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Statistical and Multifractal Evaluation of Soil Compaction in a Vineyard

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One of the detrimental effects caused by agricultural machines is soil compaction, which can be defined by an increase in soil bulk density. Soil compaction often has a negative impact on plant growth, since it reduces the macroporosity and soil permeability and increases resistance to penetration. Our research explored the effect of the agricultural machinery on soil when trafficking through a vineyard at a small spatial scale, based on the evaluation of the soil compaction status. The objectives of this study were: i) to quantify soil bulk density along transects following wine row, wheel track and outside track, and, ii) to characterize the variability of the bulk density along these transects using multifractal analysis. The field work was conducted at the experimental farm of EVEGA (Viticulture and Enology Centre of Galicia) located in Ponte San Clodio, Leiro, Orense, Spain. Three parallel transects were marked on positions with contrasting machine traffic effects, i.e. vine row, wheel-track and outside-track. Undisturbed samples were collected in 16 points of each transect, spaced 0.50 m apart, for bulk density determination using the cylinder method. Samples were taken in autumn 2011, after grape harvest. Since soil between vine rows was tilled and homogenized beginning spring 2011, cumulative effects of traffic during the vine growth period could be evaluated. The distribution patterns of soil bulk density were characterized by multifractal analysis carried out by the method of moments. Multifractality was assessed by several indexes derived from the mass exponent, τ_q, the generalized dimension, D_q, and the singularity spectrum, $f(\alpha)$, curves. Mean soil bulk density values determined for vine row, outside-track and wheel-track transects were 1.212 kg dm^{-3}, 1.259 kg dm^{-3}and 1.582 kg dm^{-3}, respectively. The respective coefficients of variation (CV) for these three transects were 7.76%, 4.82% and 2.03%. Therefore mean bulk density under wheel-track was 30.5% higher than along the vine row. Vine row and outside-track positions showed not significant differences between means. The bulk density of the wheel-track transect also showed the lowest CV. The multifractal spectra of the three transects were asymmetric curves, rather short toward the left and much longer toward the right. The width of the right deviating shaped multifractal spectra was ranked as: wine row $>$ outside-track $\approx$ wheel-track. Entropy dimension, D_1, was 0.998, 0.992 and 0.992 for vine row, outside-track and track transects, respectively. These results show different patterns of variability of bulk density for parallel transects. They also suggest that multifractal parameters may be useful in assessing the variability of other soil properties such as soil particle density, soil porosity or soil water content, at different spatial scales as well.

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