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Mapping the geogenic radon potential considering multiple environmental covariates by applying multivariate adaptive regression splines (MARS)

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Radon (Rn) is a ubiquitous radioactive gas that is known to be the second largest cause of lung cancer after smoking. Rn enters houses mainly via advective flux from soil gas and generally accumulates in the cellar and on lower floor levels. Prioritization of Rn protection measures requires the delineation of Rn priority areas, i.e. areas with a high probability of significantly elevated indoor Rn concentration. Following the European Basic Safety Standards which form the framework of European Rn regulation, all EU Member States are required to delineate Rn priority areas. One possibility to this end is using the geogenic Rn potential (GRP), which quantifies availability of geogenic Rn for infiltration into buildings. It is defined as a function of Rn concentration in soil gas and soil gas permeability.
Current GRP maps rely on various geostatistical approaches (Collocated Cokriging, Regression Kriging, Gaussian Simulation etc.) considering selected co-variates (e.g. geology, uranium concentration in soil). However, the processes of generation, release, transport and exhalation of Rn is known to be extremely complex resulting in high spatial and temporal variability. Due to its complexity, the utilization of more environmental co-variates seems to be promising for improving GRP prediction accuracy.
In this study, we use $\sim$ 4,000 point measurements of soil gas Rn concentration and soil gas permeability across Germany in combination with >100 environmental co-variates (predictors) for building a multivariate adaptive regression spline (MARS) model. MARS is a machine learning algorithm which can deal with numerical and categorical predictors simultaneously. Potential candidate predictors are geological units, hydrogeological units, soil type units, soil grain size distribution, soil hydraulic properties, soil moisture data, tectonic fault data, radionuclide concentration in topsoil and geomorphological parameters.
The final MARS model for estimating soil gas Rn concentration includes 17 informative predictors. The most important ones are geological and hydrogeological unit, top soil silt content, uranium concentration in top soil and soil landscape unit. For predicting soil gas permeability 11 informative predictors were selected with geological and hydrogeological unit, geomorphological parameters (elevation, slope, SAGA Wetness Index) and parameters describing the hydraulic conductivity curve being the most informative.
The results of the MARS model will be compared with other machine algorithms such as artificial neural networks or random forests. The proposed approach will allow a higher spatial resolution of the GRP map (at least 2 km) than achieved so far with simpler methods (10 km). This is possible because the output resolution depends on the spatial resolution of the relevant predictors rather than on measurement density of one set of point measurements only, as done so far.