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Spatial assessment of potential wind-driven soil loss using the Wind Erosion Equation

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Abstract: Wind erosion represents a locally significant soil degradation process in the Czech Republic, particularly in intensively farmed lowland regions. While areas susceptible to wind erosion have been previously identified, spatially explicit quantification of potential soil loss expressed in t/ha per year at the national scale has so far been lacking. This study presents a comprehensive assessment of potential wind-driven soil loss across the Czech Republic using the Wind Erosion Equation (WEQ). Special attention is given to the soil erodibility index (I), which was derived from extensive laboratory analyses of soil aggregates and evaluated using multiple statistical representations (Q_{25}, median, mean, Q_{75}, and Q_{90}). The resulting variants were used to quantify the sensitivity of modelled soil loss to erodibility assumptions and to compare exceedance of national (9 t/ha per year) and European (2 t/ha per year) reference limits. Results show substantial spatial variability in index I and associated soil loss estimates. Using the recommended median-based variant, approximately 10% of agricultural land exceeds the European reference limit, while only 0.8% exceeds the national threshold. Higher quantile scenarios (Q_{75} and Q_{90}) identify erosion hotspots in dry lowland regions and are suitable for preventive planning. The presented outputs provide the first spatially consistent national framework for assessing potential wind erosion losses in the Czech Republic.

Keywords: agricultural land; preventive planning; soil erodibility; soil loss modelling; WEQ; wind erosion

Wind erosion is one of the primary processes contributing to soil degradation, negatively affecting soil fertility and the long-term sustainability of agricultural production. The removal of topsoil reduces organic matter, nutrient content and soil fertility, structure, and biological activity, leading to lower crop yields. Moreover, fine particles transported by the wind can deteriorate air quality and cause secondary deposition on adjacent land or water bodies, resulting in additional adverse impacts beyond the threatened site itself (Funk et al. 2004; Borrelli et al. 2017). Globally, wind erosion is increasingly studied

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not only as a driver of soil degradation but also in relation to particulate matter (PM10) emissions and their effects on climate and human health (Borrelli et al. 2017; Webb & Pierre 2018). In arid and semi-arid regions (e.g., USA, China, Iran), wind-induced soil loss is comparable to water erosion (Funk et al. 2004). Studies indicate that soil vulnerability to wind erosion is largely determined by the content of fine particles and aggregate stability (Zobeck et al. 2003; Diaz-Zorita et al. 2002; Amézketa et al. 2003; Colazo & Buschiazzo 2010; Qian et al. 2019).

The influence of climate change on wind erosion is a major focus of intensive international research. An increase in erosion events has been linked to more frequent droughts and stronger winds (Edwards et al. 2019). Studies from other countries also highlight a growing risk of wind erosion in Central Europe, including the Czech Republic (Kron et al. 2019; Lackóová et al. 2023). Wind erosion occurrence in the Czech Republic is often associated with areas of low precipitation and light to medium-heavy soils. To effectively plan soil protection measures (Středová et al. 2021) developed a complex methodological protocol expressed as a "road map" to identify and classify the risk of wind erosion given as potential wind erosion degrees and their subsequent distribution into six categories. This general risk level estimation should be followed by quantifying potential annual soil loss in t/ha per year, which can be determined using various empirical or process-empirical models. The most widely applied approaches are the Wind Erosion Equation (WEQ; Woodruff & Siddoway 1965; Schwab et al. 1993) and its revised form, the Revised Wind Erosion Equation (RWEQ; Fryrear et al. 1998; Borrelli et al. 2017). The RWEQ model is based on the original WEQ equation but incorporates additional process-oriented parameters. It considers the temporal dynamics of vegetation cover, variability in wind speed and direction, soil moisture, and the spatial distribution of erosion intensity within a plot (Fryrear et al. 1998; Tatarko 2001; Borrelli et al. 2017). As a result, it provides more realistic estimates, particularly at the scale of individual plots, and enables the evaluation of the effectiveness of specific management practices or changes (Van Pelt & Zobeck 2004; Singh 2023). However, its implementation requires high-quality input data and is more complex, which limits its widespread application.

WEQ was developed from long-term field experiments conducted in the American Great Plains and has since become the foundation for global wind erosion assessment. The equation estimates soil loss as a function of five key factors: soil erodibility (I), surface roughness (K), climate (C), vegetation cover (V), field length (L) and the effectiveness of protective barriers. Although empirical in nature, its main advantage lies in requiring relatively few input data, making it suitable for large-scale applications (Skidmore 1986; Hagen 1991; Singh 2023; Blanco & Lal 2023). Currently, WEQ represents the standard methodological approach for estimating potential soil loss due to wind erosion. Results obtained using this equation are employed to identify high-risk areas and design protective measures in agricultural landscapes. While originally developed under different environmental conditions, its conceptual framework is universal and provides a reliable basis for comparative risk erosion assessment across regions. In the Czech Republic, several authors addressed this topic in the 1970s (e.g. Pasák 1966; Vrána 1978). The method was later published at the national level, but only for the local-scale applications, by Kozlovsky Dufková et al. (2019). However, a comprehensive assessment of soil loss in t/ha per year for the entire country is still lacking. One of the key input parameters for estimating soil loss is the soil erodibility index I, which reflects the susceptibility of soil to wind erosion on flat, smooth, vegetation-covered surfaces.

In the Czech Republic, spatial determination of the WEQ index I is generally facilitated by the existence of a national database of rated Evaluated Soil-Ecological Units (ESEU). This database covers the entire agricultural land and is continuously updated at a rate of approximately 30 000 hectares per year. The ESEU system, where each code consists of five digits (see, for example, Vopravil et al. 2021), is a unique national agro-genetic classification closely linked to an international morphogenetic classification systems (IUSS Working Group WRB 2022). The core of the ESEU code is formed by the Main Soil Unit (MSU) which aggregates soils within similar key soil properties, such as texture, soil-forming substrate, degree of hydromorphism and also exhibit comparable agronomic and production potential. The ESEU system currently comprises 2 995 codes and 89 MSUs, which are grouped into 15 basic categories. When MSU are combined with real field soil data index I might be determined with a sufficient accuracy.

The aim of this article is to determine the spatial variability of the WEQ factors across the Czech Republic and to develop reference maps for the potential soil loss due to wind erosion. Main objectives of the study:

- Develop a spatially explicit soil erodibility index (I) layer for the Czech Republic based on laboratory-derived soil properties and multiple statistical representations.
- Quantify potential annual soil loss due to wind erosion (t/ha per year) at the national scale using the WEQ model implemented in a high-resolution GIS framework.
- Evaluate the sensitivity of WEQ outputs to different statistical variants of factor I and identify a reference approach suitable for national-scale wind erosion assessment and land management applications.

MATERIAL AND METHODS

Study area. The study was conducted in the Czech Republic (Central Europe), where wind erosion is a major contributor to soil degradation. The model was applied exclusively to predominantly intensively farmed land in dry and warm regions identified as having a high potential risk of wind erosion, which, according to Středová et al. (2021), predominantly occurs at altitudes below 500 m a.s.l. (Figure 1).

WEQ. WEQ provides an estimate of the potential annual soil loss. However, it is an empirical model and does not fully account for the complex interactions, combinations, and spatial variability of erosion processes and wind erosion factors. As mentioned earlier, Wind Erosion Equation (WEQ) was first introduced by Woodruff and Siddoway (1965) and expressed as:

$$E = f(I, K, C, L, V) \tag{1}$$

where:

E – potential average annual soil loss (t/ha per year);

I – soil erodibility index, representing susceptibility to wind erosion in t/ha per year on flat, smooth, vegetation-free land;

K – soil ridge roughness factor;

C – climatic factor;

L – length factor expressed as a width of the unsheltered field (m);

V – vegetative cover factor.

WEQ was later adapted for GIS applications by Schwab et al. (1993), who derived two equations for calculating the average annual soil loss. Based on the analysis of individual factors in this study,

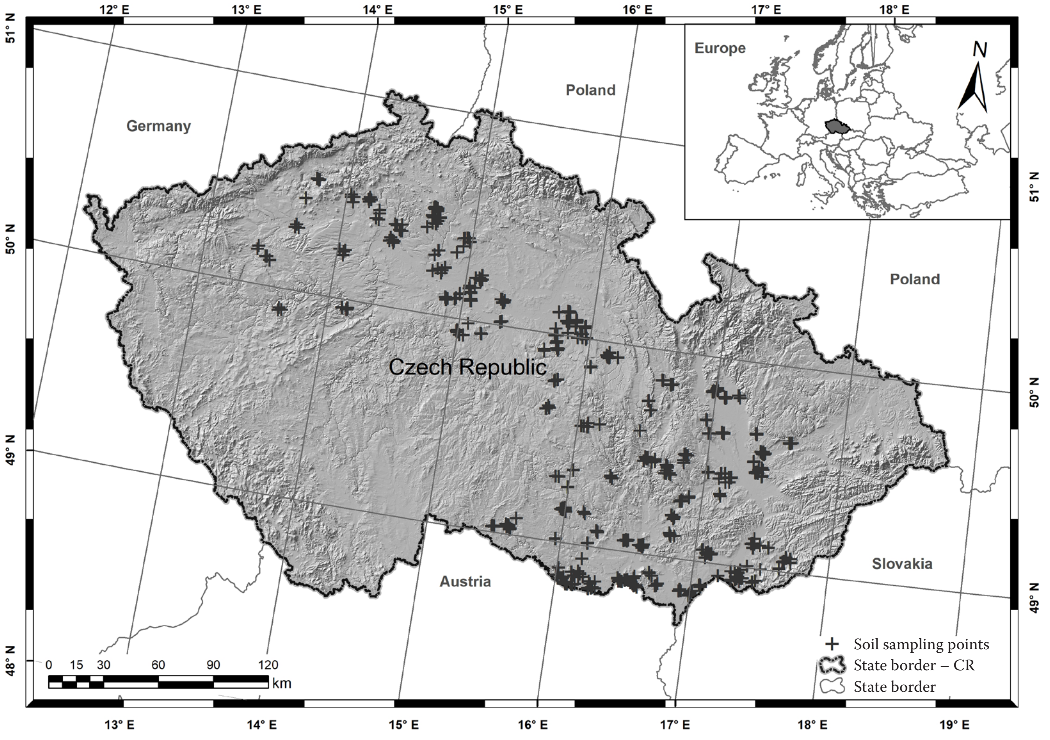

Figure 1. Overview map of soil sampling locations

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Equation (2) was selected as appropriate for determining soil loss due to wind erosion under the conditions of the Czech Republic.

$$E = 0.0015 \times 2.718^{\left(\frac{-V}{4500}\right)} \times \left[I^{1.87} \times K^{2} \times \left(\frac{C}{100}\right)^{1.3} \times L^{0.3} \right] \qquad (2)$$

Based on the results of calculations performed for IKCL in this study, Equation (3) was used.

Soil erodibility index I. Index I primarily depends on the proportion of non-erodible soil particles that are not moved by wind, i.e. particles larger than 0.84 mm. The size distribution of these particles is determined through laboratory analysis using dry sieving.

To calculate index I within the WEQ model, the following equation proposed by Schwab et al. (1993) was applied:

$$I = 525 \times (2.718)^{-0.04\ \text{NEF}} \ \ (\text{t/ha per year}) \qquad (3)$$

where:

NEF – non-erodible fraction of soil (%) determined by dry sieving through a 0.84 mm sieve.

The assessment of index I was linked to MSUs (spatial resolution up to 0.5 ha), which capture the spatial variability of soil erodibility and related parameters in accordance with national and international soil classification systems. Of the total 89 MSUs, several were excluded from detailed laboratory soil sampling, primarily those with very limited occurrence in the Czech Republic or associated with specific conditions (e.g. slopes exceeding 12°, strongly hydromorphic soils, or locations above 500 m a.s.l.) covered mostly by permanent grassland, where higher resistance to wind erosion can reasonably be assumed. In total, 64 MSU codes were analysed. The location and optimisation of the sampling points were carried out in cooperation with the State Land Office, which manages and continuously updates MSU database.

In total, approximately 850 soil samples taken from the soil surface to a depth of 25 mm were collected during spring seasons between 2021 and 2024. Samples were air-dried, homogenised, and subjected to aggregate analysis following López et al. (2007) to determine NEF. Additional analyses included grain size composition, organic matter content (Cox), and carbonate content ($CaCO_3$). These data were primarily used for soil classification and can subsequently be used to inform RWEQ erodibility estimates (Fryrear et al. 1994; Borrelli et al. 2017). There is no standardized procedure for statistically representing soil erodibility in the current literature. Some authors use the mean value of the erodibility index (e.g., Fryrear et al. 1998; Guo et al. 2013), while others apply the median or quantile range to eliminate the influence of extreme values (Mezösi et al. 2015). Since of Index I values show significant variability within MSU, several statistical variants (Q_{25}, median, mean, Q_{75}, and Q_{90}) were selected for this study. This approach enables the creation of multiple scenarios, from optimistic (Q_{25}) to conservative (Q_{90}), reflecting international methodological practices and allowing comparison with soil loss limits used in Europe and the Czech Republic.

Climatic factor C. Factor C is defined by the interaction between wind speed and soil surface moisture. Ideally, meteorological data would be collected directly under field conditions to capture the local variability. However, due to the absence of such detailed data, C was quantified using standard climatological datasets (Project FW06010399, supported by the Technology Agency of the Czech Republic and the Ministry of Industry and Trade of the Czech Republic under the TREND Programme). The C factor layer was calculated for the entire Czech Republic using the equation proposed Chepil (1962) and Chepil et al. (1962), based on data from the Czech Hydrometeorological Institute (CHMI) and the DMR 4G digital terrain model (©ČÚZK). The equation used to calculate the erosion climate factor was that according to Chepil et al. (1962), Blanco-Canqui and Lal (2008). The following relationship was used for all stations:

$$C = 386 \times \frac{u^{3}}{(\text{PE})^{2}} \qquad (4)$$

where:

C – climatic factor;

u – average annual wind speed (m/s);

PE – Thornthwaite's irrigation index.

The Thornthwaite irrigation index is calculated as:

$$\text{PE index} = 3.16 \sum_{i=1}^{12} \left(\frac{Pi}{1.8Ti + 22} \right)^{10/9} \qquad (5)$$

where:

Pi – average monthly precipitation (mm);

Ti – average monthly air temperature (°C).

For the calculation, long-term monthly averages of precipitation and air temperature were obtained for 162 climatological stations over the period 1991–2020. Monthly PE values were calculated and combined with wind speed data to derive C factor values. The choice of wind speed input significantly influences C. Using average daily wind speeds (2.3 m/s) results in lower values compared to speeds measured at 2 p.m. (3.1 m/s). For this study, wind speed at 2 p.m. was used, as this period typically coincides with the driest soil surface conditions (due to higher air temperature and evaporation) and the greatest likelihood of particle transport. A point layer of C values was created in ArcGIS (ESRI) for the period 1991–2020. These values were then interpolated across the Czech Republic using regression kriging with altitude dependence, implemented via ProClimDB software tools.

Length factor L. The factor L represents the length of the unsheltered field in the direction of the prevailing wind, i.e. the distance over which the wind can act on the surface without any significant obstruction.

For this study, the L-factor layer was generated for agricultural land using the Land Parcel Identification System (LPIS) database, up to an elevation of 500 m a.s.l., based on the fourth-generation Digital Terrain Model (DMR 4G, ©ČÚZK). When creating this layer, the presence of vegetation barriers and built-up areas, which reduce wind speed and thus shorten the effective length of the unprotected section were considered. Vegetative barriers were identified using national geospatial datasets and orthophotos and were processed as vector features prior to the raster-based modelling. Barriers included windbreaks, tree lines, small forest patches and other continuous woody vegetation capable of reducing wind speed and interrupting the effective length of the unsheltered field. Isolated trees or small shrub patches were not considered, as they do not represent an effective aerodynamic barrier. The identification of these elements was performed in a vector layer preserving their true spatial geometry. The final raster resolution of 5 × 5 m was applied only during the integration of WEQ factors within the GIS modelling framework. This approach ensured that narrow linear vegetation barriers were retained and properly reflected in the calculation of the L factor. The calculation direction of the L factor was based on the map of prevailing wind directions in the Czech Republic (Kučera et al. 2023).

Soil ridge roughness factor (K). This factor expresses the influence of surface roughness on erosion processes (Schwab et al. 1993; Blanco-Canqui & Lal 2008). As roughness varies significantly throughout the year due to farming practices and weather conditions, it is not possible to determine a representative average value. Therefore, for the purposes of calculating potential wind erosion, a flat surface was assumed, and K was set to 1. Setting the surface roughness factor K to a value of 1 represents a simplifying assumption corresponding to the modelling of potential erosion on a smooth surface without the protective effect of agronomic practices. This approach was adopted to establish a reference, i.e. maximum potential of wind erosion under conditions of minimal soil surface protection. However, it should be emphasised that actual K values vary considerably throughout the year depending on the tillage system, seasonal changes in surface structure, and the presence of crop residues. Consequently, this assumption may lead to an overestimation of soil loss in areas where soil conservation practices are actively applied.

Vegetative cover factor (V). V factor reflects the protective effect of vegetation, considering its amount, type, and spatial arrangement (Williams et al. 1984; Armbrust & Lyles 1985; Blanco-Canqui & Lal 2008). The value is typically derived from biomass converted to a small-grain equivalent (Lyles & Allison 1981). In the Czech Republic, wind erosion occurs mainly in spring and partly in autumn, when the soil is largely unprotected by vegetation. For this study, the V factor was set to 1 to represent potential erosion conditions.

Soil loss limit. Currently, there is no legally binding uniform limit for soil loss caused specifically by wind erosion in the Czech Republic or at the EU level, unlike water erosion, where limits are clearly defined. For this study, the limits established for water erosion were adopted. The national limit for soil loss due to water erosion is currently 9 t/ha per year (Podhrázská et al. 2024; Decree 240/2021). The recommended European limit for soil loss due to water erosion is 2 t/ha per year (based on European studies e.g. Panagos et al. 2015; Borrelli et al. 2017) which is widely used as a reference for sustainable soil loss, ensuring the preservation of soil functions and topsoil formation. These limits are used for comparative and interpretative purposes only, and not as mechanistic analogues between the two erosion processes. While the physical mechanisms differ, both erosion types ultimately remove topsoil and diminish soil fertility. Thus, applying the established tolerable soil loss framework provides a meaningful context for interpreting wind erosion estimates, especially in the absence of wind-specific regulatory thresholds.

Model implementation. Potential soil loss due to wind erosion was modelled using the WEQ within the ArcGIS Pro (ESRI) geographic information system. Layers I and C were processed at the national scale with a uniform spatial resolution of 5 × 5 m, while layer L was generated with the same resolution but only for areas below 500 m a.s.l., in accordance with the availability of climate data and the methodology for assessing prevailing wind directions.

The processing of individual factors employed Spatial Analyst, Raster Calculator, Slope and Flow Length tools, along with standard ArcGIS Pro geoprocessing procedures. The final output was a raster layer representing potential soil loss due to wind erosion (t/ha per year), obtained by synthesising layers I, C, and L according to the WEQ equation. For interpretability, calculated values were extracted for LPIS (Land Parcel Identification System) areas and linked to MSUs. The resulting dataset is the first spatially uniform quantification of potential soil loss due to wind across the Czech Republic. It serves as a basis for further analysis, validation and the design of soil protection measures.

RESULTS AND DISCUSSION

This study builds on previous research on wind erosion at the European (Borrelli et al. 2017) and Czech (Podhrázská et al. 2024) levels, aiming to thoroughly assess wind erosion potential and refine the WEQ factors. The results focus on the variability of index I and its influence on potential soil loss due to wind erosion.

Index I. Index I represents the potential loss of soil from a flat, smooth, unvegetated surface and is a key parameter in the WEQ equation. The boxplot in Figure 2 visualises data variability and the distribution of Index I. The central box delimits the interquartile range (IQR), covering the middle 50% of the data (25th to the 75th percentile). The median is marked by a horizontal line inside the box, and the mean is represented by a cross. Whiskers extend to the outermost data points within 1.5 times the IQR, while outliers beyond this range are plotted as individual points. The median and interquartile values are mainly concentrated within the 40–100 t/ha per year range, whereas the upper quantile (Q_{90}) reaches significantly higher values, exceeding 300 t/ha per year for certain MSUs (e.g. MSU 04, 17, 21, 31 and 55). Soils in these MSU can generally be classified according to the World Reference Base (WRB) as follows: Arenic Chernozem, Arenic Phaeozem, Arenic Calcic Chernozem, Arenic Endocalcic Chernozem (MSU 04); Arenic Luvisol (MSU 17); Arenic Regosol, Haplic Calcaric Arenosol (MSU 21); Arenic Calcaric Regosol, Arenic Rendzic Leptosol, Arenic Cambisol (MSU 31) and Psephitic Fluvisol, Arenic Fluvisol (MSU 55). The results indicate that some soils are extremely erodible, primarily due to their texture and the low proportion of NEF.

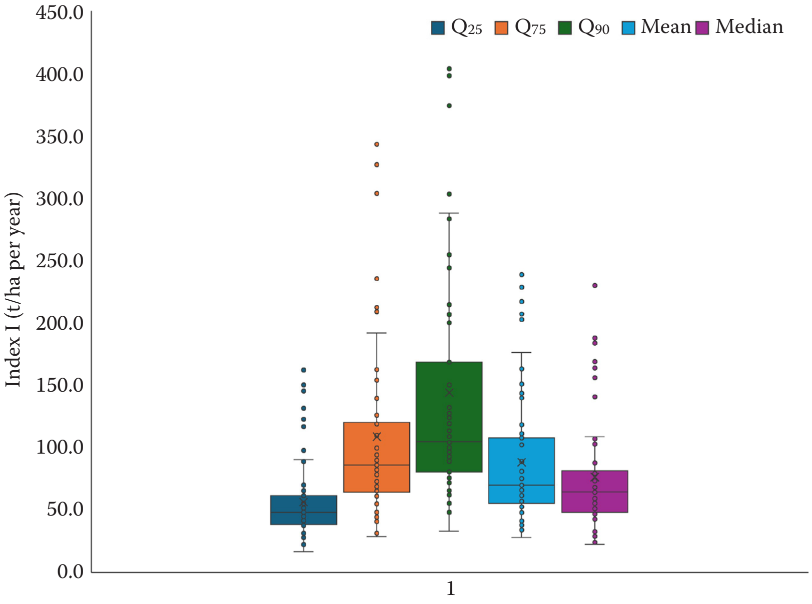

Figure 2. Box plot showing summary statistics of index I data

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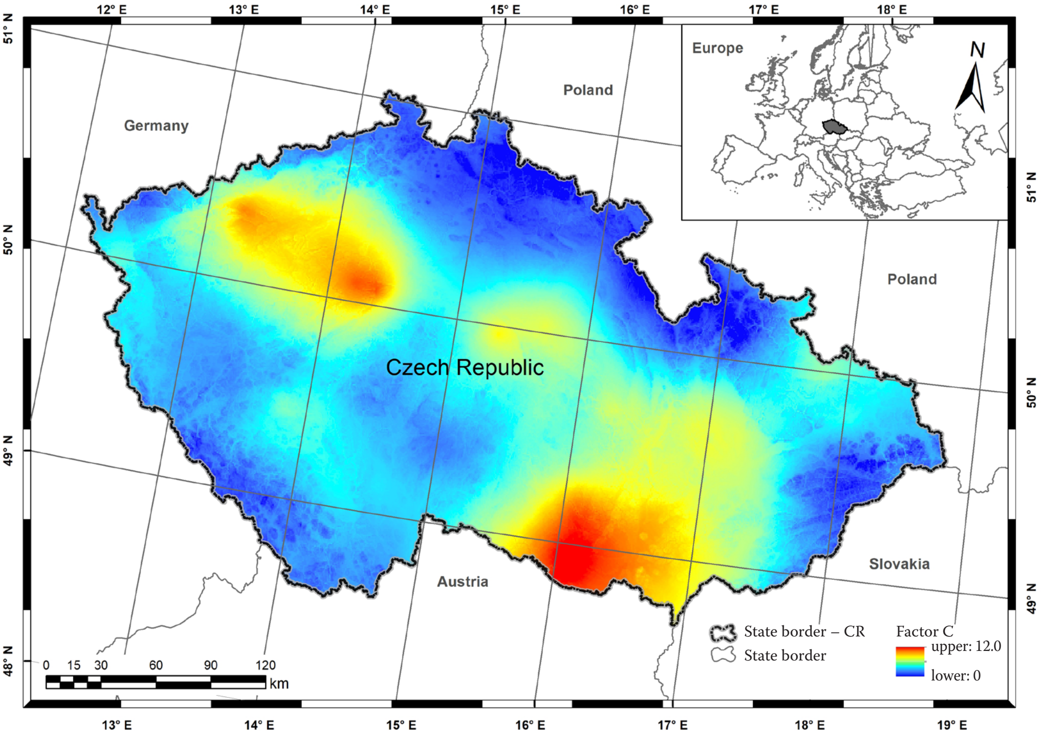

Figure 3. Map of factor C spatial distribution

Factor C. The resulting C layer is the basis for calculating soil erosion loss and identifying areas at higher risk of wind erosion. Figure 3 illustrates the spatial distribution of climate factor C in the Czech Republic, which reveals significant regional variability, reflecting a combination of climatic and orographic factors. Higher C values are particularly evident in the lowland areas, where higher wind speeds and lower soil moisture are commonplace. Interpolating the data using regression kriging captured the smooth transition between regions and eliminated local extremes. The climatic factor C was derived from long-term average wind speed values and climatic data for the period 1991–2020. This approach corresponds to the standard application of the WEQ model at the national scale and enables spatially consistent comparison of erosion potential. Similarly, the average annual wind speed is the only climatic parameter that controls wind erosivity in the German Institute for Standardization's (DIN 19706:2013). Extreme events with high wind speeds are not taken into account at all. This concept is suitable for a general classification of areas prone to wind erosion (Scheper et al. 2021). However, it should be emphasised that wind erosion often occurs in short-term, high-intensity episodes that may be attenuated in mean values. The model therefore represents the long-term erosion potential rather than extreme episodic events. Future applications of the obtained results may include scenarios based on extreme erosion events or projections that account for climate change.

Potential average annual soil loss (E). Table 1 summarises the proportion of agricultural land exceeding the soil loss thresholds for different statistical variants of index I). Two reference limits of soil loss were applied for quantification of endangered areas: 2 t/ha per year (European recommendation) and 9 t/ha per year (Czech national limit. The analysis reveals substantial variability in the extent of potential soil loss depending on the statistical approach (Median, Mean, Q_{25}, Q_{75} and Q_{90}). Most agricultural land in the studied area falls below the 2 t/ha per year threshold, indicating low wind erosion risk. The proportion of land in this category ranges from 66% (Q_{90}) to 96% (Q_{25}), with the median scenario presenting 89.9% of land below this limit. Areas exceeding 2 t/ha per year account for 10.1% of agricultural land, representing approximately 265 000 ha. When applying the higher limit of 9 t/ha per year, more than 98% of agricultural land stays under the threshold (99.17% in the median variant, i.e. approximately 2.6 million

Table 1. Percentage and area of agricultural land exceeding and not exceeding soil loss limits for different index I variants

Variants index I/limit (t/ha per year)	Percentage representation (%)				Area (ha)			
	≤ 2.0	> 2.0	≤ 9.0	> 9.0	≤ 2.0	> 2.0	≤ 9.0	> 9.0
Median	89.9	10.1	99.2	0.8	2 357 179	264 839	2 600 242	21 776
Average	86.1	13.9	98.7	1.3	2 258 277	363 741	2 588 035	33 983
Q_{25}	96.1	3.9	99.9	0.02	2 519 956	102 062	2 621 510	508
Q_{75}	78.4	21.6	96.6	3.4	2 054 644	567 374	2 532 265	89 753
Q_{90}	66.2	33.8	93.6	6.4	1 735 892	886 126	2 453 856	168 162

hectares). Depending on the statistical variant, only 0.8–6.4% of the territory can be classified as highly vulnerable to wind erosion, corresponding to an area of 21–168 000 hectares. Comparing individual statistical approaches reveals that choosing extreme quantiles (Q_{25} and Q_{90}) produces markedly different erosion risk estimates: under Q_{25}, erosion is negligible, whereas under Q_{90}, the area at risk increases by more than fivefold. The median scenario (Figure 4) provides a balanced and representative estimate, reflecting the actual conditions of most MSUs.

Table 2 summarises the basic statistical characteristics of the five potential soil loss variants (E), derived from different representative soil erodibility values (Q_{25}, Q_{75}, Q_{90}, median, and mean). The metrics include maximum, mean and median values.

Variant E for I Q_{90} achieves the highest soil loss values (MAX = 144.43 t/ha per year, MEAN = 2.99 t/ha per year), reflecting conditions of increased erodibility typical of the most vulnerable soils within MSUs. In contrast, E for I Q_{25} exhibits the lowest values (MEAN = 0.53, MEDIAN = 0.29), reflecting a conservative scenario for soils with low susceptibility to wind erosion. E for I MEDIAN and E for I MEAN demonstrate moderate erosion load (MEAN = 0.96–1.15 t/ha per year), corresponding to prevailing conditions in the Czech agricultural landscape. Median values of 0.49–0.58 confirm that most of the territory falls into the low-to-moderate erosion risk

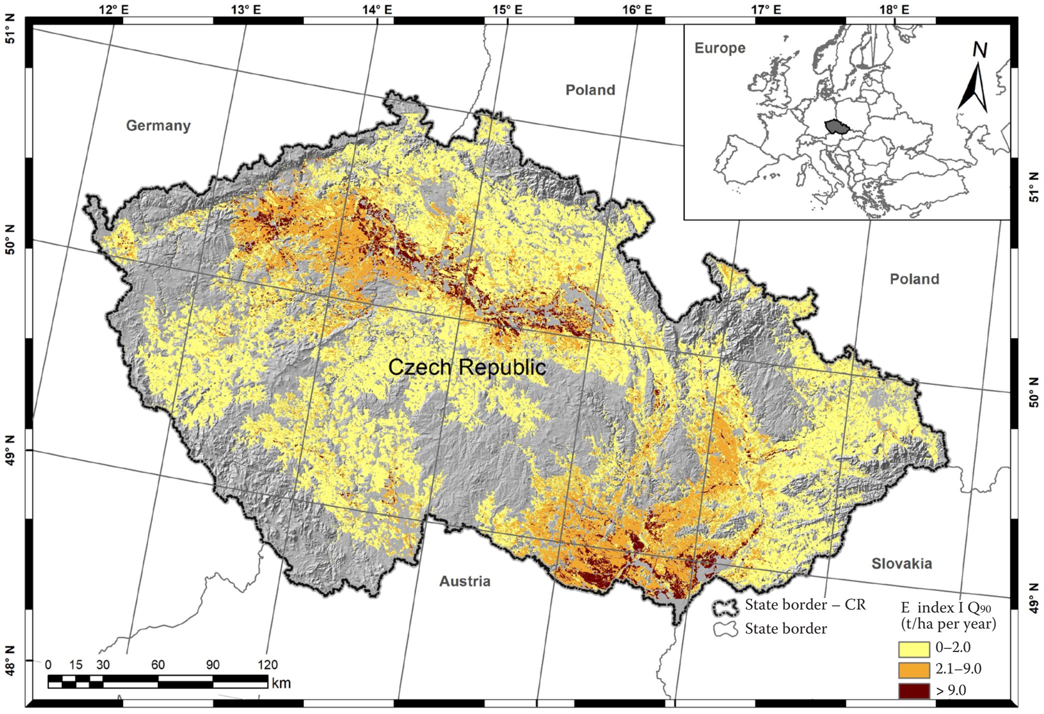

Figure 4. Potential soil loss due to wind erosion (t/ha per year) according to Schwab et al. (1993) for index I Q_{90} values

Table 2. Comparison of potential annual soil loss (t/ha per year) due to wind erosion (E) based on different index (I) values

I variants	E		
	MAX	MEAN	MEDIAN
Q_{25}	17.36	0.53	0.29
Q_{75}	74.59	1.78	0.82
Q_{90}	144.43	2.99	1.20
MEDIAN	36.23	0.96	0.49
MEAN	38.76	1.15	0.58

category, while higher maximum values of 36.23–38.76 indicate localised hotspots of vulnerability.

These results clearly demonstrate that the using of statistical measures and subsequent choice of index I significantly influences modelled erosion levels, particularly in Q_{90} scenario, where extreme values increase substantially. The reduced set of metrics (MAX, MEAN, and MEDIAN) provides a robust yet clear basis for interpreting spatial erosion patterns and comparing WEQ model variants.

Comparison with European assessment. The results of WEQ modelling for the Czech Republic can be compared with the European study by Borrelli et al. (2017), which applied the RWEQ model and for the Czech Republic reported average potential soil loss of 0.45 t/ha per year and a maximum of 7.2 t/ha per year. While the European assessment provides a general overview of wind erosion risk, its coarse spatial resolution (~1 km^2) limits the ability to capture variability in soil erodibility and local management practices. In contrast, the WEQ model implemented in this study uses a fine resolution of 5 × 5 m and incorporates national datasets (MSU, LPIS), enabling precise identification of erosion hotspots. These differences account for the observed variability in results and underscore the benefits of implementing the WEQ model at a national scale for precise delineation of risk areas. Consequently, high-resolution WEQ modelling represents an essential tool for targeted wind erosion assessment and strategic soil conservation planning in the Czech Republic.

CONCLUSION

This study provides the first comprehensive national-scale quantification of potential soil loss due to wind erosion in the Czech Republic expressed in t/ha per year. By integrating detailed soil data with high-resolution WEQ modelling, the results reveal pronounced spatial variability in wind erosion risk that cannot be captured by continental-scale assessments.

The analysis demonstrates that the choice of statistical representation of the soil erodibility index (I) has a substantial influence on estimated soil loss. Among the evaluated variants, the median-based approach offers the most balanced representation of erosion risk by limiting the influence of extreme values while preserving spatial variability across soil units. In contrast, mean-based and upper-quantile variants (Q_{75} and Q_{90}) tend to overestimate erosion extent but are useful for sensitivity analyses and preventive planning in particularly vulnerable regions.

Although the overall national wind erosion risk is moderate, distinct hotspots occur in dry lowland areas, where potential soil loss locally exceeds sustainable thresholds. These findings underline the need for targeted soil protection measures and systematic monitoring within Czech agricultural landscapes. The presented methodology establishes a robust framework for national wind erosion assessment and provides a foundation for future evaluations under changing climatic conditions.

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