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Assessment of selected methods for estimating wind speed in a foothill landscape (using the example of Ciężkowice, southern Poland)

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The main objective of the research was to assess the suitability of power and logarithmic formulas and selected ground roughness classifications for estimating wind speed at altitudes higher than the standard altitude at which meteorological measurements are made (10 m AGL). The study used average 10-minute wind speeds from a wind mast at a height of 10 and 40 m AGL from the period 05.2008-06.2010 (data made available by the Central Technical Organisation in Tarnów). The met mast was located in a hilly landscape on an unwooded plateau at an altitude of 370 m ASL, about 120 m above the valley floor, in an area used for agricultural purposes in the Ciężkowice Foothills (southern Poland). The data was subjected to statistical analysis, its completeness was checked, and erroneous values were removed. Next, the wind speed was estimated for 40 m AGL using data from 10 m AGL, based on the power formula and the logarithmic formula.

To determine the roughness of the terrain nine classifications were used, which were developed for different types of terrain and have varying numbers of classes: Davenport (1965), Jensen and Franck (1965), the Polish wind standard PN-77/B-02011 (1977), the ISO/TC 98/SC 3 WG2N42E standard (1977), ESDU 82086 (1982), Żmuda (1986), Wiering (1996), and the European wind standard EN 1991 1-4 (2005), which is the currently binding Polish wind standard PN-EN 1991 1-4 (2008).

The roughness classes were established on the basis of topographic maps, aerial photographs and field reconnaissance. The roughness of the terrain was estimated for an area within a radius of 1.5-2.0 km from the wind mast. The suitability of the power and logarithmic formulas and the selected ground roughness classifications for estimating wind speed was determined by calculating the differences between the wind speeds measured and estimated at a height of 40 m AGL. The Wilcoxon test was used to assess the statistical significance of the differences.

The results show that, in a landscape of varied relief, the estimation of wind speed using logarithmic and power formulas generates quite large errors of overestimation and underestimation. The roughness classifications used in the research do not take into account areas characterized by varied relief; they also overlook the presence of specific terrain forms. It was shown that the magnitude of error varies depending on the speed and direction of the wind, its vertical gradient, the time of day and season of the year. Greater errors in the estimation of wind speed at a height of 40 m AGL were found in the colder half of the year than the hotter half. Statistically significant undervaluation errors were found, irrespective of the terrain roughness classification used, for winds from the ESE-SE-SSE-S-SSW sector.