Action Plan for high priority renewable energy initiatives in Southern and Eastern Mediterranean Area
SSP - Contract No. 044125

Work package N° 2
Identification and prioritisation of potential demonstration sites for wind and concentrated solar projects in the Southern and Eastern Mediterranean area

Deliverable N° D 2.2 and D2.3

Title:

Potential demonstration sites for wind and concentrating solar power projects

and

Ranked list of potential demonstration sites for wind and concentrating solar power projects

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1 Development of exclusion maps

Aim of WP2 is the definition of exclusion criteria for Wind Power Plants (WIND) and Concentrating Solar Power Plants (CSP) and the development of exclusion maps for each partner country (Algeria, Jordan, Tunisia and Turkey). Together with resource maps of wind speed and direct normal irradiance at ground (WP1), potential regions and sites within each country can be identified for future demonstration projects. For compiling all exclusion criteria, a Geographic Information System (GIS) is used. A GIS can easily combine and analyse spatial information and data. The purpose of the present deliverable, D2.3, is the realization of the exclusion maps for each target country and identification of potential demonstration sites. With the combination of the exclusion maps and the resource maps, together with locally applicable criteria, it is possible to define the exact location of the most promising sites for Wind and CSP demonstration sites development.

In principle, the criteria definition and the ideal methodology that should be used in a GIS assessment for wind or CSP plant siting has been defined in the deliverable 2.1. In that report it was not taken into account the availability of accurate GIS data sets that could provide information about the defined criteria, which is a fundamental requirement of applying each criteria.

In the scope of this report, D2.3, the data set availability has been checked. As a result of this process, several criteria defined in D2.1 could not be applied due the lack of high resolution data. This is the case of the so called evaluation criteria, which application has revealed too ambitious to be applied in these times, due to the lack of high quality trustable data. An example of this obstacle is the roughness criteria for wind plants. It was conceived as a directional criterion depending on the direction of the prevailing winds, taking into account that in that direction the earth surface smoothness requirement should be maximized in order to elevate the efficiency of the turbines. However, as GIS information about it has been impossible to gather, this criteria should be used in a local basis. In this case, a worst case analysis has been adopted in the GIS assessment of eligibility criteria, so that the toughest criteria requirements have been extended in order to apply the criteria. For instance, in the case of roughness criteria the permitted sites should have a round shaped zone of a radius of 7.5 km in which the roughness class is equal or lower than 2, which are the initially requirements just for the prevailing wind direction.

Anyway, with the foreseeable availability of high quality data, the designed methodology of assessment defined in D2.1 will be completely applicable for future siting analysis.

1.1 WIND exclusion criteria

The definition of the parameters for WIND was performed by ACCIONA and LABEIN, while DLR has executed the GIS analysis. Table 1 gives the defined parameters, the defined values and the applied database.

For example “orography”: To take orography into account, the value slope is defined as exclusion criteria. Wind power plants can be built up in areas with a slope within a range of 20%. Therefore, all regions with a slope higher than 20% must be excluded. The digital elevation model GLOBE and the GIS is used to calculate the slope.

Parameters for Wind	Exclusion value	Data to be applied
Land cover		
Water bodies	yes	GLC
Sand Surfaces	yes	GLC
Topography		
Roughness	Settlements and forests with security zone of 7.5km	GLC
Orography	slope > 20% (exclude valleys "manually")	GLOBE
Electricity Grid		
Distances to the Grid	distance > 75 km	DCW, data of country partners
Environment		
Population safety	distance < 500m	GLC
Land use		
Settlements	yes	GLC
Industry	yes	GLC, DCW
Agriculture	yes	GLC
Protected Areas	yes	WDPA
Cultural Heritage	yes	WDPA
Military	yes	DCW
Infrastructures	yes	DCW
Resources		
Minimum resource	At least 7.0 m/s at 50m height or wind class 4	Resource data from WP 1

Table 1: Definition of exclusion parameters for Wind Power Plants

1.2 CSP exclusion parameters

The definition of the parameters for CSP was performed by DLR. Table 2 gives the defined parameters, the defined values and the applied database that base on former works of DLR and of the EU-project INDITEP (2005)

For example "orography": To take orography into account, the value slope is defined as a exclusion criteria. Concentrating Solar Power Plants (parabolic trough technology) can be built up in areas with a slope within a range of 2.1%. Therefore, all regions with a slope higher than 2.1% must be excluded.

Parameters for CSP	Eligibility value	Data to be applied
Topography		
Orography	slope > 2,1 %	GLOBE
Land Cover		
Sea	yes	GLC
Inland Water	yes	GLC
Forest	yes	GLC
Swamp	yes	GLC
Agriculture	yes	GLC
Rice Culture	yes	GLC
Hydrology		
Permanent Inland Water	yes	GLC
Non-Permanent Inland Water	yes	GLC
Regularly Flooded Area	yes	GLC
Geomorphology		
Shifting Sand, Dunes	yes plus security zone for shifting sands 10 km	GLC
Salt Pans	yes	GLC
Glaciers	yes	GLC
Security Zone for Glaciers	yes	GLC
Land Use		
Settlement	yes	GLC, DCW
Airport	yes	DCW
Oil or Gas Fields	yes	DCW
Mine, Quarry	yes	DCW
Desalination Plant	yes	DCW
Protected and Restricted Area	yes	WDPA
Resources		
Minimum resource	1900 kWh/a for technical feasibility recommended	Resource data from WP 1

Table 2: Definition of exclusion parameters for Concentrating Solar Power Plants

The use data are taken from:

GLOBE – The "Global Land One-Kilometer Base Elevation" for elevation and slope information

GLC / USGS – U.S. Geological Survey" for landcover and land use information

WDPA – World Commission on Protected Areas" for protected areas information

DCW – Digital Char of the World" for land use information

1.3 GIS-Analysis

After the definition of exclusion criteria, all data were prepared and compiled with a Geographical-Information-System (GIS). All used data have a spatial resolution of 1km².

For the GIS-analysis, following order of criteria was adapted:

1.) Settlements (Industry and Population)

2.) Hydrology

3.) Protected areas

4.) Landcover/Landuse

5.) Slope

6.) Geomorphology

7.) Distance to Power Grid (for WIND)

This means, that first all settlements were excluded (with security zone of 7.5km for WIND), then second all rivers and lakes and so on. This order was selected to develop clear arranged and smart maps.

In order to apply the criteria about terrain availability it has been defined the optimal commercial wind turbine sizing to be used in the assessments, because of the relationship between the number and sizing of wind turbines in a wind farm and the necessity of terrain, as it is described in D2.1. It seems that the most cost effective option could be a 1.5MW wind turbine, as ACCIONA AW-1500, which could be constructed in rotor diameters as large as 82m. An adequate number of these turbines for a wind demonstration site could be three, with a total installed capacity of 4.5MW. With these figures the terrain availability is around 2-2.5km^2. Anyway, as for the application of the roughness criteria through the usage of the land cover/land use screen is has been defined a security zone of 7.5km around each site, the requirements for both terrain availability and population safety criterias will be always guaranteed.

The turbine selection is also a compulsory step in order to realize the financial assessment in WP4.

As example, the following figures show the stepwise results of the GIS-analysis for WIND with the used order as describe above. Data of parameter 1-6 are available for the complete world. Due to GIS-performing issues a rectangle window was selected for the analysis. As final step, the countries (Algeria, Jordan, Tunisia and Turkey) were clipped.

1.3.1 Settlements

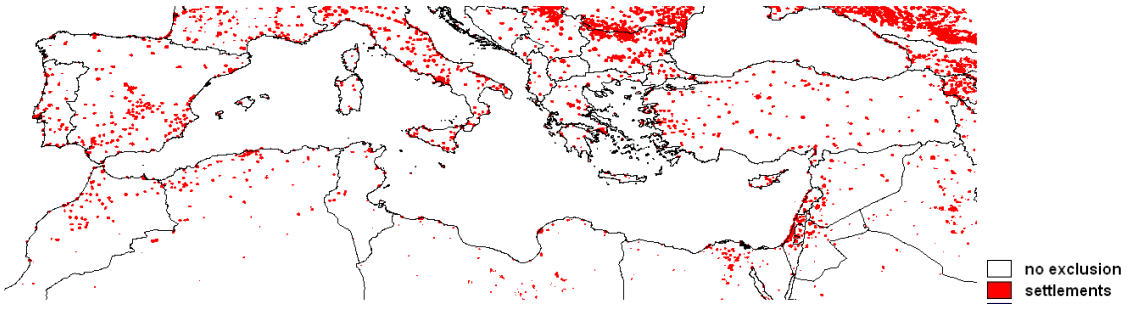


Figure 1: Excluded regions due to parameter settlements

1.3.2 Hydrology

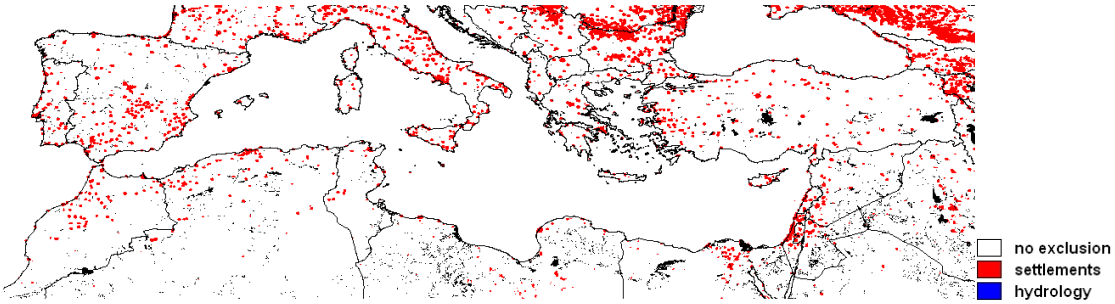


Figure 2: Excluded regions due to parameter settlements and hydrology

1.3.3 Protected Areas

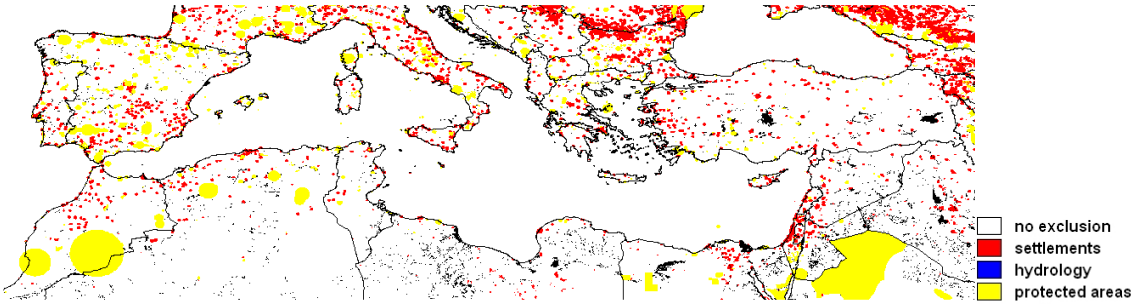


Figure 3: Excluded regions due to parameter settlements, hydrology and protected areas

1.3.4 Landcover

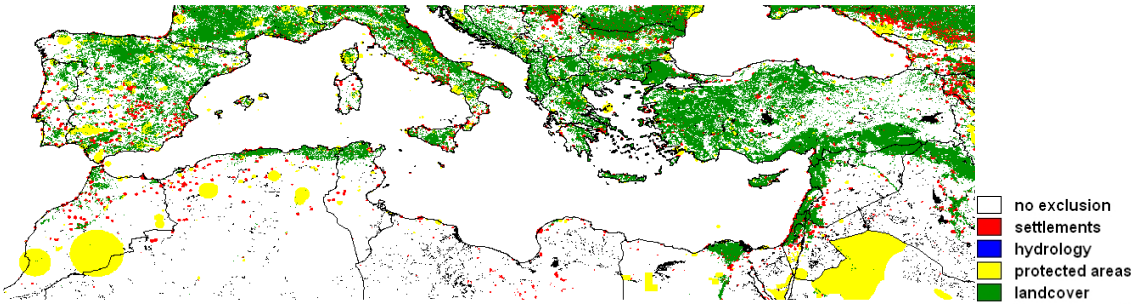


Figure 4: Excluded regions due to parameter settlements, hydrology, protected areas and landcover

1.3.5 Slope

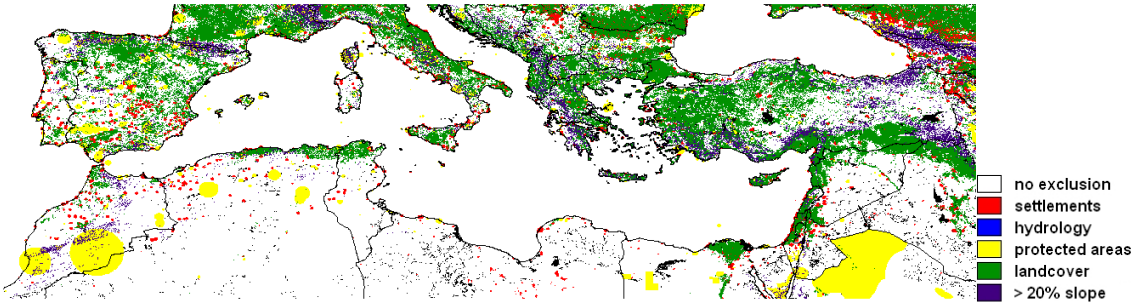


Figure 5: Excluded regions due to parameter settlements, hydrology, protected areas, landcover and slope

1.3.6 Geomorphology

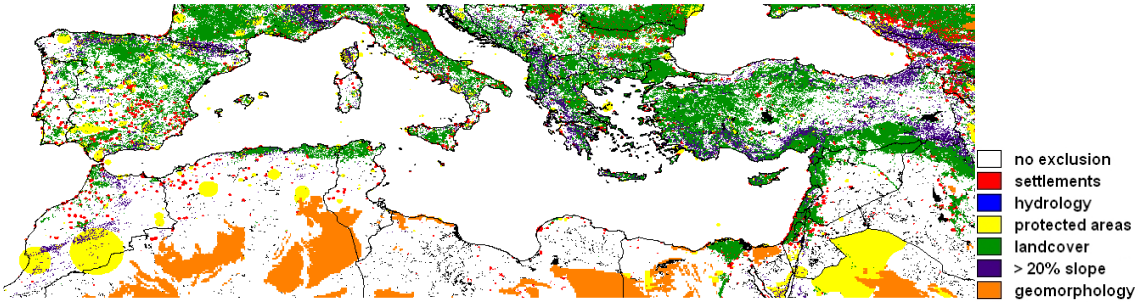


Figure 6: Excluded regions due to parameter settlements, hydrology, protected areas, landcover, slope and geomorphology

1.3.7 Distance to Power Grid

The information on the power grid for Algeria and Tunisia is based on DCW-data. For Turkey and Jordan data provided by the project country partner are used. Areas with a distance more than 75 km to the next power grid are excluded for potential sites.

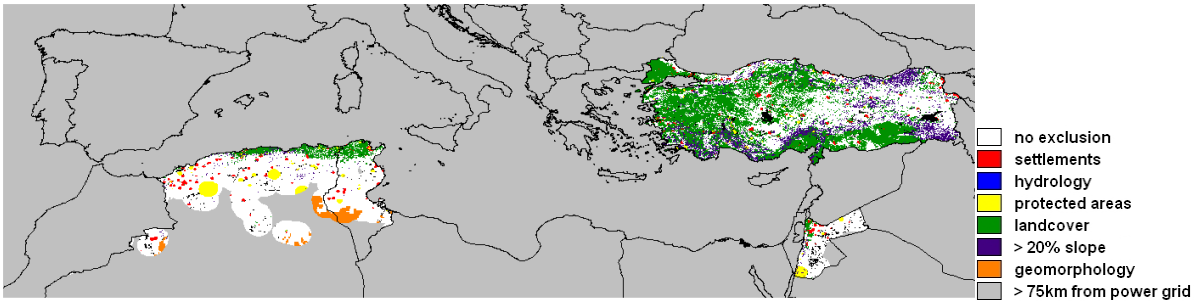


Figure 7: Excluded regions due to parameter settlements, hydrology, protected areas, landcover, slope, geomorphology and distance to power grid

1.4 Country specific results

As final result the potential sites for each country for CSP and WIND can be detected. All white (non-marked) pixels are not excluded and therefore potential demonstration sites. Together with resource maps from WP1 and locally applicable criteria, best sites can be selected.

1.4.1 Algeria:

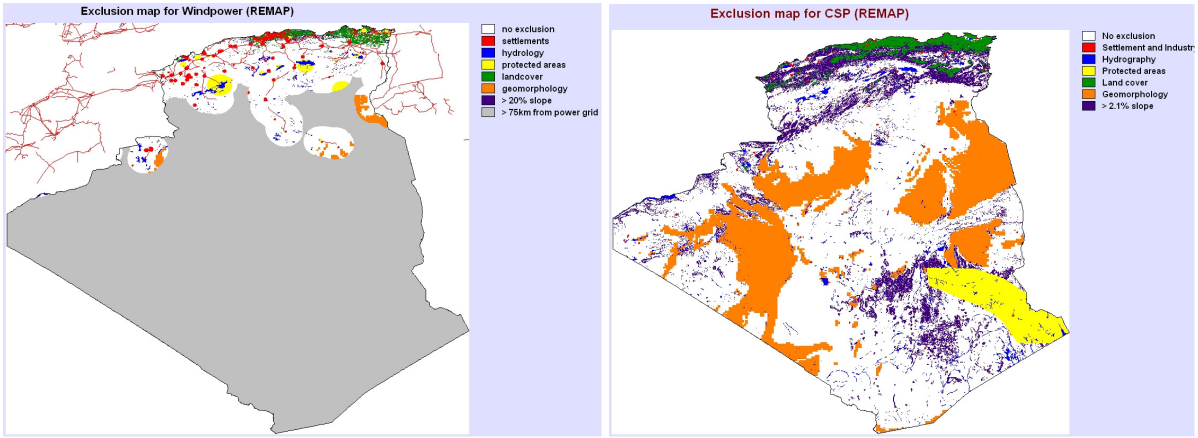


Figure 8: Exclusion map for WIND (left) and CSP (right) for Algeria based on exclusion criteria described in table 1 and table 2

1.4.2 Jordan:

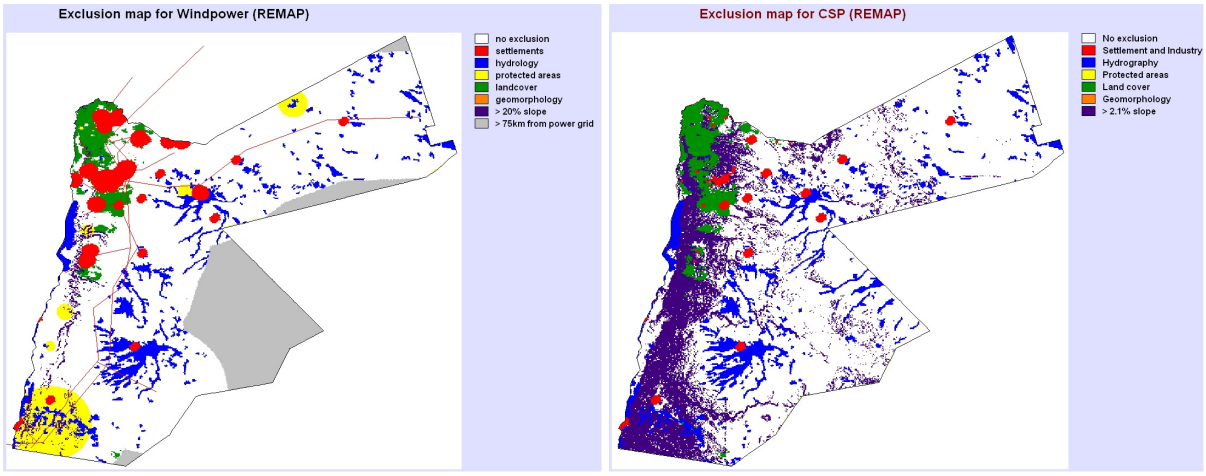


Figure 9: Exclusion map for WIND (left) and CSP (right) for Jordan based on exclusion criteria described in table 1 and table 2

1.4.3 Tunisia:

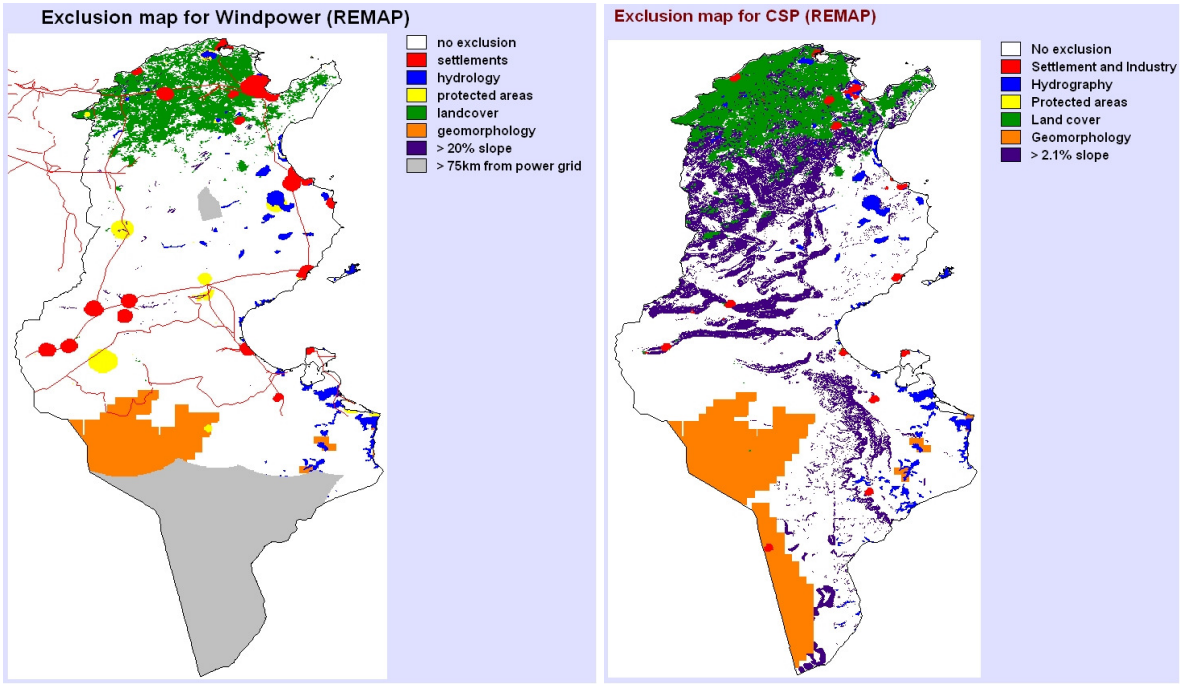
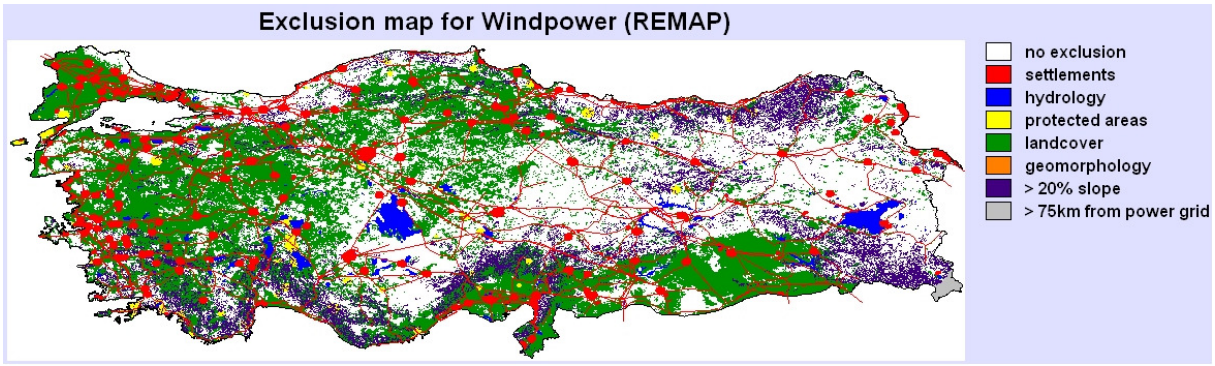


Figure 10: Exclusion map for WIND (left) and CSP (right) for Tunisia based on exclusion criteria described in table 1 and table 2

1.4.4 Turkey:



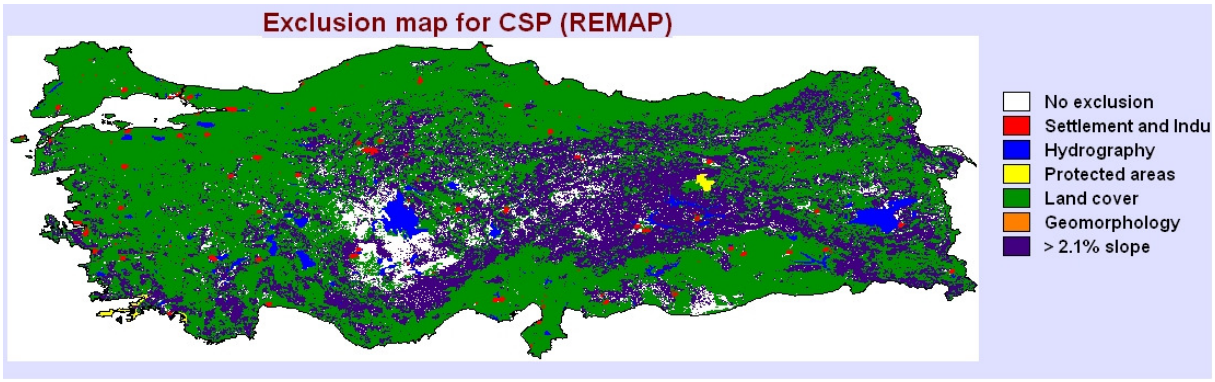


Figure 11: Exclusion map for WIND (left) and CSP (right) for Turkey based on exclusion criteria described in table 1 and table 2

2 Site Ranking for CSP

A site ranking has only been done for CSP, as for wind power no suitable high resolution maps of the wind resource have been available (see D1.1). The methodology will be shown with the example of Tunisia.

Exclusion maps are not the sole decision criterion for siting of CSP power plants. Distances to infrastructure (power lines, network nodes, streets) and to the electricity demand (settlements) are also important criteria. The idea of the ranking done is to assign to each criteria a number of points, 2-20 for the resource, 0-5 to transmission lines, 0-10 for network nodes, 0-5 for streets and 0-5 for the demand. These points are added to get an indication on the quality of a site. The result will be a map which shows a qualitative ranking for all potential CSP sites.

Following values/ranges and weightings are suggested:

Parameter	**Values / Range**				**Indicator Points**
Solar Resource	Turkey	Algeria	Jordan	Tunisia	
(annual sum DNI) [kWh/m]	>=2200	>=2800	>=2700	>=2500	20
	2150 - <2200	2700 - <2800	2600 - <2700	2400 - <2500	18
	2100 - <2150	2600 - <2700	2500 - <2600	2300 - >2400	16
	2050 - <2100	2500 - <2600	2400 - <2500	2200 - <2300	14
	2000 - <2050	2400 - <2500	2300 - >2400	2100 - <2200	12
	1950 - <2000	2300 - >2400	2200 - <2300	2000 - >2100	10
	1900 - <1950	2200 - <2300	2100 - <2200	1900 - <2000	8
	1850 - <1900	2100 - <2200	2000 - >2100	1800 - <1900	6
	1800 - <1850	2000 - >2100	1900 - <2000	1700 - <1800	4
	1750 - <1800	1900 - <2000	1800 - <1900	1600 - <1700	2

Distance to transmission lines [km] (date of data: 2008)		
	<5	5
	>5 – 10	4
	>10 – 15	3
	>15 – 20	2
	>20 – 25	1
	>25	0
Distance to electricity stations [km] (date of data: 2008)		
	<5	10
	>5 - 10	8
	>10 - 15	6
	>15 - 20	4
	>20 - 25	2
	>25	0
Distance to settlements [km]		
	<10	5
	>10 - 20	4
	>20 - 30	3
	>30 - 40	2
	>40 - 50	1
	>50	0
Distance to roads [km] (date of data: 1998)		
	<5	5
	>5 - 10	4
	>10 - 15	3
	>15 - 20	2
	>20 - 25	1
	>25	0

Table 3: Used parameter, their values and weighting for the ranking analysis (without cogeneration cooling)

For each parameter the indicator points are determined for each single pixel. The following figures show the underlying data and the resulting indicator points for each parameter for the partner country Tunisia.

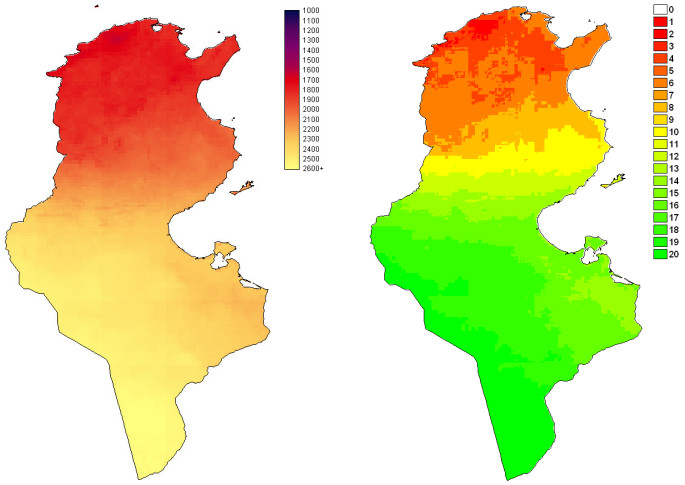


Figure 12: Direct normal irradiance and the resulting points (source: DLR).

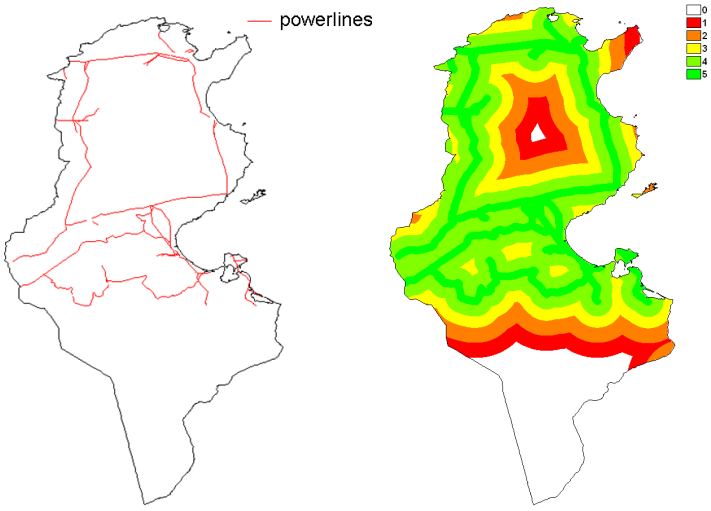


Figure 13: Powerlines network and electricity substations and the resulting points (source DLR).

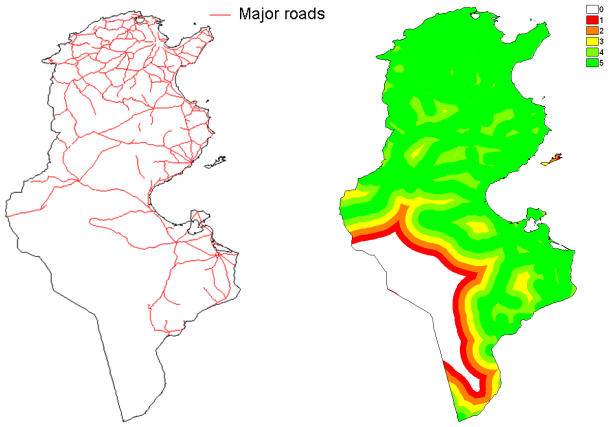


Figure 14: Major roads (source: DCW) and the resulting points (source: DLR).

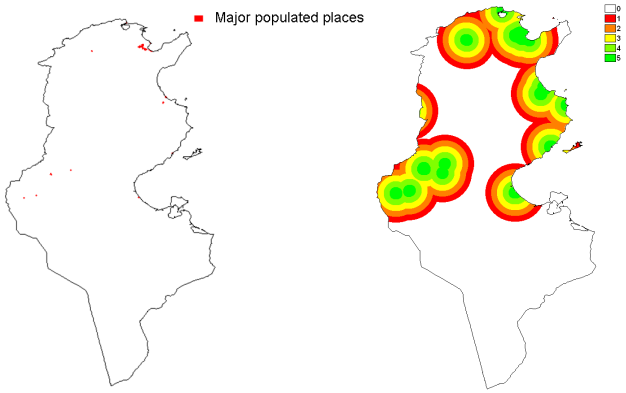


Figure 15: Population Density and resulting points (source DLR)

Figure 16 shows the final ranking by adding all indicator points. Even though the best solar resources of Tunisia are in the very south, the best sites are located in the middle of the country, where demand and infrastructure is near and the resources are very good.

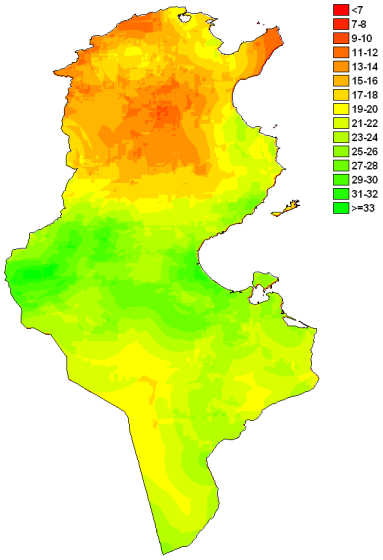


Figure 16: Ranking based on the sum of the points as shown in the previous figures and described in table 3 (source: DLR).

2.1 CSP Site Ranking for Algeria

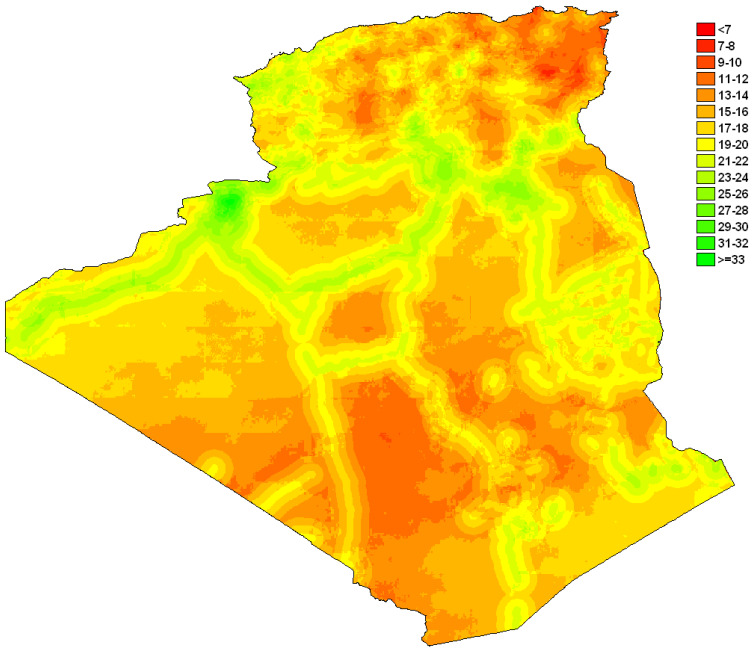


Figure 17: CSP Site ranking for Algeria

The ranking map of Algeria that the most interesting sites are located in the Northwest, where there is demand and infrastructure and good resources.

2.2 CSP Site Ranking for Turkey

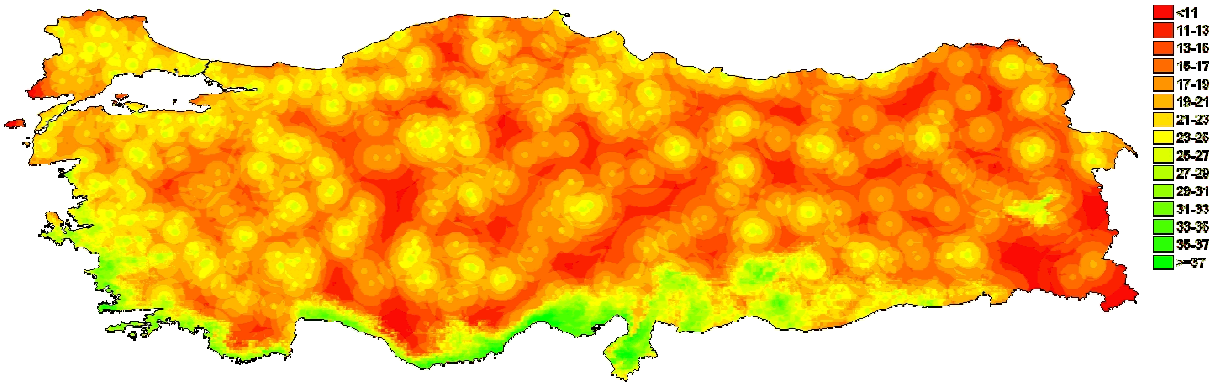


Figure 18: CSP Site Ranking for Turkey

The ranking map for turkey shows the best sites at the south coast, where there are good resources and infrastructure. The infrastructure for power lines and streets is very dense, so they nearly do not show. The most visible feature is the distance to settlements.

2.3 CSP Site Ranking for Jordan

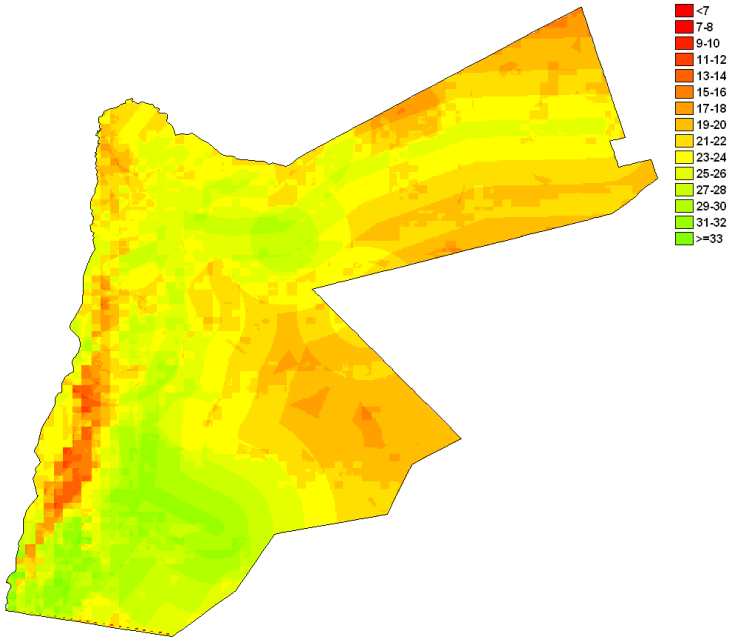


Figure 19: CSP Site Ranking for Tunisia

Jordan has the best CSP sites down towards the south of the country where the resource is very high and towards the east along the transmission line.

3 Identification and Prioritization of potential demonstration sites

The next step within the project is identification of possible demonstration sites. This involves far more criteria than those developed within this report. But the presented results are one step in narrowing down the number of possible sites. The final selection of demonstration sites will depend on more parameters as local energy demand, available infrastructure for demonstration (as exiting power facilities, nearby research institutes) and nation economic development plans.

The selection is aimed to be done at high level stakeholder workshops within the target countries. There the results of WP1 on resources and the results of the WP2 will be presented. The resulting maps have been included as overlays into the software Google Earth. This allowed a direct zoom into interesting sites the workshops.

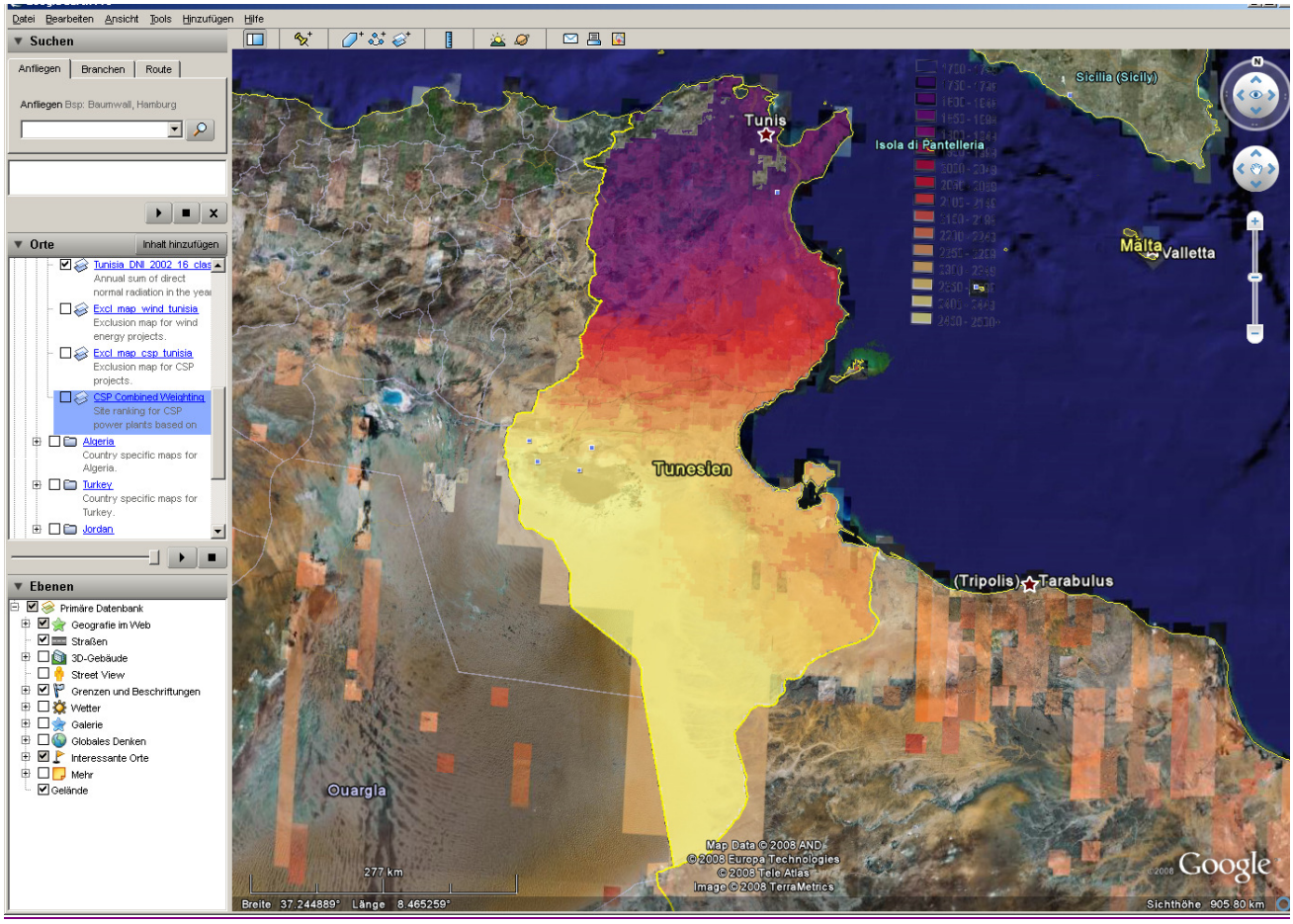


Figure 20: Solar resource map in Google Earth

Figure 20 shows a DNI resource map as an overlay within Google Earth. On the left side, different maps can be selected with the check boxes. The maps are included as semitransparent overlays to be able to view the underlying information from Google Earth.

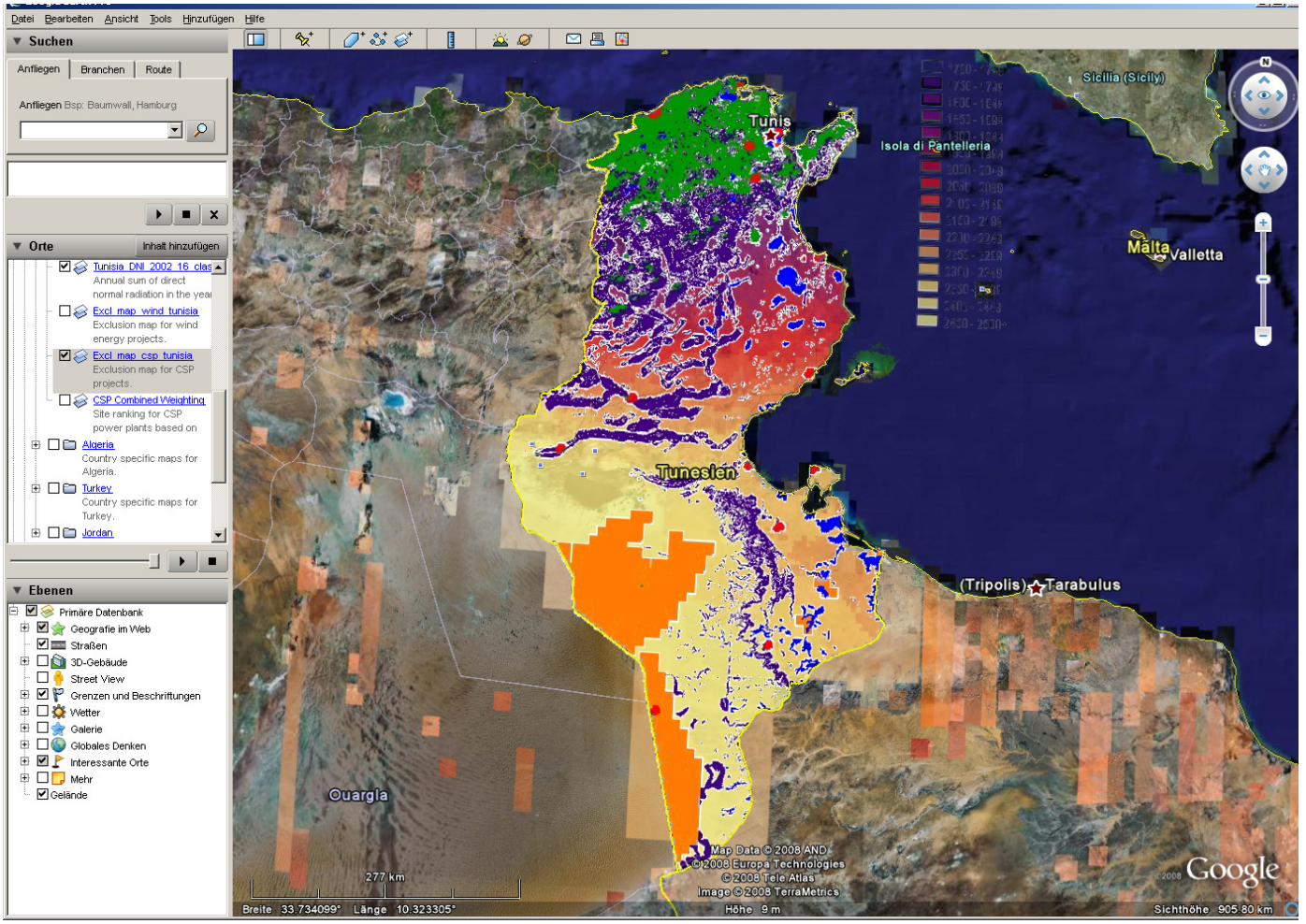


Figure 21: Exclusion map overlaid to the resource map

Figure 21 shows an overlay of a resource map and an exclusion maps. These two maps can be used to narrow down suitable sites with good resources.

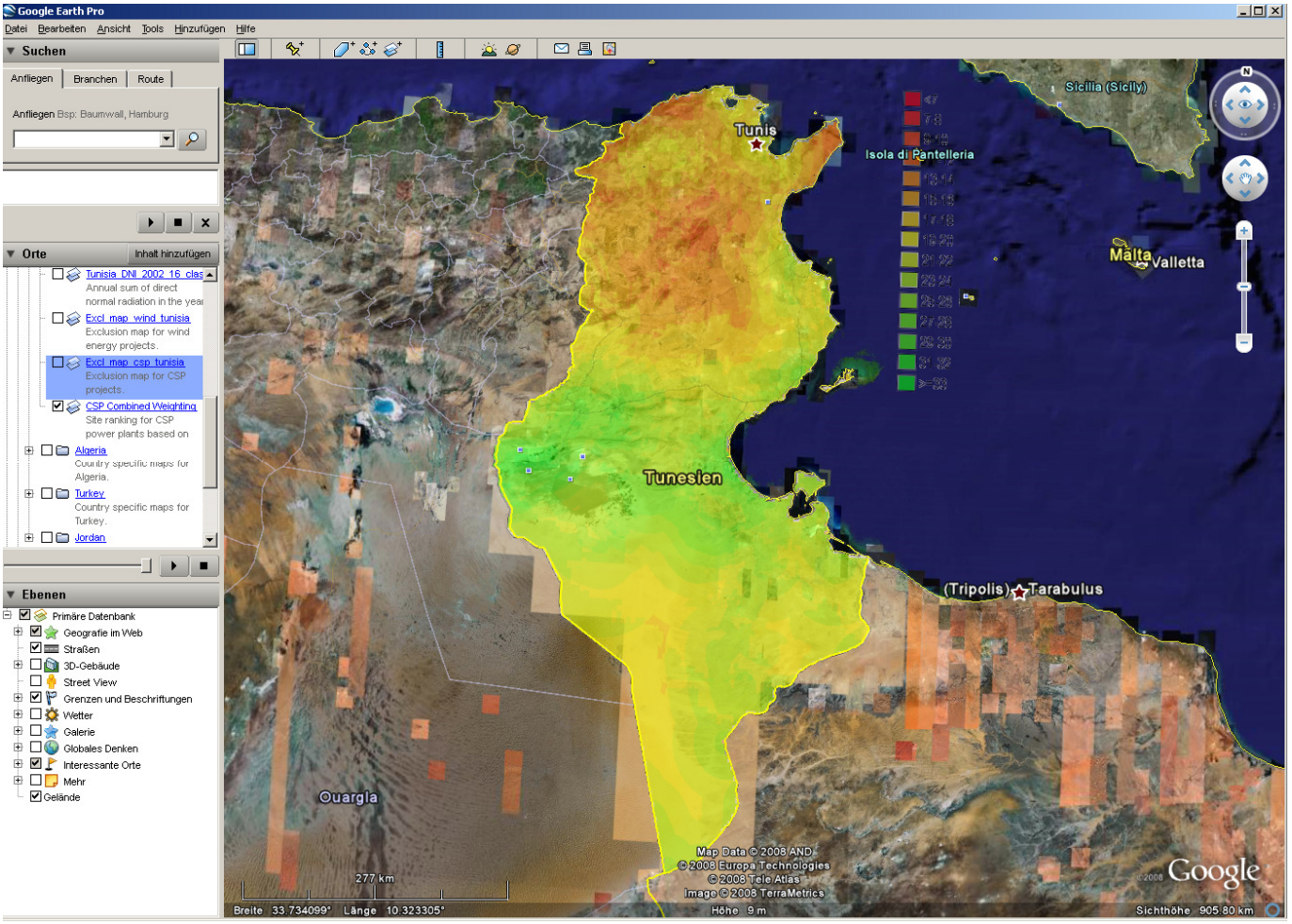


Figure 22: Site ranking in Google Earth

Figure 22 shows a site ranking as a Google overlay which can be again combined with an exclusion map as it is shown in figure Figure 23. These overlays are again semitransparent to able to view the underlying imagery of Google Earth.

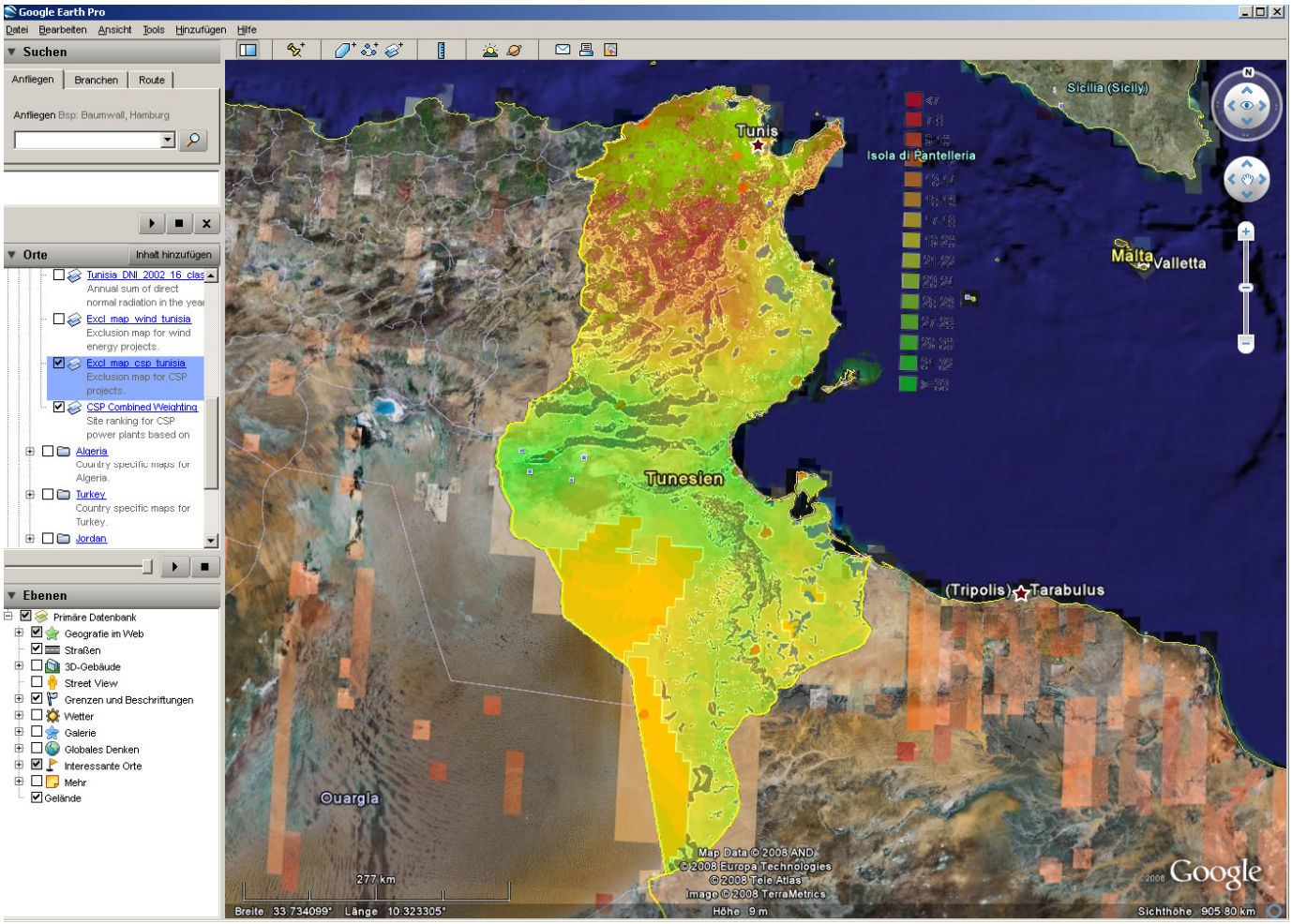


Figure 23: Semitransparent site ranking and exclusion map

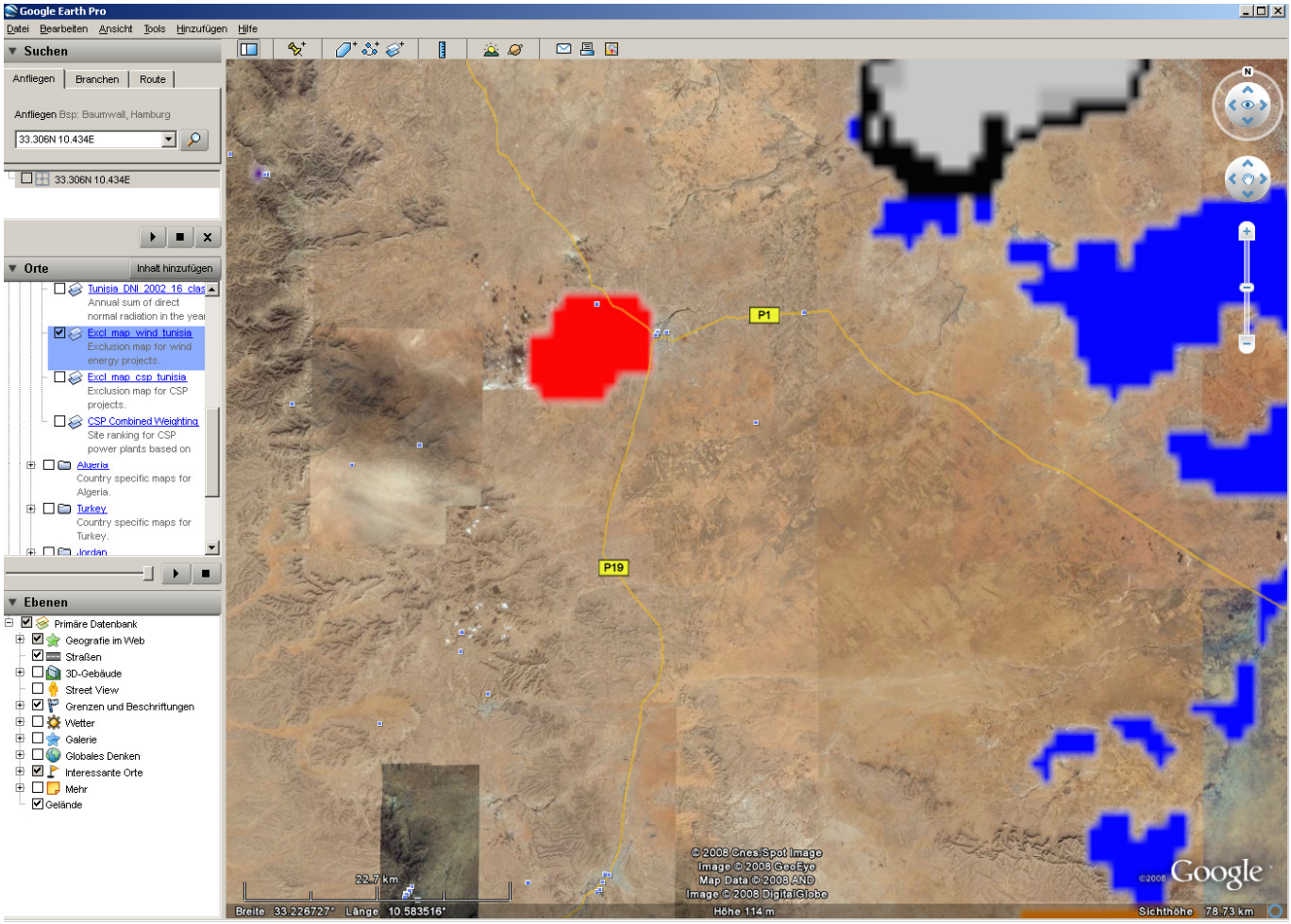


Figure 24: Zoom into an interesting site with exclusion map

Finally figureFigure 24 shows a sample zoom into an interesting site. Here the exclusion map is used as an overlay. The city in the middle of the image with its security zone can clearly be seen. The blue areas are excluded due to hydrology. This site is close to the coast, so most of the blue marking is the Mediterranean Sea. One very interesting feature is the access to various geolocated images, shown here as small blue squares. They can give interesting additional information on the surface properties nearby.

3.1 Selected sites in Algeria

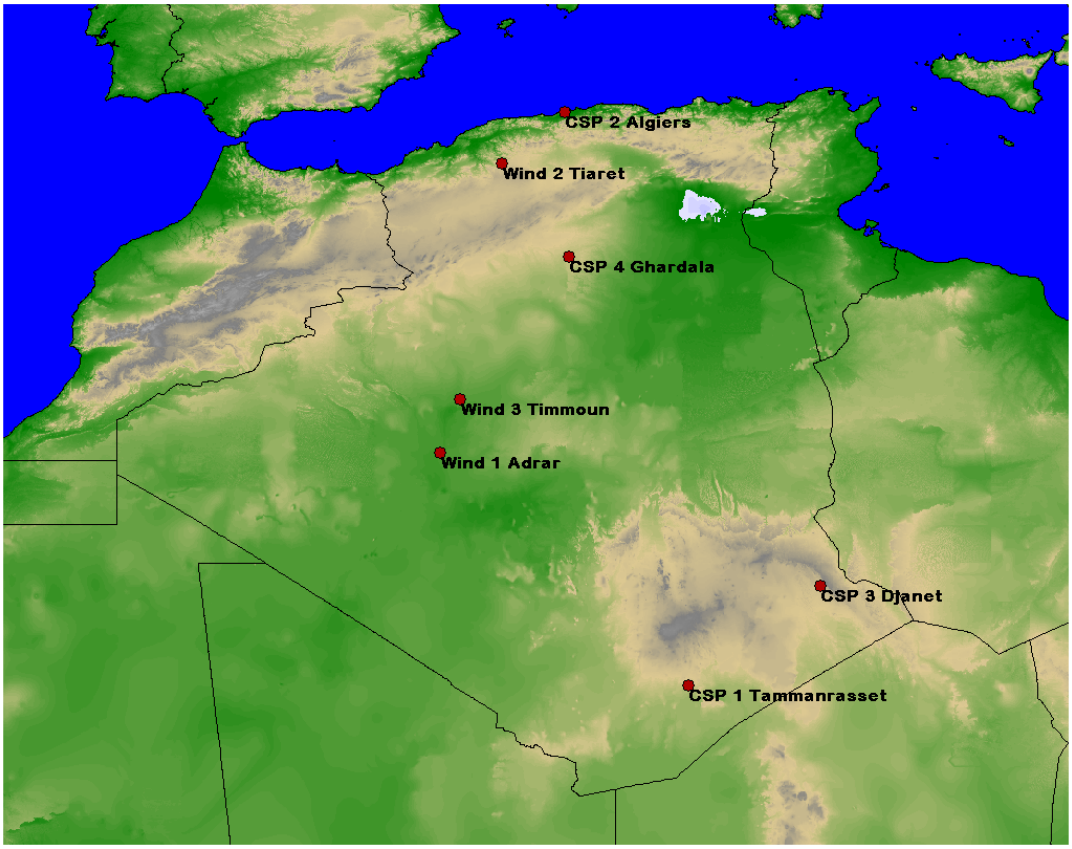


Figure 25: Selected CSP and wind power sites in Algeria

Site name	Resource level	Data source
CSP 1 Tammanrasset	2660 kWh/m²	DLR DNI map 2002
CSP 2 Algiers	2000 kWh/m²	DLR DNI map 2002
CSP 3 Djanet	2620 kWh/m²	DLR DNI map 2002
CSP 4 Ghardala	2560 kWh/m²	DLR DNI map 2002
Wind 1 Adrar	8 m/s	Algerian wind atlas at 50m height
Wind 2 Tiaret	8 m/s	Algerian wind atlas at 50m height
Wind 3 Timmoun	7.5 m/s	Algerian wind atlas at 50m height

Table 4: Selected sites and resource levels in Algeria

3.2 Selected sites in Tunisia

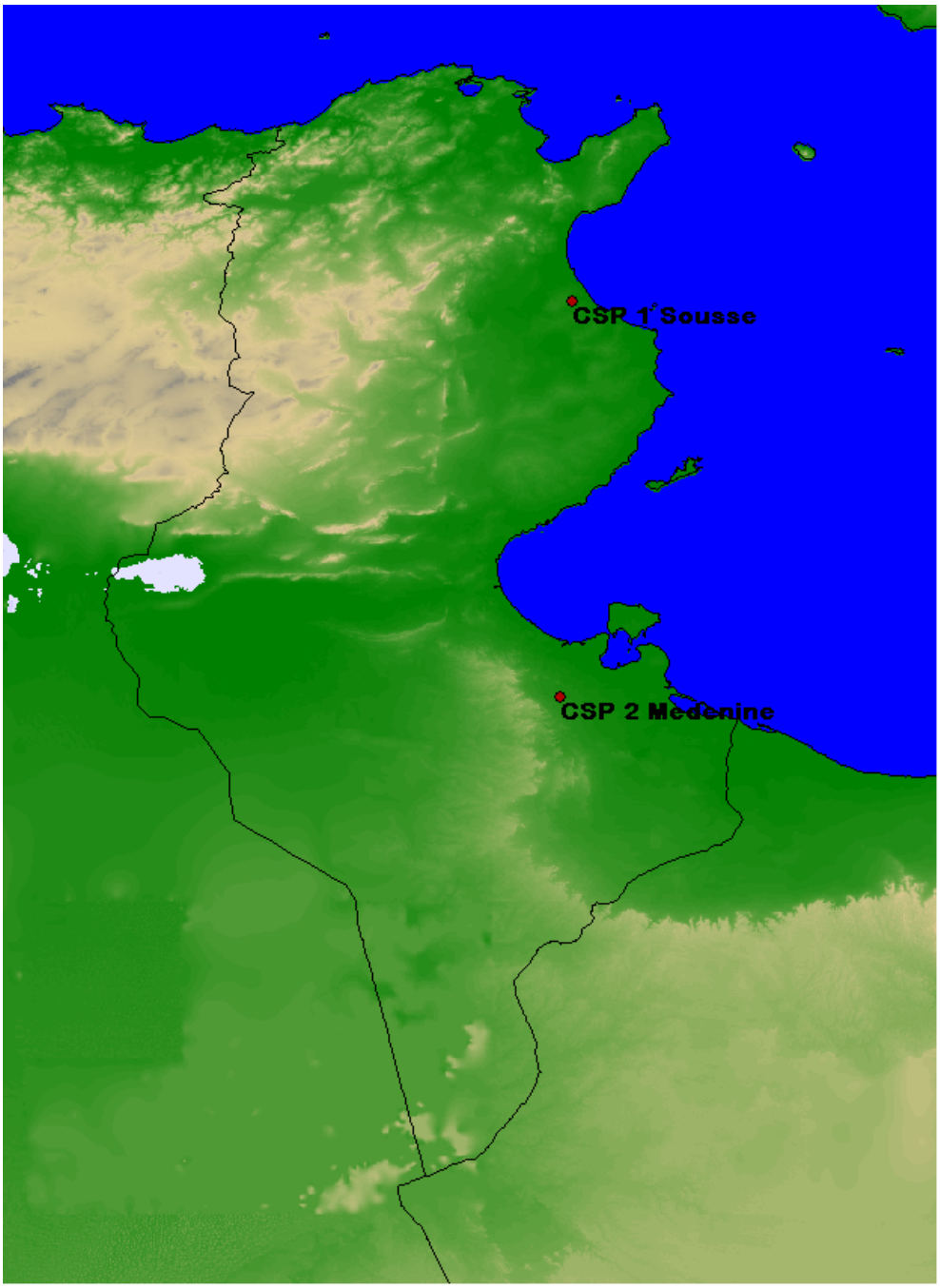


Figure 26: Selected CSP sites in Tunisia

Site name	Resource level	Data source
CSP 1 Sousse	1920 kWh/m²	DLR DNI map 2002
CSP 2 Medenine	2300 kWh/m²	DLR DNI map 2002

Table 5: Selected sites and resource levels in Tunisia

3.3 Selected sites in Turkey

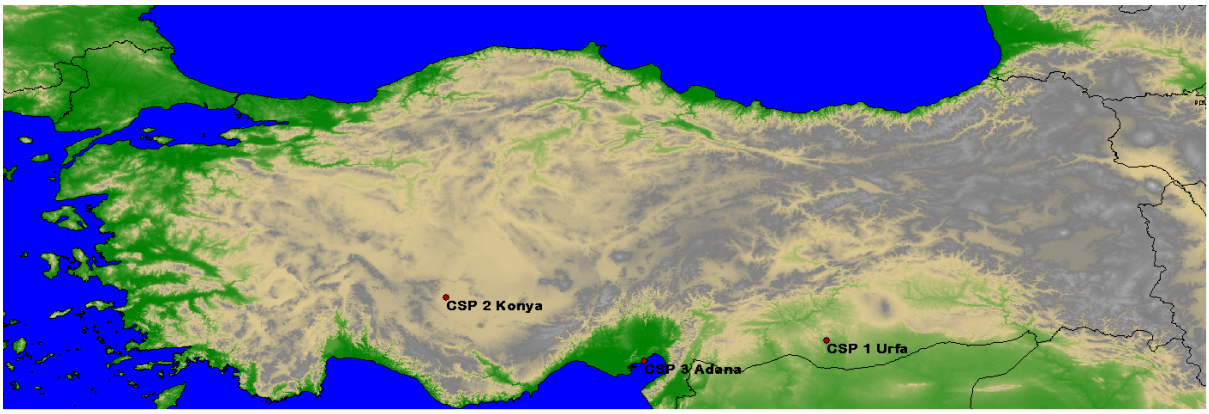


Figure 27: Selected CSP sites in Turkey

Site name	Resource level	Data source
CSP 1 Urfa	1900 kWh/m²	DLR DNI map 2002
CSP 2 Konya	1450 kWh/m²	DLR DNI map 2002
CSP 3 Adana	1980 kWh/m²	DLR DNI map 2002

Table 6: Selected sites and resource levels in Turkey

3.4 Selected sites in Jordan

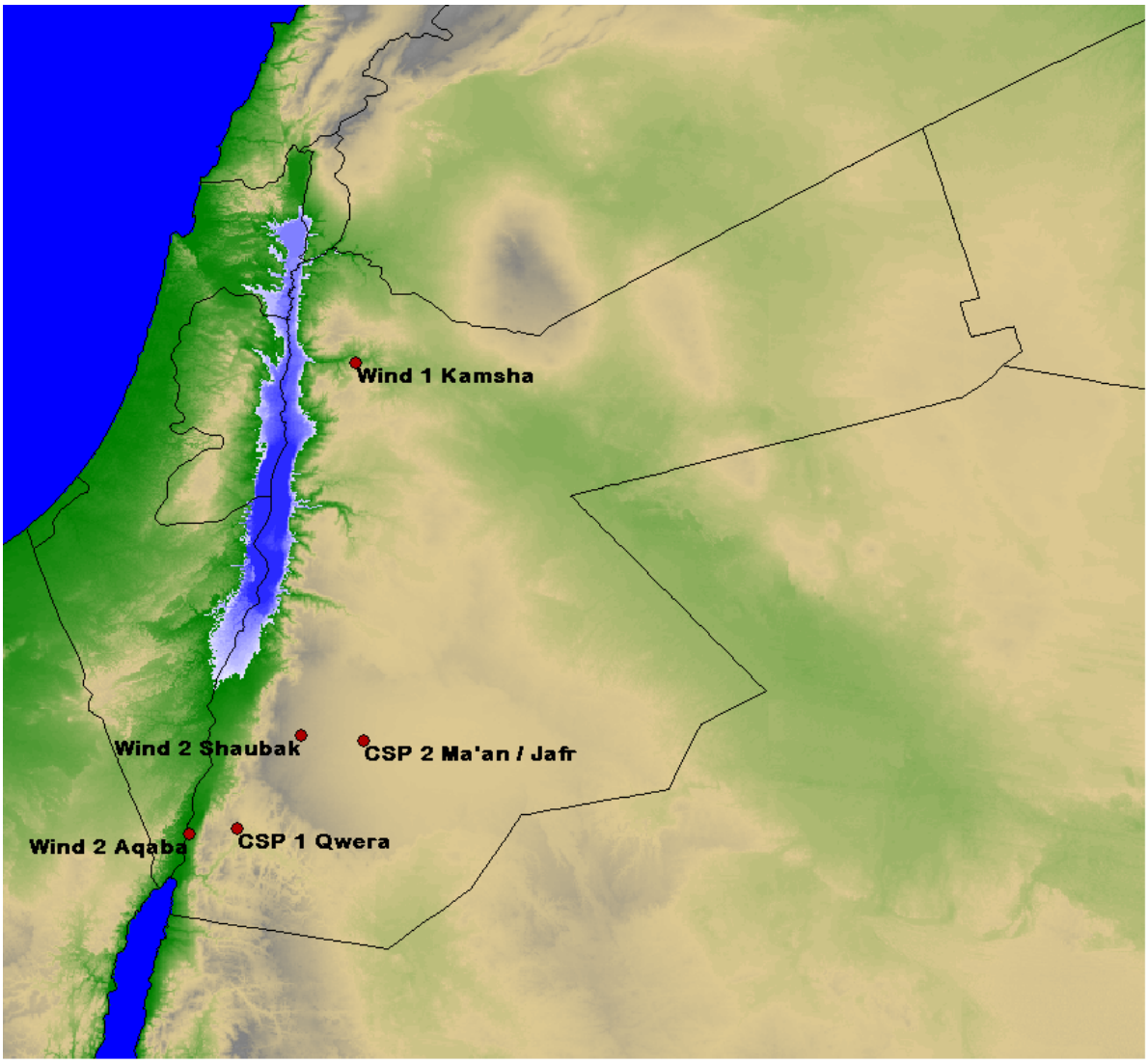


Figure 28: Selected CSP and wind power sites in Jordan

Site name	Resource level	Data source
CSP 1 Qwera	2370 kWh/m²	DLR DNI map 2002
CSP 2 Ma'an /Jafr	2550 kWh/m²	DLR DNI map 2002
Wind 1 Kamsha	5.5 m/s	Jordan wind atlas
Wind 2 Shaubak	7.5 m/s	Jordan wind altas
Wind 3 Aqaba	7.0 m/s	Jordan wind altas

Table 7: Selected sites and resource levels in Jordan

References

Inditep (2005): Project Inditep: Integration of DSG Technology for Electricity Production, Final Publishable Report, Contract-Nor. ENK5-CT-2001-00540