RadoNorm
Managing risks from radon and NORM

Statistical methods for the identification of buildings and areas with high radon levels – a review

Sebastian Baumann, Sara Antignani, Joan Frédéric Rey, Valeria Gruber, Christian di Carlo, Joëlle Goyette Pernot, Francesco Bochicchio

WP 2.4 Institutions: ISS, IRSN, HES-SO, AGES, SURO

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This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

Statistical methods to identify building and areas with high radon levels

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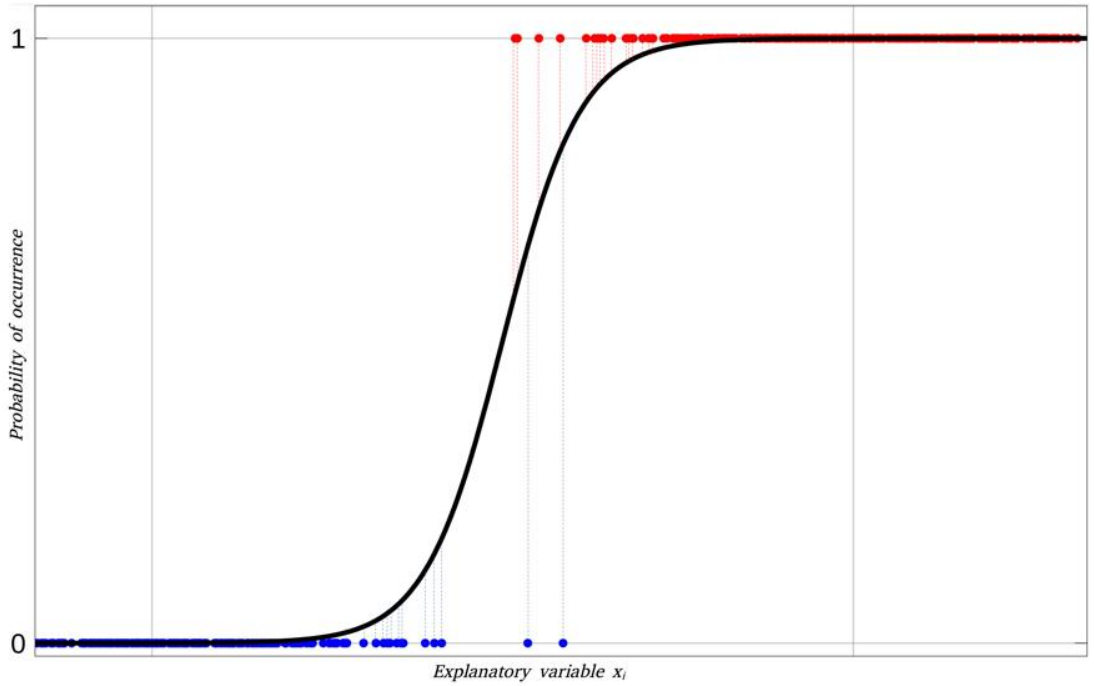
- Overview
- Literature review
- Outlook



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Statistical methods to identify building and areas with high radon levels

Why?

- Estimate Radon Hazard
- Establish regulations and legislation
- Focus of resources
- Areas where the radon concentration exceeds the national reference level
- Remediation and Preventive measures

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Foundation

- How to identify buildings and areas with high radon levels?
  - Measurements
    - Radon in air, soil gas, uranium concentration, permeability …
  - Additional Information
    - Geology, building characteristics, climate, using habits …

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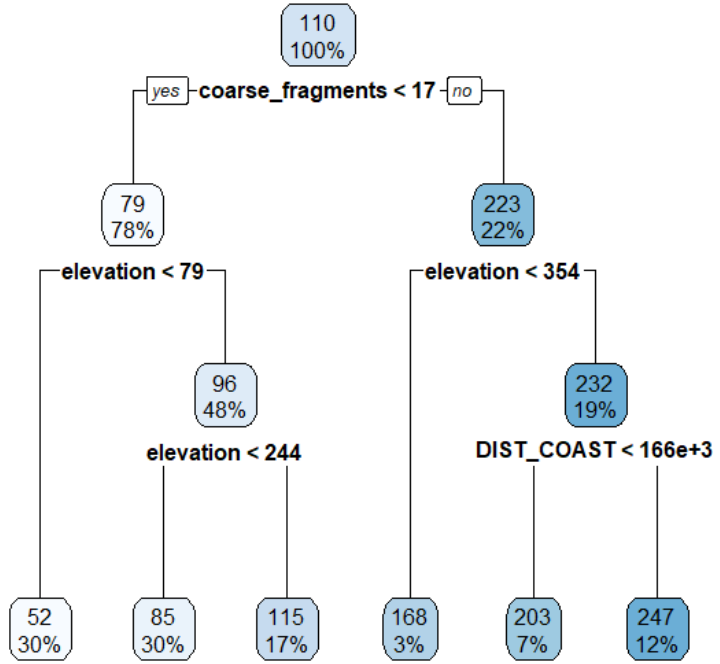
Statistical Models

- Target Variable ~ Model (Predictors)
  - Example :

IRC ~ Random Forest { Building Characteristics
Geogenic Factors
Climate ….



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Statistical Models

- Target Variable ~ Model (Predictors)
  - Example :

IRC ~ Random Forest { Building Characteristics; Geogenic Factors; Climate ….

Goals:

- Prediction:
  - Can we predict indoor radon concentrations with the gathered information accuratly?
- Inference:
  - Are there certain conditions under which certain radon levels are more likely?

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Literature Review

- Done seperatly for areas and buildings
- Key words (buildings):
  - in the title, the words "radon", or "(222)Rn", or "222Rn", or "Rn-222",
  - **AND** in the title, the word "building*", or "dwelling*", or "hous*", or "school*", or "workplace*", or "indoor*",
  - **AND** in the title or abstract, the word "factor*", or "characteristic*", or "feature*", or "parameter*",
  - **AND** in the title or abstract, the word "identif*", or "detect*", or "predict*", or "forecast*", or "affect*", or "influenc*", or "impact*",
  - **AND** in the title or abstract, the word "high*", or "elevated", or "exceed*", or "above", or "quantile*",
  - **AND** in the title or abstract, the word "approach*", or "method*".
- Databases: Web of Science, Scopus and PubMed

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Literature Review

- Done seperatly for areas and buildings
- Key words (areas):
  - in the title or abstract, the words "radon", or "(222)Rn", or "222Rn", or "Rn-222",
  - **AND** in the title or abstract, the words "radon prone area*" or "priority area*" or "high radon level*" or “elevated radon level*" or "high radon concentration*" or "high radon exposure*" or "high radon potential" or "high background" or "radon affected area*"
  - **AND** iii) in the title or abstract, the words "method*" or "approach*" or "mapping"
  - **AND NOT** in the title or abstract, the word "transform*".
- Databases: Scopus and PubMed

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Literature Review

- Done seperatly for areas and buildings
- Number of publications selected (without duplicates):
  - 197 publications for buildings
  - 492 publications for areas

- Manual selection workflow:
  - Title
  - Abstract
  - Full Publications

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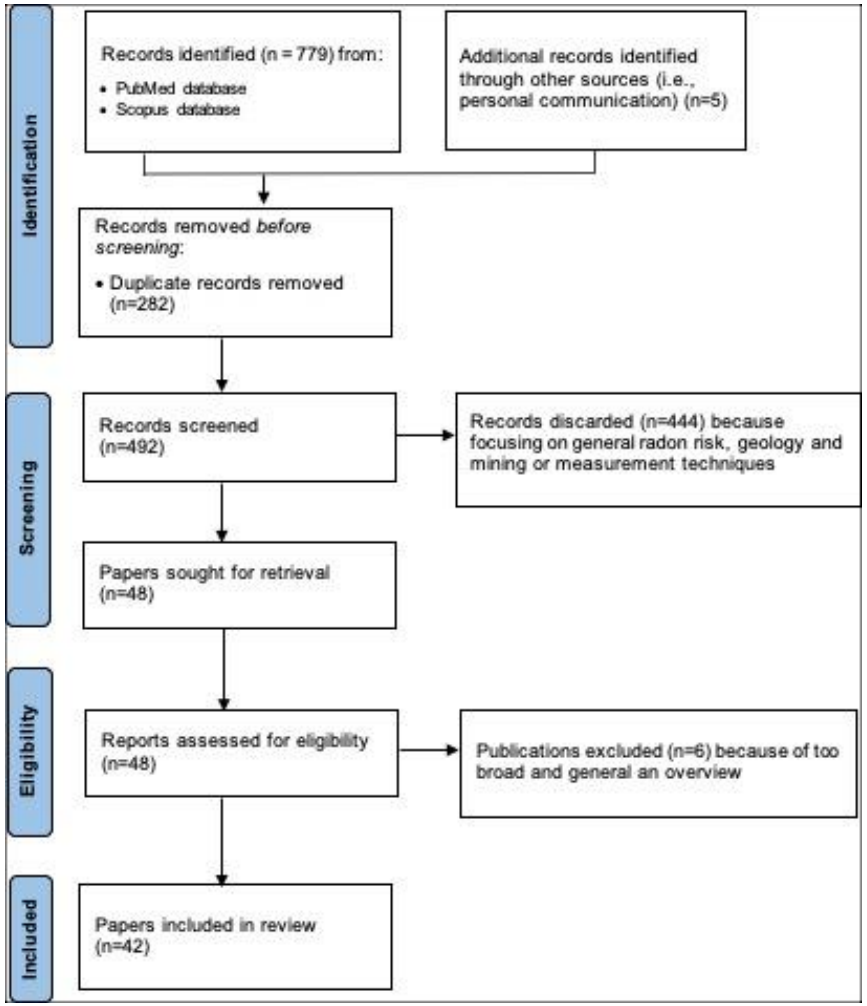
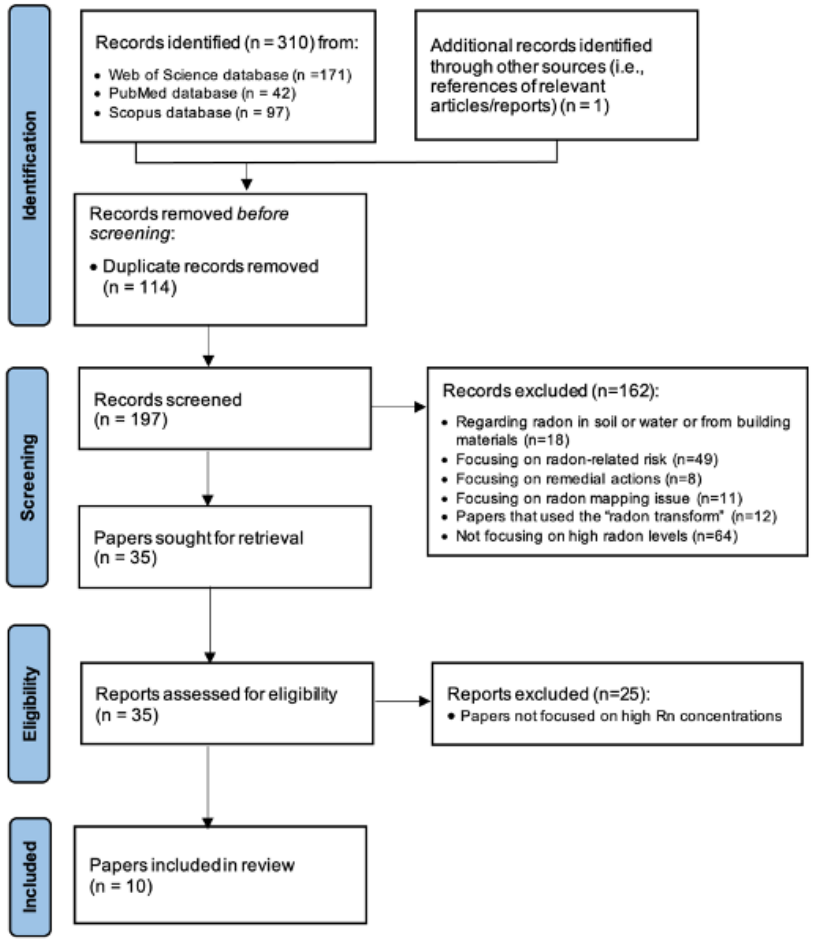
Literature review – selection workflow





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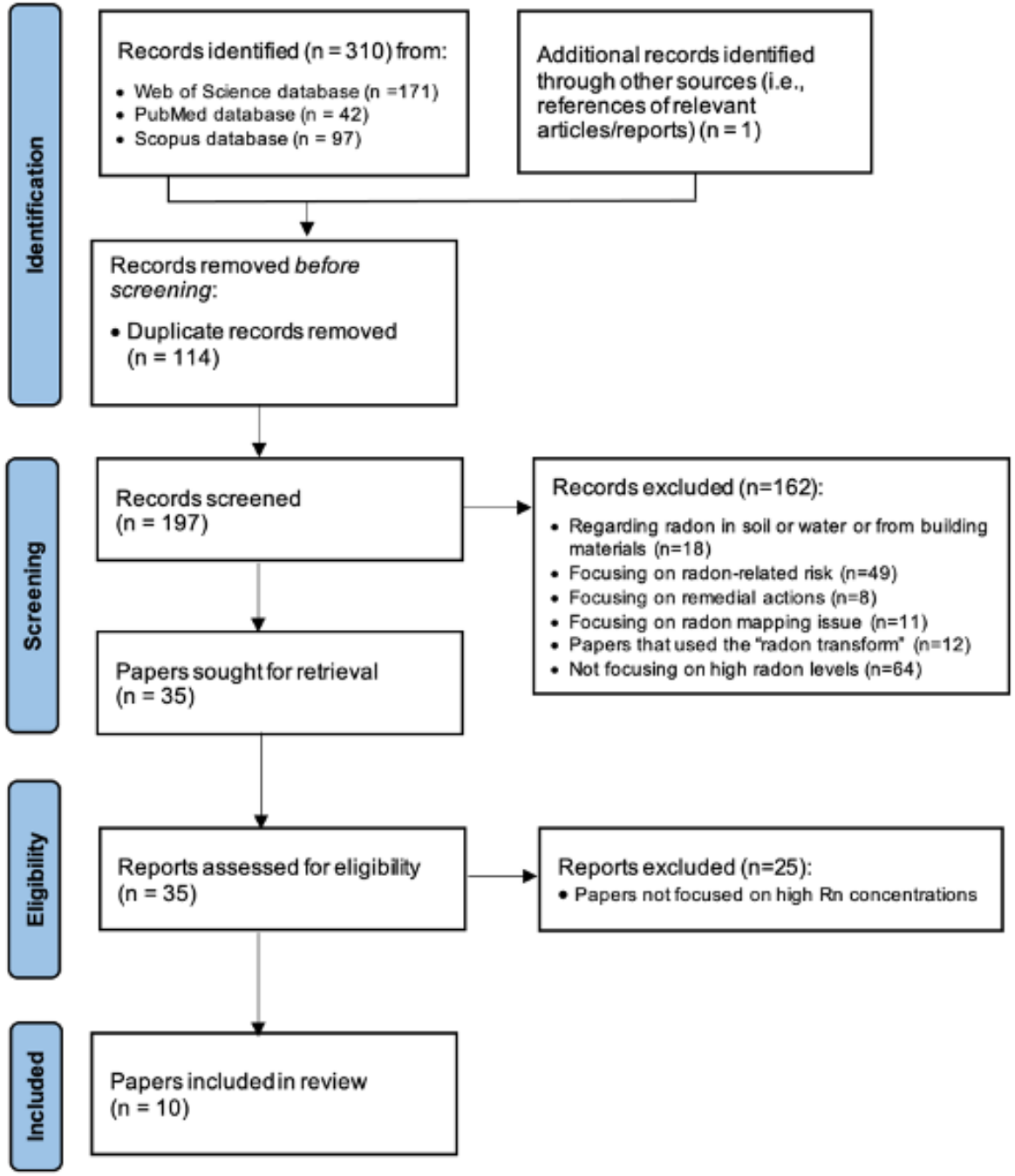
Main reasons to reject:

- General radon risk
- Medical studies
- Measurement techniques
- Remediation
- Radon in Water
- Mining and Geology



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Literature Review - selection workflow

- Number of publications selected after manual selection:
  - **10** (197) publications for buildings
  - **42** (492) publications for areas
- Analysis and characterisation of different statistical methods:
  - Statistical methods
  - Geostaistical methods
  - Machine learining methods

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Literature review findings

- Quantile and logistic regression

- Conditions of application:
  - Predifine quantile level or threshhold
  - Sound data set
- Main findings:
  - Well known predictors show impact (location, building age, floor level …)
  - Impact of predictors can change with selected quantile/threshhold

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Literature review findings

- Geostatistical methods (Invrese distance weighting, Kriging, geographically weighted regression)

- Conditions of application:
  - Georeferenced and sound data
  - Predifine variogram, power parameters or spatial weights

- Main findings:
  - Used in many applications producing radon maps
  - Strongly depend on the spatial sample distribution of the data

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Literature review findings

- Machine Learning methods (Random Forest, Support Vector Machines, Artificial Neural Network)
- Conditions of application:
  - Sound data basis
  - Hyperparamater setting
  - Test and Training data split (consider spatial autocorrelation)
  - Performance evaluation
- Main findings:
  - Powerful models for prediction but not especially designed for prediction of high values
  - Modifications of the target value or the evaluation metric might be a valid strategy to focus on high radon levels.

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Literature Review - findings

- Usually statistical models are applied to predict the average radon concentration - good models can also predict high radon levels.
- Comparability of publications and their results is very limited, due to different …
  - Data basis
  - Data manipulation
  - Models
  - Performance evaluation

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Literature Review – findings/outook

- The overall workflow from data handling to performance evaluation might be more important than the actual method (machine learning perspective)
- Possible workflow adaptions to characterize high radon levels
  - a) Penalize samples with high values when training the model and for performance evaluation (weights)
  - Adopt performance evaluation (loss function) (e.g. quantile regression for machine learning methods)
  - b) Transform the regression task in a classification task, where the high values are a separate class
  - c) Duplicate samples with high values

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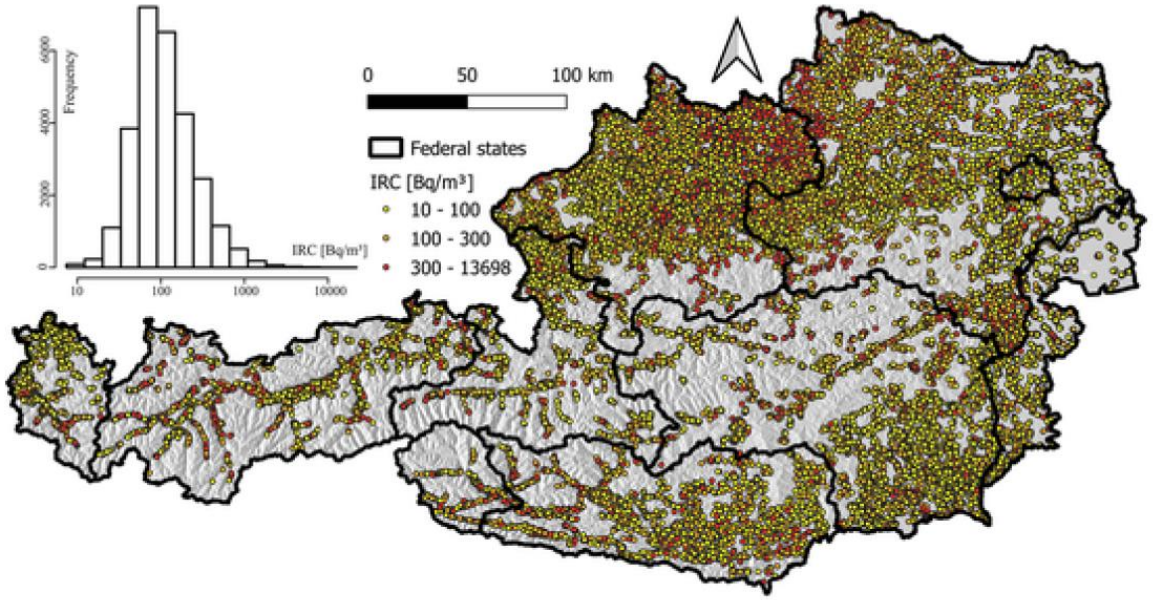
WP 2.4.1 - outlook

- Evaluation and comparison of different methods on exhaustive IRC data sets:
  - Austria, France, Italy, Switzerland
  - ~ 200.000 measured buildings (IRC)
  - Additional Information as

    Building charcteristics, location
- To awnser:
  - Which methods and predictors to use

  for the identification of high radon levels



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WP 2.4.1 – additional research questions

- What are the predictors with the most impact regarding the identification of buildings and areas with high radon levels? – Does the impact change for the prediction of certain levels?
- If a model accuratly predicts high radon levels – is there a possible downside? (Sensitivity, Specificity)
- Trade of between weigthing the importance of high target values and the model depending on only a few samples?
- Is there a performance evaluation (loss function) that is better suited for the prediction of high values and can this be used for different methods (quantile regression)?

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