

Effects of ammonia on soil in Scotland with different farming techniques.

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Background

- Agricultural activities causes ammonia release in soil and atmosphere (Behera et al., 2013).
- The use of fertilisers causes increase in ammonia volatilisation (Cameron et al., 2013).
- Ammonia release causes soil acidification (Van Damme et al., 2018).
- Amount of organic matter in soil determines soil quality (Pimentel et al., 2014).

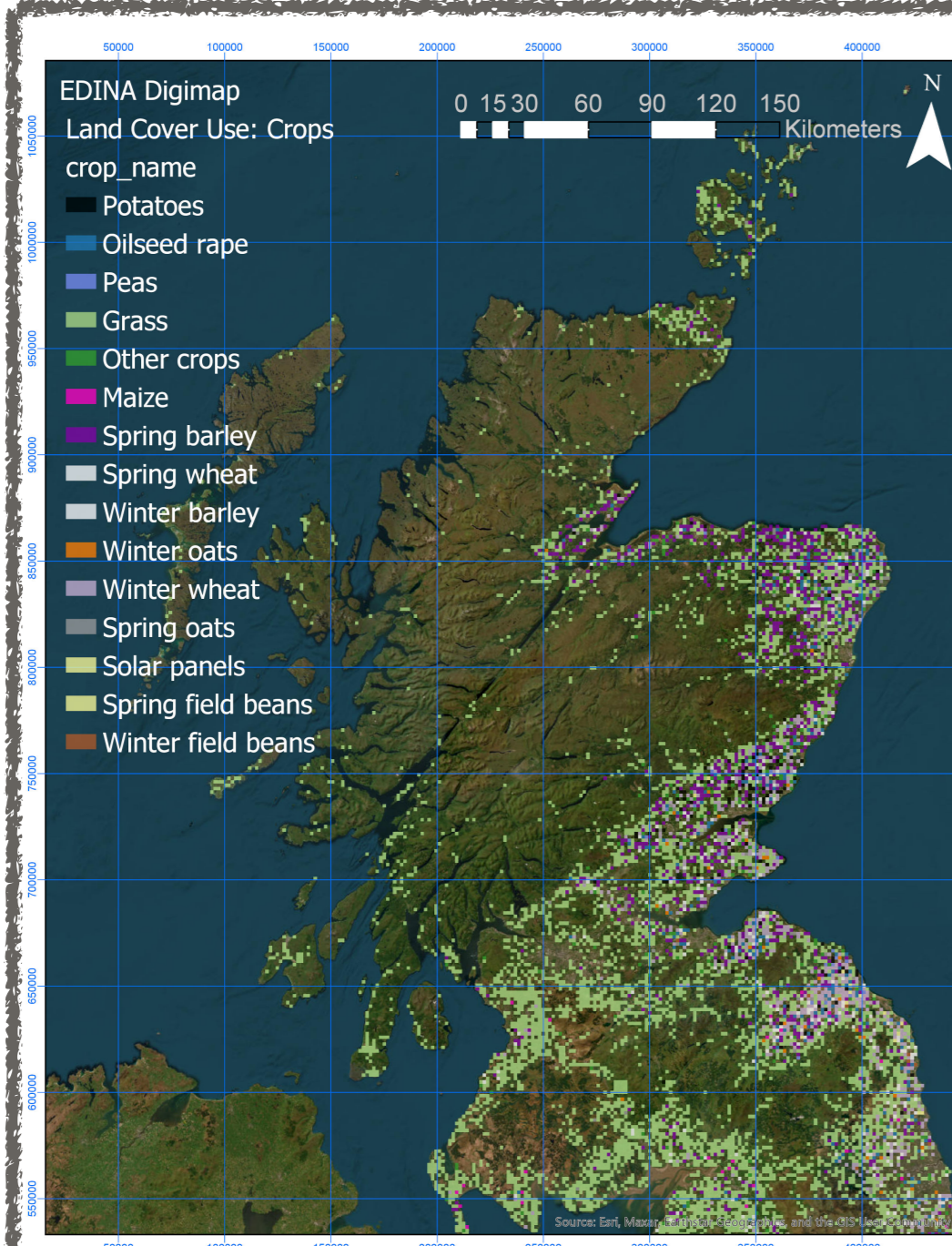


Fig. 1. Agriculture in Scotland

Key Questions

- Does effects of ammonia differ on soil between organic and conventional farms?
- How much the soil acidification differs between organic and conventional farms?
- Does soil composition differ between organic and conventional farms?

Aims

- Perform spatial analysis to study the effects of ammonia on soil with different farming techniques.
- Create a Model to identify better soil composition across Scotland.

Objectives

- Fieldwork & Geospatial analysis.
- Soil composition analysis.
- Comparative study for different methods of farming.
- Multi-criteria Analysis based model.

Methodology

Process 1: Field Work & Geospatial Analysis

- Field Work visits in Aberdeenshire.
- Field Work & Geospatial datasets representation in ArcGIS Pro.
- Visualisation and transformation of geospatial and field work data
- Overlay maps, comparison & analysis.

Process 2: Modelling

- Multi-criteria Analysis based model using AHP method
- Defining Goal, Criteria, and Alternatives
- Prioritisation, Scoring and Raking of alternatives.
- Identify preferred alternative.

Fieldwork

- pH levels measurement & farming practices survey.

Dates	Location	Method	Farm Type	pH
13/06/23	SRUC Tulloch	Organic	Arable	6.8
13/06/23	SRUC Tulloch	Organic	Grazing	6.4
16/06/23	New Aberdour	Organic	Arable	6.4
16/06/23	New Aberdour	Organic	Grazing	6.7
16/06/23	New Aberdour	Organic	Silage	6.8
26/06/23	SRUC Conventional	Conventional	Arable	5.6
26/06/23	SRUC Conventional	Conventional	Grazing	5.9
26/06/23	SRUC Conventional	Conventional	Silage	6.4

Table 1. Fieldwork data from Aberdeenshire

- Farm survey about conventional/organic method, # of years, arable/pastoral/mixed, product, fertiliser/pesticide used, type of soil (<https://arcc.is/1fuOb5>).

Agricultural Region (Geospatial Analysis)

- No Class 1 (very wide range of crops) land in Scotland.
- Limited Class 2 land (wide range of crops).
- Majority of agricultural region is Class 3 (good yield) or Class 4 (narrow range of crops) land in Scotland.
- Rest of Scotland is Class 5 (improved grassland), Class 6 (rough grazing) and Class 7 (limited agricultural value).

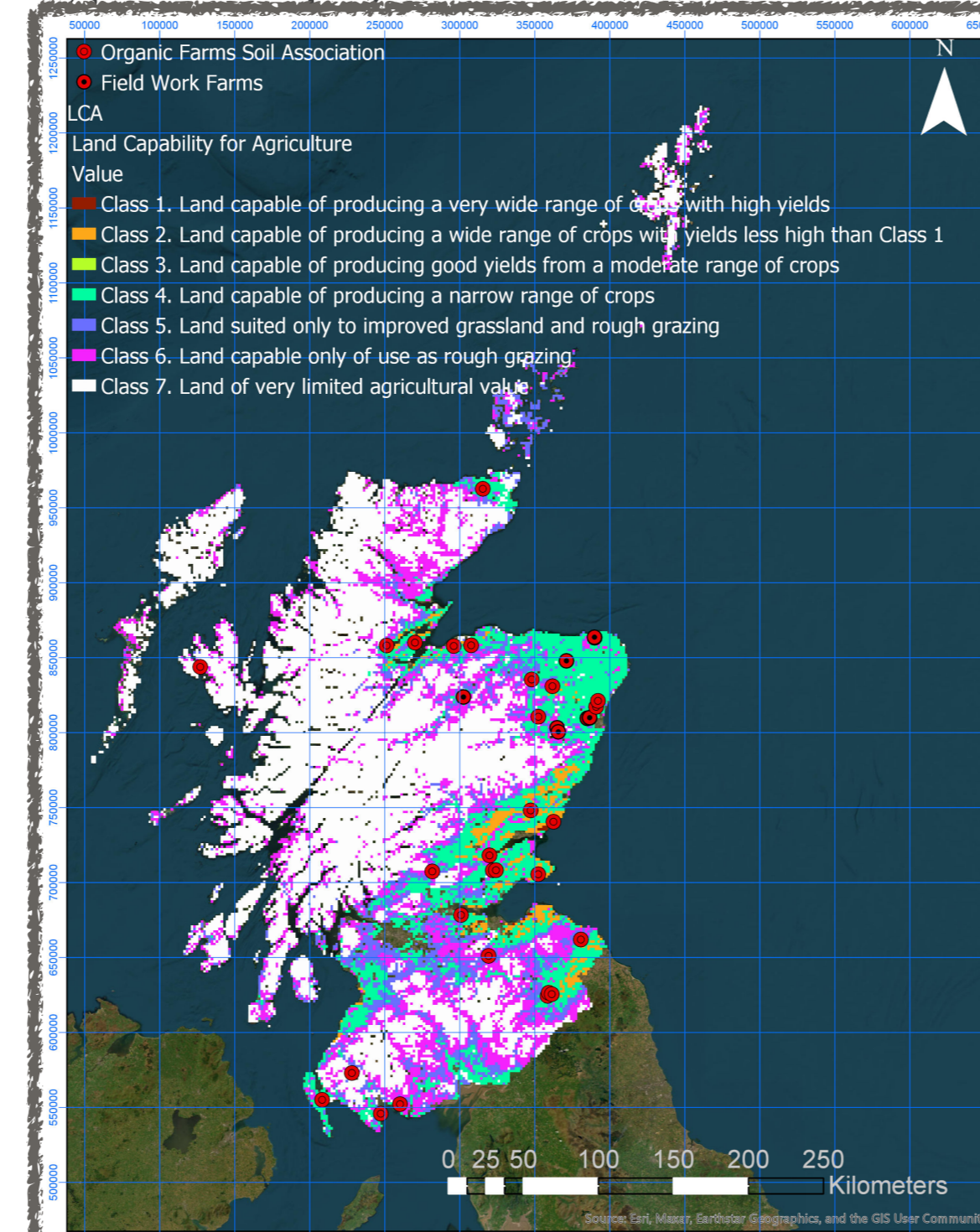


Fig. 2. Land classes in Scotland

Agricultural Ammonia & Organic Farms

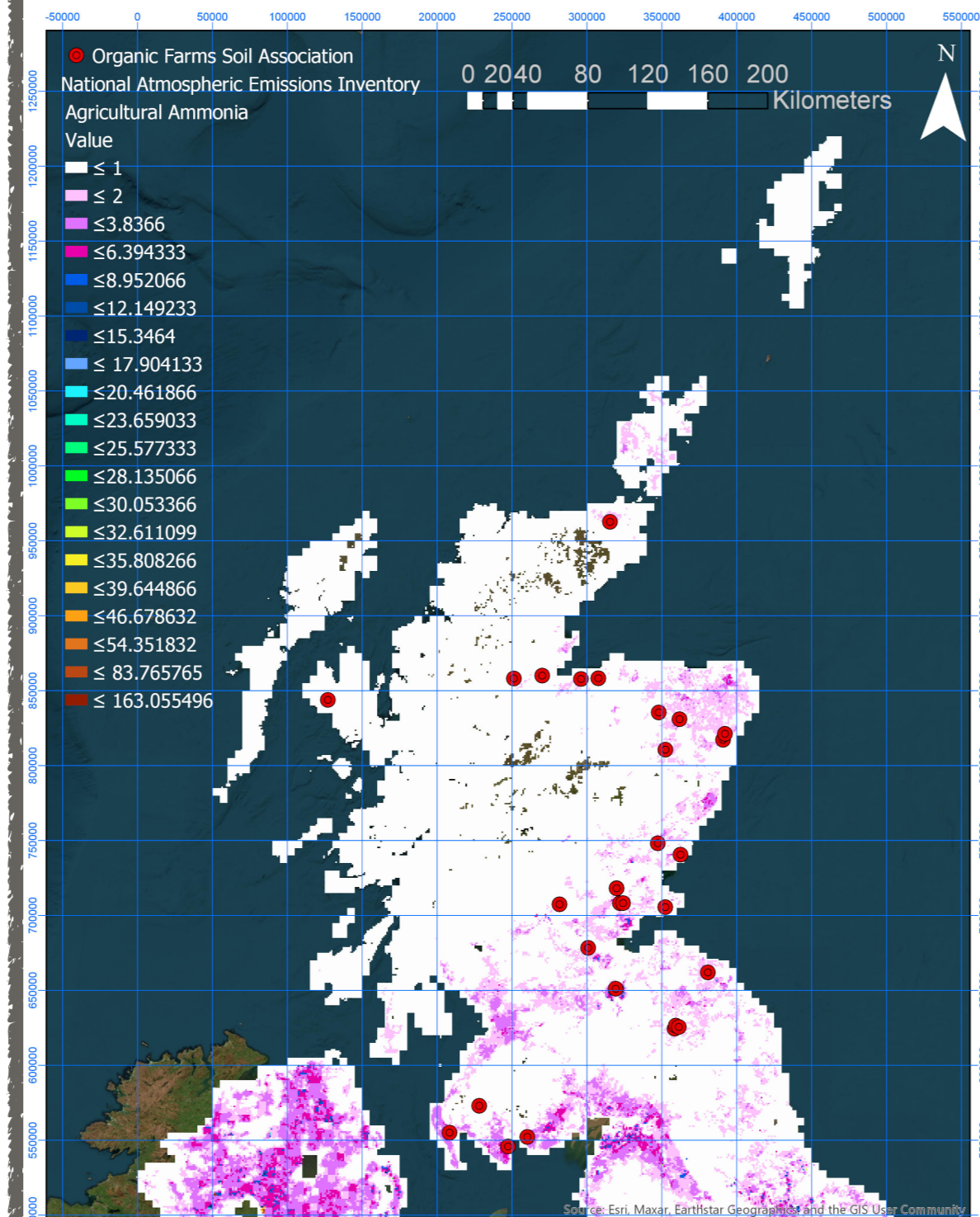


Fig. 3. Agricultural Ammonia at organic farms

- Ammonia releases into atmosphere from soil (Killpack et al., 2022).
- More than 1 tonne/km² of ammonia emissions found in agricultural region of Scotland.
- Less than 1 tonne/km² of ammonia was found at 21 out of 29 organic farms.
- Organic farms have comparatively lesser ammonia emissions compared to others.

Soil Analysis (UKSO Dataset)

Loss-on-ignition (LOI) is % of organic matter (higher the better). Agricultural region in Scotland has lower LOI compared to other regions.

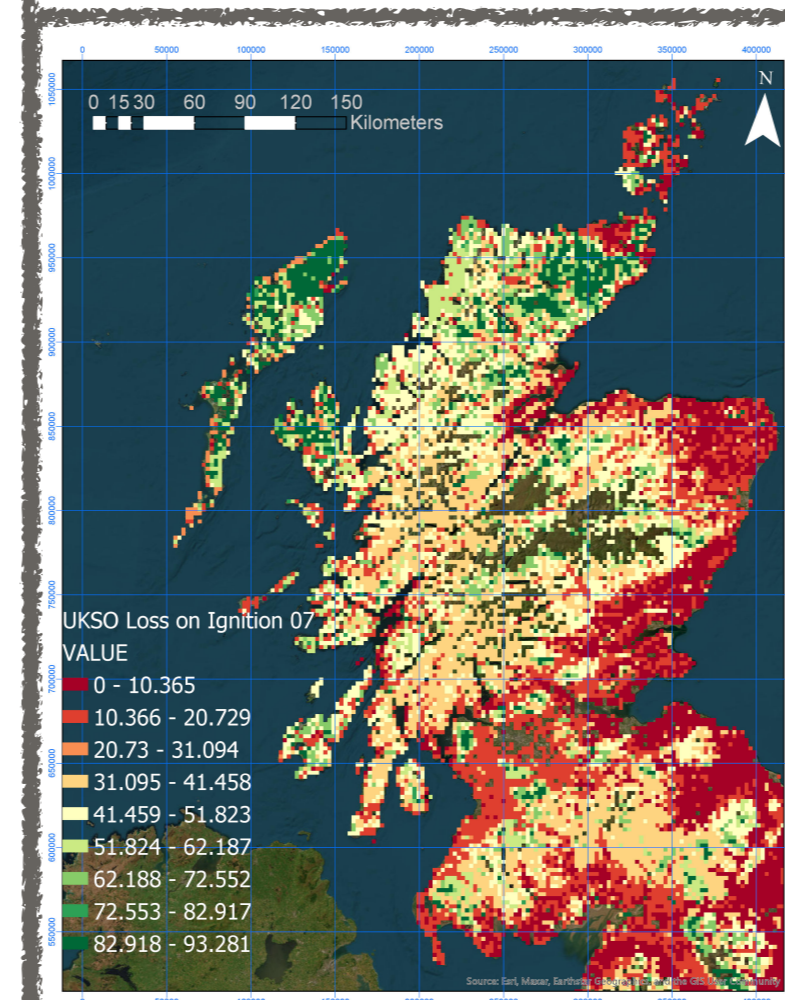


Fig. 4. Loss-on-ignition

Agricultural region in Scotland is within expected range of Carbon to Nitrogen Ratio between 1-15.

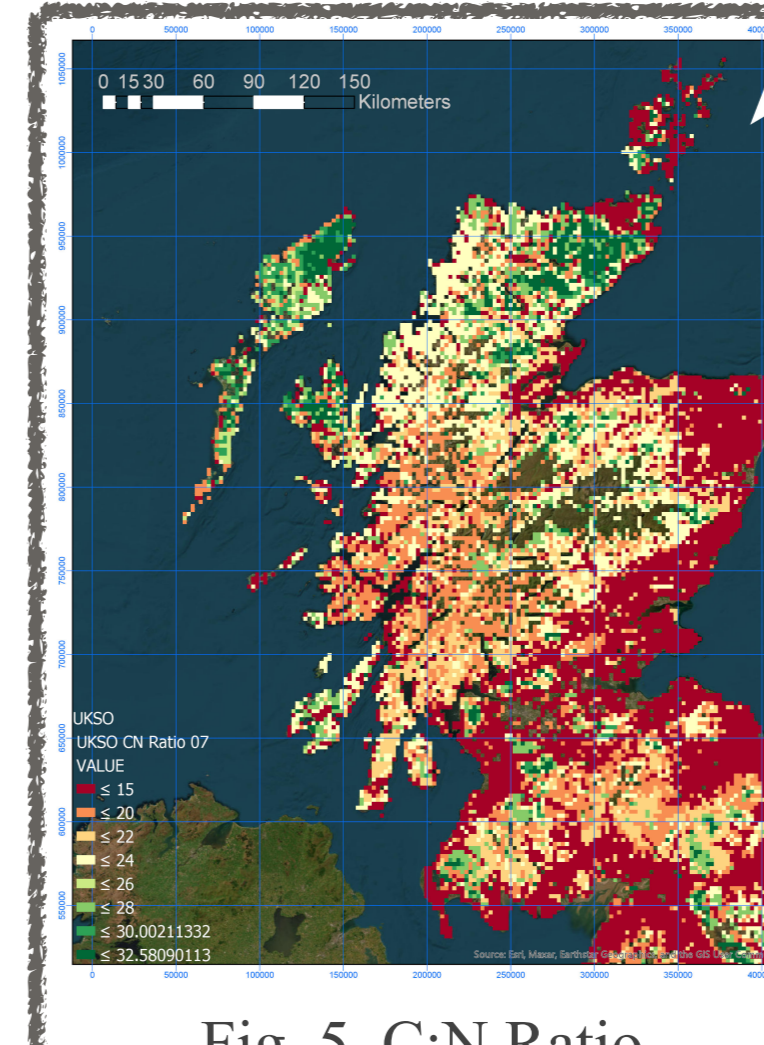


Fig. 5. C:N Ratio

Nitrogen Concentration in agricultural region is lower than expected range of 0.5 to 2.5 percent.

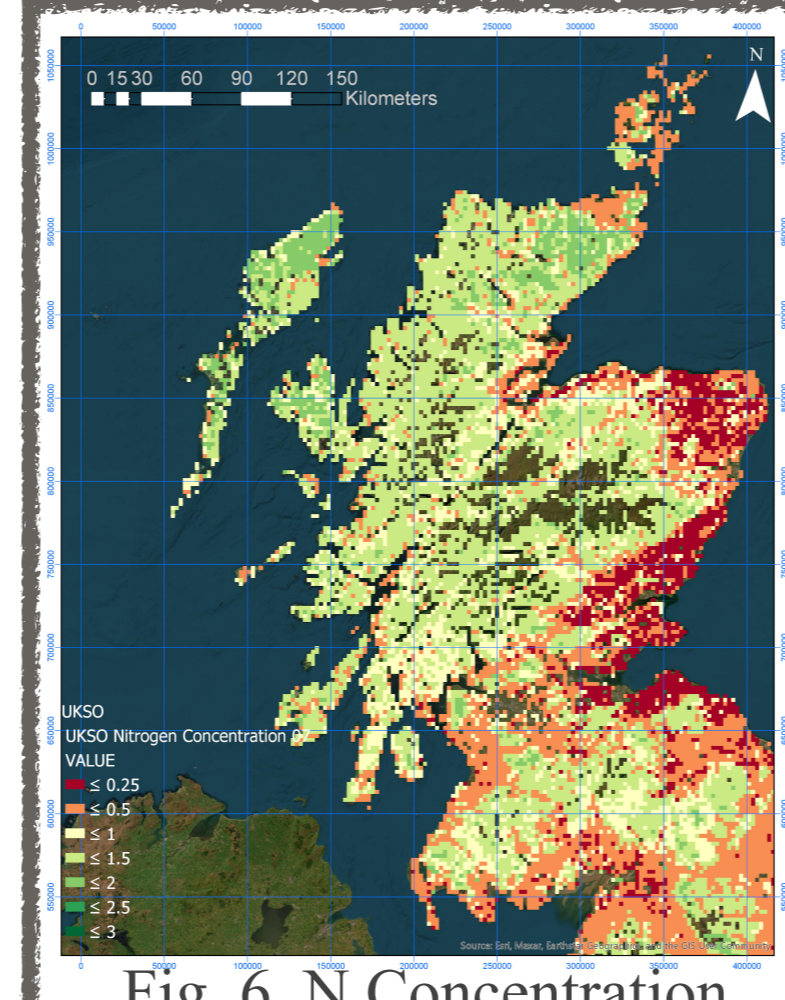


Fig. 6. N Concentration

Agricultural region in Scotland has higher (6-8) pH levels but within expected range between 5.5 and 8.

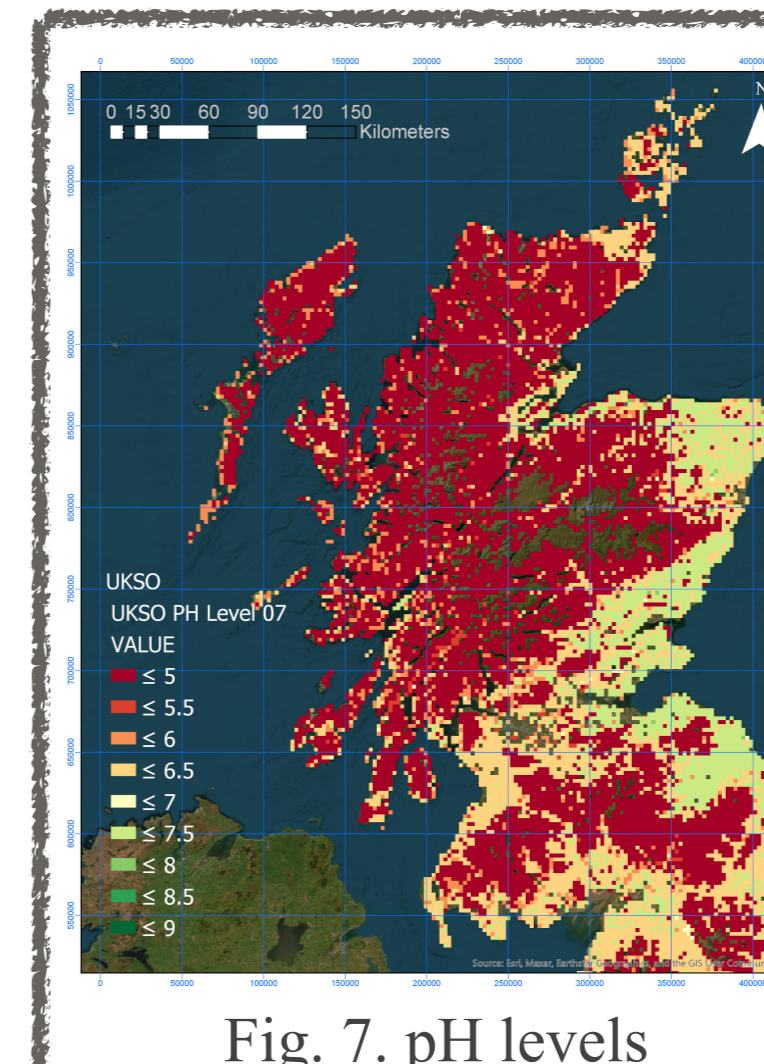


Fig. 7. pH levels

Agricultural region in Scotland has higher bulk density (lower the better).

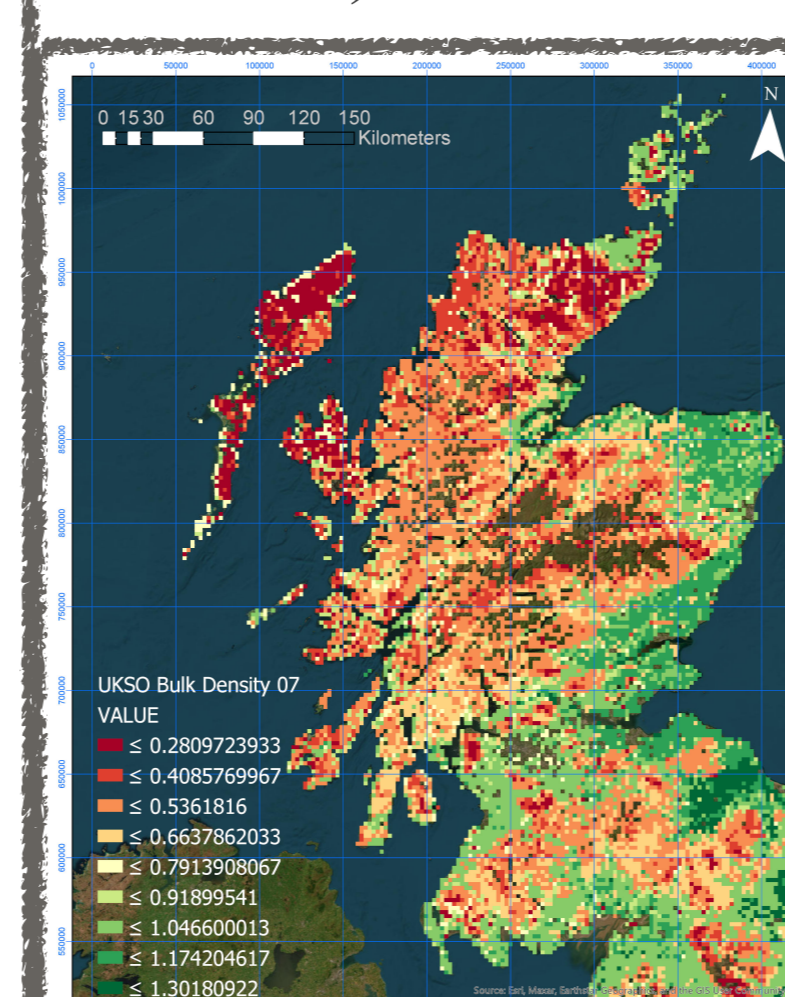


Fig. 8. Bulk Density

Agricultural region in Scotland has significantly higher Olsen-Phosphorus levels than expected between 10 to 40 mg/kg.

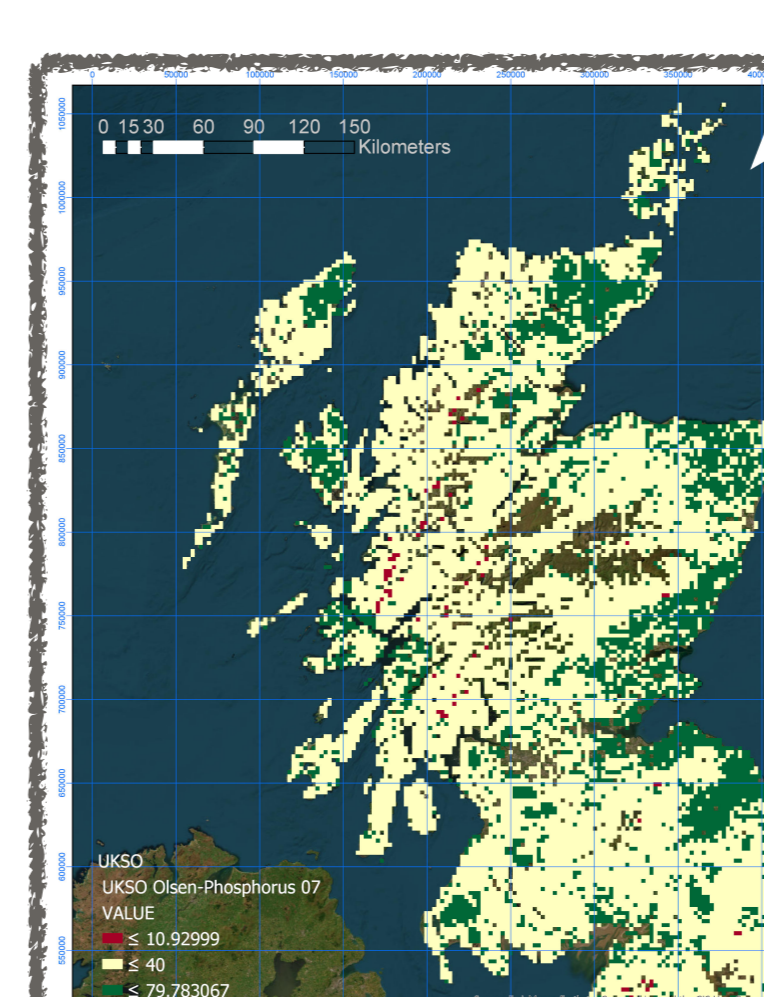


Fig. 9. Olsen Phosphorus

Soil Comparison in Agricultural Region

Soil Attribute	Organic Farms (Mean)	Agriculture Region (Mean)
Bulk Density	0.97 g/cm ³	0.94 g/cm ³
C:N Ratio	12.40	12.92
Carbon Concentration	63.53 g/kg	70.45 g/kg
LOI	10.87%	12.12%
Nitrogen Concentration	0.38%	0.45%
Olsen Phosphorus	36.83 mg/kg	35.73 mg/kg
pH levels	6.2	6.18

Table 2. Soil comparison in agricultural region

- Negligible difference found between average soil compositions attributes of organic farms and rest of the agricultural region in Scotland.
- Organic farms can also be maintained similar to other farms.

Multi-criteria Analysis Model (MCA with AHP)

MCA & AHP: Analytical Hierarchy Process (AHP) is a discrete method of Multi-criteria Analysis to reduce a decision problem with too many factors make it humanly possible to solve (Dean, 2022).

Goal: Identify better soil composition.

Alternatives: Land Classes (UKSO LCM Classes), namely Bog, Arable and Horticulture, Coniferous Woodland, Broadleaved Woodland, Improved Grassland, Rough Grassland, Heather Grassland, Acid Grassland, Heather, Neutral Grassland, Fen, Marsh and Swampland.

List of criteria / pair-wise matrix:

Criteria	pH (Avg)	Olsen -P (Avg)	Bulk D (Avg)	CN Ratio (Avg)	NCONC (Avg)	CCO NC (Avg)	LOI (Avg)	Weights = 1/Σcolumns
pH (Avg)	1	2	3	4	5	6	7	0.04
Olsen-P (Avg)	1/2	1	2	3	4	5	6	0.05
BulkD (Avg)	1/3	1/2	1	2	3	4	5	0.06
CN Ratio (Avg)	1/4	1/3	1/2	1	2	3	4	0.09
NCONC (Avg)	1/5	1/4	1/3	1/2	1	2	3	0.14
CCO NC (Avg)	1/6	1/5	1/4	1/3	1/2	1	2	0.22
LOI (Avg)	1/7	1/6	1/5	1/4	1/3	1/2	1	0.39

Table 3. List of criteria and pair-wise matrix

Top 3 ranked alternatives after standardisation:

Alternatives	Criteria							Rank
wj × xj(a)	LOI (Avg)	NCONC (Avg)	CN Ratio (Avg)	BulkD (Avg)	Olsen-P (Avg)	pH (Avg)	v(a)	
Bog	0.39	0.14	0.00	0.06	0.05	0.00	0.63	1
Fen, Marsh and Swampland	0.19	0.14	0.06	0.05	0.05	0.04	0.51	2
Heather Grassland	0.24	0.14	0.02	0.06	0.05	0.00	0.50	3

Table 4. Top 3 ranked land classes (alternatives)

Conclusion

- Fieldwork highlighted arable conventional farm has lower pH by up to 1.0 unit compared to organic arable farms.
- Agricultural ammonia was found lower than 1 tonne/km² at 21 out of 29 organic farms compared to rest of agricultural region in Scotland.
- No significant difference found in average soil composition values between organic farms & entire agricultural region in Scotland.
- MCA model found Bog land class to have better soil composition due to high organic matter and carbon content.

Cited References

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