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Variance based sensitivity analysis of the RUSLE model in the E.U. parameter space

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Soil degradation through erosion is a major issue on a global scale, especially as the pressure on soils increases with increasing population, changing diets, and increase in land use changes. Measurements are plot specific and expensive, so most of the erosion assessment are done through modelling. The most used model for estimating soil water erosion worldwide is the Revised Universal Soil Loss Equation (RUSLE), which is an “ensemble” model with semi-empirical factors that can be determined using different equations, depending on scale of interest, geographical location, data availability. The –joint Research Centre (JRC) uses RUSLE to estimate water erosion potential in EU using spatial datasets collected by the European Soil Data Centre (ESDAC), as explained in a series of published articles. Model sensitivity analyses are a powerful tool for analysts and policy makers, especially for empirical and semi-empirical models like RUSLE, to assess model robustness, factor prioritization, and variance cutting. A sensitivity analysis was conducted on RUSLE by Estrada-Carmona et al. (2017) on a global (dishomogenous) parameter space using a Random Forest approach to calculate the relative relevance index. However, sensitivity analyses are dependent on the extent of the parameter space analysed and, especially for non-linear non-additive models like RUSLE, variance based methods are usually preferred.

Therefore, we performed a global sensitivity analysis of the RUSLE model as used by the JRC, using variance based methods and over the parameter space of the EU. The objective were to: (a) check the robustness of RUSLE in the EU parameter space, (b) define the most relevant factors on which to concentrate the attention (policy assessment) and (c) assess the interaction between these factors.

We analysed the spatial data provided by ESDAC to define the probability distribution of the model factors (the parameter space). We then sampled the parameter space with a low-discrepancy method and run the model on the whole dataset. We used the model output to: (a) plot the behaviour of the model to changes in single factors with scatterplots, (b) calculate the variance sensitivity index first order, (c) calculate the total sensitivity order, (d) analyse the relevant interactions between factors, first looking at the sensitivity indices, then using visual methods to show the model behaviour.

The results show that the C factor has the greater influence on the erosion estimates, followed by

R and K_{st}, accounting for ~0.35, ~0.21 and ~0.0.04 of the erosion estimates variance, respectively. This is especially interesting, since it is possible to act on C and, hence, control erosion processes. The dependence on R, however, is troubling, since its average value will probably increase in time due to climate change. K_{st} can be affected only partially by increasing soil organic matter or soil stoniness. The analysis of the total effects show that C, R and K_{st} are all interacting between them. The P factor seems hardly relevant at this scale, hence it could be simply fixed, something already done in some studies, e.g. Gianinetto et al. 2019.