Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Example of using outdoor radon and radon flux maps for the estimation of radon priority areas

Baumann S., Gruber V., Cinelli G.

Training Course #2_PTB Braunschweig (DE), 15 March 2023

Legal Basis

- Sets reference level for dwellings and workplaces: 300 Bq/m³

Requires:

- elaboration of Rn Action Plans;
- **identification** of "Rn priority areas"- RPA
- **remediation** of workplaces;
- **prevention** for residential buildings.

ISSN 1977-0677

Official Journal of the European Union

L 13

English edition — Legislation — Volume 57, 17 January 2014

Contents

II *Non-legislative acts*

DIRECTIVES

★ Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom 1

Price: EUR 4

EN

Acts whose titles are printed in light type are those relating to day-to-day management of agricultural matters, and are generally valid for a limited period.

The titles of all other acts are printed in bold type and preceded by an asterisk.

https://eur-lex.europa.eu/eli/dir/2013/59/oj

Radon Priority Areas

Art. 103,3; Radon Priority Areas (RPA):

"Member States shall identify areas where the radon concentration (as an annual average) in a significant number of buildings is expected to exceed the national reference level."

Conc

Art. 54

In area … with public access and workplaces must be measur… RL, remediated. New buildings: particular Rn prevention. Strategy to reduce Rn in dwellings.

Detect Radon Priority Areas:

There is **not a "fixed" definition**, and different criteria may be applied.

Political decision (and data availability)

Radon Maps

PURPOSE:

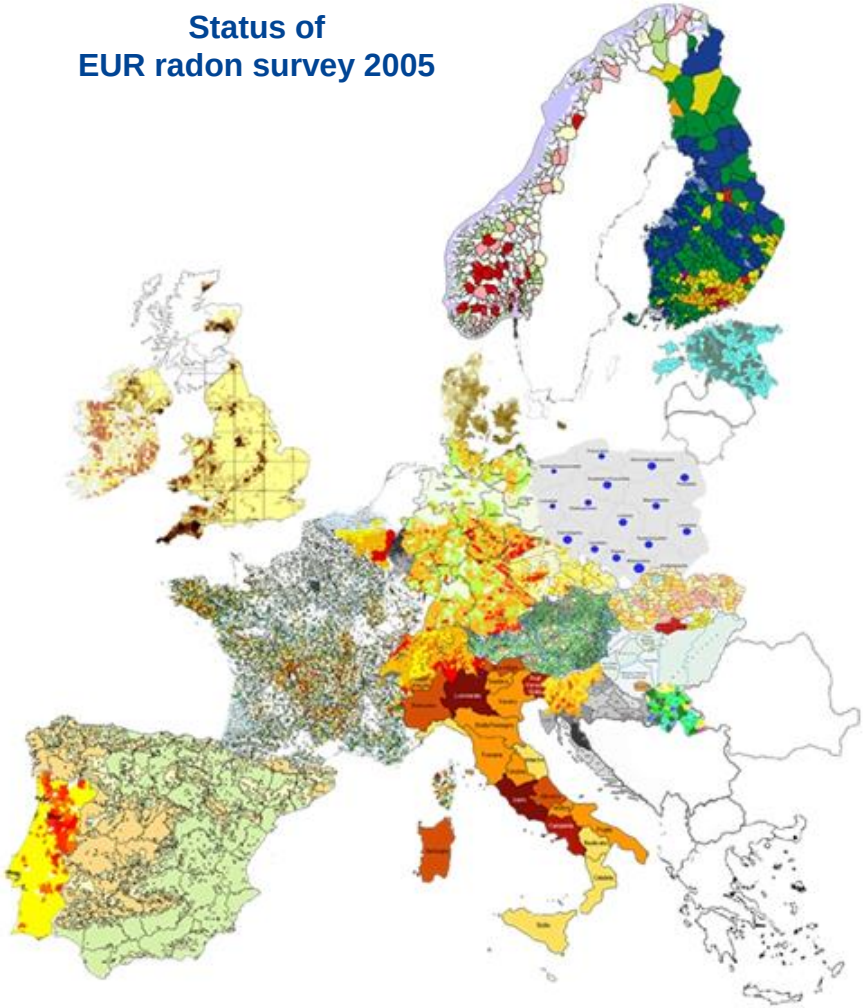
- **Display**: describe the actual situation, **Information of stakeholders** (public, legislators, administrations, professionals)

- **Identify** radon priority areas (as in article 103), **decision support**

Status of EUR radon survey 2005

EUR radon survey 2005:

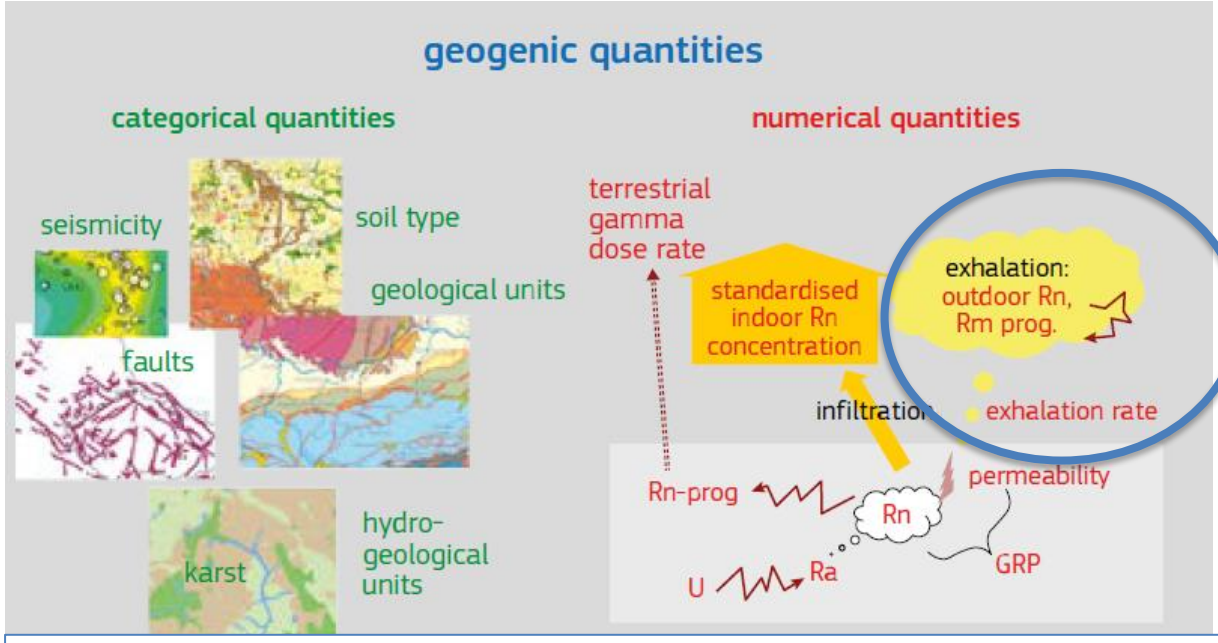
- Many countries had radon “maps” (indoor conc., radon potential etc.)
- Measurement techniques and strategies differ between countries
- Different mapping methods and visualization techniques
- => Colourful patchwork (but not very useful for analysis)



Dubois, G. (2005): An Overview of Radon Surveys in Europe
EUR Report 21892

Radon maps: Input Quantities

- Indoor radon
- **geogenic parameters** (radon in soil gas, soil permeability, geology, faults, soil type, Ra-U concentrations in soil/rock, **outdoor radon, radon flux** etc…)



European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (Eds.), ***European Atlas of Natural Radiation****, Publication Office of the European Union, Luxembourg, 2019.*

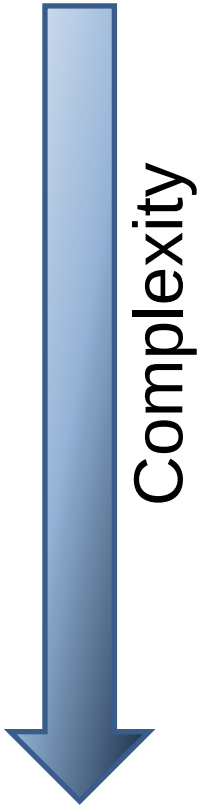
Resolution

Depend on radon data density and scope of the map

- Grid (1x1 km, 100x100 m, 10x10 km)
- Municipalities
- Postal code
- Geological unit, lithological or stratigraphic (at which detail?)

Mapping Methods:

- Display observed (raw) data
- Basic statistics (e.g. AM)
- Geostatistics: using nearby observation (and (optionally) limited number of co-variables) to predict (e.g. kriging, IDW, moving average)
- Machine Learning: Regression, using many co-variables. Not necessarily an influence of nearby observations on the predicted value



Possible Output quantities

- Arithmetic mean or expectation in cell
- % above reference level
- Classes 4-5-6...10
- Geogenic Radon Potential
- Geogenic Radon Hazard Index - GHRI
- Status RPA yes / undecided / no

Outdoor radon and radon flux for radon mapping

Objective:

Can outdoor radon and radon flux improve the prediction of areas with high radon potential?

Workflow:

- Test outdoor radon and radon flux as input features along with other predictors (geology, soil properties, weather) in a machine learning workflow.

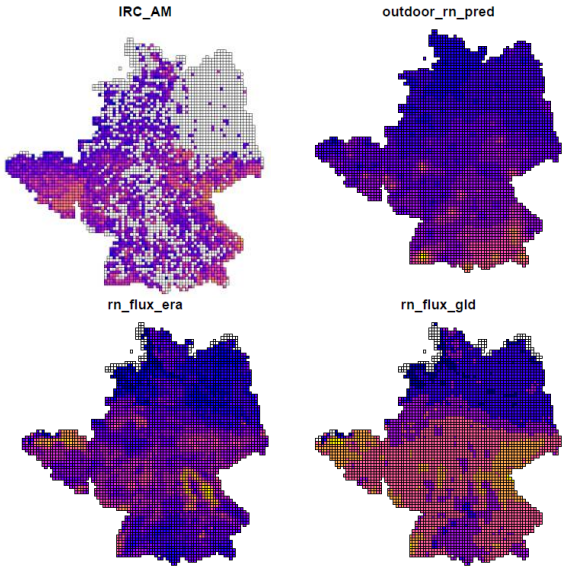
Assumption:

- Indoor radon concentrations can be used to represent the radon potential of an area.

Outdoor radon and radon flux for radon mapping

Input data

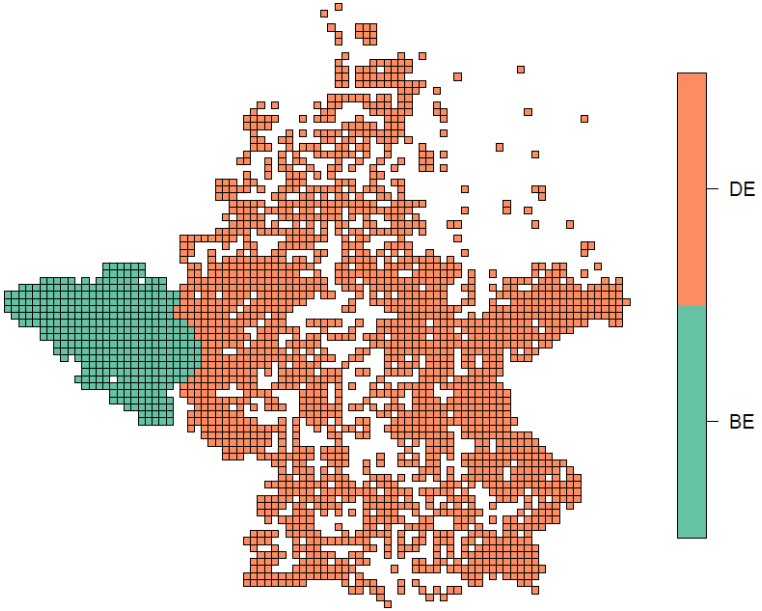
- Target value:
  - Indoor radon concentrations (European Atlas of Natural Radiation)
  - 10 x 10 km grid
  - Only groundfloor
  - Min 10 measurements per grid
- Predictors:
  - Outdoor radon (only available for DE and BE)
  - Radon flux maps
  - Geological and hydrological maps
  - Soil composition data (uranium, thorium, etc.)
  - Weather data



Outdoor radon and radon flux for radon mapping

Training – Test set split

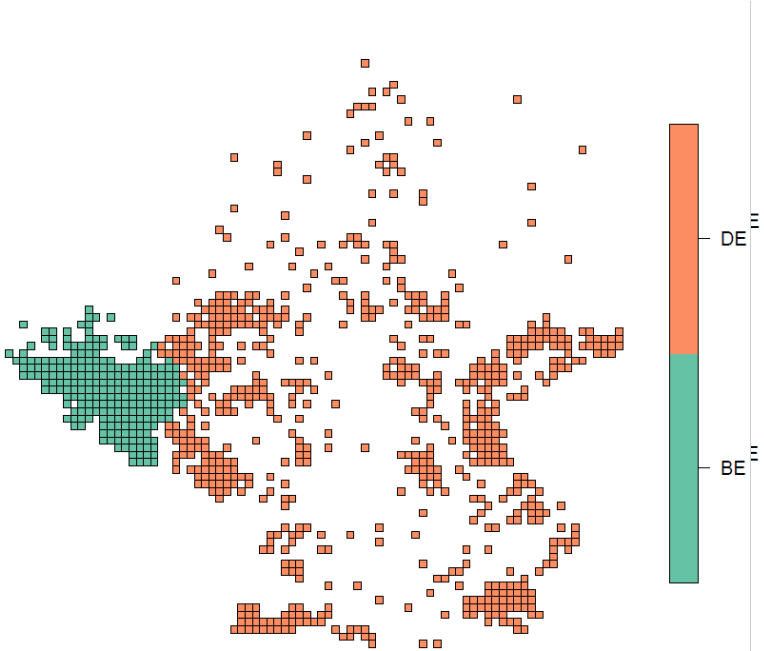
- Indoor radon concentrations (our target value) show spatial autocorrelation and different national radon survey designs
- To avoid autocorrelation when testing the performance of our model we split training (DE) and test data (BE) by countries
- Doing so we also test if models developed in one country can be used for other countries
- The training data is used to build the model
- The test data is only used for performance evaluatior



Outdoor radon and radon flux for radon mapping

Training – Test set split

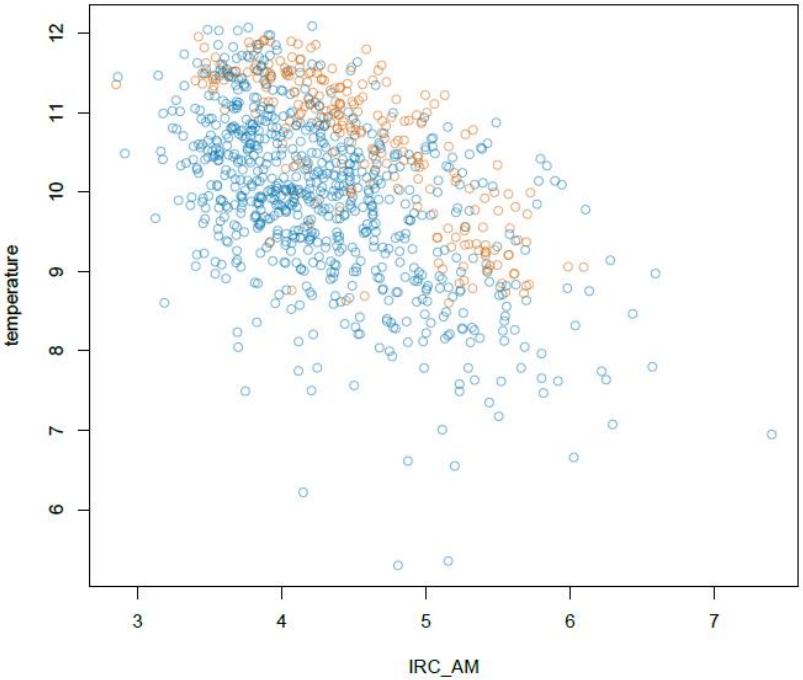
- Indoor radon concentrations (our target value) show spatial autocorrelation and different national radon survey designs
- To avoid autocorrelation when testing the performance of our model we split training (DE) and test data (BE) by countries
- Doing so we also test if models developed in one country can be used for other countries
- The training data is used to build the model
- The test data only for performance evaluation
- 979 grid cells with complete information (min 10 IRC observations)



Outdoor radon and radon flux for radon mapping

Pairwise Correlations of IRC and predictors – Examples

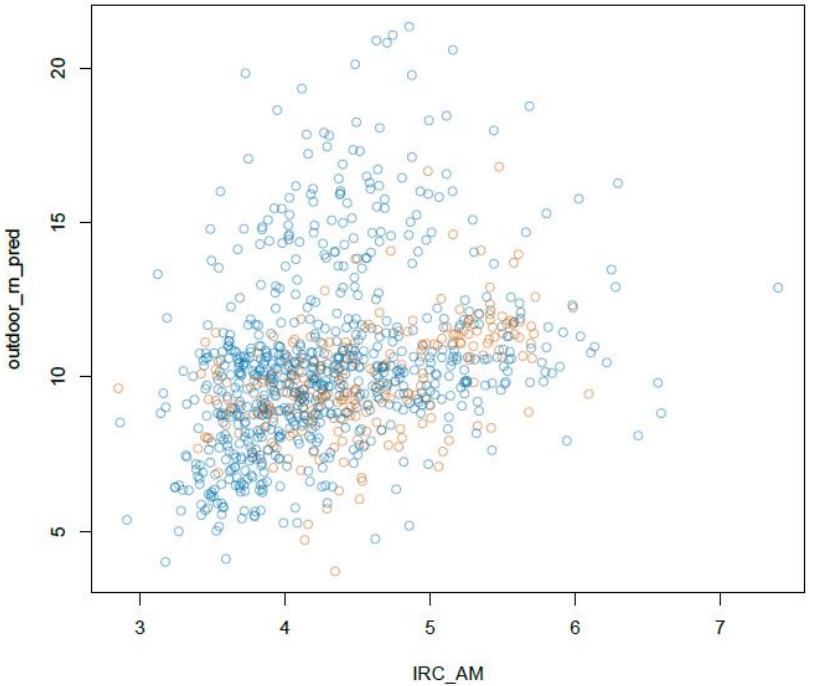
Predictor	rho	rho BE	rho DE
Elevation	**0,50**	**0,80**	**0,53**
Temperature	**-0,46**	**-0,78**	**-0,50**
Outdoor radon	**0,40**	**0,50**	**0,40**
Slope	**-0,40**	**-0,69**	**-0,41**
Thorium	**0,37**	**0,70**	**0,35**
Pressure	**0,30**	**0,72**	0,29
Uranium	0,29	-0,17	**0,49**
Wind speed	-0,20	**-0,48**	-0,18
Rn Flux GLDA	0,19	**-0,55**	**0,36**
Rn Flux ERA5	-0,04	**-0,65**	0,07



Outdoor radon and radon flux for radon mapping

Pairwise Correlations of IRC and predictors – Examples

Predictor	rho	rho BE	rho DE
Elevation	**0,50**	**0,80**	**0,53**
Temperature	**-0,46**	**-0,78**	**-0,50**
Outdoor radon	**0,40**	**0,50**	**0,40**
Slope	**-0,40**	**-0,69**	**-0,41**
Thorium	**0,37**	**0,70**	**0,35**
Preassure	**0,30**	**0,72**	0,29
Uranium	0,29	-0,17	**0,49**
Wind speed	-0,20	**-0,48**	-0,18
Radon Flux GLDA	0,19	**-0,55**	**0,36**
Rn Flux ERA5	-0,04	**-0,65**	0,07



Outdoor radon and radon flux for radon mapping

Random forest models

- Non linear machine-learning techinque
- Multiple decision trees are assembled to predict a target value

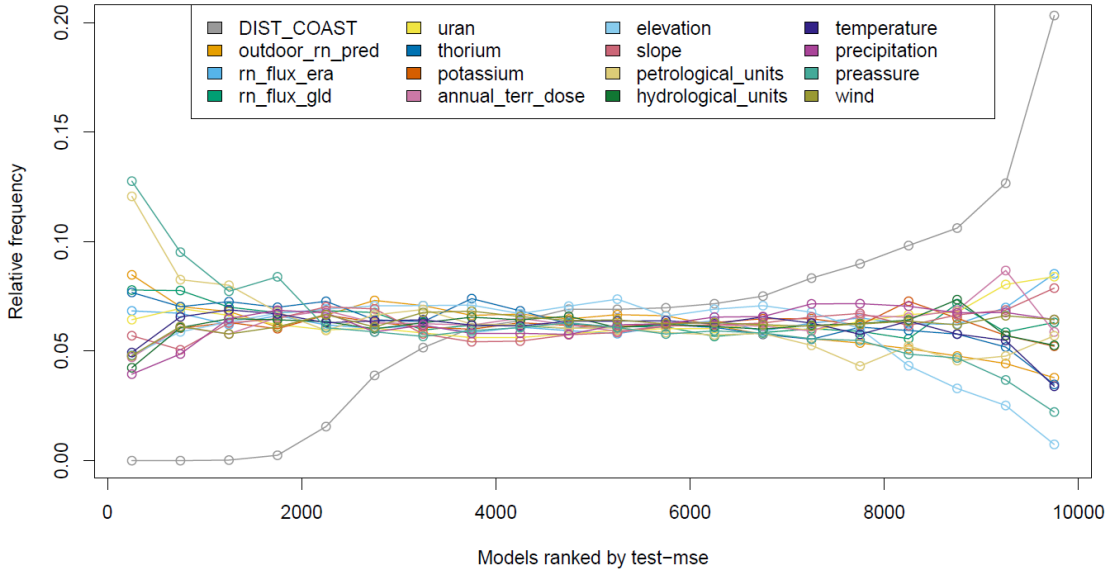
Model Selection

- Build 10.000 Models with different model parameters and predictors
- Calculate the mean squared error (MSE) of the predictions and true values on the test set (Belgium data)
- Rank the models by the MSE of the test set, and analyse which features are important

Outdoor radon and radon flux for radon mapping

Random forest – model selection

- The number of predictors and the selection have the highest impact of model performance
- **Very high** relative frequency: **Petrological units, preassure**
- **Above average** in the top ranked models: **outdoor radon, both radon fluxes, thorium, uranium**
- **Very low**: **distance to coast**

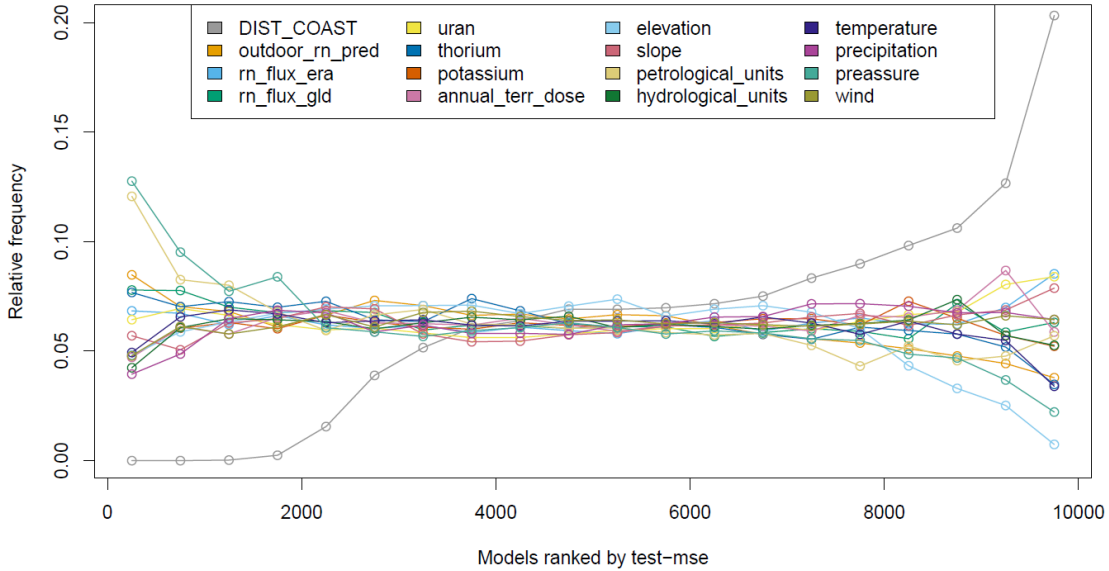


Outdoor radon and radon flux for radon mapping

Random forest – model selection

The best model uses the following six predictors:

- **outdoor radon**
- **radon flux (ERA5)**
- **thorium**
- **slope**
- **petrological units**
- and **pressure**.



Outdoor radon and radon flux for radon mapping

Objective:

Can outdoor radon and radon flux improve the prediction of areas with high radon potential?

Result:

- Outdoor radon and radon flux can improve predictions and are included as predictors in the best model out of 10.000 models.
- Performence of the model was evaluated by the mean squared error of the test data (Belgium data)
- Still other predictors are essential: geological information, soil composition, terrain, weather data.

Detailed description of the methodology and results in preparation!!!

Thanks, Danke, Grazie

giorgia.cinelli@enea.it

sebastian.baumann@ages.at