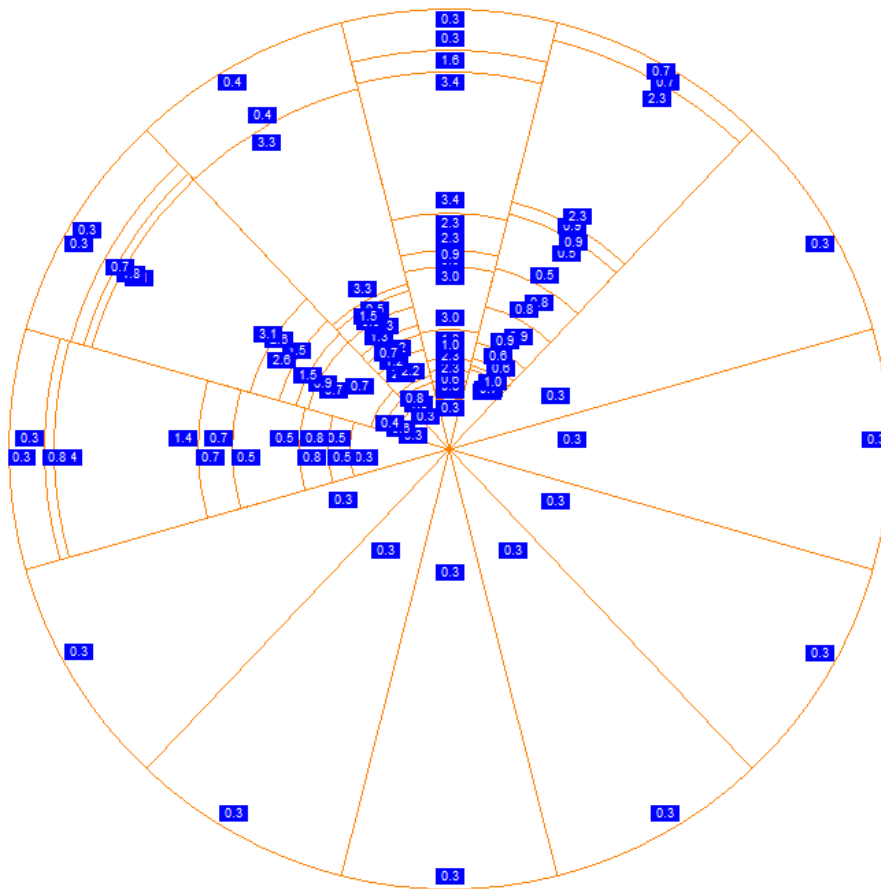


windPRO / Energy

Roughness in windPRO



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Front cover

The front cover shows a roughness rose.

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1 Roughness maps in windPRO

Roughness defines the surface texture, and it is quantified by the vertical deviation of the terrain surface from its ideal form. Large deviations are translated as rough surfaces, while small variations will define very smooth surfaces, such as water or desert. In energy calculation roughness plays an important role, among other factors, in defining how a change in the terrain surface influences the wind profile and consequently the energy output.

1.1 Roughness definition in WAsP flow model

The European Wind Atlas [1] characterises the roughness of a surface by the size and distribution of the elements it contains. Older WAsP versions (before version 10.2) can handle roughness as roughness maps and roses, while present versions do require roughness maps as user input. It should be mentioned, however, that present versions will *internally* convert the roughness maps to roughness roses and use only the roses for modelling purposes.

A roughness rose is a table specifying the roughness values for the segments within each of typically 12 30-degree sectors, centred on a single point of interest in the terrain, typically at the location of the Site data object. The table consists of roughness values and distances to the next roughness change for each sector as illustrated in Figure 1. Each sector is divided in sections. The division in sections is linked to the roughness change encountered within that sector.

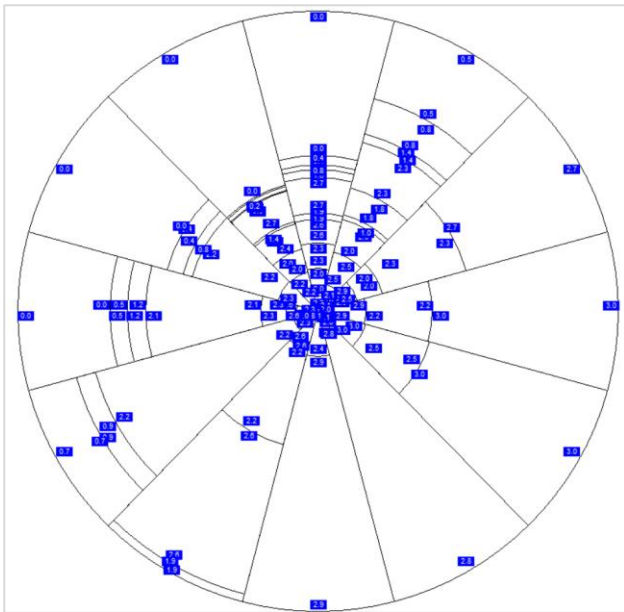


Figure 1: Roughness rose showing the roughness class change in each of the 12 sectors.

| Sector | Roughness at WTG | Distance to 1. change | Roughness after 1. change | Distance to 2. change | Roughness after 2. change | Distance to 3. change | Roughness after 3. change | Distance to 4. change | Roughness after 4. change | Distance to 5. change | Roughness after 5. change |
|--------|------------------|-----------------------|---------------------------|-----------------------|---------------------------|-----------------------|---------------------------|-----------------------|---------------------------|-----------------------|---------------------------|
| 0-N | 0.1106 | 1,238 | 0.2470 | 2,048 | 0.1021 | 5,526 | 0.1611 | 8,752 | 0.2305 | 11,743 | 0.0906 |
| 1-NNE | 0.1060 | 979 | 0.3370 | 1,873 | 0.1199 | 3,563 | 0.2123 | 7,825 | 0.0982 | 12,089 | 0.0309 |
| 2-ENE | 0.1165 | 1,476 | 0.2209 | 2,181 | 0.3599 | 4,419 | 0.1871 | 5,249 | 0.1030 | 8,536 | 0.1481 |
| 3-E | 0.3383 | 239 | 0.1080 | 2,050 | 0.3281 | 6,095 | 0.1353 | 14,492 | 0.3763 | 0 | |
| 4-ESE | 0.3852 | 272 | 0.1029 | 2,066 | 0.3861 | 6,359 | 0.1873 | 14,720 | 0.3827 | 0 | |
| 5-SSE | 0.3909 | 364 | 0.1122 | 2,632 | 0.3143 | 0 | | | | | |
| 6-S | 0.1834 | 5,812 | 0.3613 | 0 | | | | | | | |
| 7-SSW | 0.3295 | 337 | 0.1440 | 1,847 | 0.2201 | 5,166 | 0.1362 | 17,529 | 0.2222 | 37,201 | 0.0934 |
| 8-WSW | 0.2217 | 253 | 0.1024 | 730 | 0.1434 | 2,201 | 0.2224 | 3,261 | 0.1395 | 29,333 | 0.0220 |
| 9-W | 0.2661 | 464 | 0.1210 | 1,335 | 0.3007 | 2,124 | 0.1039 | 2,795 | 0.2279 | 4,093 | 0.1487 |
| 10-WNW | 0.1586 | 5,288 | 0.1243 | 16,640 | 0.0136 | 17,847 | 0.0018 | 19,910 | 0.0002 | 0 | |
| 11-NNW | 0.3835 | 32 | 0.1245 | 5,261 | 0.1053 | 8,268 | 0.1704 | 11,484 | 0.0465 | 11,837 | 0.2680 |

Table 1: Roughness table showing roughness change on each sector and distance to each roughness change

The different terrain types have been categorized in four main roughness classes (Figure 2), starting with roughness class 0 categorized as very smooth surface (e.g. water bodies), to class 4, representing very rough surfaces (e.g. large cities). The surface roughness is also defined as roughness length, measured in m, with a range of 10^{-4} to 1.6m. [1].

| Roughness class | Roughness length | Relative energy % | |
|-----------------|------------------|-------------------|---|
| 0 | 0,0002 | 100 | Water areas. |
| 0,5 | 0,0024 | 73 | Mixed Water and land area or very smooth land. |
| 1 | 0,03 | 52 | Open farmland with no crossing hedges and with scattered buildings. Only smooth hills. |
| 1,5 | 0,055 | 45 | Famland with some buildings and crossing hedges of 8 m height and about 1250 m apart. |
| 2 | 0,10 | 39 | Famland with some buildings and crossing hedges of 8 m height and 800 m apart. |
| 2,5 | 0,20 | 31 | Famland with closed appearance and dense vegetation - crossing hedges of 8 m height and 250 m apart. |
| 3 | 0,40 | 24 | Villages, small towns, very closed farmland with many or high hedges, Forrest, many abrupt orographic changes, etc. |
| 3.5 | 0,80 | 18 | Large towns, cities with extended build-up areas. |
| 4 | 1,6 | 13 | Large cities with build-up areas and high buildings. |

Figure 2: The standard roughness values, defined as class and length.

WASP methodology or Wind Atlas Methodology generates Generalized Wind Climates (GWC)², by making use of the wind measurements in the region, and local terrain effects, such as roughness, orography, and local obstacles. The process involves cleaning the local wind measurements of local terrain effects, mentioned above, and generates a Generalized Wind Climate which represents the “cleaned” wind profile and is represented as a matrix of sector-wise Weibull parameters for several standard heights and standard roughness classes.

Further, all local effects (orography, roughness, and obstacles) are reapplied at each turbine location and height to generate a turbine specific wind profile. In the latter stage, WASP flow model is called through windPRO to interpolate between the specified standard heights and roughness as part of the flow modelling

1.2 Roughness in windPRO

In windPRO, an appropriate roughness description is required for calculations where WASP flow model is utilized. Currently, all such calculations in windPRO require a Site data object where the roughness will be linked. These calculations are:

- STATGEN (generation of wind atlas/statistic)
- WASP Interface (energy prediction at a single position based on a wind atlas)
- RESOURCE (generation of wind resource map)
- PARK (energy prediction for wind farms based on wind atlas)

Apart from these calculations, several tools within windPRO use the WASP flow model and require a site data object with a defined roughness line. Such tools are the Meteo Object and Meteo Analyzer, where analysis like vertical profile prediction or cross predictions use the WASP flow model and consequently the surface roughness.

² Older WASP terminology: Wind Atlas or LIB file; windPRO terminology: (Regional) Wind Statistic; additional file format in windPRO: WWS

In windPRO, WASP flow model reads the surface roughness from the site data object in the form of roughness lines (length). When using WASP versions before 10.2, roughness can be provided as roughness roses as well.

windPRO shows a large degree of flexibility when it comes to defining surface roughness, as follows:

1.2.1 Online import of roughness areas or roughness lines

windPRO provides a [global online database](#) with online roughness areas maps and online roughness line maps, which can be downloaded by the user directly in the project through the use of an Area object and consequently a Line object.

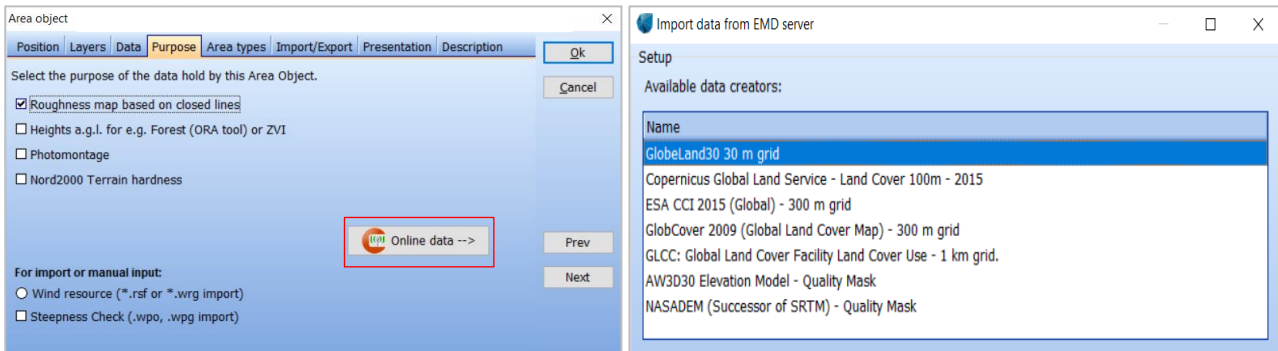




Figure 3: Import roughness maps online in windPRO.

It should be noted that these online data sources originally are land use maps, for which the land use classes have been later classified with a certain roughness value. As land use and roughness do not correlate in all cases, users of these online data sources are urgently advised to check the roughnesses assigned to the land uses in the specific region they are working in.

Checking (and modifying) the roughness values is easiest done with data downloaded into the Area object. This is also the object where further editing is easiest, e.g. adding of missing features near the site, or border adaptations of existing roughness areas. In windPRO versions prior to 3.5, please note that crossing lines and overlapping areas are not permitted. In windPRO 3.5 and later, if areas overlap, the higher roughness value will prevail. After a roughness map in an Area object is ready for use, it must be converted to roughness lines in .WPO or .MAP format, as these are the only file formats usable directly in WASP calculations.

Using the Line object directly for working with Online data sources is rather recommended if you are certain that the assigned roughness values in the area are correct and that no modifications are necessary. Doing manual modifications to roughness lines in the line object can easily lead to inconsistencies in the resulting map, so it is not recommended unless you're very familiar with the limitations of the file format.

1.2.2 Manual digitalization, in the form of roughness areas or roughness lines

A typical procedure working with roughness in windPRO is to make a roughness map using the Area object  and export it to a roughness lines which is subsequently loaded in a Line object . This line object is further used by WASP, in any of the calculations described above.

To manually create a roughness area, the user should insert an Area object, select the Purpose to Roughness map, insert/define area types and start digitizing on a terrestrial map.

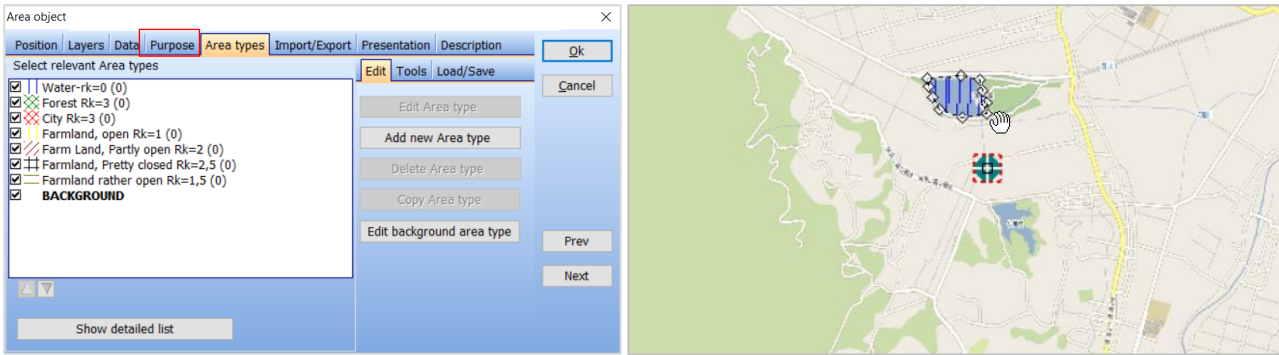


Figure 4: Manual digitalization of roughness

1.2.3 Import roughness areas or lines from different file types

Both the Line object and Area object allows the user to import roughness maps from the file formats presented in Figure 5.

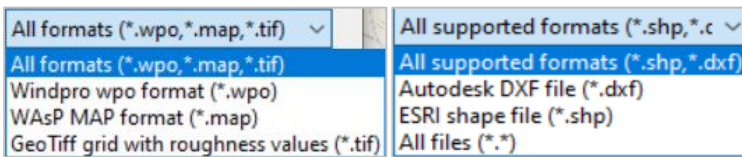


Figure 5: Files types that can be imported in a Line object (left) and in an Area object (right).

1.2.4 Manual definition of roughness rose

This option is only directly available for modelling with WAsP versions 6 -10.0. Additionally, the method described below to import roughness roses from roughness line files can lead to interesting insights about how all WAsP versions (also the latest ones) handle roughness maps internally.

The roughness rose information can be specified directly in a table for each sector. The rose will be used for all positions in the calculation (e.g. the measurement mast / turbine positions). This is so regardless of the position of the site data object holding the rose relative to e.g. the mast position. A minor exception is the energy calculation with several Site data objects selected, each holding a roughness rose. In that case the Site data object (including its roughness rose) nearest to each turbine will be used for that turbine position.

The user has the option to create a roughness rose by importing/converting roughness data from three different sources, as presented in Figure 6.

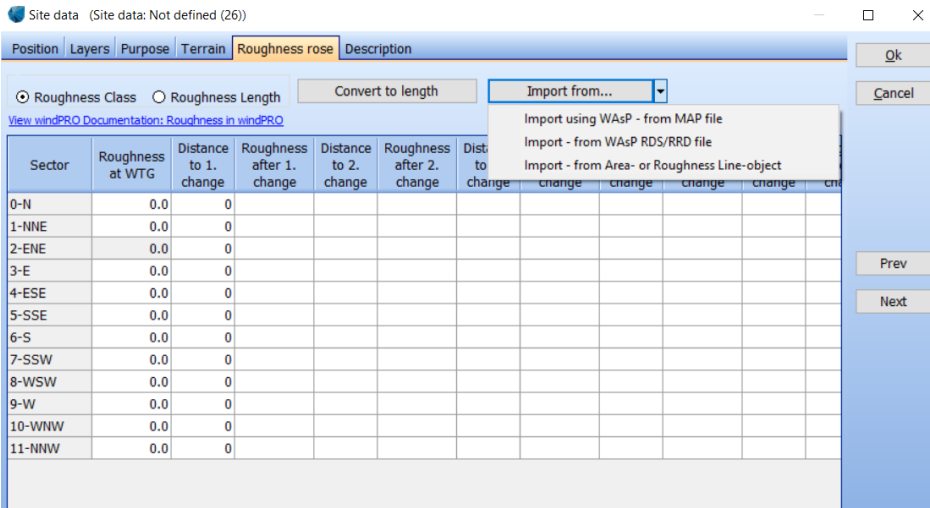


Figure 6: Options to create/import a roughness rose.

The three options allow the user to

- import a roughness rose by letting any version of WAsP generate it from a .map (or .wpo) file.
- load an already defined roughness rose in RDS or RRD file format
- or to import a roughness line object or roughness area object and convert it to a roughness rose using a windPRO internal algorithm. Please note that this conversion routine is not fully consistent with WAsP’s.

This import/convert tool is a good way to gain insight in the way WAsP handles and interprets complex maps of roughness lines. It exhibits to which degree details are important in a roughness line map. Spending time on refining details of roughness lines might end up not being used in the end – as WAsPs conversion to a roughness rose is so much simplified that a coarser and much faster roughness digitization would have resulted in the same roughness rose and thus WAsP result.

2 Sources

[1] I. Troen and E. Lundtang Petersen, “European Wind Atlas,” Riso National Laboratory, 1989.