



European Radon Week 2020

JRC Workshop

Alternatives for indoor radon mapping: an Irish case study

Javier Elío

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An Chomhairle um Thaighde in Éirinn



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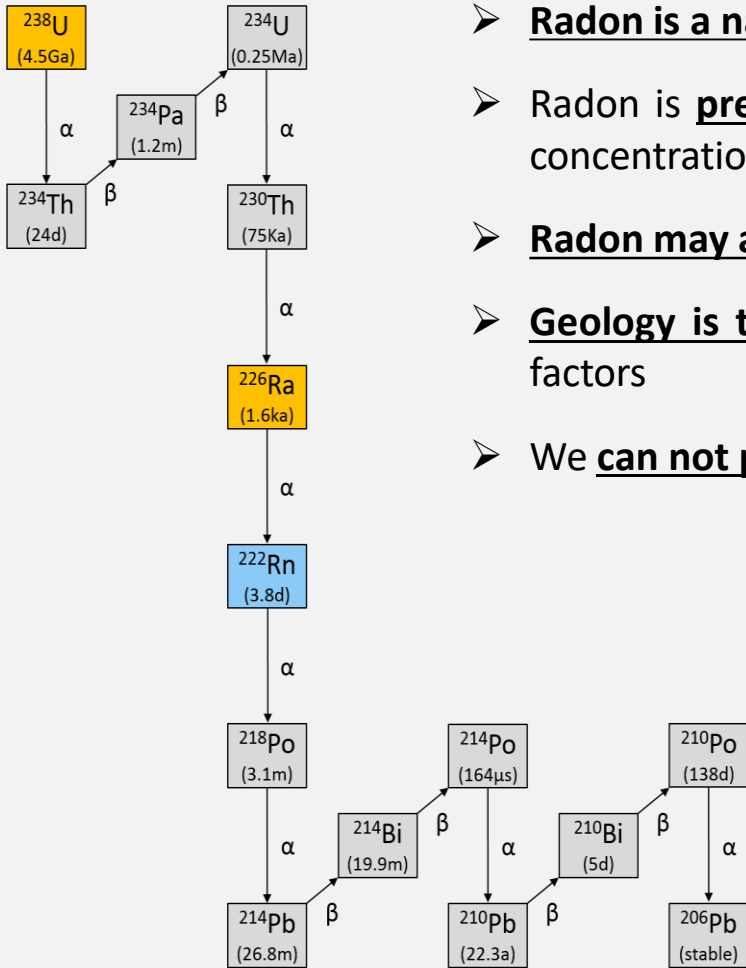


Environmental Protection Agency

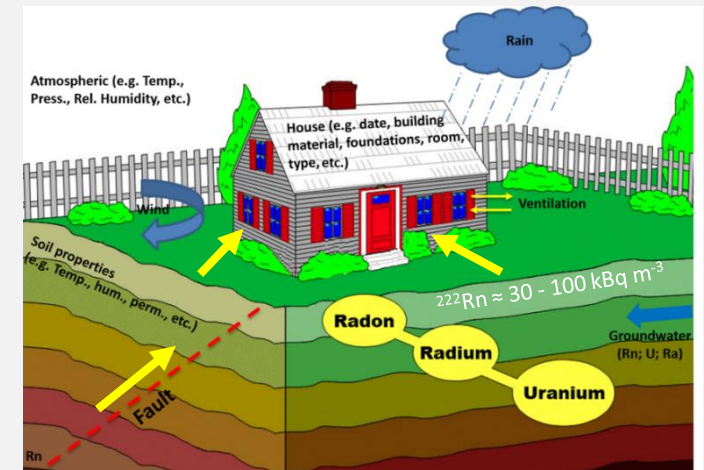
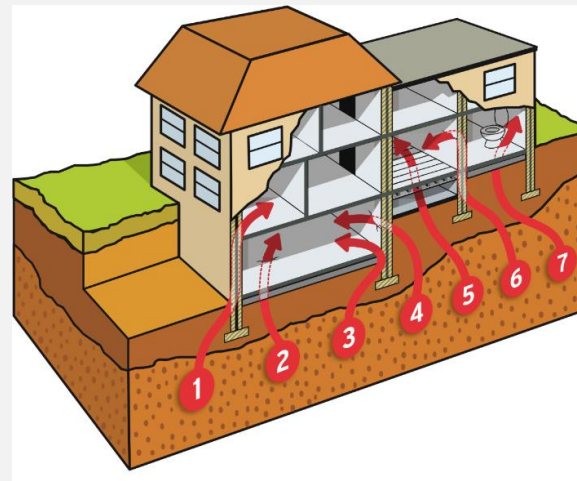


Department of
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**Geological Survey
of Northern Ireland**

Radon in dwellings



- **Radon is a natural radioactive gas** which forms as a decay product in the radioactive decay series of uranium.
- Radon is **present in all soils** at low levels, when radon reach the atmosphere it is diluted easily and outdoor concentration is normally low.
- **Radon may accumulate in indoor air** and reach high concentrations.
- **Geology is the main factor** controlling indoor radon concentration; however, it may be affected by multiple factors
- We **can not predict** the indoor radon concentration in a particular house!!



Legal background

Basic Safety Standards (BSS)

Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation.

<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2014:013:TOC> (OJ L, 17.01.2014)

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 relevant national reference level.”

Conceptual definition, which has to be translated into an *operable* definition.

Art. 54, 74, annex XVIII; Radon Action Plan:

In areas according Art.103,3: Buildings with public access and workplaces must be measured and if above RL, remediated. New buildings: particular Rn prevention. Strategy to reduce Rn in dwellings.

Reference level (RL): must be $\leq 300 \text{ Bq/m}^3$ (BSS Art 54,1 & 74,1)

These areas are called Radon Priority Areas (RPA) to indicate priority in taking action
(It does not mean “no action” in No-RPA).



Radon mapping

➤ Detect Radon Priority Areas:

- ❖ There is **not a “natural” definition**, and different criteria may be applied. For example:
 - AM in the area > Threshold;
 - Prob[InRn > Reference level] > Threshold;
 - AM of the area represents the upper X% (e.g. 90th Percentile);
 - Collective exposure (AM x Population) is among the upper X%.
- ❖ **Political decision** (and data availability)

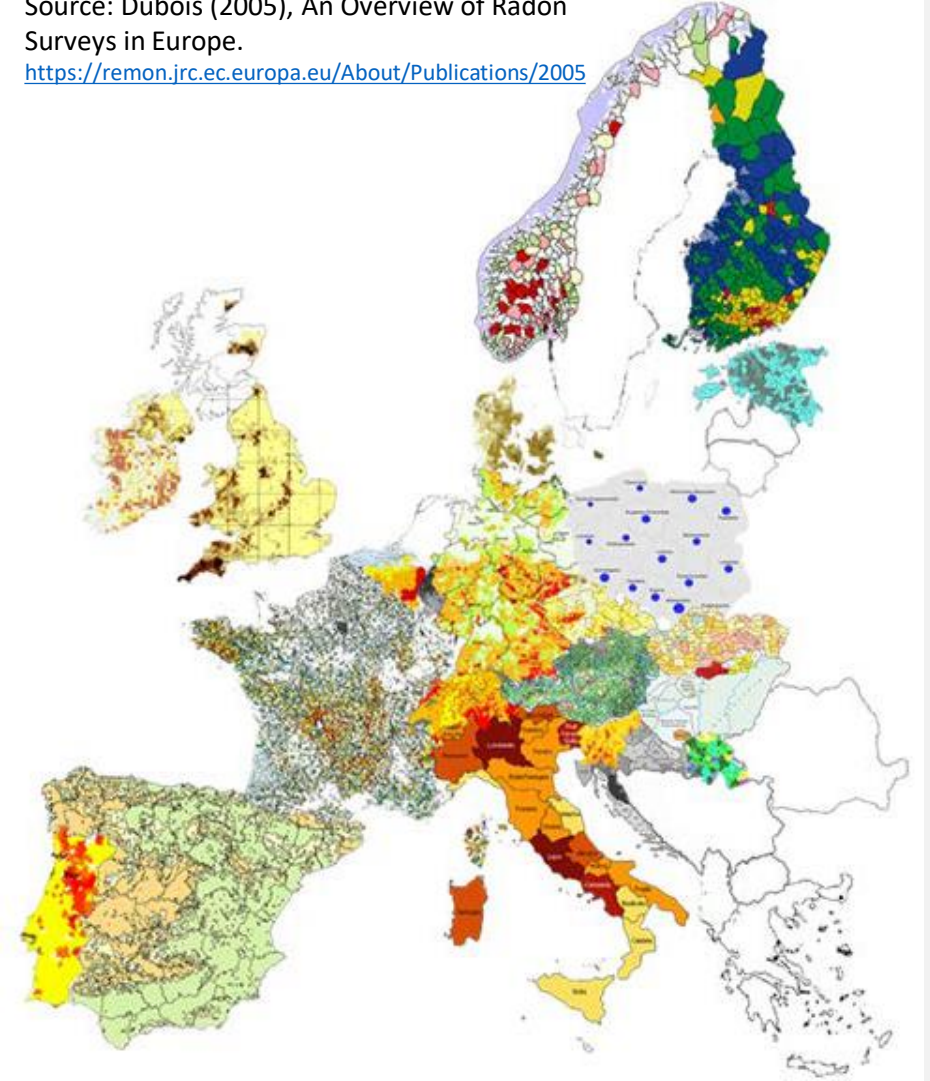
➤ Accurate mapping is important:

- ❖ To increase public awareness of radioactive environment.
- ❖ To target homeowners so remediation work can be carried out.
- ❖ As it may affect building regulations; e.g. all new homes in “Radon Priority Areas” must be build with a radon barrier.

➤ Two types of maps depending on the datasets used:

- ❖ Indoor Radon Maps: based on indoor radon measurements.
- ❖ Geogenic Radon Maps: based on geological information.

Source: Dubois (2005), An Overview of Radon Surveys in Europe.
<https://remon.jrc.ec.europa.eu/About/Publications/2005>



The radon map of Ireland

www.radon.ie

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Today is World Cancer Day. Did you know? Long-term exposure to high radon levels increases the risk of contracting lung cancer. Visit bit.ly/2HvM4y6 for more info. #DoTheRadonTest @EPAireland @IrishCancerSoc

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You are here: Home > Radiation > Radon Map

Radon Map

Radon
Monitoring and Assessment
Radiation Exposure and Health
Regulation
Emergencies
Measurement Services
EMF

Here you can see a map showing the areas predicted to be at particular risk from radon, called High Radon Areas. A High Radon Area is any area where it is predicted that 10 per cent or more of homes will exceed the Reference Level of 200 becquerel per cubic metre (Bq/m³). Any area that is coloured light or dark brown on the map is a High Radon Area.

The Government's Building Regulations require that all new homes in High Radon Areas are installed with a radon barrier. Read more about protecting your building from radon.

Please note: A high radon level can be found in any home in any part of the country, but these homes are more likely to be located in High Radon Areas. You can now search using your Eircode (e.g. D14YR62 - please ensure you do not leave a space) Find out more about the Radon Map.

Select County: Choose County Select Town: Choose Town

Search an address: Search an address

Opacity

Map Legend
Estimated percentage of homes above the Reference Levels

- < 1%
- 1% - 5%
- 5% - 10%
- 10% - 20%
- > 20%

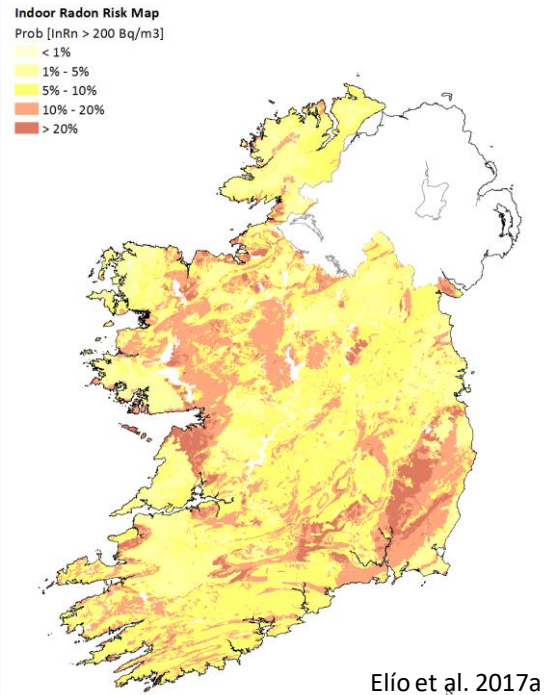
EPA, OSI | Esri, FAO, NOAA

1. Based on indoor measurements.
2. Indoor radon was sampled using passive alpha track detectors (CR-39), which were located in homes for a minimum of 3 months and seasonally adjusted to give an annual value.
3. Estimate the probability of having an indoor concentration > 200 Bq m⁻³ in grids of 10x10 km (i.e. <1%, 1-5%, >5-10%, >10-20% and >20%).
4. “high Risk Area” was defined as the area in which ≥10% of homes are above the reference level.
5. Estimated that > 7% of the national building stock has high radon concentration (> 200 Bq m⁻³).
6. Over 320,000 people may be living in homes with high radon concentrations.
7. 35% of the houses with high radon concentration are in areas classified as “I Risk Area”.

Alternatives?

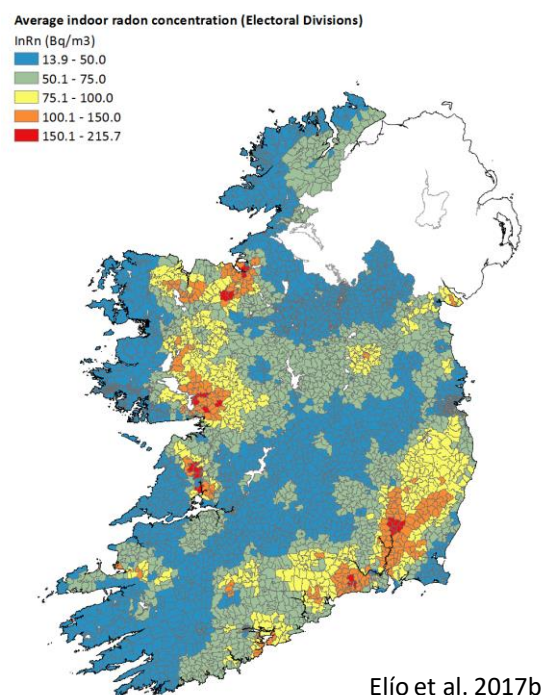
National Indoor Radon Risk Map

A new indoor radon risk map of Ireland



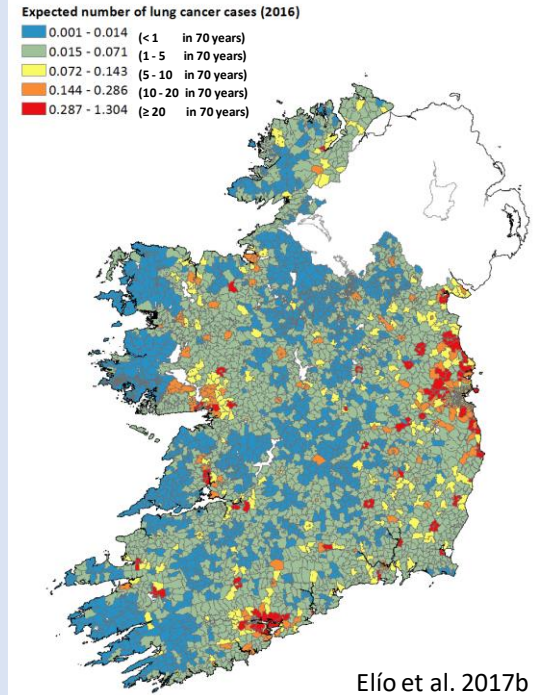
Average Indoor Radon Map

Average radon concentration in an area



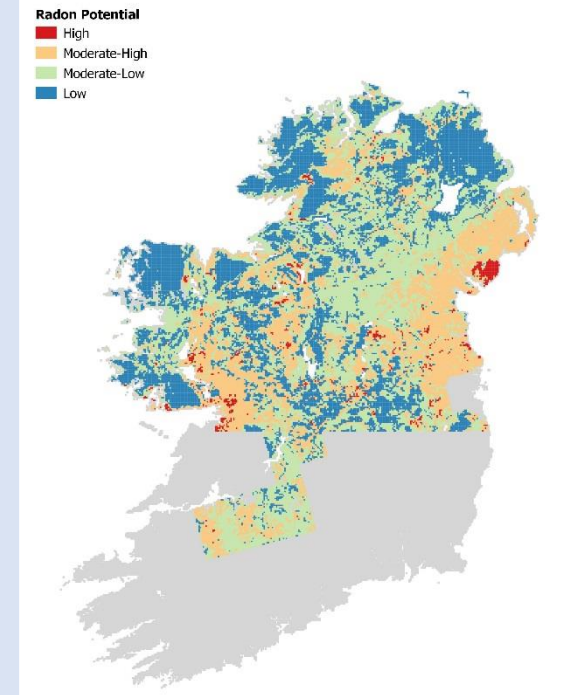
Health effects of Radon Exposure

Lung cancer cases attributed to radon exposure



Radon Potential Map

Soil-gas radon concentration and subsoil permeability



Probabilistic maps



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

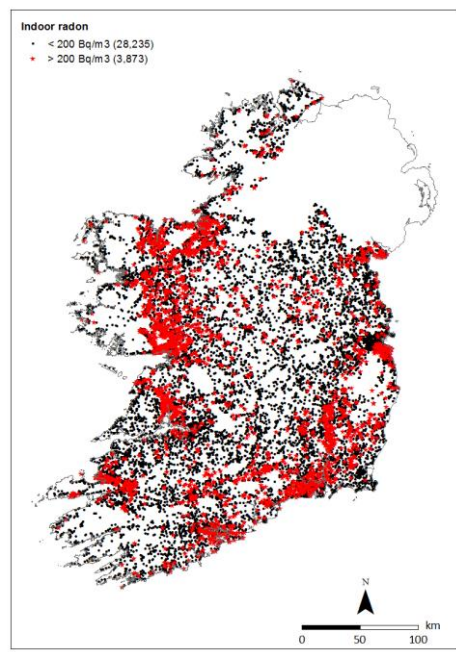
Science of the Total Environment

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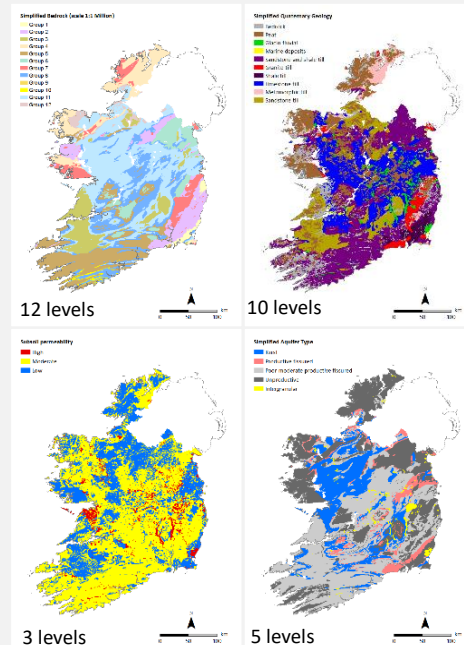


Logistic regression model for detecting radon prone areas in Ireland

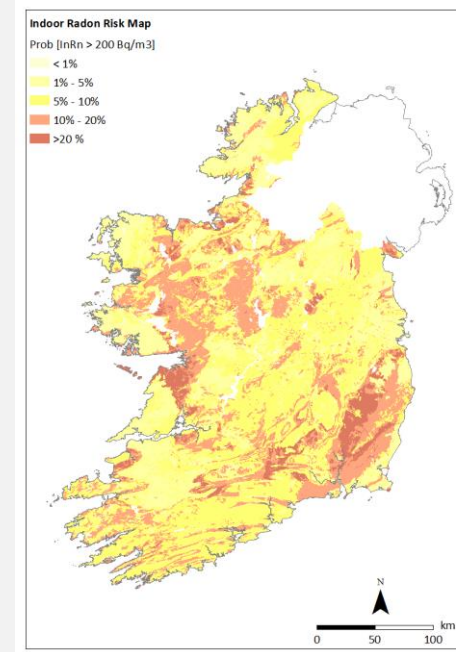
J. Elío^a, Q. Crowley^{a,*}, R. Scanlon^b, J. Hodgson^b, S. Long^c



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=



- 10% of the population (460 k) may live in a house with an indoor radon concentration above 200 Bqm⁻³
- 43% of them (195 k) in areas classified as “Non-high Risk”.
- Increase public awareness at national scale.

Radon exposure



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

Environment International

journal homepage: www.elsevier.com/locate/envint

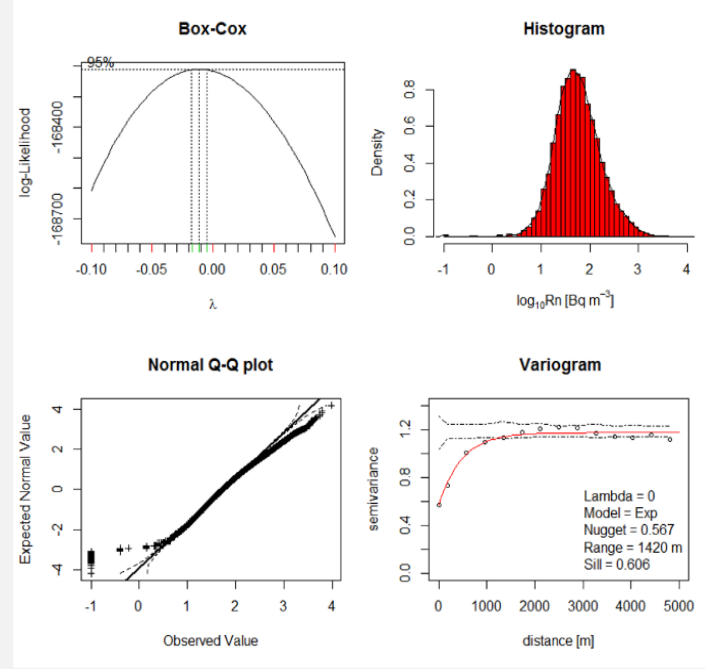
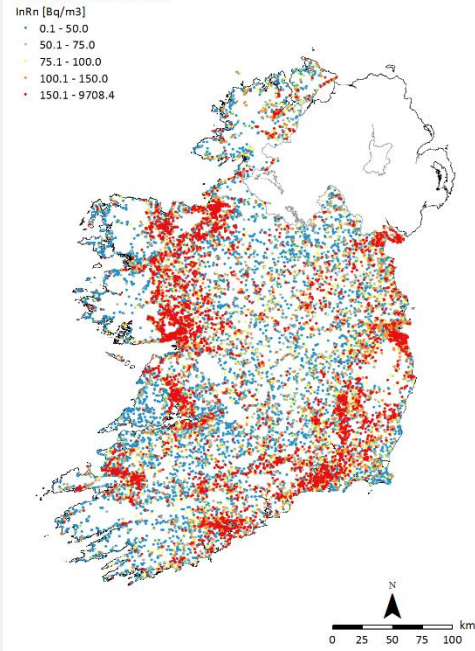


Estimation of residential radon exposure and definition of Radon Priority Areas based on expected lung cancer incidence

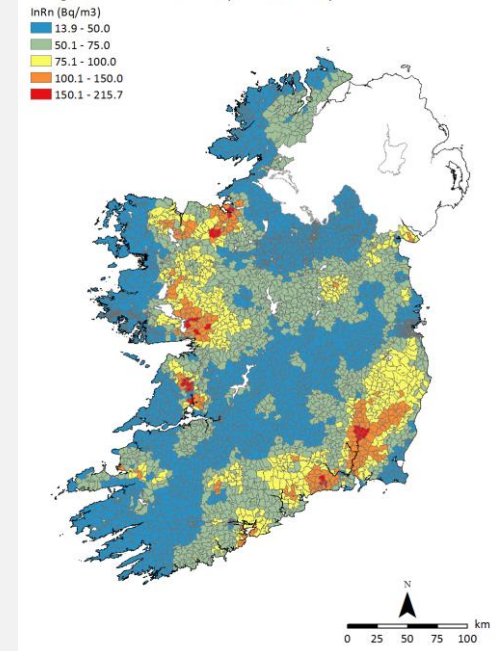


Elío J.^a, Crowley Q.^{a,*}, Scanlon R.^b, Hodgson J.^b, Zgaga L.^c

Indoor radon measurements

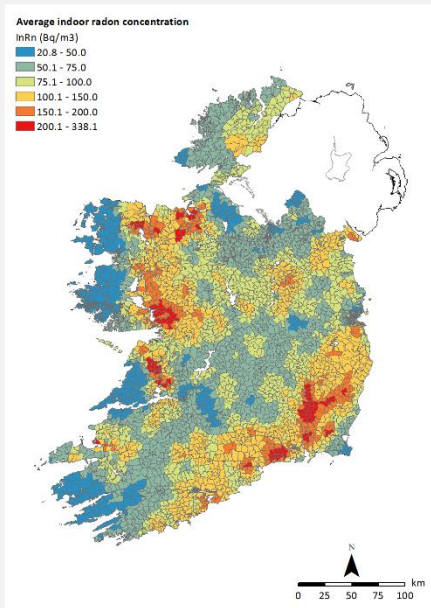


Average indoor radon concentration (Electoral Divisions)



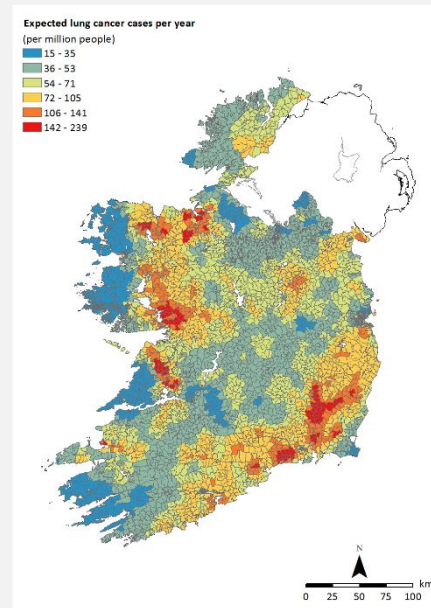
Radon exposure

Average indoor radon concentration (EDs)



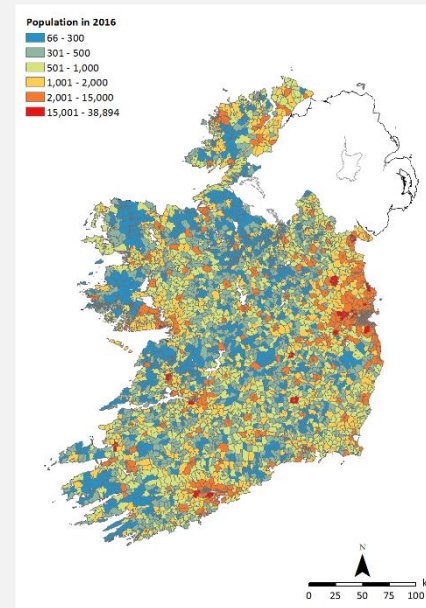
a) Annual effective dose (mSv y^{-1}):

Expected lung cancer cases per year



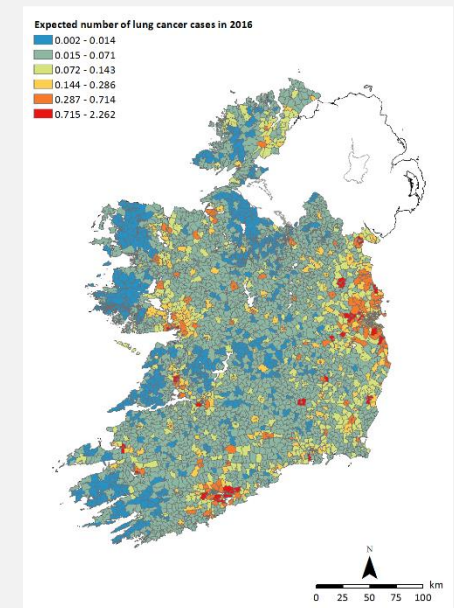
b) Expected lung cancer cases per year per million people:

Population density



c) Population density by EDs:

Expected number of lung cancer cases (2016)



d) Annual lung cancer cases:

$$D = C_{Rn} \cdot F_E \cdot T \cdot F_O \cdot F_D$$



$$ELCC = 18 [mSv^{-1} y] \cdot D [mSv y^{-1}]$$



Year 2016

Average: 1400 inhabitants
Range: 66 - 38,900
Areas: 0.04 km^2 - 162 km^2

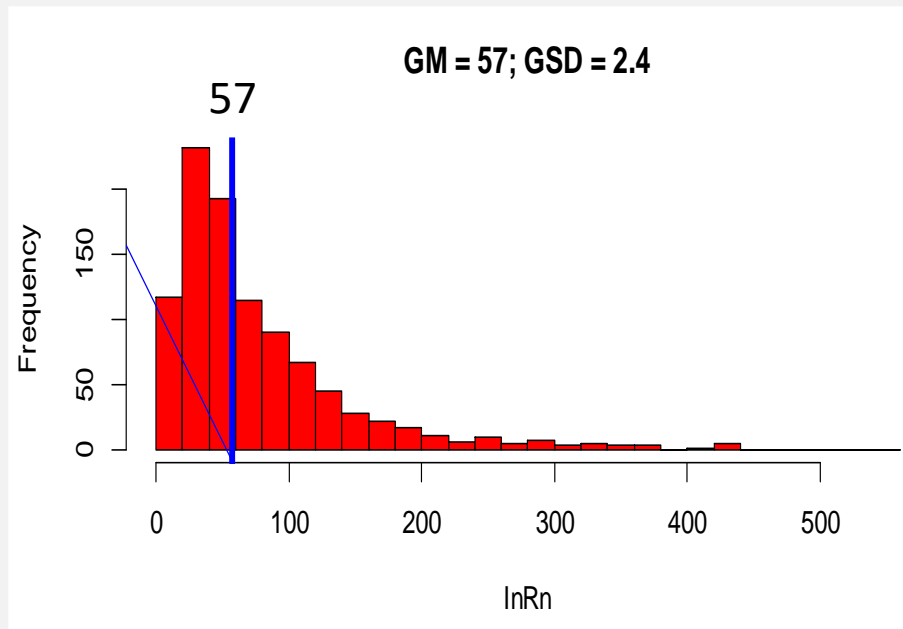


286 [$CI_{95\%}$: 150 - 474] for 2016

276 [$CI_{95\%}$: 144 - 457] for 2011

Radon exposure

Indoor Radon \approx lognormal distribution



Radon Exposure by Electoral Divisions

Average (Bq m ⁻³)	EDs	Population		ELCC*	
		2011	2016	2011	2016
20 - 25	4	1,791	1,683	0	0
25 - 50	324	394,630	405,230	12	12
50 - 75	1,229	1,966,203	2,048,778	87	91
75 - 100	850	1,121,589	1,167,142	68	71
100 - 125	451	517,534	533,289	41	42
125 - 150	267	251,055	258,696	24	25
150 - 175	132	174,096	182,087	20	21
175 - 200	68	89,221	91,546	12	12
200 - 225	46	34,158	34,906	5	5
225 - 250	17	16,055	16,298	3	3
250 - 275	11	11,247	11,544	2	2
275 - 338	10	10,673	10,666	2	2
Total	3,409	4,588,252	4,761,865	276	286

*ELCC: Estimated lung cancer cases

- Most people are exposed to a radon concentration below 200 Bq m⁻³, is it efficient to define a radon-priority area only based on the reference level?
- Should be included the possible health effects (i.g. expected lung cancer incidences)?
- Include housing/population data (e.g. total number of dwellings with a indoor radon concentration higher than the reference level / People who may be exposed to high radon concentrations)?

Radon Potential

Radon risk based solely on geogenic factors (e.g. Neznal formula)

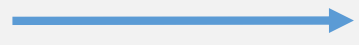
$$RP = \frac{C_{Rn}}{(-\log_{10}(k) - 10)}$$

Risk Classification

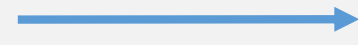
Soil Permeability	Low	Low	Low	Moderate Low	Moderate Low	Moderate High	High
	Moderate	Low	Moderate Low	Moderate High	Moderate High	High	High
	High	Low	Moderate High	High	High	High	High
		Very Low	Low	Moderate	High	Very High	Ext. High
Radon soil-gas							

Soil-gas radon predictions (Airborne data)

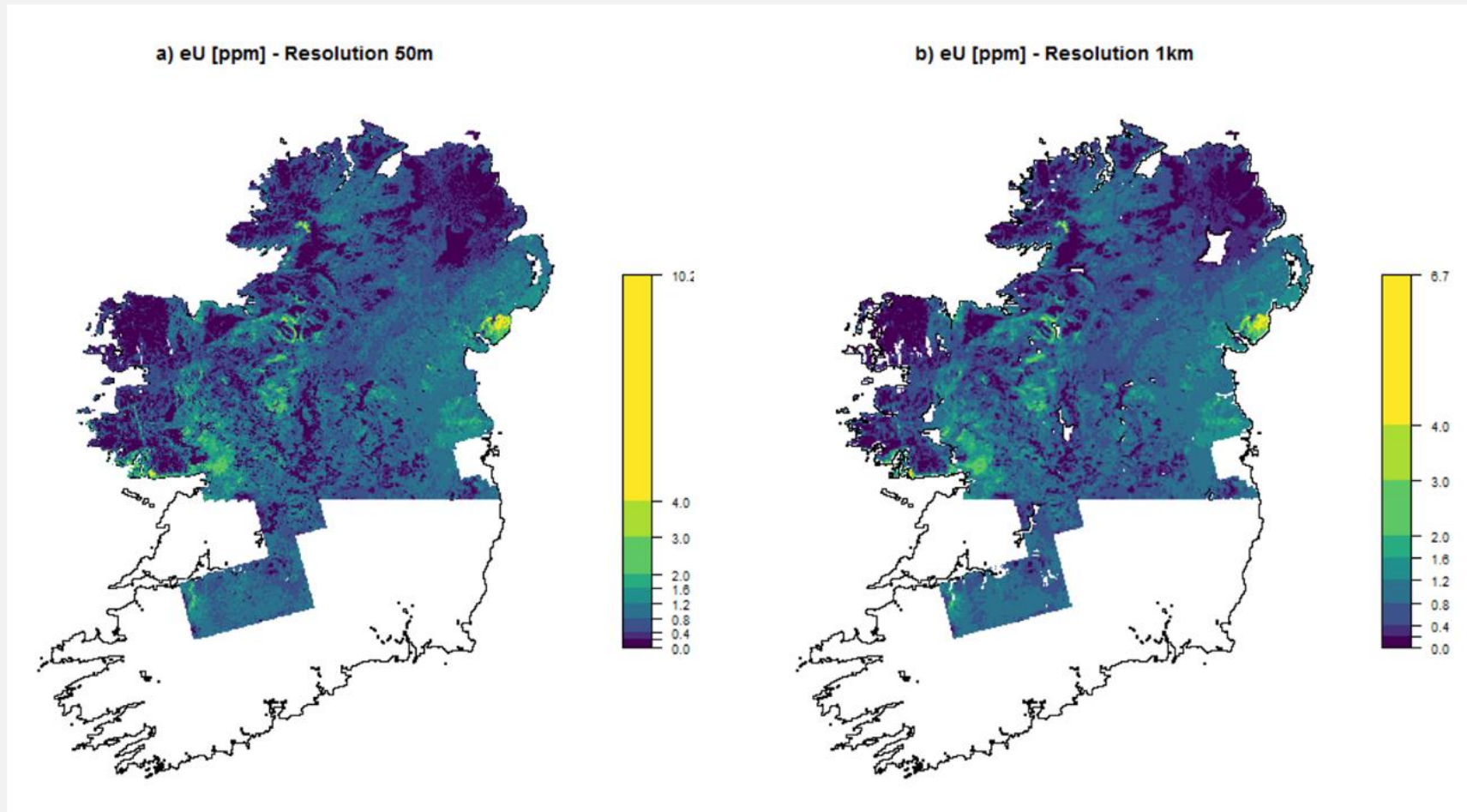
Radiometric data (^{238}U)



Radium (^{226}Ra)



Radon (^{222}Rn)



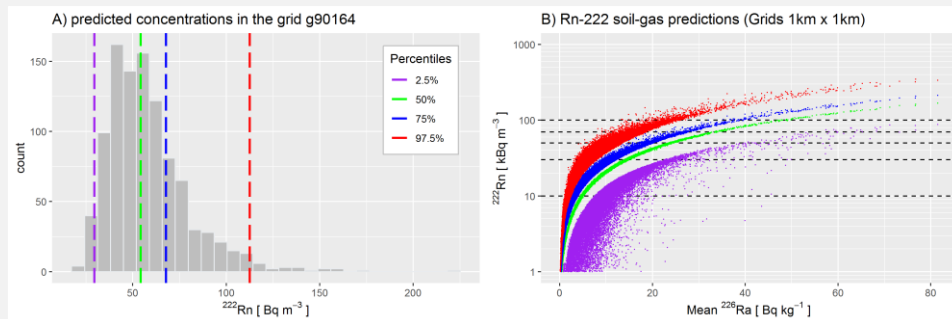
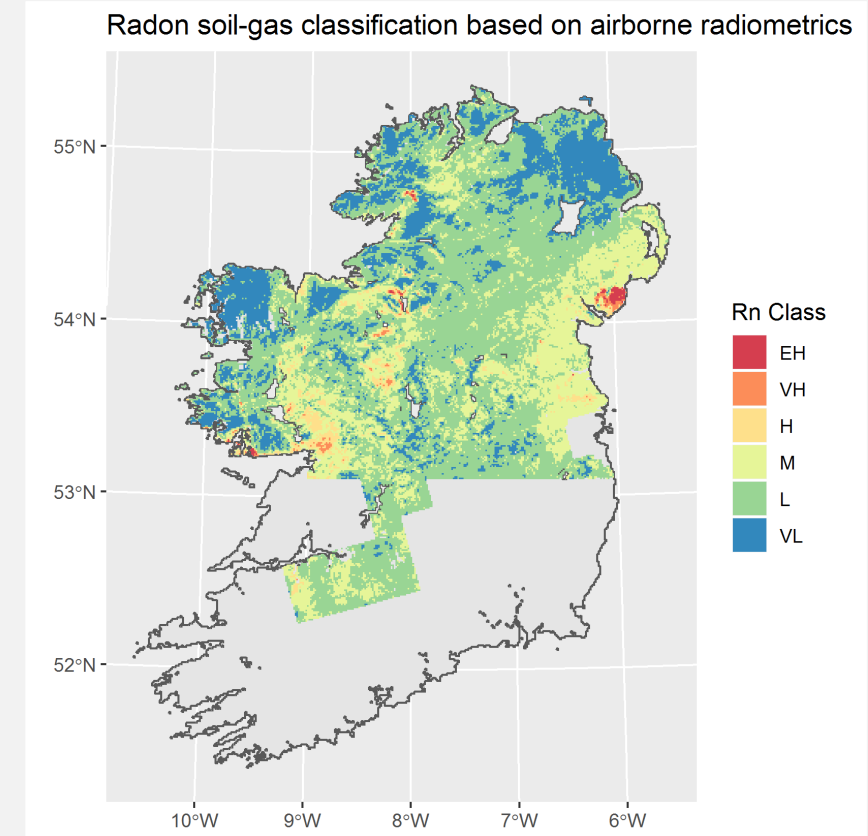
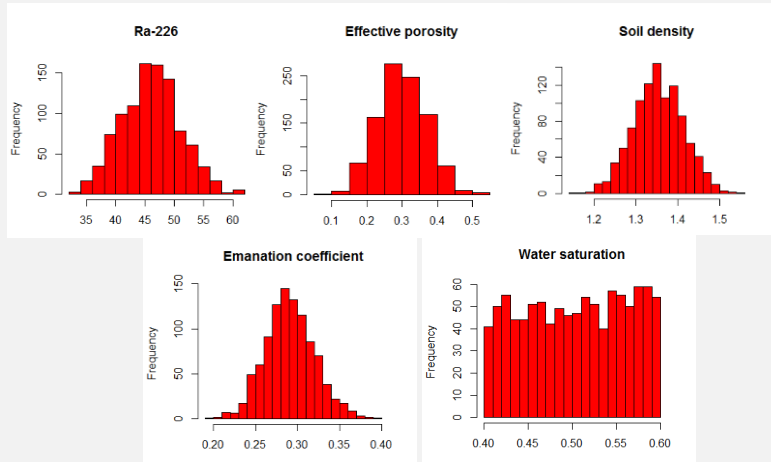
Soil-gas radon predictions (Airborne data)

Radiometric data (^{238}U)

Radium (^{226}Ra)

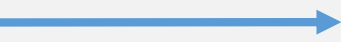
Radon (^{222}Rn)

$$C_{Rn} = \frac{C_{Ra} \cdot \varepsilon \cdot \rho}{n} \cdot \frac{1}{1 - S_F + S_F K_{W/Air}}$$



Soil-gas radon predictions (Airborne data)

Radiometric data (^{238}U)

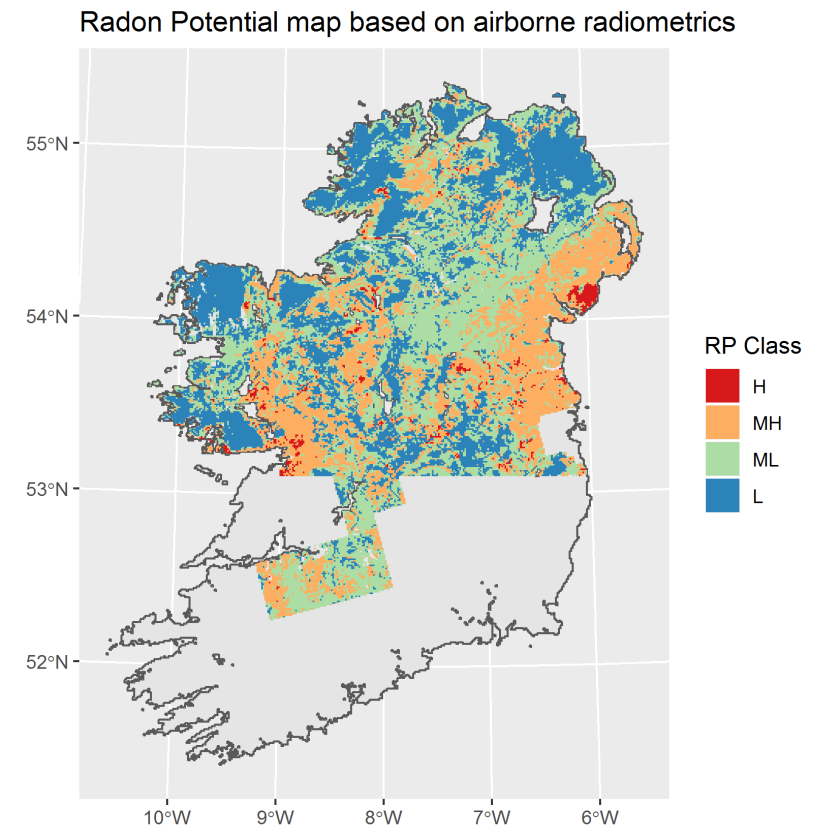
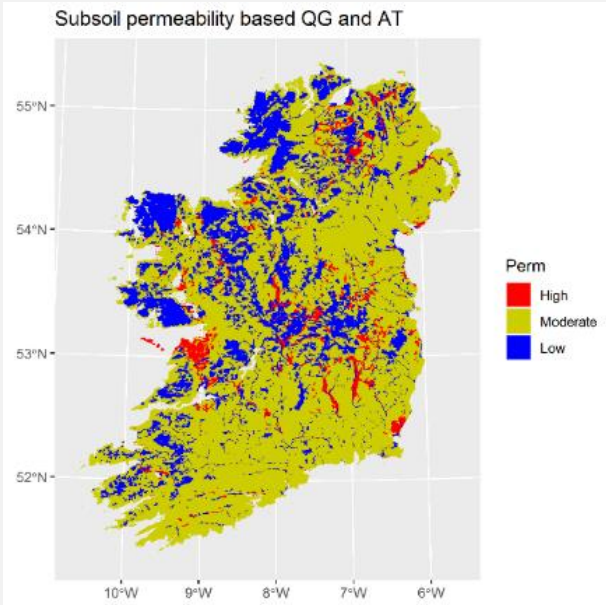
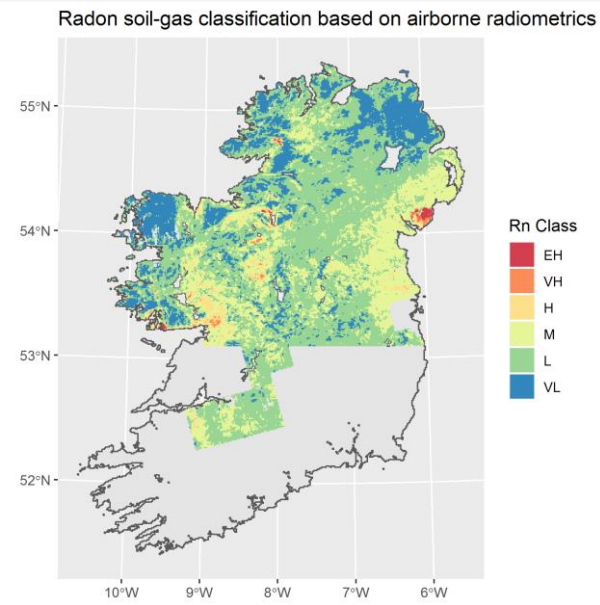


Radium (^{226}Ra)



Radon (^{222}Rn)

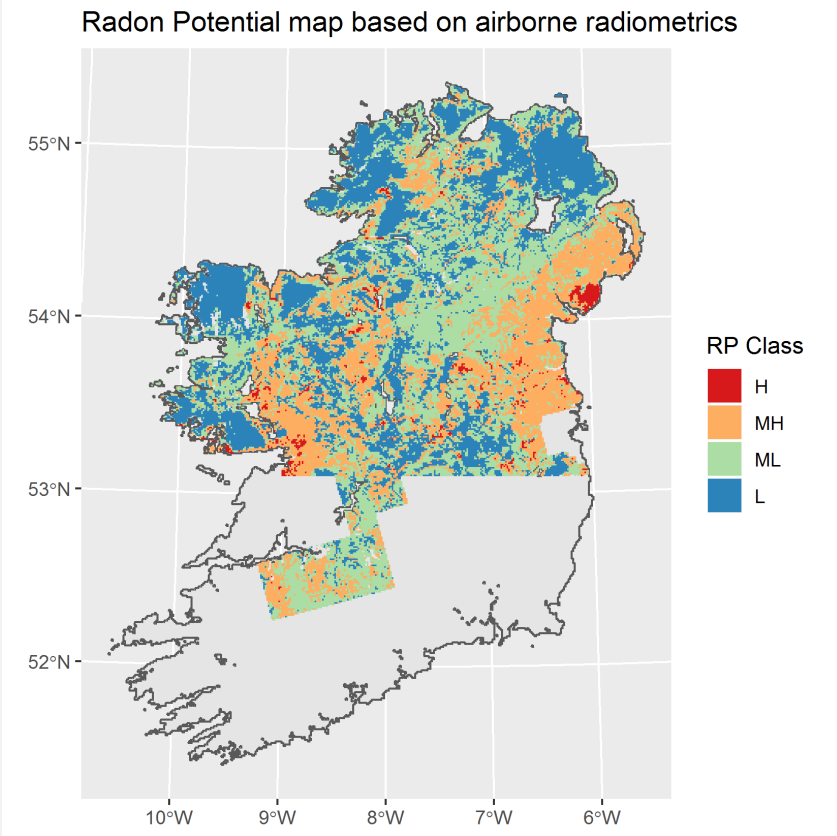
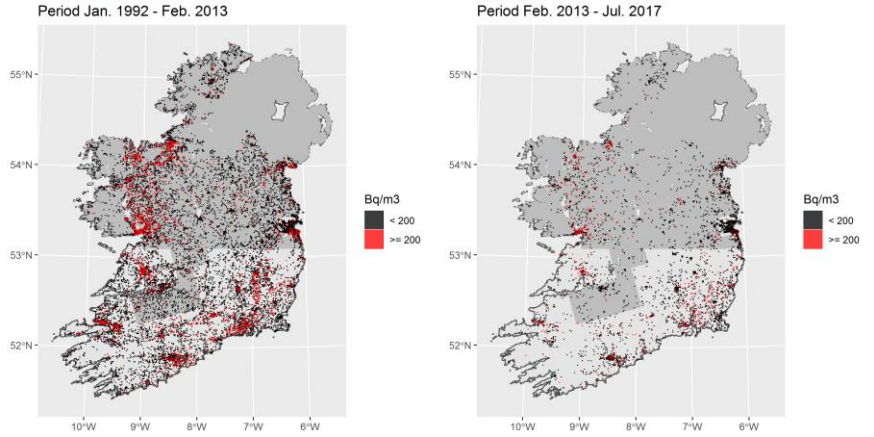
$$RP = \frac{C_{Rn}}{(-\log_{10}(k) - 10)}$$



Soil-gas radon predictions (Airborne data)

Radiometric data (^{238}U) \longrightarrow Radium (^{226}Ra) \longrightarrow Radon (^{222}Rn)

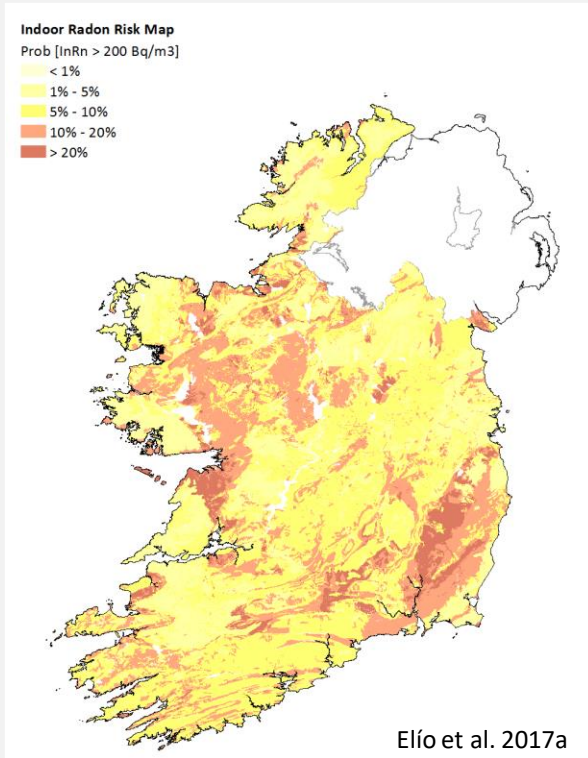
$$RP = \frac{C_{Rn}}{(-\log_{10}(k) - 10)}$$



Radon Potential	Indoor Radon		Sampled dwellings			Binomial distribution		
	GM	GSD	≤ R.L.	> R.L.	Total	Prob.	LCI	UCI
L	46.22	2.42	1,547	115	1,662	6.92	5.75	8.25
M-L	55.39	2.40	6,165	564	6,729	8.38	7.73	9.07
M-H	74.88	2.74	6,583	1,306	7,889	16.55	15.74	17.39
H	86.48	2.95	431	121	552	21.92	18.54	25.61
Total	63.59	2.62	14,726	2,106	16,832	12.51	12.01	13.02

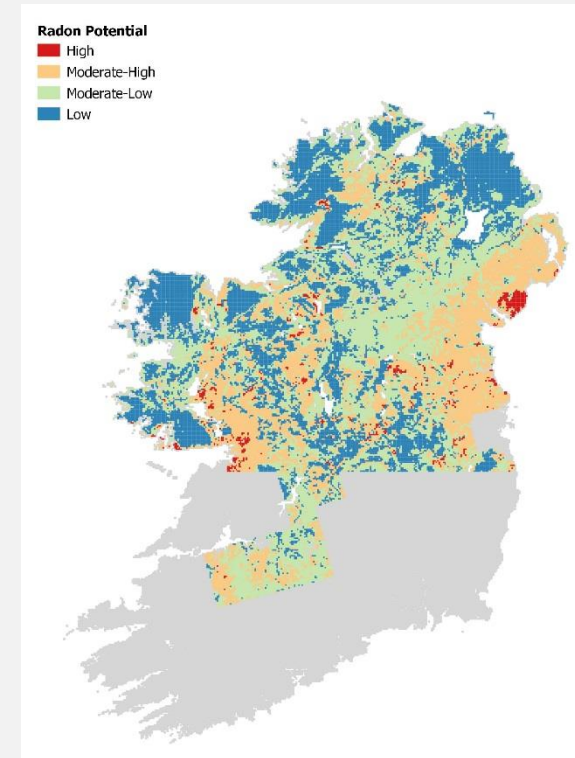
Summary

Probabilistic maps



1. Prob[InRn > 200 Bq m⁻³]
2. Divided a country in radon risk categories
3. No of dwellings/population that may be affected by high radon concentrations:
 - Approx. 185,000 dwellings in Ireland.
 - Up to 460,000 people

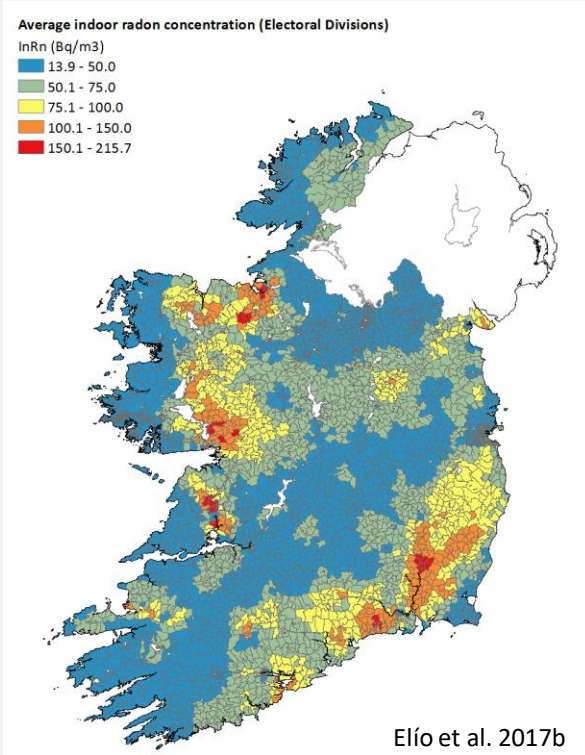
Geogenic radon map



1. Risk classification only based on radon source (i.e. soil-gas radon concentration) and its availability to move into a building (i.e. soil permeability).
2. Independent of anthropogenic factors, e.g. house type (**with caution**), and it does not change with time (?).
3. Possibility to characterize areas for radon risk where indoor radon measurements are not available.

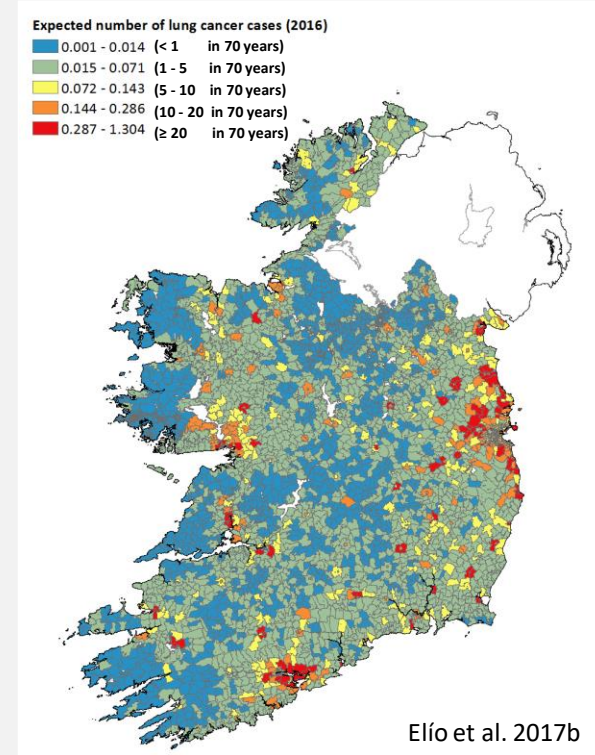
Summary

Average concentration



1. Average concentration.
2. Calculate the effective dose (ranges from 0.8 to 13.3 mSv y⁻¹).
3. Analyse the possible adverse health effects:
 - lung cancer.
 - Others: skin, stomach or brain cancer, Non-hodgkin's lymphoma, etc.

health effects



1. Expected radon-related lung cancer incidence (by EDs).
2. Knowing the population density, the expected radon-related lung cancer cases may be estimated:
 - In 2016 ≈ 286 (CI_{95%}: 150 – 474)
 - In 2011 ≈ 276 (CI_{95%}: 144 – 457)

Conclusions

- Radon maps are essential to **target geographic areas** where radon preventive or remediation measures should be implemented.
- Radon maps **do not predict** the Indoor Radon concentration in a particular house. **Test your house!!!**
- A better definition of Radon Priority Areas (RPA) will ultimately assist regulators and local authorities to design a proper **strategy to minimise radon exposure** in the built environment.
- There is **NOT an unique definition** of RPA (political decision which is taken with limited information).
- Criteria should be **flexible** to be re-defined when new data/knowledge are available.
- Geology is the main factor that controls the indoor radon concentration; however, **other factors can be as important as geology**. For example:
 - Geographical location (e.g. altitude, coastal areas, urban/rural areas)
 - Environmental factors (e.g. barometric pressure, precipitation and temperature)
 - Building characteristics (e.g. building materials, type, date)

Conclusions

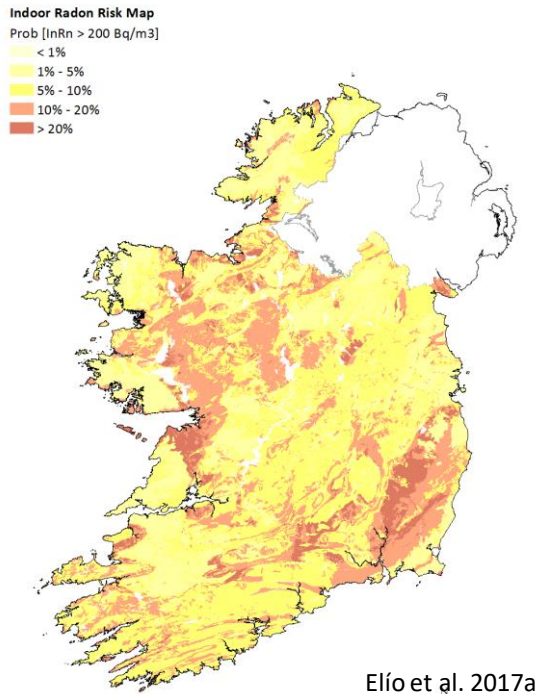
- A **National Radon Plan** should have two targets:
 - a) **Protection of individuals:** reduce extremes, even if only one person is affected.
 - b) **Protection of the collective:** reduction collective dose.

- The definition of **RPA** requires therefore **multiple approaches**, not mutually exclusive.
 - a) **Protection of individuals:** detect individual houses with high indoor radon concentration, or prevent the accumulation of radon indoors in high risk areas (e.g. building regulations). here is where *probabilistic and geogenic radon maps* are useful.
 - b) **Protection of the collective:** policy focused on where the majority of the collective dose occurs. Such areas are where the highest radon-related lung cancer incidence is expected, even if indoor radon concentrations are relatively low; this is where maps showing *average indoor radon concentration and radon-related lung cancer incidence* are essential.

Use all available options

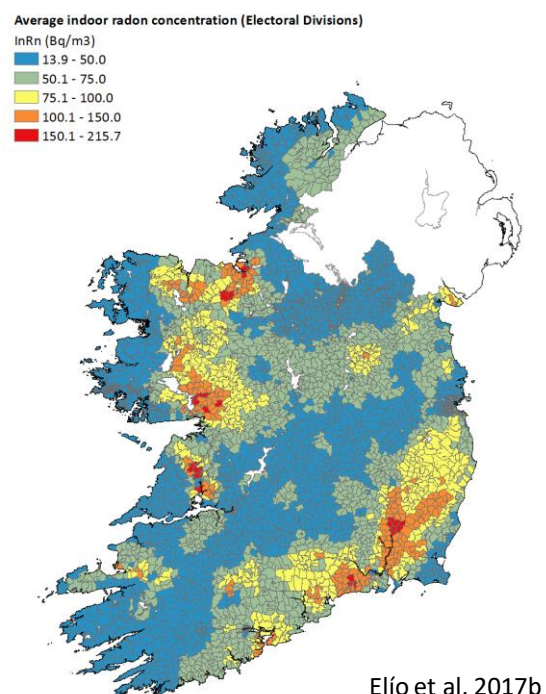
National Indoor Radon Risk Map

A new indoor radon risk map of Ireland



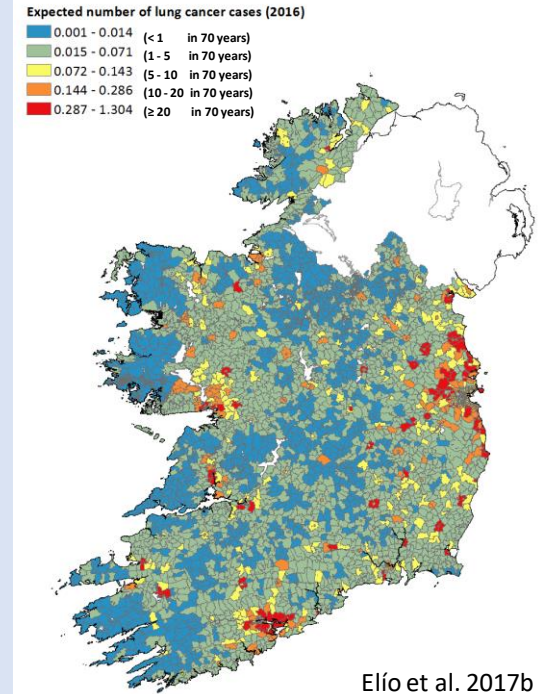
Average Indoor Radon Map

Average radon concentration in an area



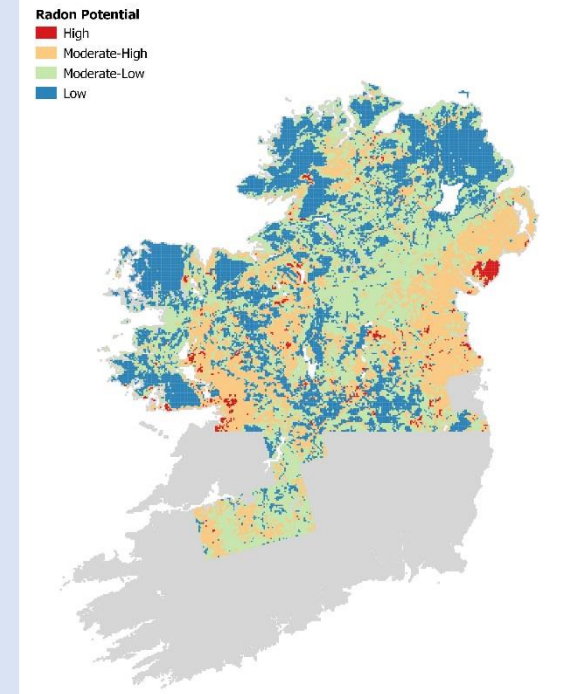
Health effects of Radon Exposure

Lung cancer cases attributed to radon exposure



Radon Potential Map



Soil-gas radon concentration and subsoil permeability




For further information

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Logistic regression model for detecting radon prone areas in Ireland 



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Estimation of residential radon exposure and definition of Radon Priority Areas based on expected lung cancer incidence 

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Environmental Earth Sciences (2019) 78:359
<https://doi.org/10.1007/s12665-019-8339-4>

ORIGINAL ARTICLE 

Rapid radon potential classification using soil-gas radon measurements in the Cooley Peninsula, County Louth, Ireland

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Utilizing multiple approaches for the definition of radon priority areas

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Thanks!!

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