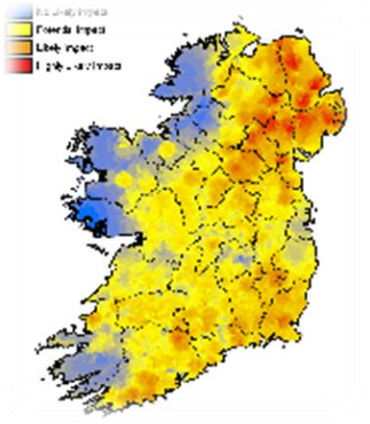
Modelling and monitoring impacts of air pollution in Ireland




David “Dáithí” Kelleghan[1]

Bill Bealey[2], Sim Tang[2], Ed Rowe[2], Laurence Jones[2], Kasia Sawicka[2], Cristina Martina Hernandez[2] Massimo Vieno[2], Sam Tomlinson[2], Thomas Cummins[3], Tom Curran[3]

[1] Teagasc

[2] UK Centre for Ecology & Hydrology

[3] University College Dublin

Introductions…

- David / Dáithí Kelleghan
- PhD
  - Ammonia emissions
  - Dispersion modelling
  - Assessing potential for ecological impacts
- Co-authored CIEEM advice on
  - air pollution and ecological impacts
- Lead author of Irish guidance
- Co-ordinating the design of Ireland's air pollution and effects monitoring network
  - Requirement of National Emissions Ceilings Directive
- Currently employed by Teagasc
  - Researching ammonia emissions from landspreading

Ireland & NH_3 Emissions

- Ireland exceeding ammonia (NH_3) emission limit
  - National Emissions Ceilings Directive
- 99% of NH_3 in Ireland comes from agriculture
  - Primarily animal wastes
- Without mitigation – emissions continually increasing
- Compliance with the EU Habitats Directive in question
  - Impacts from NH_3 on sensitive sites

Buckley, et al. (2020). An Analysis of the Cost of the Abatement of Ammonia Emissions in Irish Agriculture to 2030. Teagasc.

Figure 2.7: Total Aggregate NH_3 Emissions under S1, S2 & S3 Scenarios with no Mitigation (kilotonnes)

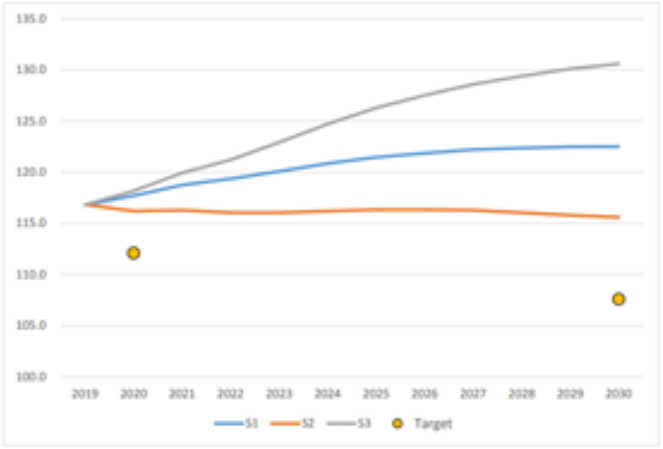
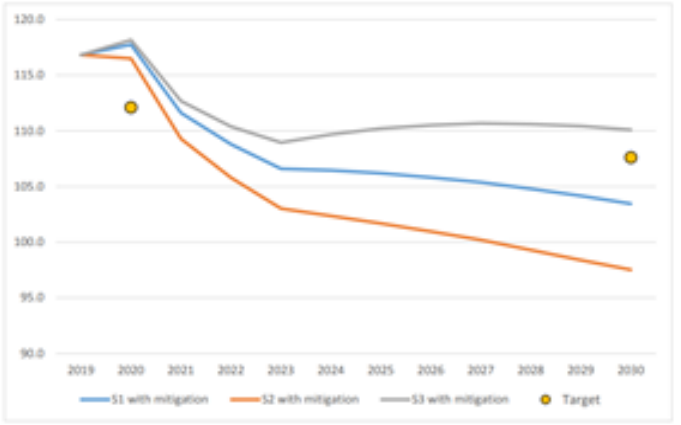


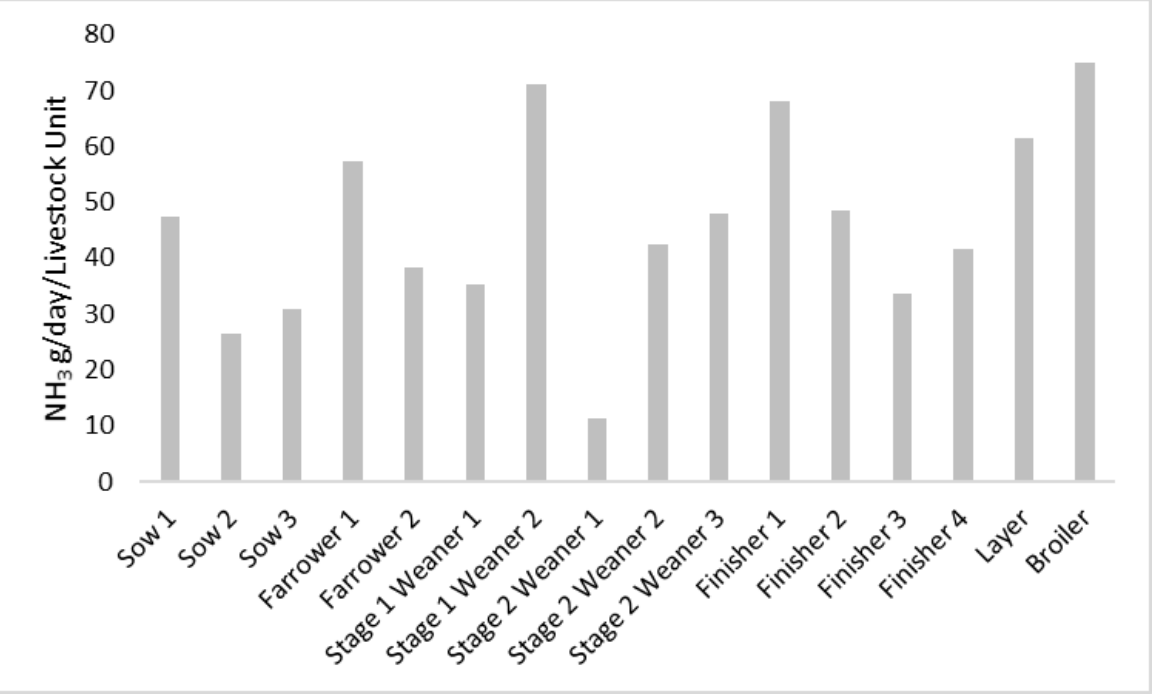
Figure 3.3: NH_3 Aggregate Levels with Full Mitigation Potential Realised (kilotonnes of NH_3)



AmmoniaN2K

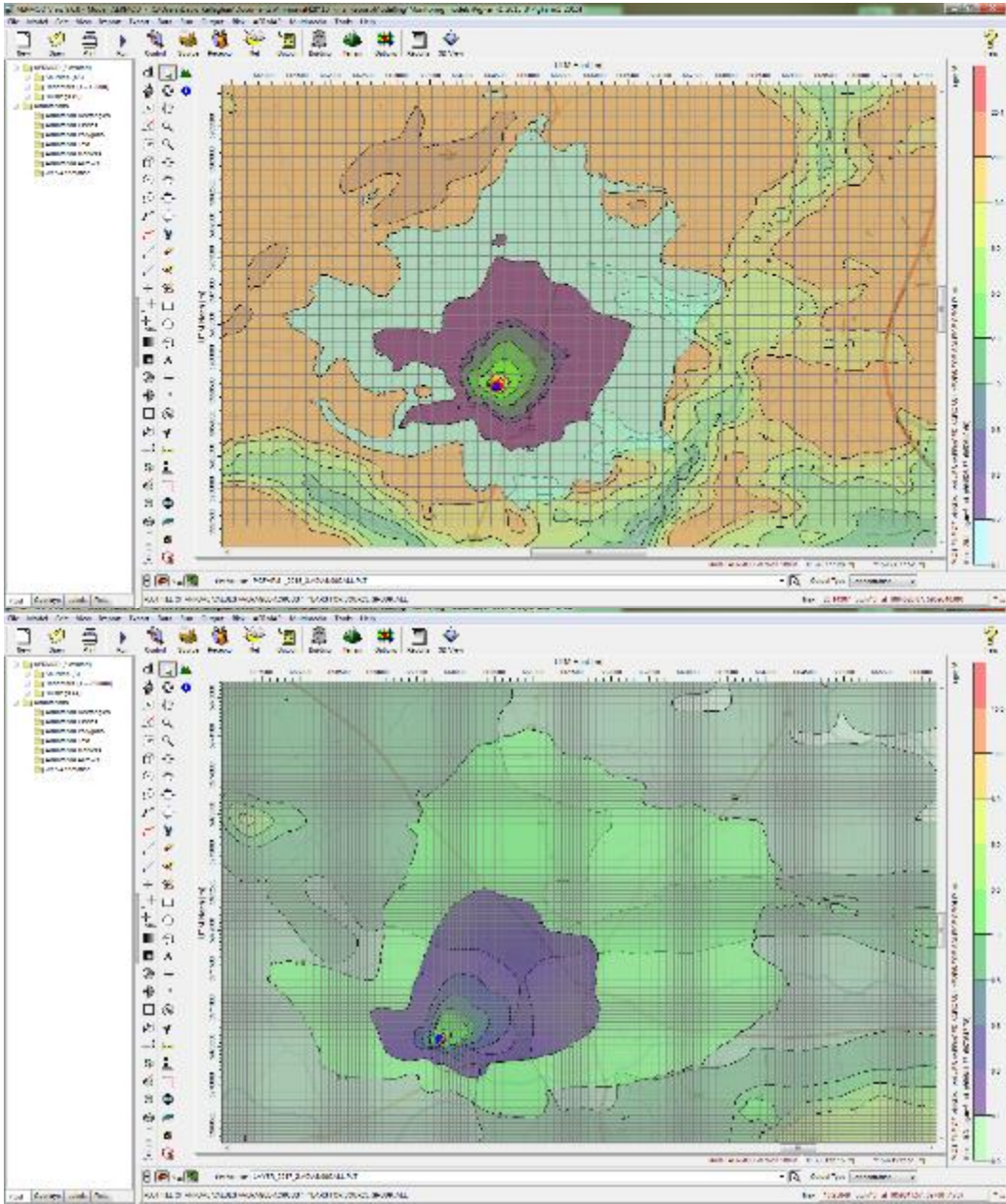
- A UCD/UWE project Funded by STRIVE, as administered by the Irish Environmental Protection Agency (EPA)
- Focus on NH_3 emissions from Irish pig & poultry farms
- Impacts on Irish Natura 2000 (N2K) Sites

Ammonia N2K

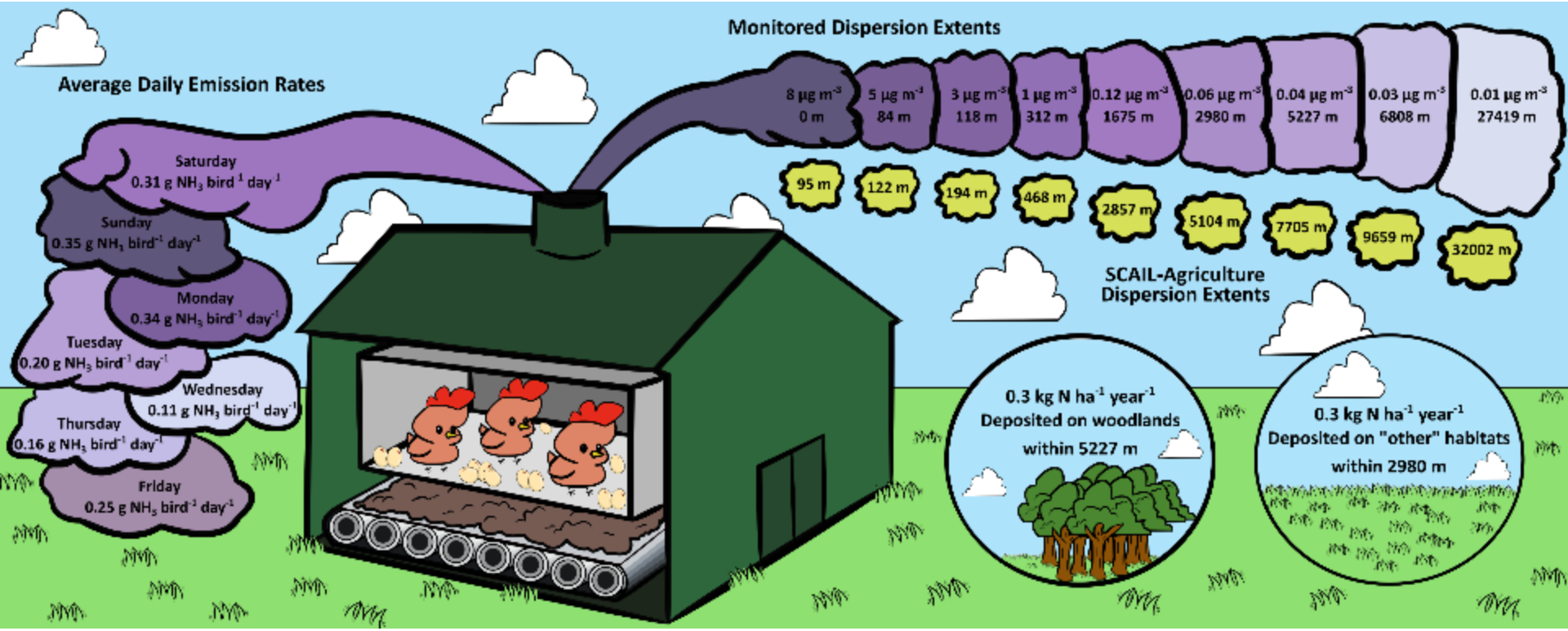

80
70
60
50
40
30
20
10
0
NH_3 g/day/Livestock Unit
Sow 1
Sow 2
Sow 3
Farrower 1
Farrower 2
Stage 1 Weaner 1
Stage 1 Weaner 2
Stage 2 Weaner 1
Stage 2 Weaner 2
Stage 2 Weaner 3
Finisher 1
Finisher 2
Finisher 3
Finisher 4
Layer
Broiler

Dispersion Modelling

- For four farms Monitored
- Generated atmospheric dispersion models
- Using Lakes © AERMOD
- Using updated;
  - emission rates
  - ventilation rates
- Used to estimate contribution to dry deposition

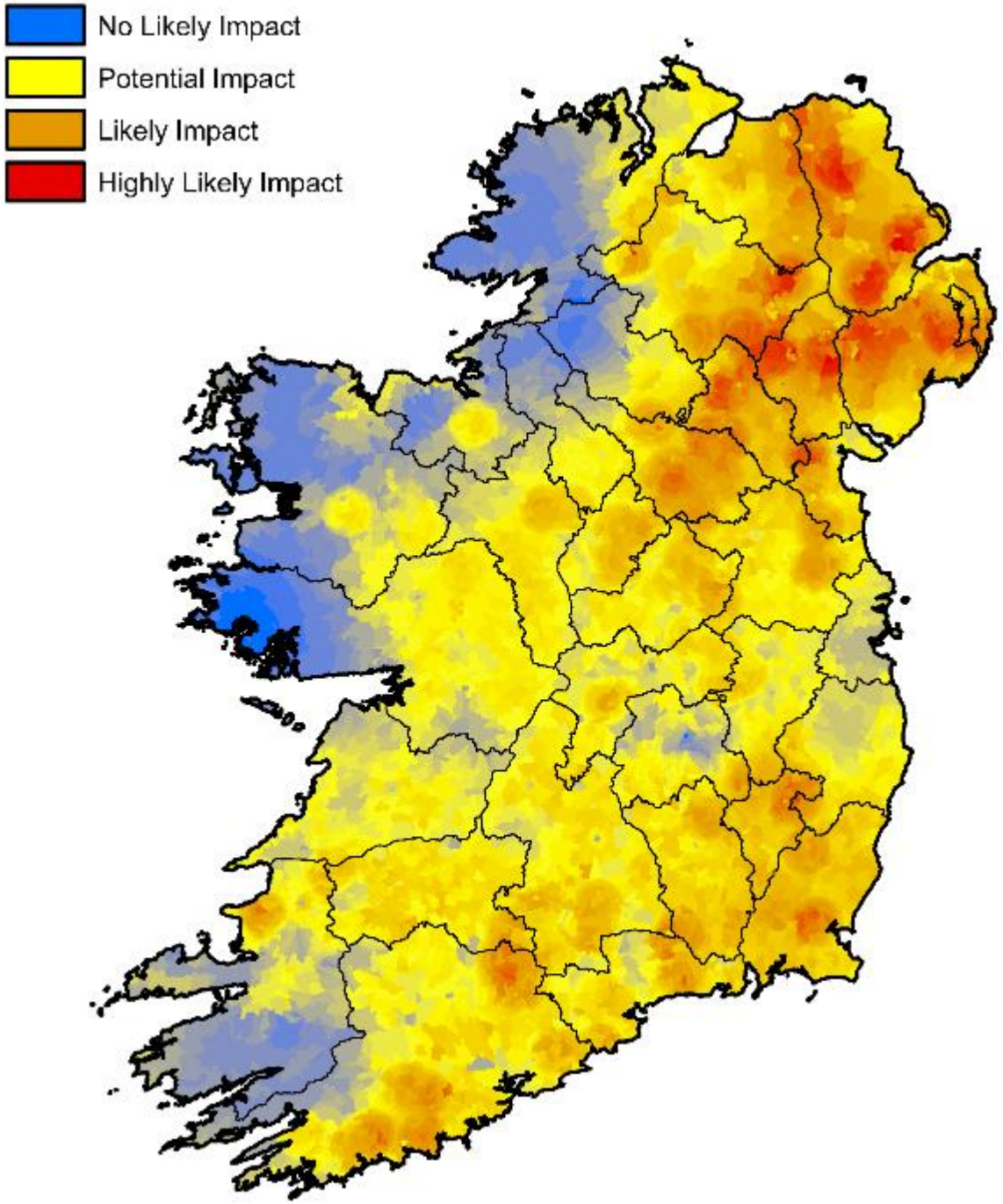


Emissions and dispersion from Layer House



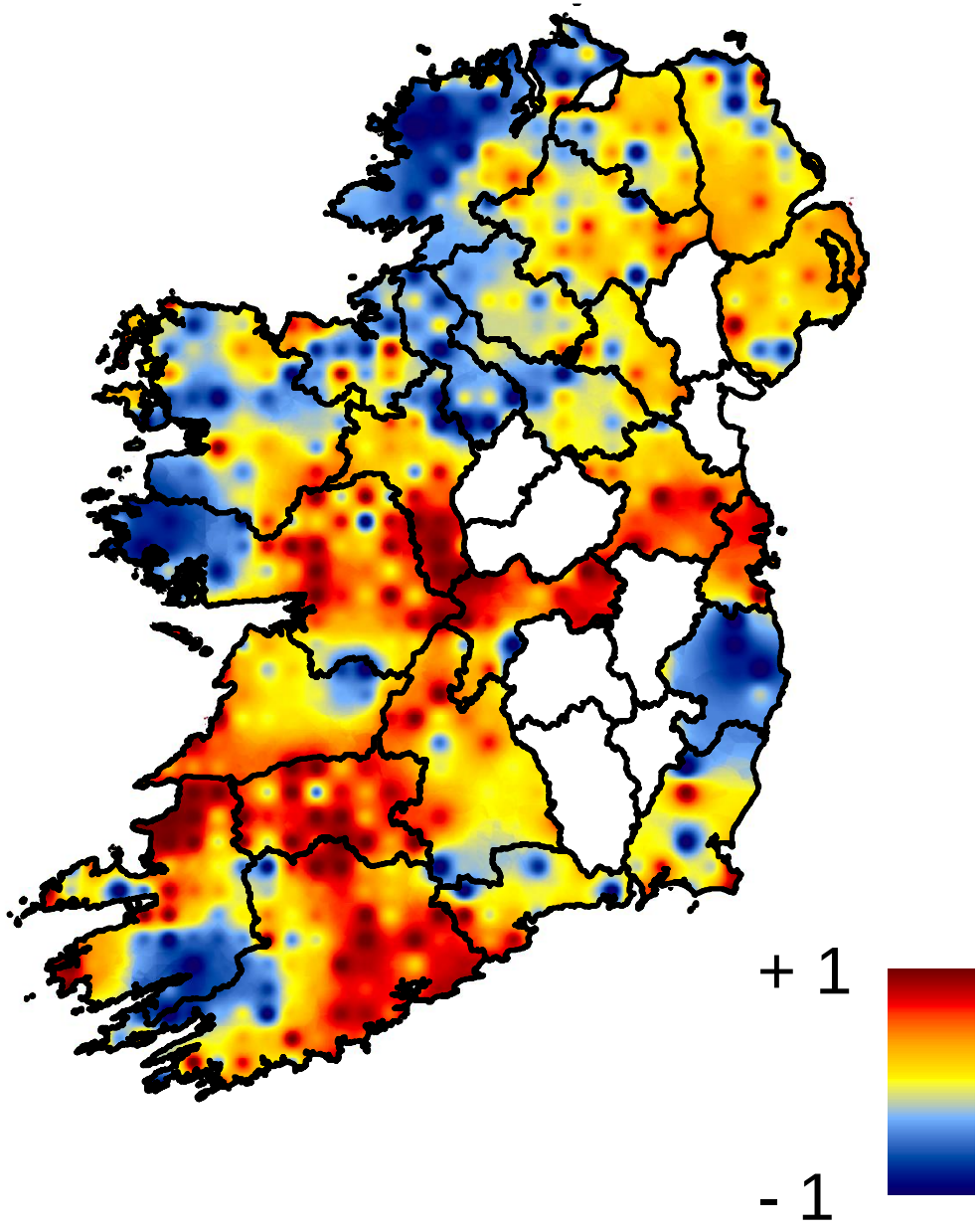
MARSH Risk Map

- **M**apping **A**mmonia **R**isk on **S**ensitive **H**abitats
- Based on likely concentrations
- Derived from;
  - Animal production intensity
  - FRAME model in Northern Ireland
  - Ambient monitoring



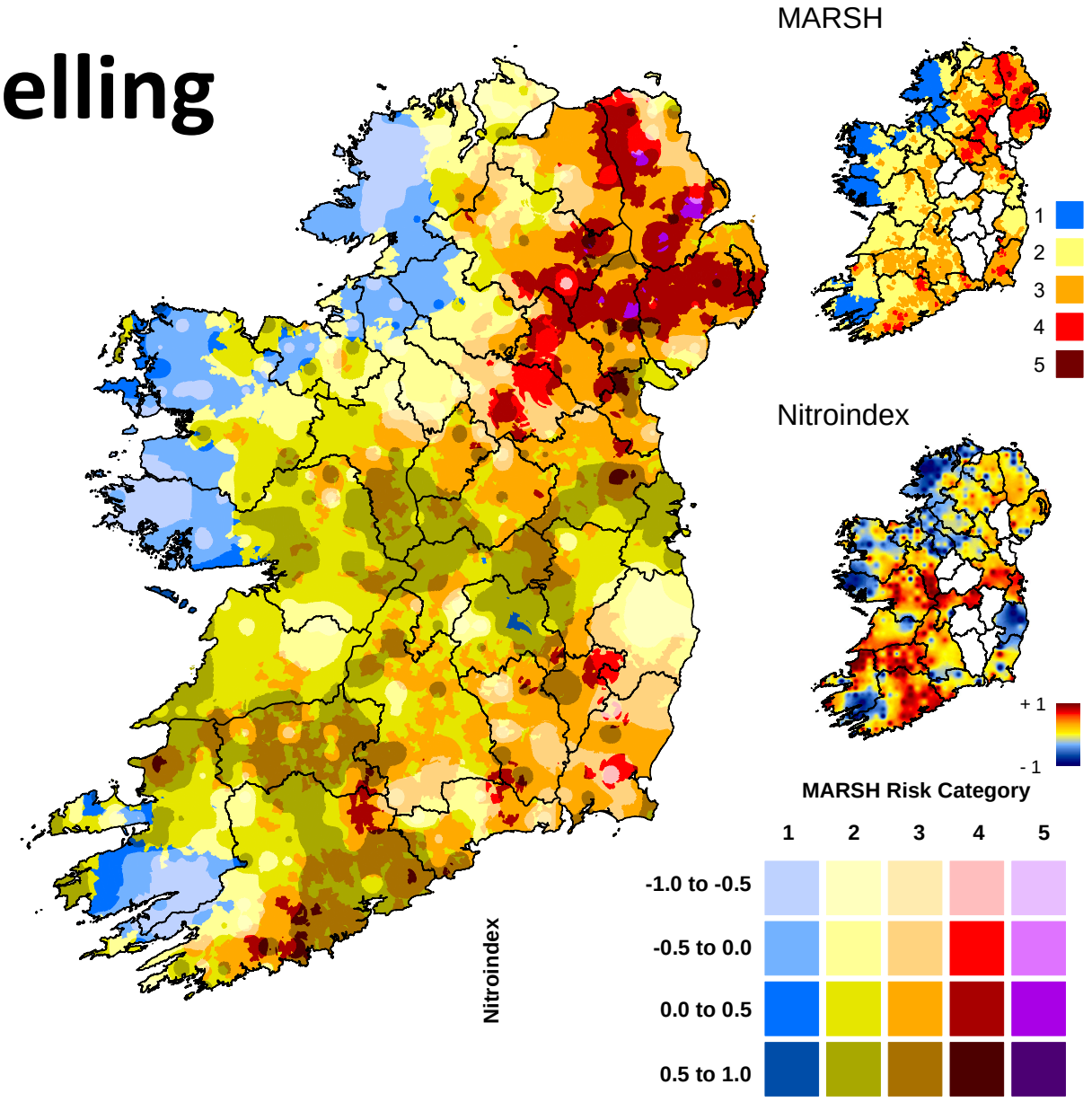
Nitroindex

- Nitrogen sensitive lichen species between 2000 – 2014
  - Provided by CEDaR
- Used Nitroindex presented in Rihm et al., 2009
  - Within 10 km grids
- Interpolated using Inverse Distance Weighted (IDW)
  - Deterministic interpolation method
- Generated scale of + 1 to – 1
  - + 1 = Nitrogen tolerant (Impacted)
  - - 1 = Nitrogen sensitive (Unimpacted)



National Modelling

- Combining MARSH & Nitroindex to produce bivariate risk map
  - Predicted concentrations (MARSH)
  - Recorded impacts (Lichen species – Nitroindex)



Ammonia N2K

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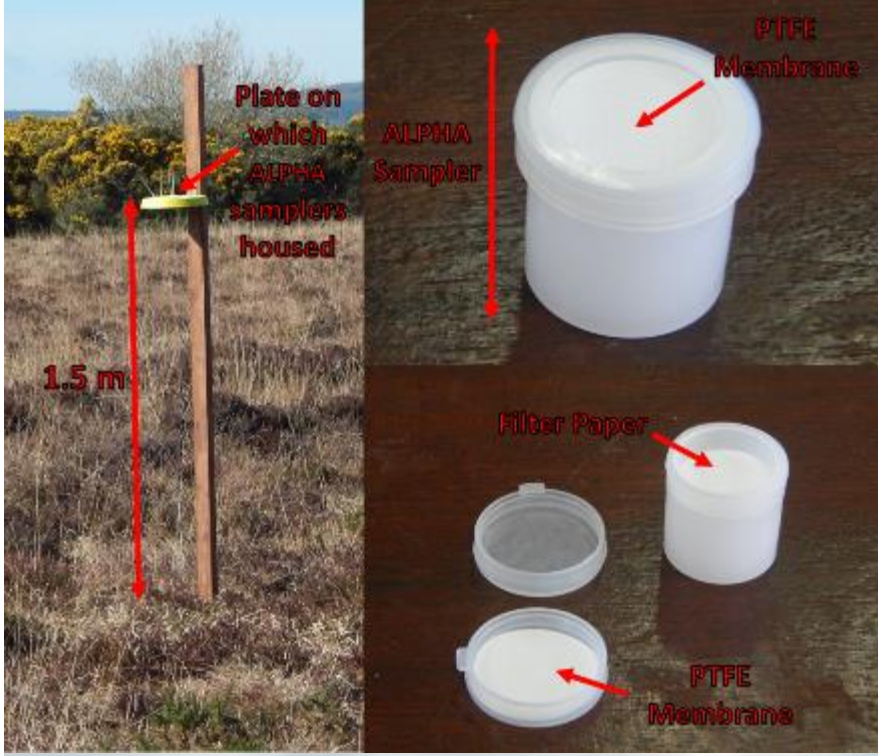
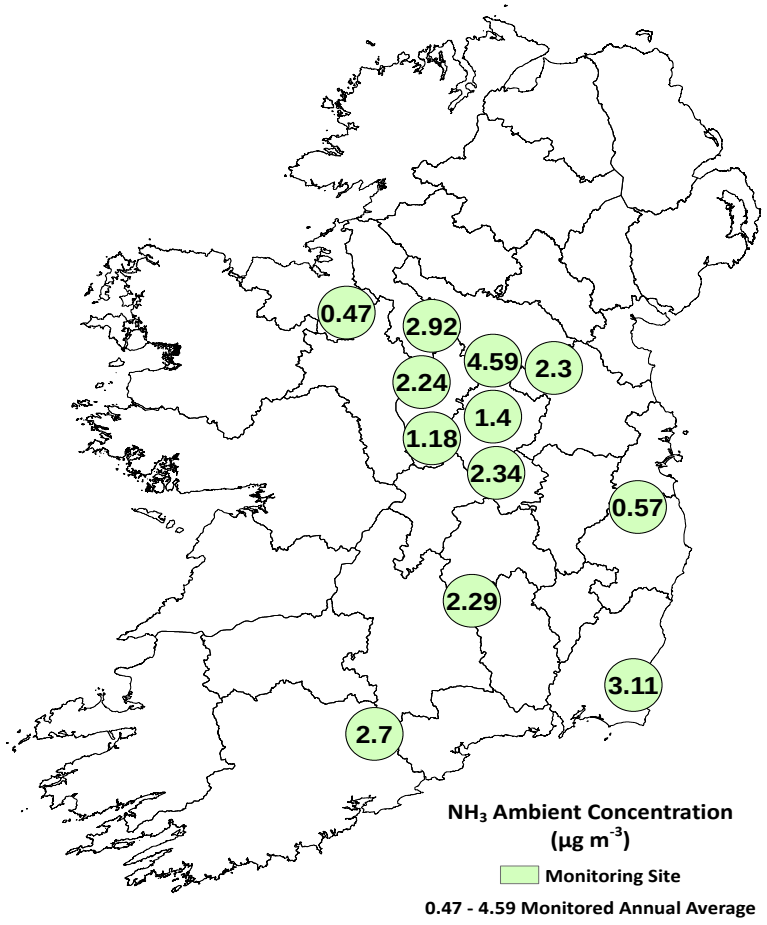
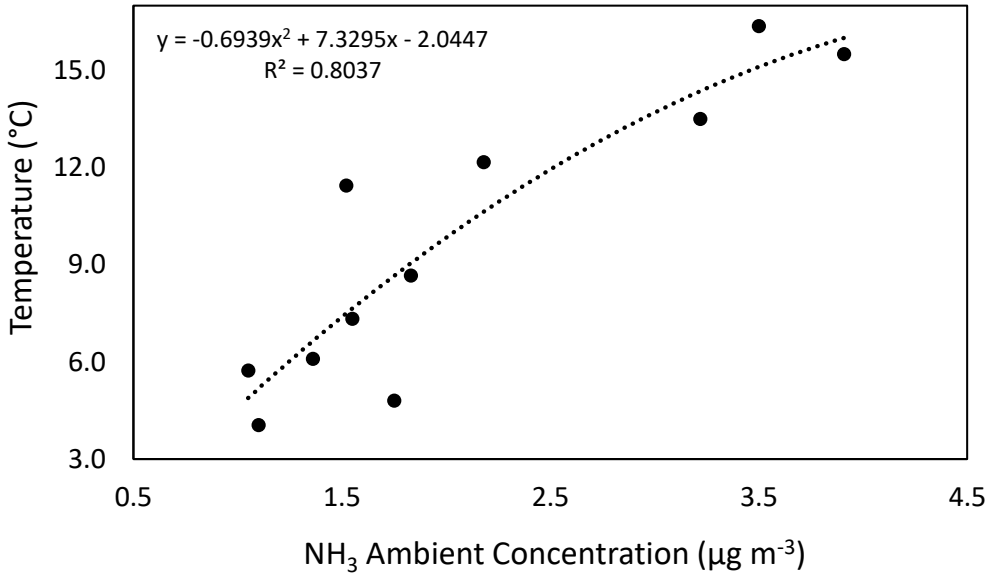
UWE BRISTOL

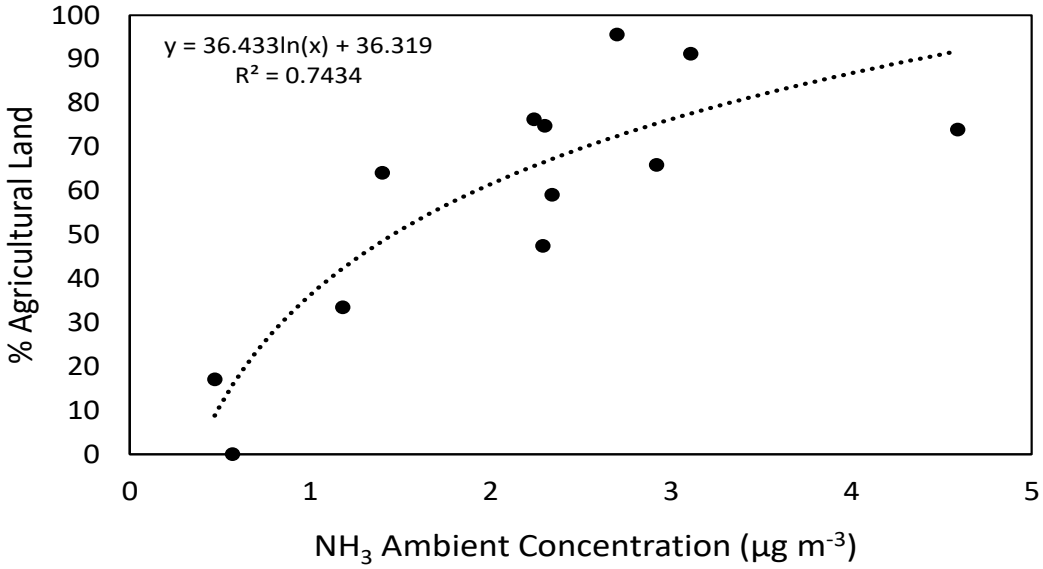
NH_3 Monitoring on Natura 2000 Sites

- ALPHA samplers
  - Adapted Low-cost Passive High Absorption
  - developed by the Centre for Ecology and Hydrology
- 12 Natura 2000 sites in Ireland
- 12 months
- in collaboration with
  - National Parks & Wildlife Service Conservation Rangers



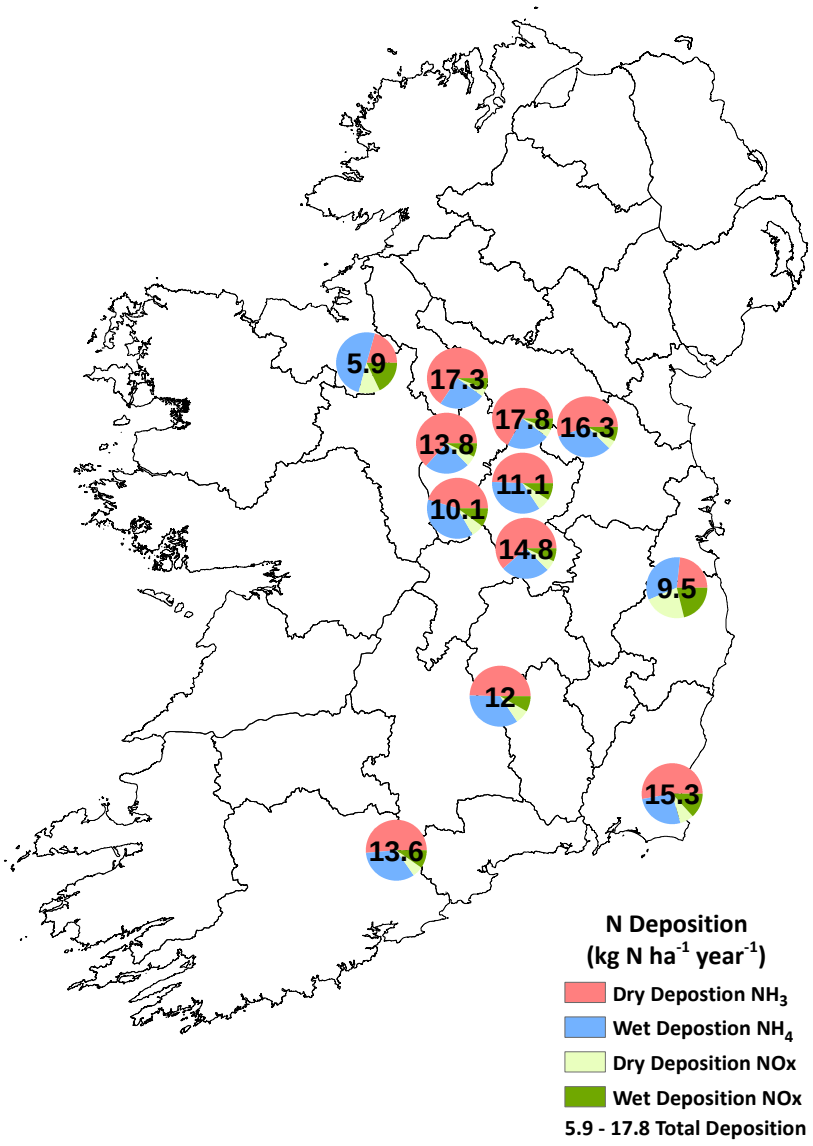

0.47
2.92
4.59
2.3
2.24
1.4
1.18
2.34
0.57
2.29
3.11
2.7
NH3 Ambient Concentration (µg m-3)
Monitoring Site
0.47 - 4.59 Monitored Annual Average


y = -0.6939x2 + 7.3295x - 2.0447
R² = 0.8037
Temperature (°C)
15.0
12.0
9.0
6.0
3.0
0.5
1.5
2.5
3.5
4.5
NH3 Ambient Concentration (µg m-3)


y = 36.433ln(x) + 36.319
R² = 0.7434
% Agricultural Land
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
NH3 Ambient Concentration (µg m-3)

Monitored Impacts

- All raised bogs monitored exceeded critical levels and loads for impacts
- Only 2 sites fell below lower critical level for lichens and moss
  - Both upland sites
  - Second site (Wicklow Mountains) exceeded critical loads
  - Due to wet deposition of nitrogen from neighbouring agriculture



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NEMN

- National Ecological Monitoring Network (NEMN) - Ireland's network
- Intended to;
  - Set up **long term** permanent sites
  - Monitor;
    - **ecological impacts** of **air pollution**
    - **concentration** and **deposition** of pollutants
- Guidance recommends the network be;
  - **Representative**
  - **Cost-effective**
  - **Risk based**

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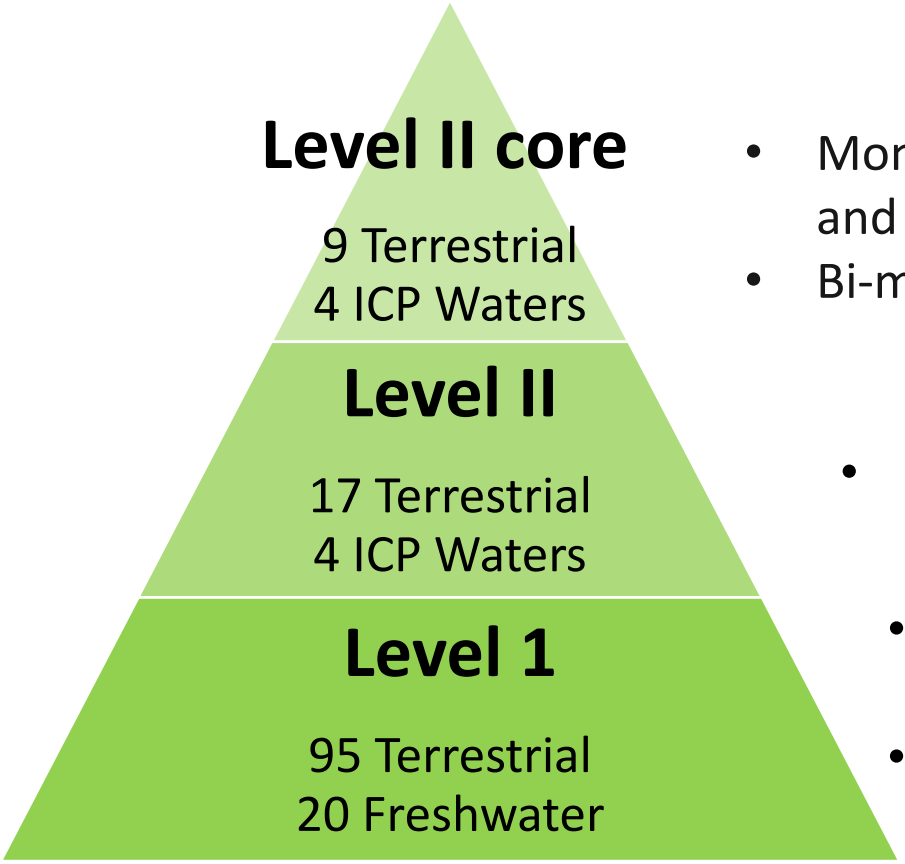
Air pollution monitoring - tiered approach



Recommendations

- Monthly gases (NH_3, HNO_3, NO_2, SO_2) and aerosols (NH_4^+, NO_3^-, SO_4^{2-})
- Bi-monthly wet deposition

- Monthly NH_3

- Modelled concentrations and deposition
- Comparison with critical levels and loads

Complemented by data from existing networks:

- National ambient AQ network (NO_x, SO_2, O_3, $PM_{2.5}$)
- EMEP (TIN, TIA, NH_3*, wet deposition)
- Met Éireann (wet deposition)
- Teagasc (NH_3 flux) / ICOS (C flux)

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NEMN – First Sites Selected

- To encourage **cost-effectiveness**
- Recommended to utilise **existing networks (ICP or Article 17)**
  - Data already collected
  - May already have funding to be carried out

- Monitoring for first submission prioritised
  - on Forests - **ICP Forests**
  - on Freshwaters - **ICP Waters**

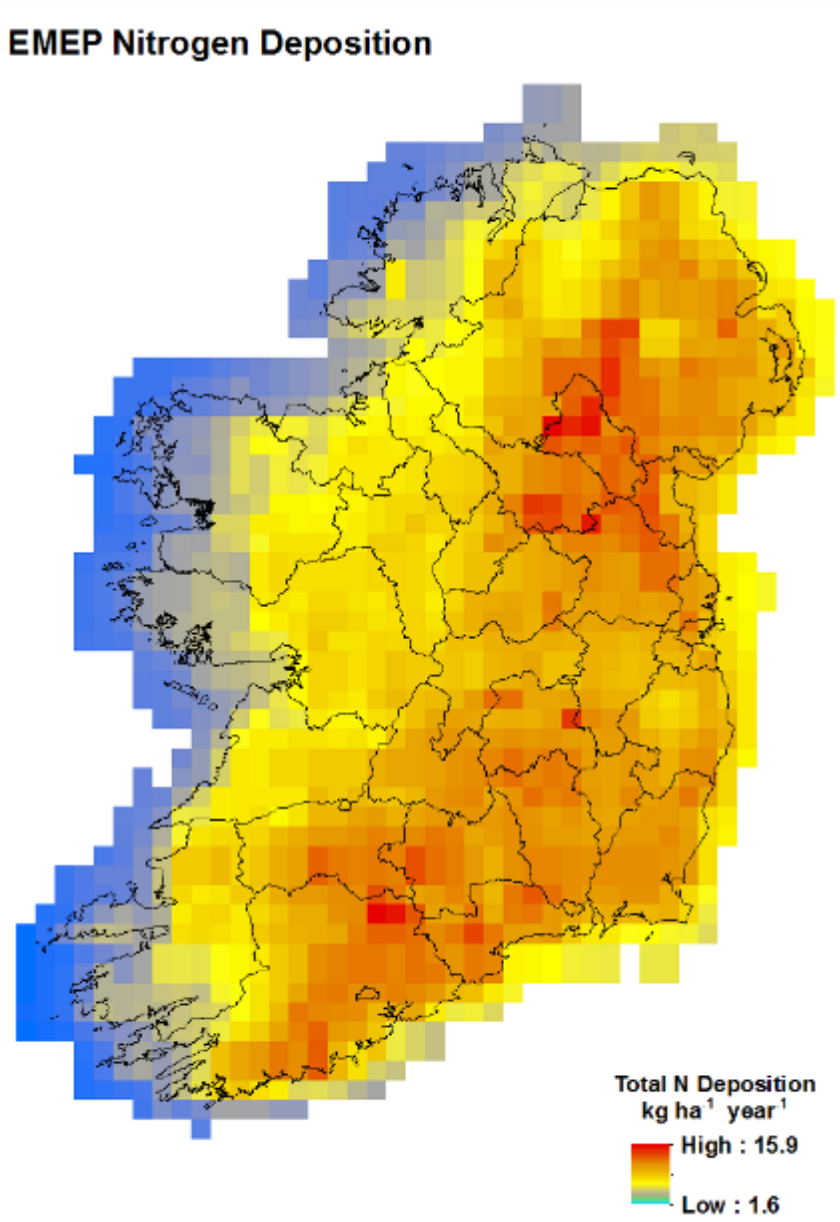
NEMN Level I: **Risk-based approach to site selection**

Sites should be:

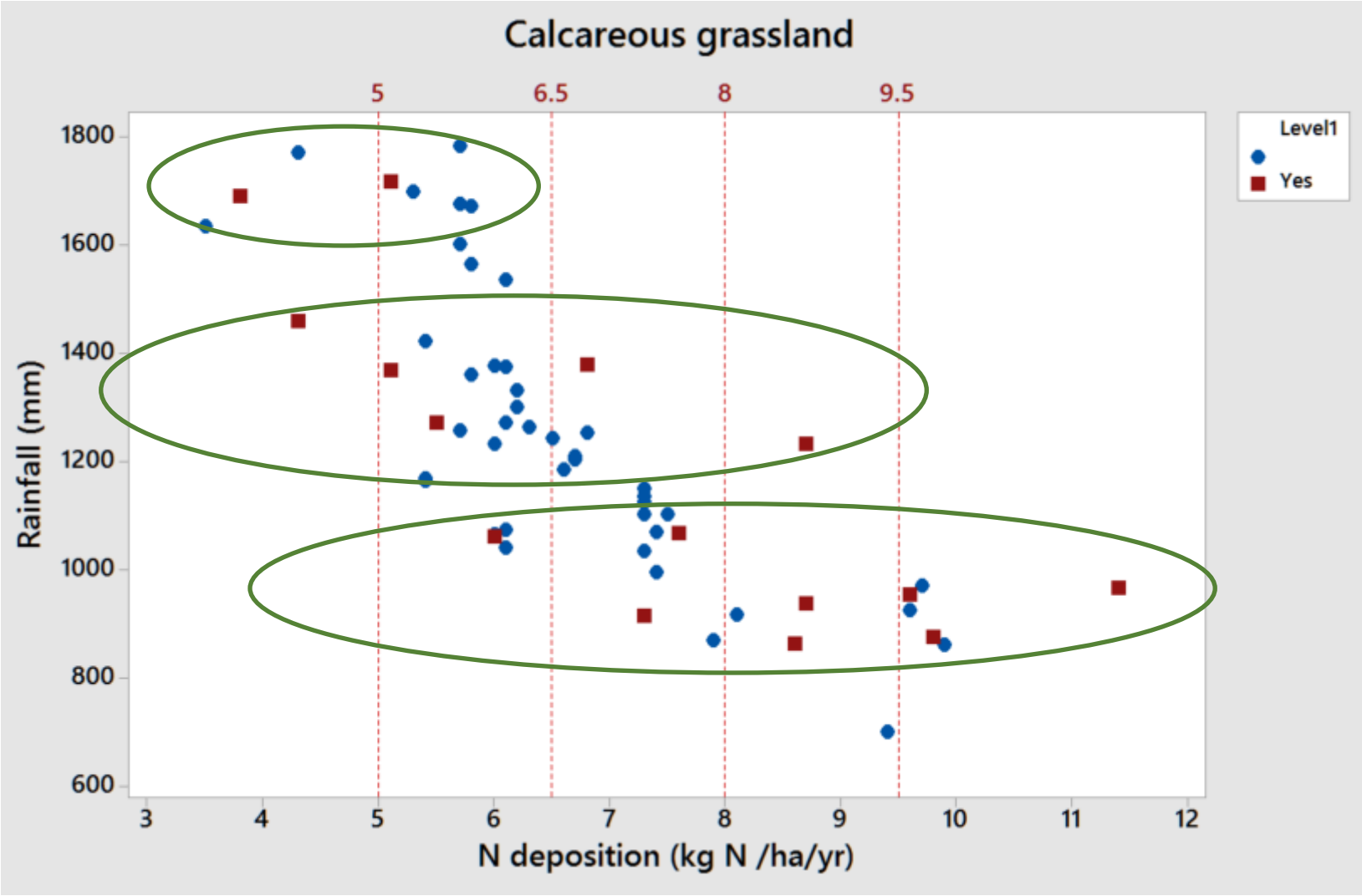
- Representative of N risk
- Take account of co-correlated or modifying factors
  - i.e. Rainfall

Selection

- 15 per habitat – selected from existing Habitats Directive monitoring schemes
- Balanced across N dep gradient (& rainfall)
- Practical considerations
  - Links to other networks, inclusion of key Level II sites

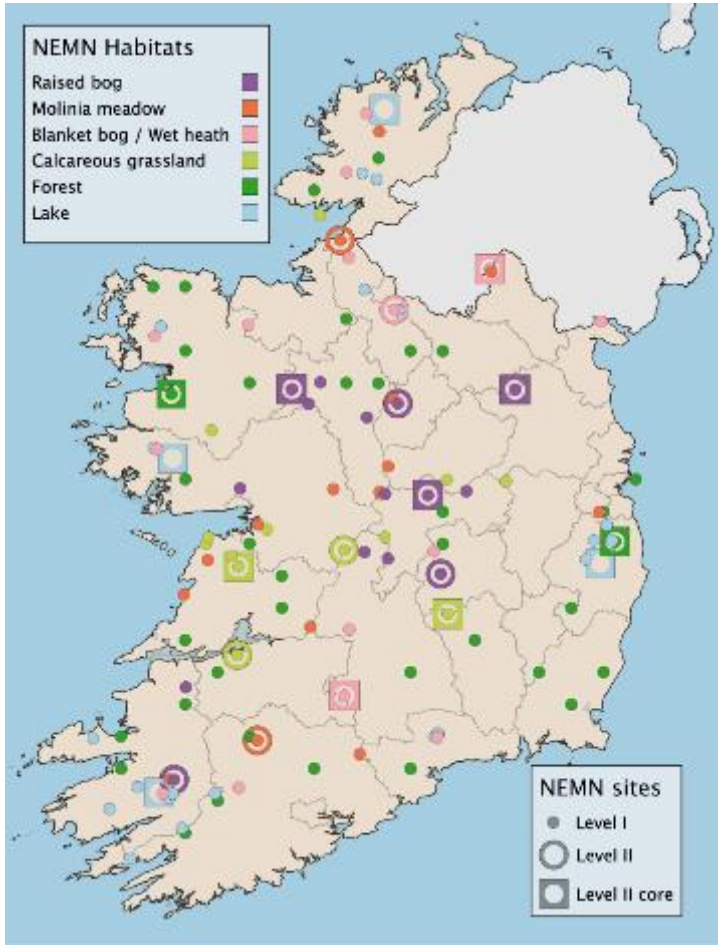


NEMN Level I: **Calcareous grassland**



NEMN Structure

- Tiered approach to site selection;
  - **Level II core** – Detailed air quality monitoring
  - **Level II** – Just NH_3 monitoring
  - **Level I** – Biodiversity & soil monitoring
  - **Level 0** – Quadrats collected during any other national surveys



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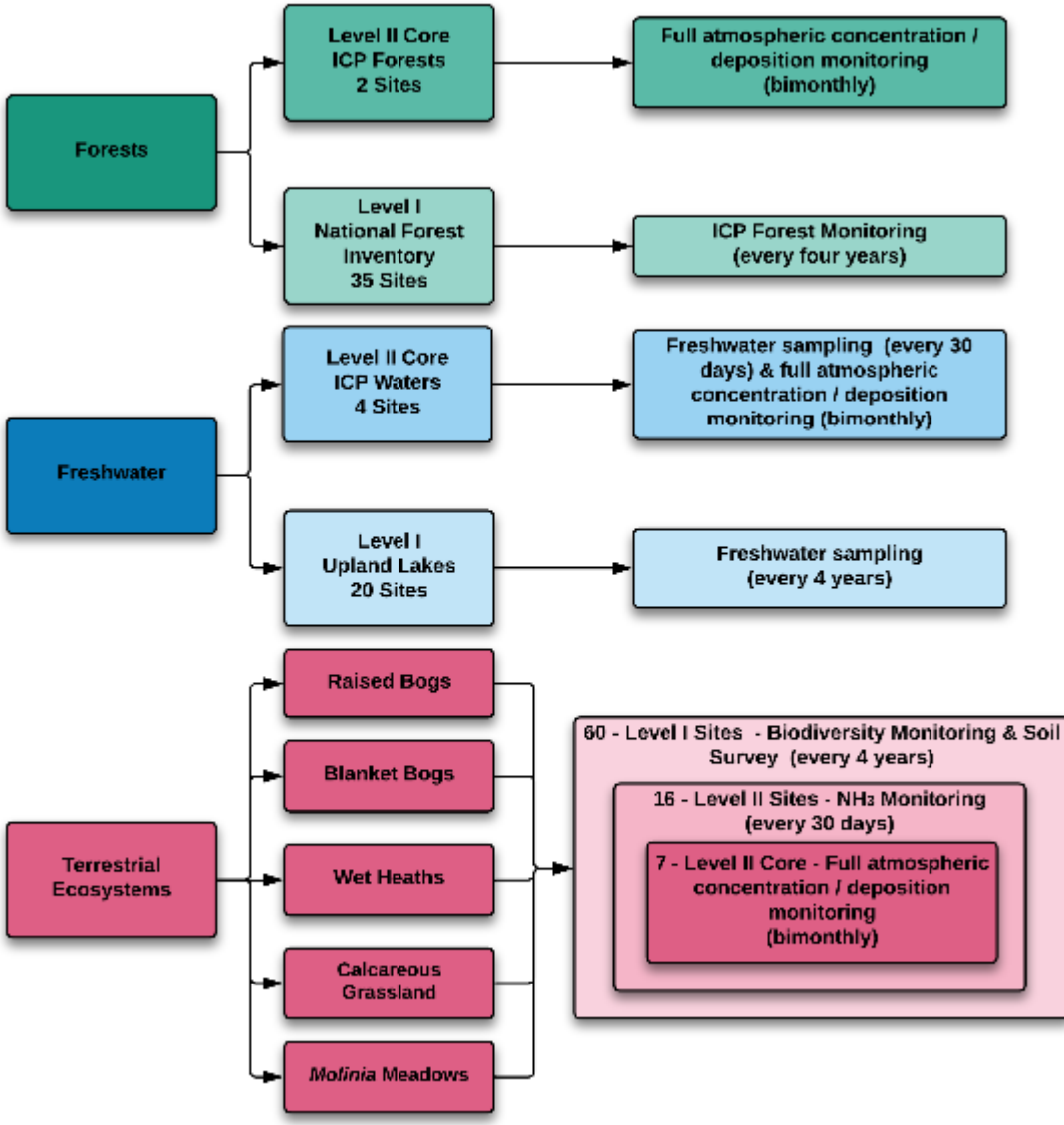
NEMN Structure

- **Department of Agriculture Food & Marine** - Forests
- **National Parks and Wildlife Service** - Terrestrial Ecosystems
- **Environmental Protection Agency -** Freshwaters

- Ensuring monitoring complies with needs of
  - **DAFM, NPWS** & **NEMN**
  - modification of standard approaches



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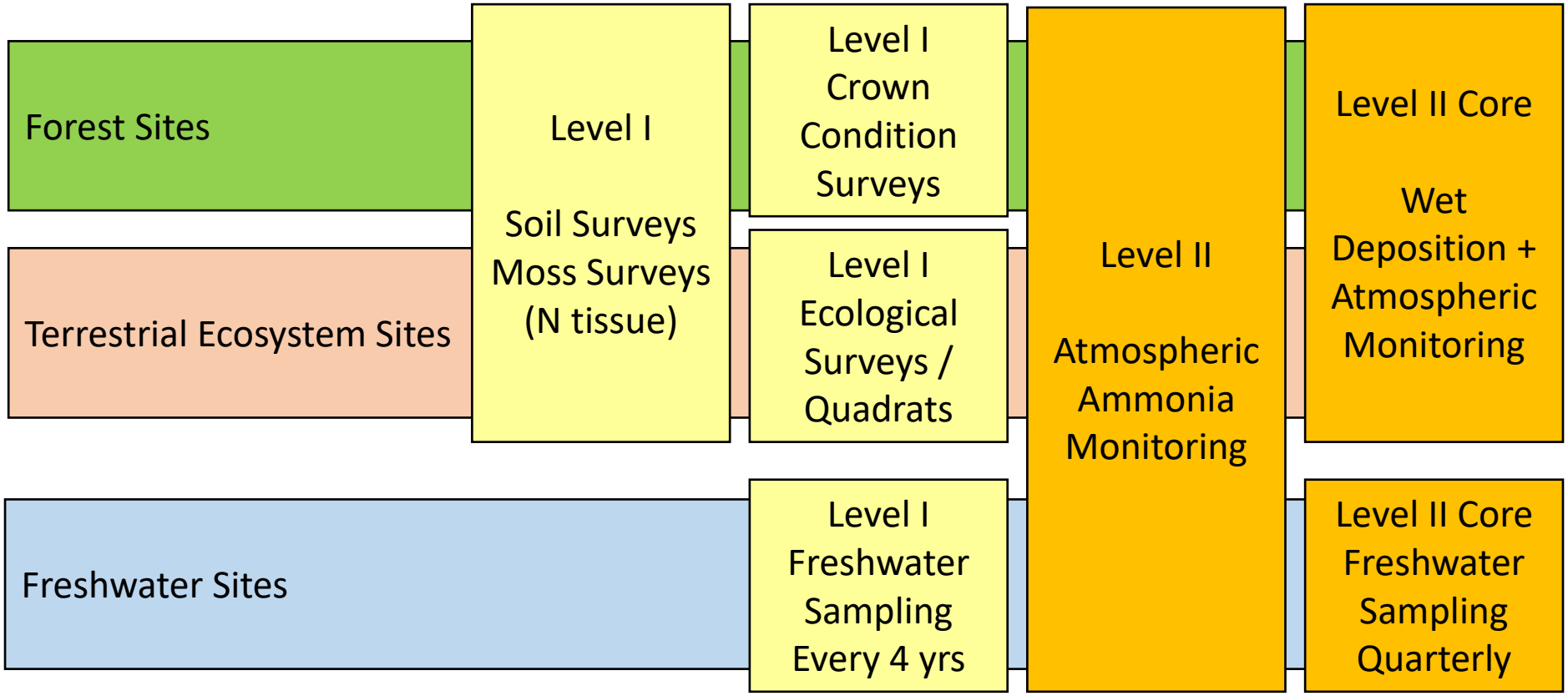
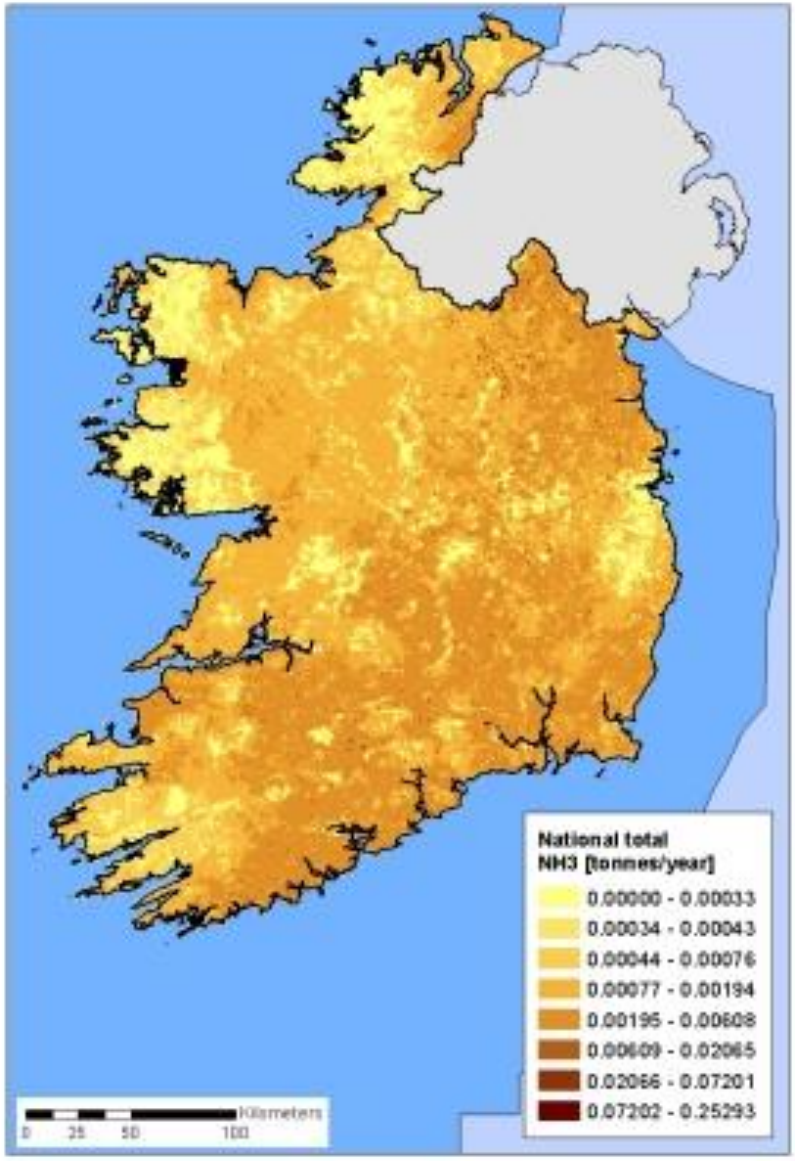
NEMN Surveys



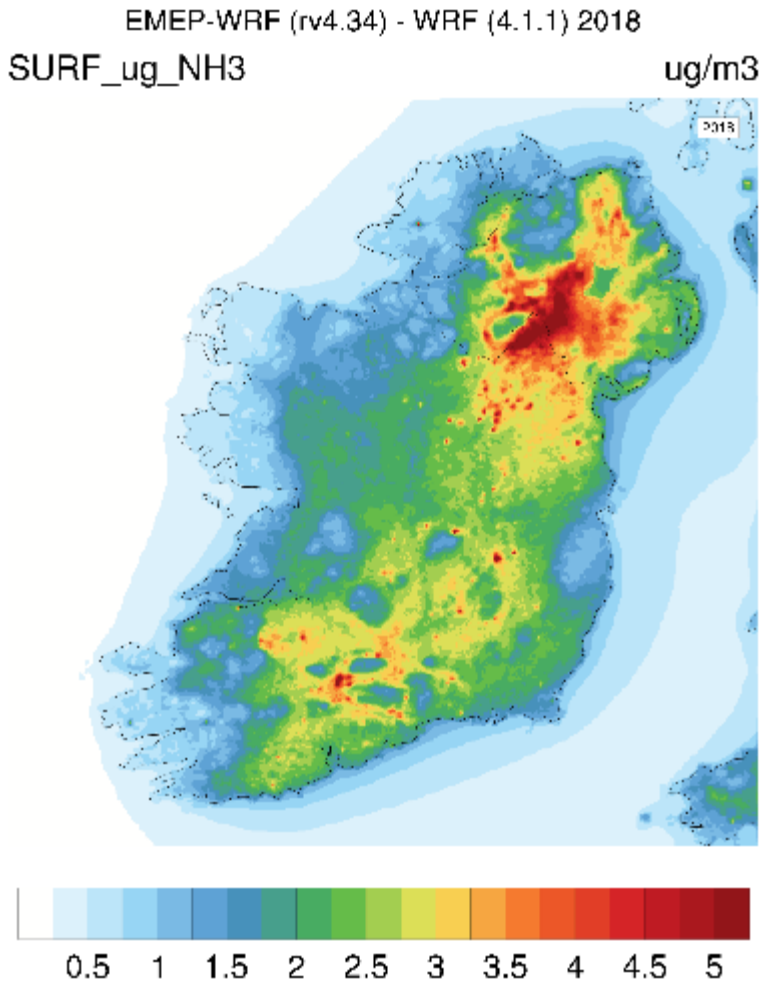
MapEIre

- Spatial NH_3 emissions inventory
- Developed by the University of Aarhus
- Updated annually with calculated national emissions
- Spatial data for cattle (c. 80% of emissions)
  - From 2010
- Locations of hotspot sources up to date as of 2015



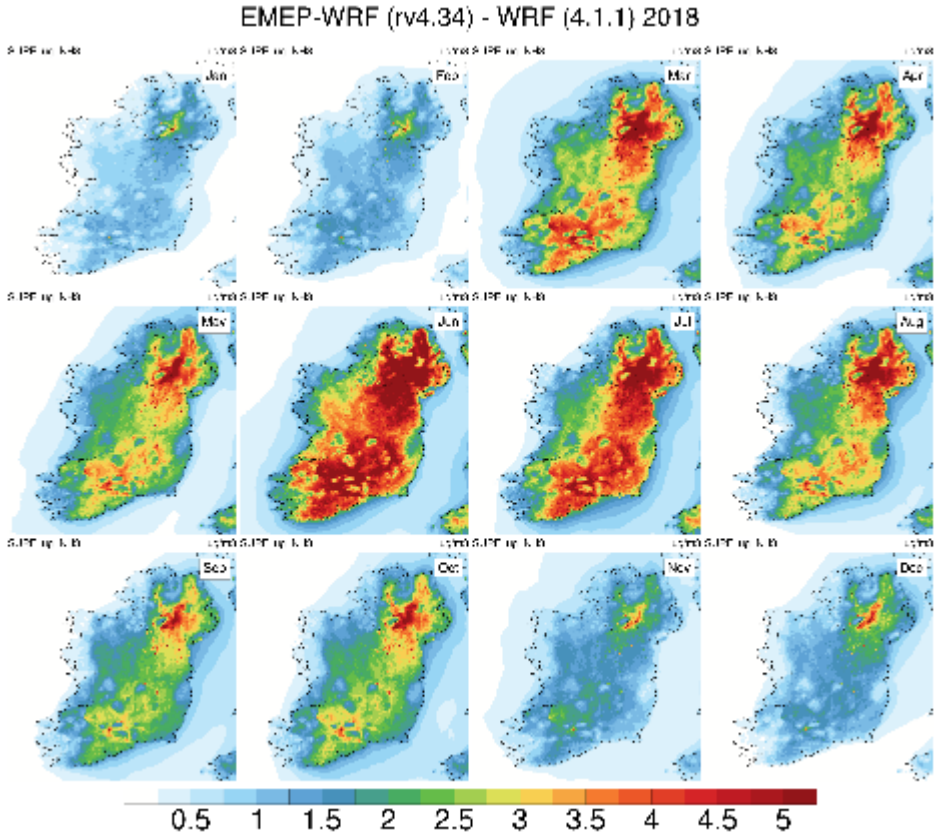
Updated modelling

- Updated models currently being developed by the UK Centre for Ecology & Hydrology
- EMEP run on 1 km^2
- Using national emission models compiled by MapEire
- Emissions model applies
  - 2018 emissions data to
  - 2010 distribution of livestock
- Includes above and below threshold pig and poultry farms as of 2015



Seasonal variation

- Similar to emissions;
- Concentrations vary seasonally
  - Highest in June
  - Lowest in January



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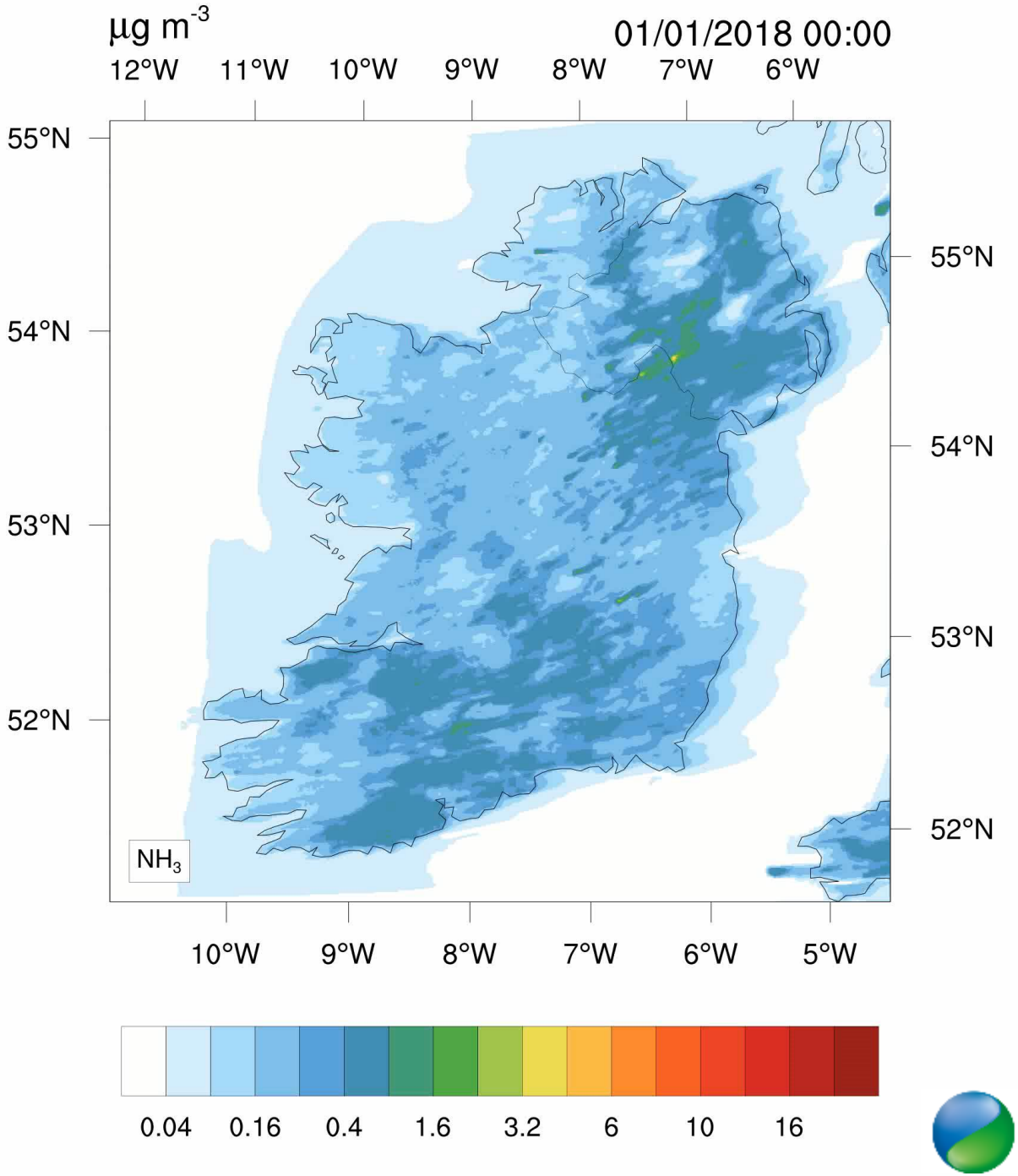

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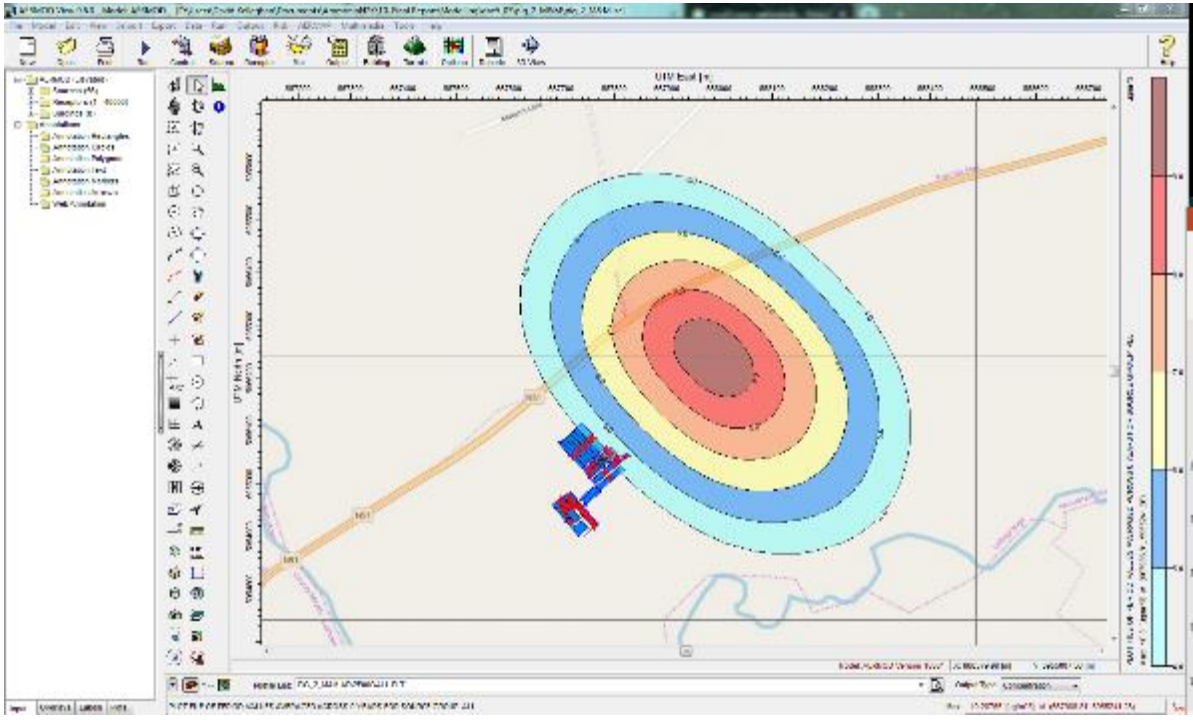
Local modelling

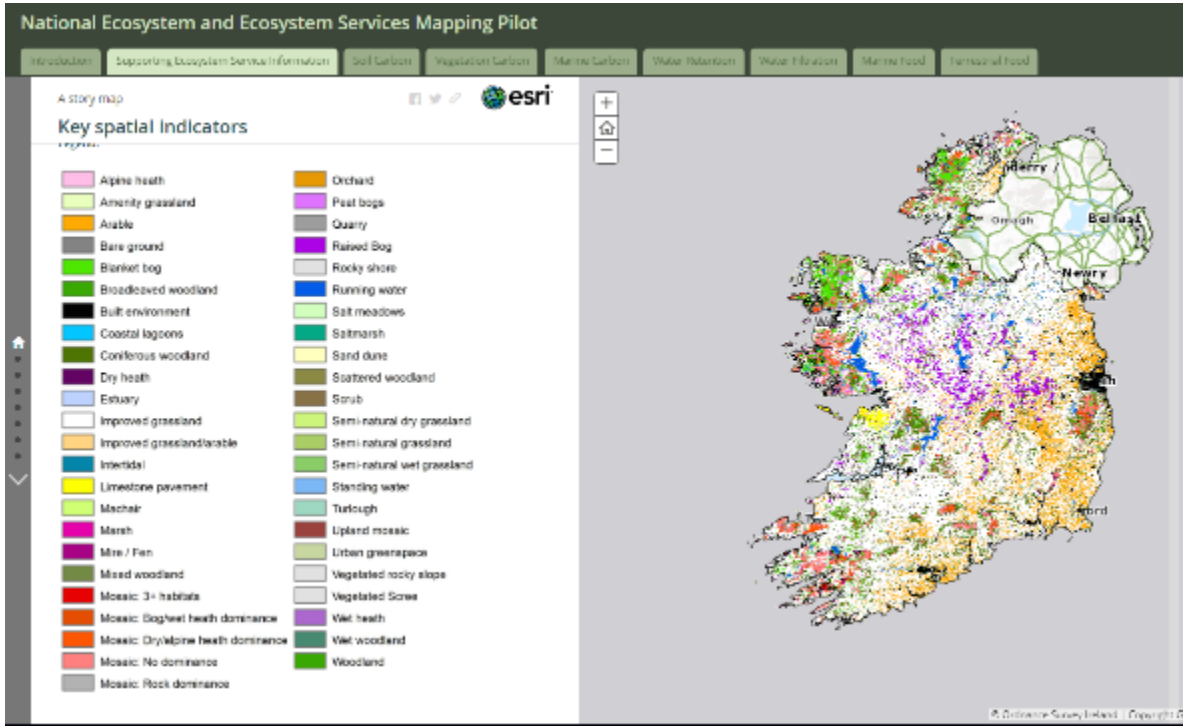
- National models don't represent high concentrations proximal hotspot sources
- For example, extent of concentrations downwind of a pig farm in Ireland below
- Important when considering end use of national models

- 9 µg m^{-3} – 320 m
- 8 µg m^{-3} – 370 m
- 7 µg m^{-3} – 415 m
- 6 µg m^{-3} – 450 m
- 5 µg m^{-3} – 500 m



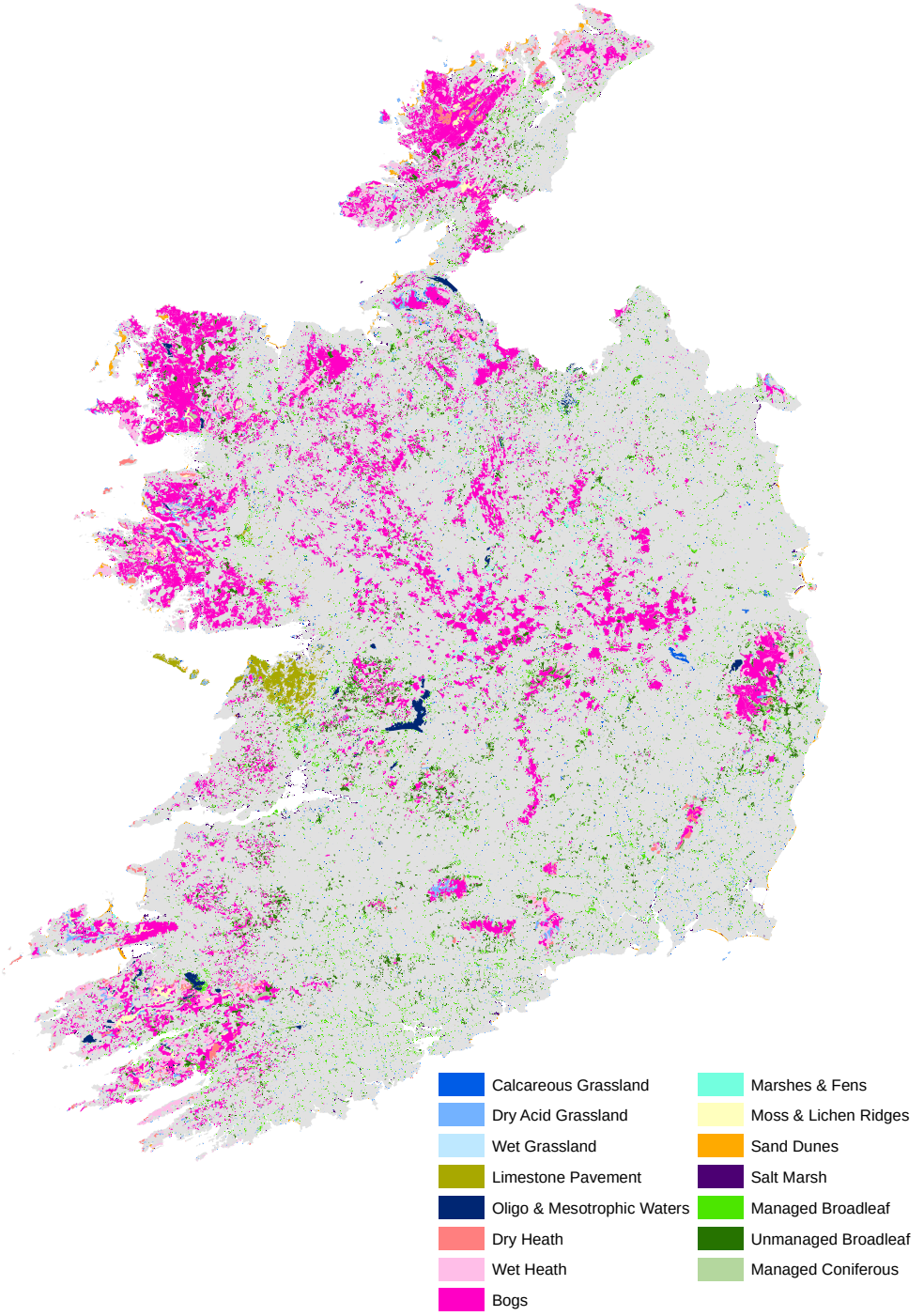
Habitats Assets Register

- Most complete picture of habitats in Ireland currently available
- Combined over 40 different habitat datasets
- Most complete national scale ecosystem services habitat map possible
- Created and maintained by National Parks and Wildlife Service



Ecosystem Receptor Map

- Based on NPWS Habitats Assets Register
- Slight modifications for some, e.g;
- Calcaerous grasslands
  - Semi natural grasslands over calcareous soils
- Oligotrophic/Mesotrophic lakes
  - Water bodies over specific bedrocks



Applied Critical Loads

- Critical loads applied based on;
- Empirical Critical Loads
- Vegetation Change Points developed for Ireland
  - University of Trent
  - e.g. Wilkins, K., Aherne, J. Bleasdale, A. (2016) **Vegetation community change points suggest that critical loads of nutrient nitrogen may be too high,** Atmospheric Environment, Volume 146, 2016,Pages 324-331, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2016.07.016.

Habitat Group	Kg N ha^{-1} $year^{-1}$
Salt Marsh	7.5
Sand Dunes	7.5
Oligotrophic and Mesotrophic Water bodies	4
Bogs	5
Marsh & Fen	7.5
Dry acid grassland	5
Wet Grassland	10
Calcareous Grassland	10
Moss & Lichen Ridges	7.5
Limestone pavement	7.5
Marsh and fen	7.5
Wet Heath	5
Dry heath	7.5
Unmanaged broadleaf woodland	10
Managed broadleaf woodland	Mass Balance
Coniferous woodland	Mass Balance

Submission to CCE

- Ireland has submitted data to CCE for;
  - nitrogen deposition
  - nutrient nitrogen critical loads

- Currently updating data to be submitted shortly;
  - New critical loads for acidity map
    - Updated evapotranspiration models
    - Updated mineralogy
  - Mass balance for managed woodlands

Conclusions

- Ireland now has hourly 1 km^2 EMEP concentration model
  - Will improve subsequent deposition models
- Best available data expands on CORINE mapping;
  - To include data from physical surveys
- National monitoring networks under NECD will benefit validation of future pan European and national models
  - Tiered approach recommended
  - European EMEP model appropriate risk base
- May want to consider use of models and interpretation by consultants when applying models during assessments

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- LinkedIn @David Kelleghan
- Research Gate @David Kelleghan