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Research Article

Erodible fraction content change in long term wind erosion duration

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Soil erosion by wind is the primary land degradation process which affects natural environments and agricultural lands. In agricultural lands, soil erosion by wind mainly results from removing of the finest and most biologically active part of the soil richest in organic matter and nutrients. Repeated exposure to wind erosion can have permanent effects on agricultural soil degradation. Knowing spatial and temporal changes in soil conditions and soil erodibility is essential to understand wind erosion processes. There are many methodologies to predict the susceptibility of landscape to erosion. The more complex is the scheme combining multiple factors, the more accurate the estimate is. There are very few studies on mapping the changes in soil grain size and erodible fraction due to wind erosion. Existing studies only deal with eroded soil units (where particles are removed – deflation) and not the eroded units (areas) to which the eroded particles are wound – accumulated. Prevailing wind direction should also be taken into account when mapping changes in erodible fractions of wind-eroded soils and the nature of the soil (whether soil particles accumulate or deflate). In this study the "historical" grain size distribution of the soil in three cadastral areas using data from complex soil survey (1968) and year 2018/2019 was analysed. Erodible fraction change was also calculated and compared for both time periods.

Keywords: grain composition change, wind erosion, erodible fraction, accumulation zones

1 Introduction

Data dealing with the extent and severity of soil degradation by the erosion of wind across the whole Europe is minimal (Chappell & Warren, 2003). Recent EU projects studies (Wind Erosion on European Light Soils (WEELS) and Wind Erosion and Loss of Soil Nutrients in Semi-Arid Spain (WELSONS), Warren, 2003) indicate reasons that there may be more areas potentially threatened by wind erosion than foreseen by the European Environment Agency (EEA, 1998) in the past. Further studies have shown that areas previously identified as only slightly affected by wind erosion (EEA, 1998) are currently experiencing extensive erosive processes (Böhner et al., 2003; Gomes et al., 2003).

Inappropriate land use and landscape management, along with growing intensive crops, increasing mechanization, increasing the size of land areas, and removing shrubs, multiply the impact of wind erosion on Europe's most vulnerable agricultural areas (Warren, 2003; Riksen et al., 2003; Funk & Reuter, 2006). Muchová and Tárníková (2018) quantified the level of anthropogenic impacts on the landscape by detection, measuring, spatial localization, evaluation, and visualization of land use/land cover changes. To better understand the geographical distribution of erosion processes in Europe, in early 2014, the JRC proposed an integrated approach of mapping the susceptibility of soil to wind erosion (Borrelli et al., 2014). Erodible soil fraction (EF) (percentage of aggregates <0.84 mm in diameter) is one of the key parameters for estimating susceptibility of soil to wind erosion (Fryrear et al., 1994; Fryrear et al., 2000). The standard method for EF determination is the dry sieving by means of a rotary sieve. Fryrear et al. (1994) proposed a multiple regression equation for calculating EF in those cases where a rotary sieve is not available. This equation considers the contents of organic matter, sand, silt, clay, and calcium carbonate as predictive variables. The EF value (for the soil surface layer 0–20 cm) was calculated for 18,730 georeferenced samples in Europe (LUCAS data set).

The objective of this ongoing study was to analyse soil grain properties of the areas, where soil erosion causes

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accumulation of eroded material in long term duration. The results of this work point to the consequences of wind erosion in time (50 years).

2 Material and methods

For the assessment of soil erosion by wind, 3 cadastral areas (Borský Svätý Jur, Kuklov and Kúty) located in the Záhorská Lowland were selected. The Záhorská Lowland lies in the south – west of Slovakia and fills the area between the Morava River in the west and the Small Carpathians in the east. Nowadays, blowing sands present, alongside river deposits, one of the most important phenomena and relief elements of this area. The sands formed during the Pleistocene by wind activity in the Trnava region. The total selected area is 8,278.55 ha. To determine the potential wind erosion threats in the selected area (Fig. 1), the data on climate classification, grain size, and characteristics of the main soil units from the soil information system were used. In the selected cadastral areas, the acreage of no erosion in the 1st category is 11,556.42 ha (32.33%), middle erosion in the 2nd category 38,99 ha (0.81%), strong erosion in the, 3rd category 1,547.01 ha (32.13%), and strong erosion in the 4th category 1,670.99 ha (34.71%).

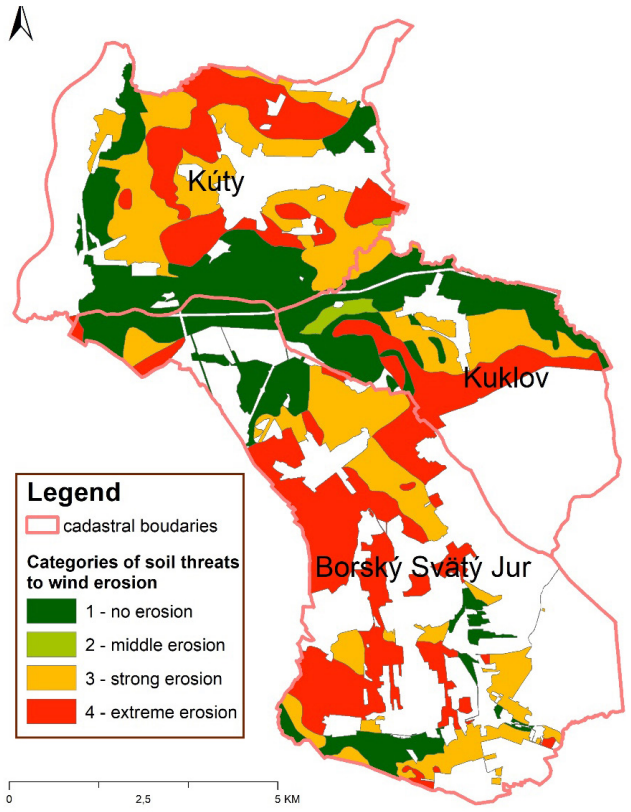


Figure 1 Categories of potential soil threats posed by wind erosion

2.1 Historical soil grain analysis

To analyse the "historical" grain size of the soil in the selected areas there were used electronic data from the Soil Complex Survey (SCS) (% content of sand, dust and clay) from years 1961–1970. Balkovič et al. (2010) created from the sand and clay content profile data at the A horizon spatial model of Slovakia (total 16, 264 georeferenced probes). The regression kriging was used for interpolation and was used as an explanatory variable including coded topsoil grain size from SCS core probes (158.478 georeferenced probes in total). The sand and clay distribution model was calculated for a 20m cell size grid. We used 39 sites (probes) in selected cadastral areas (Fig. 2).

The historical soil grain analysis showed that 43% of the arable soils consists of more than 90% of sand soil particles. 56% of the arable soils consists of less than 10% of clay soil particles.

To calculate erodible fraction of soils, a multiple regression equation developed by Fryrear et al. (1994) based on the soil's texture and chemical properties (Fryrear et al., 2000) was used:

$$EF = \frac{29.9 + 0.31S_a + 0.17S_i + 0.33S_c - 2.59OM - 0.95CaCO_3}{100} \quad (1)$$

where:
– all variables are expressed as a percentage; S_a – the soil sand content; S_i – the soil silt content; S_c – the ratio of sand to clay contents; OM – the organic matter content; $CaCO_3$ – the calcium carbonate content

2.2 Present soil grain analysis

Based on the data gained from SCS, all probes together with S-JTSK coordinates for 3 cadastral areas of interest were selected. Based on a well-defined location from SCS, the handheld GPS Trimble JUNO 3B and the software TopoL MOBILE were used directly in the field, to locate the site of the original SCS probe and took the sample from the soil surface (5 cm). A significant methodological problem associated with determining soil particle distribution is the preparation of soil samples. Kondrlová et al. (2012) discuss the derivation of a quick and simple sample preparation method for determining soil grain fractions by laser diffraction analysis using laser analyser ANALYSETTE 22 MicroTec plus.

During the field mapping, there were identified the locations (Fig. 3) where dust particles were accumulated during wind erosion events which led to a significant change in the soils´ grain composition.

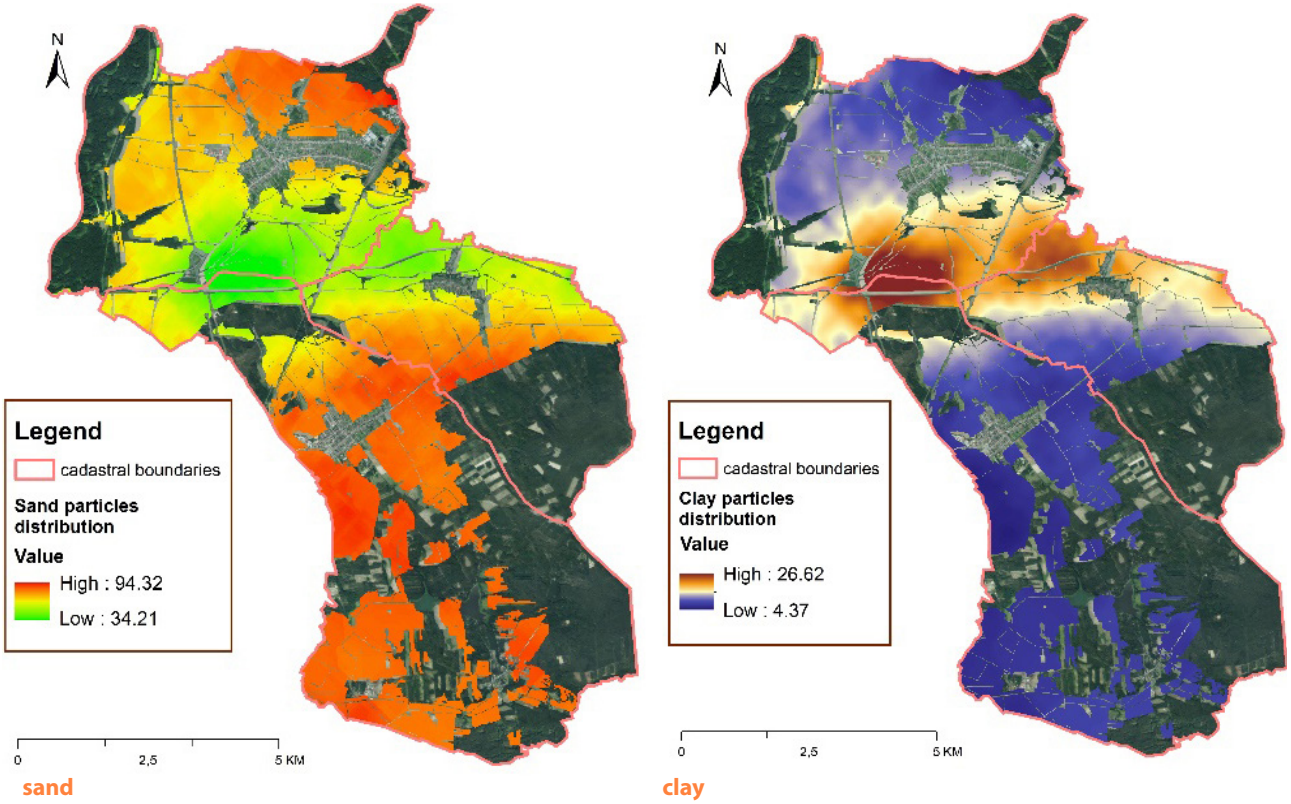


Figure 2 Soil particles distribution based on SCS



Figure 3 Accumulating locations of eroded particles in cadastral areas

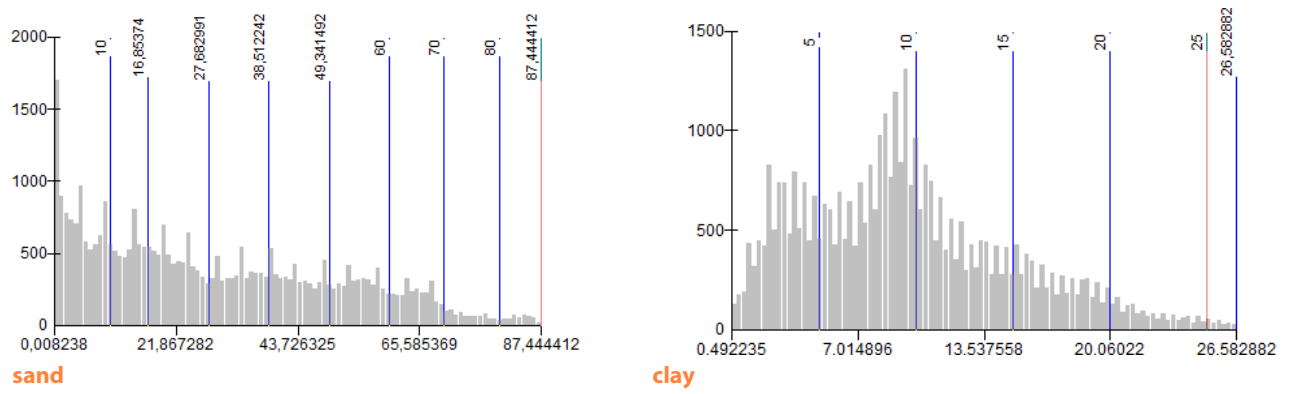


Figure 4 Histogram of grain distribution of present mapping

The histogram (Fig. 4) of measured (2018/2019) grain distribution for sand fraction shows that % distribution of sand content has rapidly decreased. 80% of the selected area has the sand content of up to 50%. Only 3% of the area is covered with the sand fraction content of more than 80%.

3 Results and discussion

The results show that the soil surface has become significantly rougher in 50 years only in a few places. However, in most areas of interest, the erosive phenomenon is manifested in the accumulation of a fraction of silt particles. Analysis of the change in the frequency of soil species occurrence in the monitored time horizon indicates a trend of growth of soil types with a significant proportion of dust particles (silt, silty loam). Sorting by erosion caused changes in soil textural class (Fig. 5). In 15 sites the soils described as loamy sands would now be described as 8× silty loams, 4× sandy loams, 2× silt, and 1× loam. The 17 sites have changed from sand to 12× sandy loam, 3× silty loam, 1× silt and loam. The 6 sites of sandy loams have changed to silty loams. In one case, sandy clay has changed to loamy sand.

Comparing the calculated EF for SCS and present mapping using the raster calculator, we obtained the erodible fraction change map over 50 years (Fig. 6). The erodible fraction values of data from SCS ranged from 28% to 62%, with a mean value of 56%. Erodible fraction of present measured data ranged from 20% to 59%, with a mean value of 49%. Comparing historical and present models, except one site, EF has decreased up to 28.4%. A mean value of EF decrease equals to 13.11%. From 39 sites, only in 2 sand content was higher in present mapping than during SCS (51.5% and 4.1%). The other 37 sites have lower sand content ranging from -20% up to -99%, average -59%. The clay content has increased in 18 sites (from 2.5% up to 68%) and decreased in 20 sites (-2.3% up to 88.3%). One site has not changed at all in clay content. The grates changes occurred in sandy, loamy sandy and sandy loam soils. The rapid increase was monitored in silt content in all sites (Fig. 7).

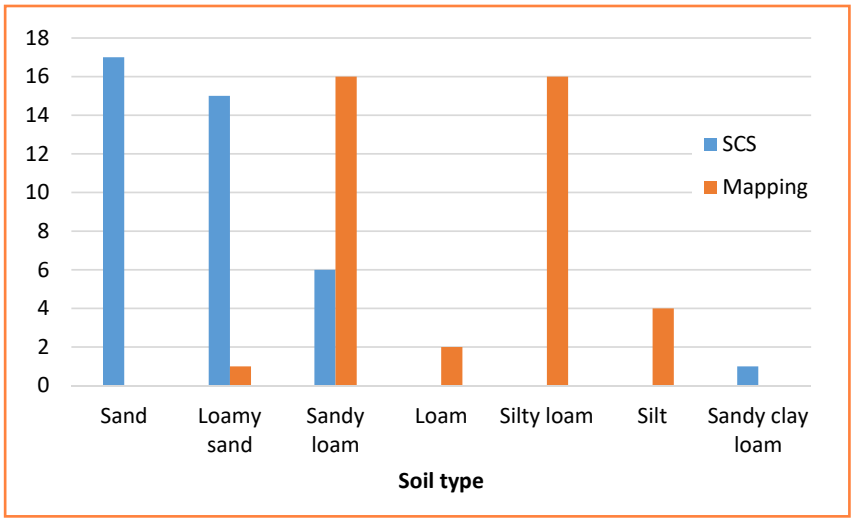


Figure 5 Soil type change between SCS and present mapping

The surface texture changed over the monitored period. Sand – size particles are generally too large to be suspended and transported long distances by wind. The reduction of sand particles does not mean that those were transported, but as the selected locations work as the accumulation zone for eroded particles, the silt and clay particles have been transported to this location over time.

The statistical dependence between SCS and present mapping using the correlation coefficient, which

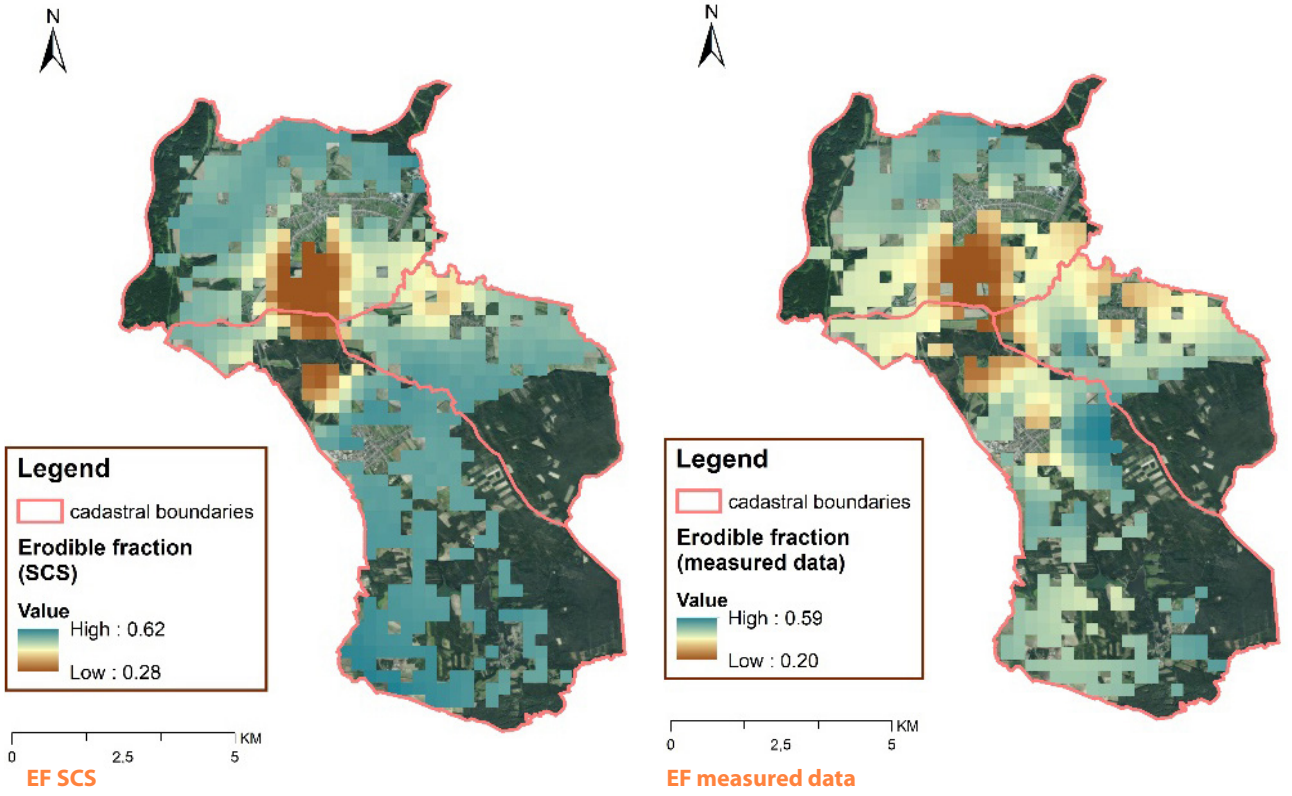


Figure 6 Map of Erodible fraction change over 50 years

measures the statistical linear relationship between the values of the variables *X* and *Y* was used. The correlation coefficient takes values from the interval <-1; +1>. In the case of independence between values of variables *X* and *Y*, correlation coefficient equals zero, there is no linear value between *X* and *Y* values dependence. Positive correlation coefficients indicate direct dependence and negative values correlate with indirect dependence. We modelled the dependence of values on a regression line. The results of the models explain the % of total variability change in grain size fraction. Correlation coefficients are very low and cannot be derived over time. The variance of the values is very high. This phenomenon explained that wind erosion not only acts in one direction (as a deflationary process) by taking away the finest particles, but also vice versa. These particles are taken from one place and transported to other sites, which act as accumulation areas in the long term.

Only a few studies have so far dealt with the quantitative linkage of the effects of wind erosion to analyse changes in grain fractions in the wind eroded soil layer. In this work, the effects of wind erosion on the soil surface due to particle size distribution (changes in sand content, silt, and clay fractions) over 50 years (1968 – data available from comprehensive soil survey and self-mapping and analysis (2018/2019) were investigated. A similar problem was analysed in the work of Li et al. (2007). They found

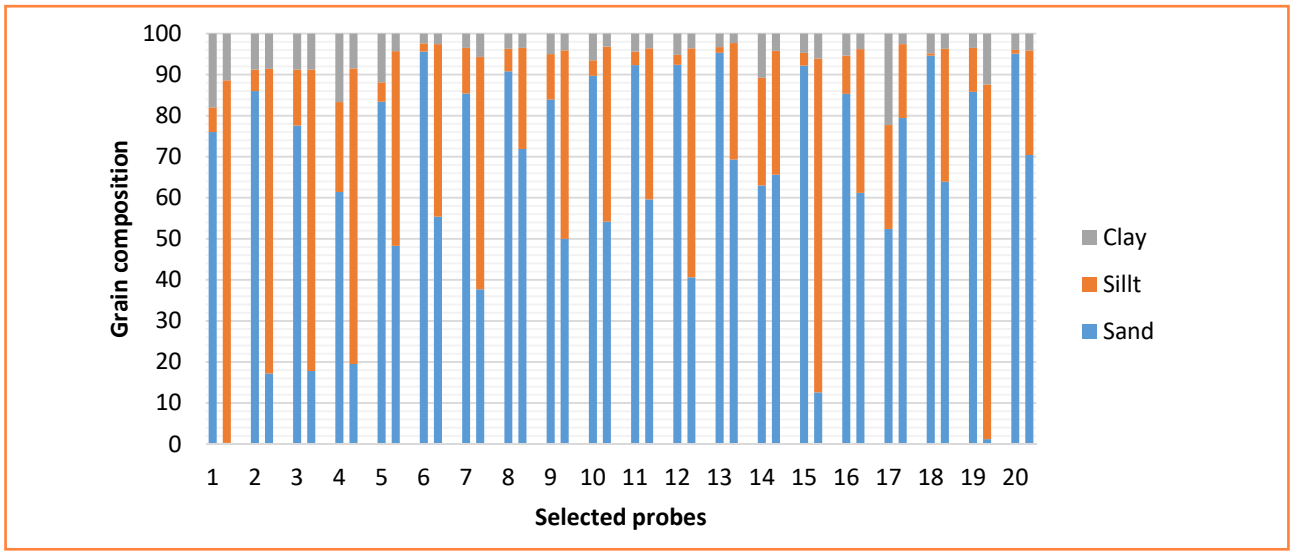


Figure 7 Comparison of grain composition in selected probes between SCS (1st line) and present mapping (2nd line of each probe)

that soil particles with a size of 250–500 μm increased significantly but decreased for particles 50–125 μm and <50 μm. Lyles and Tatarko (1986) show an example of the grain composition of agricultural soils. They compared changes in grain size composition in the top 10 cm layer at 10 sites in Kansas during the 36 years between 1948 and 1984. The proportion of the grain size fraction of sand increased in general. The most significant changes were experienced on medium sandy and sandy (coarse-grained) soils. Lyles and Tatarko (1986) found out that sand content increased over the 36 years due to wind erosion by 6,5% and reduced the silt content by 7.2%. Leys and McTainsh (1994) found out in their research that wind erosion caused increase in particles with a size >250 μm and decrease in particles with a diameter of 75–210 μm and <2 μm for 20 weeks. The process of wind erosion resulted in the effective removal of soil particles with a size of 50–125 μm (very fine sand) and <50 μm (silt and clay) during the 2 years of the experimental period. These observations suggest that fine soil particles were preferably carried away by increased wind erosion intensity (Li et al., 2007).

Comparison of SCS (1968) and present mapping (2018/2019) data revealed the opposite trend of the wind erosion phenomenon. There was a predominant decrease in sand particles´ content and increase silt and clay particles, which may be because it is a territory where transport prevails the finest particles and their accumulation at short distances from the erosion site. The distribution change in the particle size is evident in favour of the silt particle fraction.

4 Conclusions

Wind erosion selectively removes smaller and lighter particles, leaving coarser and denser particles behind. However, there are also locations where the eroded material is accumulated and changes the grain soil properties in favour of silt and clay particles. The objective of this study was to analyse soil grain properties of the areas where soil erosion causes accumulation of eroded material in long term duration. The results of this work point to the consequences of wind erosion in time (50 years). Continuous transport of soil particles during erosion phenomena can cause a dramatic change in soil composition. Authors dealing with this issue have analysed only areas where fine particles are carried away so far. There are also locations where the finest particles accumulate (whether in the windbreak area or forest edges or field inclinations). The results of this work clearly indicate a change in the grain composition of the eroded field. However, it has not been possible to get a trend of the dependence of this change over time yet.

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