<p><b>Good</b>, suitable for 50 MW and more.  Area is limited eastwards by the sea (1 km) and southwards by olive farms and the city of El Masrá (3 km).</p>	<p><b>Very good</b>, suitable for 50 MW and more.  Limitations will be the olive farms and the crests in the east and the west.</p>	<p><b>Good</b>, suitable for 50 MW and more.  Although the area is free of obstacles, with smooth the major limitation will be a huge military area (shooting range) in the west.</p>	<p><b>Moderate</b>, might be suitable for 50 MW, depending on the possibility to build wind turbines into existing olive farms</p>	<p><b>Good</b>, suitable for 50 MW and more.  Distance has to be maintained to the grid line in the west.</p>	<p><b>Moderate</b>, might be suitable for 50 MW, depending on the distance that has to be kept to houses and villages.</p>
<p><b>Access</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>	<p><b>Very good</b></p>

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Site Issue	P17a	P05a	P13a	P14	P16	P03	P07	P15b	P06a	P10	P19
<b>Grid connection</b>	<b>Very good.</b> 30 kV grid line in a distance of 200 m parallel to the asphalt road. Distance to next STEG HV sub-station (Bir Mcharga) is 20 km.	<b>Moderate.</b> A 30 kV grid line in a distance of 24 km in south-west and 36 km in north. Distance to the next STEG HV sub-stations (Kasserine Nord and Kasserine Sud) is 35 km.	<b>Good.</b> Distance to a 30 kV grid line and a STEG HV sub-station is 17 km.	<b>Moderate.</b> Distance to STEG HV sub-station (Kebili) is 30 km. No major grid lines in the near surroundings.	<b>Very good.</b> Distance to STEG HV sub-station (Zarziz) is 5 km. Distance to major grid line is 2 km.	<b>Very good.</b> Distance to STEG HV sub-station (Zarziz) is 30 km, distance to major grid line is 5 km.	<b>Good.</b> Distance to STEG HV sub-station (Tataouine) is 15 km. No major grid lines in the surroundings.	<b>Very good.</b> Distance to STEG HV sub-stations is 45 km. Distance to 30kV grid is 1.5 km.	<b>Good.</b> Distance to STEG HV sub-station (Skhira) is 11 km. Distance to 90kV grid line is 8 km.	<b>Very good.</b> Distance to STEG HV sub-station (name unknown) is 1.5 km. Distance to 90kV grid line is 2 km.	<b>Moderate.</b> Distance to STEG HV sub-station (Menzel Tetmine and Korba) is 30 km. No major grid lines in the surrounding s.
<b>NIM<sup>9</sup> Nearest Long Term Stations</b>	SILIANA (~59 km)	KASSERINE (~53 km)	TOZEUR (~22 km)	GABES (~98 km)	JERBA (~49 km) MEDENINE (~46 km)	MEDENINE (~64 km)	TATAOUINE (~13 km)	GABES (~44 km)	SFAX (~65 km) GABES (~60 km)	NABEUL (~32 km)	NABEUL (~42 km) KELIBIA (~40 km)

Table 21: Tabular summary

<sup>9</sup> Institut National de la Météorologie

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The national strategy welcomes a wind farm connection that is not in the same concentrated area in the North of Tunisia, where already 190 MW wind farm capacity is installed or planned. Therefore sites in the southern regions are more favorable in political terms.

Distributing wind energy geographically in such way and in some significant distance to the electricity generation centers in the north of the country, also has the advantage that the grid transmission losses for electricity transmitted from north to the south are lower.

Another positive aspect is that it is unlikely that suddenly in the north as well as in the south no wind is available at all. By the increased accumulated firm capacity, for which the grid balancing and load management is easier and the grid stability is increased.

A problem might be the grid connection as well as the electrical transportation capacities from the south to the north. Nevertheless 8 out of the 11 sites have a good or very good grid connection possibility in close distance.

## 5 Recommendations

Taking into account the aspects presented in table 21 a ranking for the sites was made. As the difference in wind potential is not very significant from one site to another and the wind resource is based on a simulation, the absolute figures were not taken into account.

The ranking is presented in the next table, where the higher points are the most recommended sites for wind resource assessments and further analyses and/or project development activities.

Name of the site visited	Province	Comments	Ranking
<b>P10</b>	Nabeul	Very good grid connection possibility, close to Tunis, limitations due to grid line and villages.	<b>–fully recommendable–</b>
<b>P17a</b>	Zaghouan	-	<b>–fully recommendable–</b>
<b>P13a</b>	Tozeur	Distance to substation and grid line: 17 km	<b>–fully recommendable–</b>
<b>P14</b>	Kebili	Distance to sub stations is notable (30 km). No grid lines in the surroundings	<b>–recommendable</b> , distance to the grid might be to big–
<b>P03</b>	Medenine	Some minor limitations in the area due to olive farms (south) and seashore (east)	<b>–recommendable</b> , area might be limited by olive farms–
<b>P15b</b>	Gabes	Good grid connection possibility, limitations due to military air shooting range	<b>–recommendable</b> , depending on the military–
<b>P05a</b>	Kasserine	Distance to major grid lines and substation is notable (more than 24 km)	<b>–recommendable</b> , distance to the grid might be to big –
<b>P07</b>	Tataouine	Distance to substation: 15 km	<b>–recommendable–</b>
<b>P16</b>	Medenine	Olive farms limit possible area. 50 MW scenario depends on environmental regulation if a wind farm can be built into an olive farm	<b>–not recommendable</b> without further investigations on the legal framework–
<b>P06a</b>	Sfax	Olive farms limit possible area. 50 MW scenario depends on environmental regulation if a wind farm can be built into an olive farm	<b>–not recommendable</b> without further investigations on the legal framework–
<b>P19</b>	Nabeul	Settlements limit possible area. 50 MW scenario depends on how close a wind farm can be installed to houses	<b>–not recommendable</b> without further investigations on the legal framework–

Table 22: Site ranking