Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-94:
Developing a new Soil Health Alert Indicator for Agricultural Landscapes Across Wales

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Abbreviations Used in this Report

ALC	Agricultural Land Classification
AMR	Anti-microbial resistance
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
EU	European Union
GMEP	Glastir Monitoring and Evaluation Programme
NFS	National Field Survey
PFAS	Per- and polyfluoroalkyl substances (forever chemicals)
SLM	Sustainable Land Management
SOM	Soil Organic Carbon
UKCEH	UK Centre for Ecology & Hydrology

Contents

1 BACKGROUND

There is a need to create a single integrated indicator of soil health in agriculture for the Agriculture (Wales) Act 2023 as one of a suite of indicators being discussed by ERAMMP as part of work commissioned by the Welsh Government.

The stakeholder community consulted agreed soil health was an important component to track progress towards sustainable production as soil underpins all agricultural production.

The 2023 Agriculture (Wales) Act establishes Sustainable Land Management (SLM) as the overarching framework for agricultural policy in Wales. Integral to SLM is the aim to ensure soils, water and crops are used for the production of goods in a way that balances the needs of the current population with our obligations to future generations (Welsh Government, 2023). Four major objectives underpin SLM's aims:

1. Sustainable production of food and other goods.
2. Mitigating and adapting to climate change.
3. Maintaining and enhancing ecosystem resilience, including the benefits they provide.
4. Conserving and enhancing cultural resources, as well as public access and engagement with the countryside.

The 2023 Agriculture (Wales) Act requires indicators and targets to be set to track progress towards the delivery of each SLM objective. Our ambition is to include soil health as part of the wider suite of indicators which are being recommended as of July 2025 to present to the wider stakeholder community. Healthy soil is integral to the sustainable production of food and fibre, sequestering carbon and preventing further greenhouse gas emissions, regulating water quality and hydroclimate risks, and preserving the heritage and breadth of ecosystem services the Welsh countryside provides. Welsh Government will make the final decision regarding the suite of indicators and appropriate targets taking into account the recommendations of the ERAMMP team and the feedback from the stakeholder community.

The approach developed follows the principles of those taken by the EU for their EUSO DashBoard[1] with a focus on trigger points The novelty of the whole approach taken for Wales is:

I. The indicator reports the percent of soils which exceed trigger points i.e. not a national average. This recognises the lack of sensitivity of a national average to change as for example, the best performing soils may improve and the least well performing soils decline with the result of no change reported in a national average. It also highlights attention on soils where issues could be leading to either inefficient production or poor habitat support.
II. Theses trigger points are developed for all our dominant habitat classes. This recognises that the function of soils differ across the landscape and we need to recognise soils have been managed to deliver those functions creating different soil conditions.
III. A 'one out- all out' approach is then following to provide a simple integrated indicator which captures the scale of soils where there is at least one potential issue which needs investigating i.e. the soil crosses one trigger point.

[1] https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/

2 Soil Properties and Their Trigger Points for Action

As part of the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP) National Field Survey (NFS), topsoil (0-15 cm) samples from up to five locations within each of 150 nationally representative 1 km survey squares were collected. ERAMMP (2021-2025) is the second time these locations have been sampled. Baseline monitoring was done from 2012-2016 under the Glastir Monitoring and Evaluation Programme (GMEP). Both surveys were conducted on an annual rolling basis and were set up by the Welsh Government to report national trends and monitor the effects of the Glastir agri-environment scheme on the environment. For each topsoil sample, a range of physical, chemical and biological soil properties were measured, which were used to report the current status and historical trends in topsoil condition across Wales (Emmett et al., 2025; Bentley et al., 2025). An additional 150 1-km squares were surveyed to ensure sufficient land which had entered the Glastir Land Management scheme was available for reporting on outcomes of the scheme but were not used for the work described here.

We used the portion of the 150 nationally representative 1-km squares and sample locations within that occur within agricultural land, as defined by the Agricultural Land Classification for Wales (Welsh Government, 2023), and which makes up more than 80% of land across Wales (Figure 2-1). Additionally, we filtered out peat soils as these require a separate methodology for assessment. Peat soils were excluded on the basis of 3 criteria (i) if organic matter >20% for at least the full top 40cm of soil; (ii) if the broad habitat was classed as “bog”; or (iii) if organic matter >80% in the top 15cm.

For the development of a Soil Health Alert Indicator for Wales, we followed a similar approach to what has been done in the EU (Veerman et al., 2020) to integrate multiple topsoil properties into a “one-out; all-out” assessment. As the “one-out; all-out” terminology suggests, should a soil be found to be outside of at least one trigger point, action should be taken to investigate further; if soils do not fall outside of any trigger points, monitoring should continue, but no further action may be required. Here, we have selected five priority properties of topsoil health:

- Soil organic matter (SOM,%)
- pH in deionised water (pH)
- Carbon to Nitrogen ratio (C:N)
- Bulk density (g/cm^3)
- Olsen phosphorus (Olsen P, mg/kg); for arable & horticulture and improved grassland habitats only

Each of these topsoil properties has been recorded for soils across Wales under nationally representative surveys, for both the GMEP and ERAMMP NFS. Additionally, some of these topsoil properties have established and habitat-specific reference values that are pertinent to optimum soil functioning, termed from here onwards as “trigger points”, which can be used to assess whether a soil may be at highest risk of degradation (see Bhogal et al., 2008, Black et al., 2008 and Merrington et al., 2006). In the case of arable and improved grass, trigger points pertain mainly to these habitats’ ability to sustain food and fibre production; for other habitats, the primary concerns centre around supporting optimum habitat conditions and minimising deleterious environmental interactions (e.g. contamination of connected terrestrial and freshwater ecosystems).

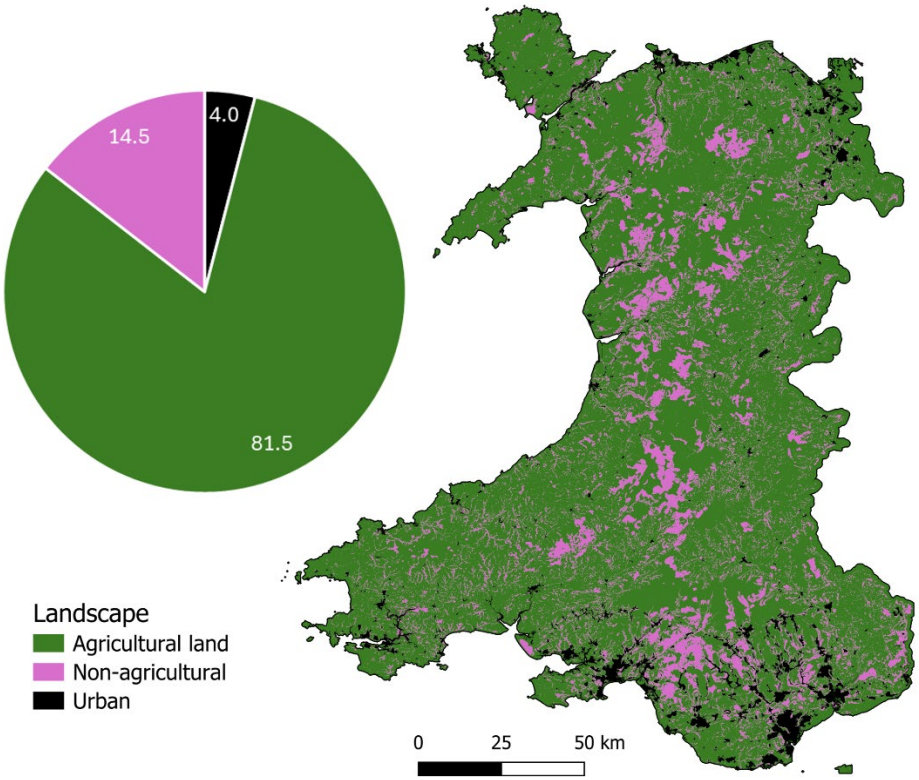

Figure 2-1 Distribution of agricultural land across Wales, according to the Predictive Agricultural Land Classification (ALC) Map version 2 (Welsh Government, 2019), with percentage coverage shown in the pie chart. Agricultural land includes arable, horticultural and grazing (including rough common grazing land). Non-agricultural land includes various "soft" uses that could be returned to agricultural use (e.g. golf courses, public parks, allotments, sports fields and soft-surfaced areas on airfields), as well as water bodies, active mineral workings and refuse tips. Urban includes built-up or "hard" uses with little potential for return to agriculture (e.g. towns, permanent caravan sites and cemeteries).

A complete set of trigger points for unique combinations of topsoil property and habitat are provided in Table 2-1 below. This development of trigger points for all dominant habitat types in Wales is critical to note as it recognises our soils have different functions and have therefore been managed differently. Soil conditions and trigger points therefore will differ reflecting these different functions.

Where trigger points were not available from existing literature, these were defined based on a set of selected distributions from the habitat-level data recorded in the GMEP survey (following an earlier approach for Great Britain by Feeney et al., 2023), as this represents the first Wales-specific national soil monitoring survey and can be used as the baseline of topsoil health in Wales. A conceptual illustration of a distribution with selected percentiles indicated is shown in Figure 2-2. The implications of this for interpretation of the indicator are elaborated on below.

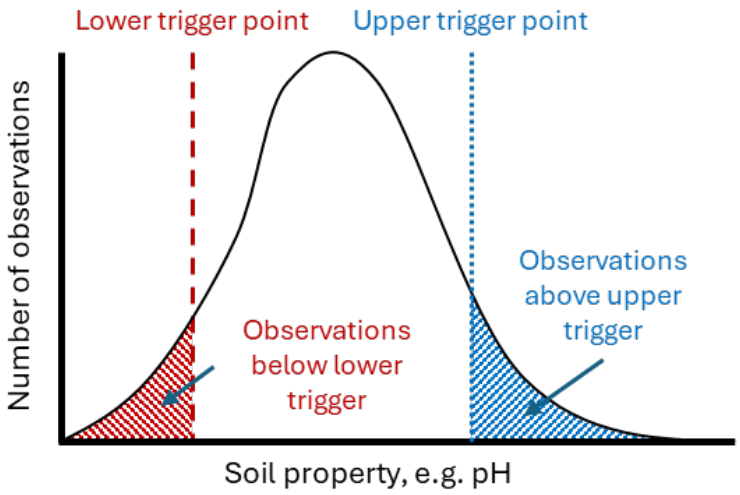

Figure 2-2 Example distribution plot for a soil property for a single habitat. In this example, a lower limit (red dashed line) marks the border between the lower tail of the distribution (e.g. the 10th percentile, with the bottom 10 % of values shaded in red) and the majority of the population; an upper limit (blue dotted line) marks the border between the upper tail of the distribution (e.g. the 90th percentile, with the top 10 % of values shaded in blue).

GMEP-derived trigger points that alert a manager that monitoring and potentially action might be required are indicated in bold typeface in Table 2-1 and were derived as follows:

- SOM – 20th percentile (bottom 20%) of each habitat's population
- C:N – 20th percentile (bottom 20%) of each habitat's population
- Bulk density – 80th percentile (top 20%) of each habitat's population
- pH – 10th and 90th percentiles (bottom 10% and top 10%, respectively) of the population (Fen, marsh & swamp only)

These trigger points were chosen as logical baselines for the soil health alert indicator, in line with expert understanding of soil health and system functioning. In systems with interdependent properties, such as soils, and where positive feedback loops exist, it is common to see uneven distributions where (as in the Pareto Principle) the lowest 20% of systems, or highest in the case of bulk density, may produce the majority of challenges. These trigger points are not indicative of a step change in soil function, but are based on the logical chain that progressively reducing the percentage of sites in these extremes will be beneficial for soil health. Some underperforming sites may not be able to cross the trigger point due to environmental factors, but it is expected to be technically or physically possible for the majority and may form part of a soil manager's plan for continual improvement.

Recognising that habitat is not the only control on soil properties, we distinguished improved and neutral grasslands (where sample sizes >100) into upland and lowland variants. This was done to capture differences in climate conditions (primarily temperature and rainfall) as well as soil types, with peaty and organo-mineral topsoils likely dominating upland compared to lowland areas. We used a threshold of 250 m to distinguish lowlands from uplands, which aligns with Natural Resources Wales's LANDMAP classification (Bullen, 2024).

Table 2-1 Topsoil property trigger points for different broad habitats in agricultural landscapes across Wales. Trigger points derived from GMEP soil sample distributions are shown in shaded cells. For Olsen P, additional upper trigger points for leaching risk (60 mg kg^{-1} Olsen P) are also shown in square brackets.

Broad Habitat	Olsen P, mg/kg [lower | upper]	pH, unitless [lower | upper]	SOM, % [lower]	Bulk density, g/cm^3 [upper]	C:N ratio, unitless [lower]
Acid grassland	-	5 | -	14.4	0.6	13
Arable & horticulture	16 | 45 [60]	6.5 | -	5	1.2	10
Bracken	-	5 | -	8.2	0.8	12
Broadleaved mixed & yew woodland	-	4.4 | -	8.2	0.8	12
Coniferous woodland	-	4.4 | -	7.2	0.8	14
Dwarf shrub heath	-	4.5 | -	18.1	0.5	14
Fen, marsh & swamp	-	4.9 | 6	14	0.7	12
Improved grassland (lowland: <250_m)	16 | 25 [60]	6 | -	7	1	9
Improved grassland (upland: >250_m)	16 | 25 [60]	6 | -	10.5	0.8	10
Neutral grassland (lowland: <250_m)	-	5 | 7	7.6	1	10
Neutral grassland (upland: >250_m)	-	5 | 7	8.7	0.8	10

3 Estimated Current Status of Soils Across Agricultural Landscapes in Wales Including Risks for Water Quality

When assessed against the trigger points in Table 2-1, 79.9% of agricultural soils sampled during the ERAMMP NFS are under-performing according to the trigger points in at least one indicator. (Figure 3-1). This is an increase of 4.8% from the 75.1% figure recorded under GMEP (Figure 3-1). These figures are well above the 60-70% of EU soils that are flagged for attention under the EU's one-out; all-out assessment (Veerman et al., 2020), and concerningly, the EU estimates are based on several more topsoil properties than used for Wales here.

Although the approach used here is in keeping with the principles of the EU approach it is not a direct implementation of the same methodology and different trigger points are used that are considered more relevant to UK/Wales conditions and critically are bespoke for different habitat types. This may limit the utility of a direct comparison.

It is worth noting that of the soils surveyed under ERAMMP that are flagged for attention by the one-out; all-out assessment, most are under-performing relative to either one or two trigger points, and hence, would hopefully require minimal intervention to pass a future assessment although cost-benefit analysis by farmers may uptake of action.

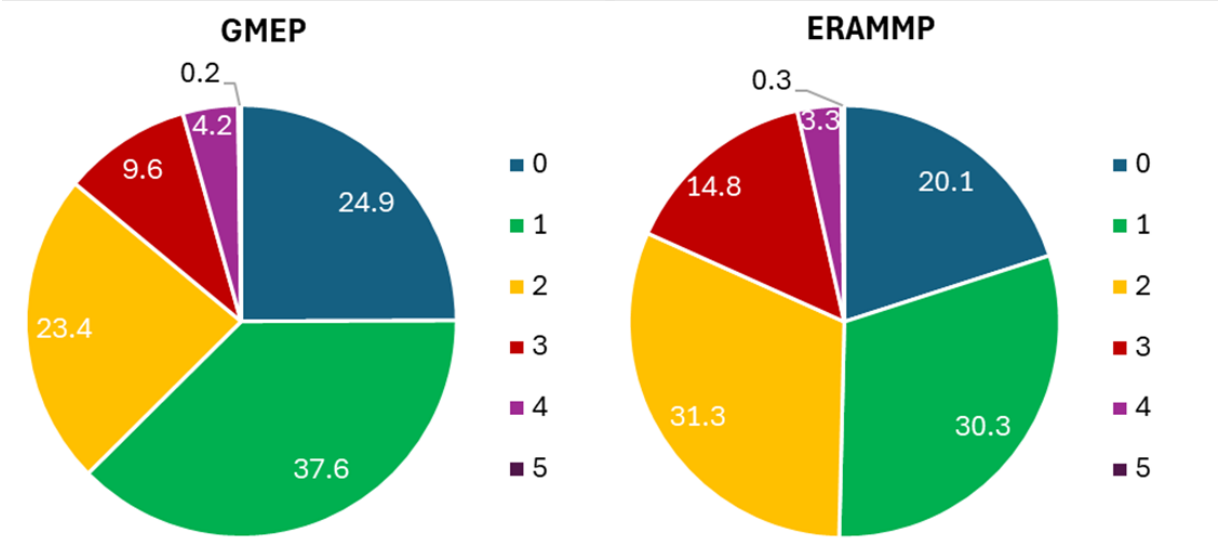

Figure 3-1 Percentages of agricultural topsoil samples in GMEP (left) and ERAMMP (right) that suggest under-performance relative to different numbers of the trigger points listed in Table 2-1. Soils are assumed to be performing adequately where there are 0 trigger point alerts.

Within our assessment, the most common causes of soils under-performing were trigger values determined from well-known thresholds in published literature (independent of baseline monitoring) for Olsen P and pH (Table 3-2), with 60.4% of samples failing one of these trigger points. By virtue of the indicator's design for trigger points of SOM, bulk density, C:N and pH in the case of Fen Marsh and Swamp, at least 20% of sites were considered to be underperforming in the baseline survey (2012-16) *a priori*, and as such, the presence of some sites underperforming relative to those trigger point 10 years later is not unexpected. However, as described elsewhere in this report, an increase in soil health would be expected to progressively reduce the number of sites underperforming against these thresholds over

time. The total number of agricultural land sites underperforming against the SOM trigger point has remained at 20% (no improvement) and increased to 23% for the C:N trigger points. The number of sites underperforming against the bulk density trigger point has increased from 20% to 31%.

Most broad habitats, with the exception of broadleaved, mixed & yew woodland, fen, marsh & swamp, and neutral grasslands, record disproportionately high percentages (85% to – in the case of Bracken – 100%) of samples that are flagged for further investigation compared to the overall figure across habitats surveyed under ERAMMP (77.2%, Table 3-1). These habitats with disproportionately high percentages of flagged samples collectively make up 64.7% of agricultural soils surveyed under ERAMMP, and 75.9% of all agricultural land flagged for further attention (Figure 3-2).

Table 3-1 Breakdown of the numbers of ERAMMP topsoil samples that cross trigger points (including none at all) by habitat indicating under-performance. Percentages are based on the populations per habitat.

Broad Habitat	Number of trigger points crossed						Within trigger point range, %	≥1 trigger point crossed, %
	None	One	Two	Three	Four	Five		
All agricultural land	80	121	125	59	13	1	20.1	79.9
Acid grassland	2	17	11	12	2	0	4.5	95.4
Arable & horticulture	3	6	16	11	1	0	8.1	91.8
Bracken	0	9	10	4	0	0	0	100
Broadleaved mixed & yew woodland	9	8	8	2	0	0	33.3	66.6
Coniferous woodland	3	13	4	0	0	0	15	85
Dwarf shrub heath	1	9	3	2	0	0	6.7	93.3
Fen, marsh & swamp	4	3	1	1	0	0	44.4	55.5
Improved grassland (lowland: <250 m)	6	26	40	16	5	0	17.2	93.6
Improved grassland (upland: >250 m)	1	4	9	7	4	1	7.7	96.1
Neutral grassland (lowland: <250 m)	35	15	17	3	1	0	49.3	50.6
Neutral grassland (upland: >250 m)	16	11	6	1	0	0	47.1	52.9

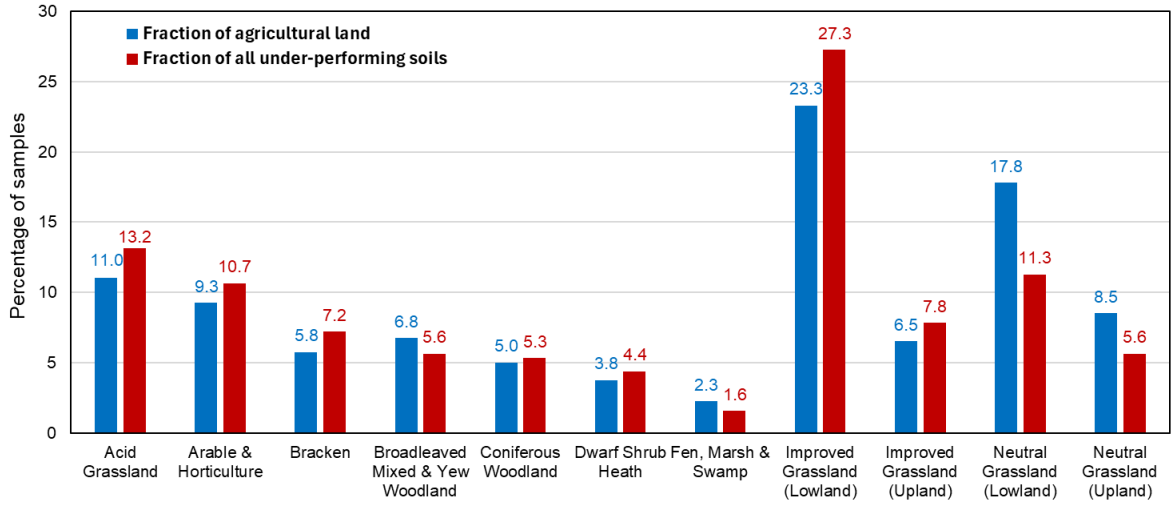

Figure 3-2 Samples in each habitat that under-perform relative to the one-out; all-out assessment as a percentage of all agricultural samples that fail (red) compared to the percentage share of habitats from agricultural land sites sampled under the ERAMMP NFS (blue).

Topsoil pH is the single most common cause of samples becoming flagged by the one-out; all-out based assessment of soil condition across Welsh agricultural landscapes, responsible for between 33.3 and 75% of apparent under-performances against trigger points per broad habitat (where pH is the most common issue; see Table 3-2). This has two likely causes: a) the low use of lime alongside inorganic fertilisers which progressively acidifies soil in improved soil which limits the efficient use of fertilisers applied, and b) legacy effects of acid rain in our poorly buffered upland unimproved soils.

While topsoil pH is a widespread concern for both upland and lowland improved grasslands, the under-performance relative to Olsen-P trigger points is an even more common issue in these habitats (75.8 and 88% of under-performance in lowland and upland improved grassland, respectively; Table 3-2). The cause of where this is an exceedance of trigger points will be the over-use of phosphorus which is not well matched to crop needs. It should also be noted however that a significant proportion (29.4 %) of agricultural soils are below the lower trigger point, implying these soils are not receiving enough phosphorus inputs to support optimum food production. This apparent under-performance relative to the lowest trigger points range from 16.2 % for arable to 48 % for upland improved grassland sites (see Figure 6-1 in Annex-1). It should be noted however, that below optimum production may reflect the management strategy of an individual farm. We emphasise again, that this soil health alert indicator should lead to investigation (and not immediate action) ensuring current soil conditions match resource needs for production for a specific field. There is a risk if lime and fertiliser are automatically added without consideration of management intensity that resources will be added that are not required to support production. Future iterations of this indicator may decide to remove the low trigger point values for Olsen-P.

For upland neutral grassland, under-performance relative to bulk density trigger points are the most common issue (35.3%), with under-performance relative to both bulk density and C:N ratio trigger points (23.9% each) being the joint most common issues for lowland neutral grassland (Table 3-2). The most common issues for fen, marsh & swamp stem from under-performance relative to trigger points of pH and C:N ratio (33.3% each; Table 3-2). The causes of these issues will be a combination of compaction from grazing animals and atmospheric deposition of both acidic and nitrogen pollutants. For Fen, Marsh and Swamp, hydrological inputs of fertiliser from adjacent improved land may also be a cause of low C:N ratios.

A more detailed breakdown of soils flagged as under-performing based on our assessment by both habitat and topsoil property is presented in Section 6 (Annex-1). In summary these results show:

- Most samples flagged by the one-out; all-out assessment for improved grasslands are driven by under-performance relative to Olsen P and pH trigger points, with pH, Olsen P and C:N ratio under-performances also common among arable & horticultural soils.
- Most arable & horticultural, acid grassland, bracken, dwarf shrub heath and coniferous woodland soils under-perform relative to pH trigger points. All of these habitats have shown a shift towards more acid conditions, potentially impairing microbial activity and nutrient availability to support plant communities.
- Nearly half of both arable & horticultural and acid grassland soils under-perform relative to C:N trigger points, implying elevated nitrogen levels and eutrophication risks for these ecosystems.
- Most soils are performing adequately according to SOM and bulk density trigger points. However, we should caution that between the GMEP and ERAMMP surveys, bulk density has increased significantly across habitats by 6-32%, and soil organic carbon concentration (which closely relates to SOM) has decreased significantly in arable & horticultural and broadleaved, mixed & yew woodland sites (Emmett et al., 2025). See Section 6 (Annex-1) for the distributions of SOM and bulk density for ERAMMP vs GMEP.

Table 3-2 Percentages of samples from agricultural landscapes taken in the ERAMMP NFS per broad habitat that under-perform relative to trigger points for each topsoil property. The largest percentages per broad habitat are indicated in bold typeface.

Broad Habitat	Fraction of all agricultural land samples, %	Olsen P	pH	SOM	Bulk density	C:N ratio
All agricultural land	100	-	**49.9**	20.1	30.7	23.3
Acid grassland	11.0	-	**75**	29.5	38.6	45.5
Arable & horticulture	9.3	40.5	**56.8**	29.7	32.4	43.2
Bracken	5.8	-	**69.6**	30.4	43.5	34.8
Broadleaved mixed & yew woodland	6.8	-	**33.3**	22.2	29.6	25.9
Coniferous woodland	5.0	-	**60**	5	10	30
Dwarf shrub heath	3.8	-	**80**	20	26.7	13.3
Fen, marsh & swamp	2.3	-	**33.3**	11.1	11.1	**33.3**
Improved grassland (lowland: <250 m)	23.3	**75.8**	65.6	12.9	29.3	5.4
Improved grassland (upland: >250 m)	6.5	**88**	73.1	23.1	46.2	19.2
Neutral grassland (lowland: <250 m)	17.8	-	12.7	21.1	**23.9**	**23.9**
Neutral grassland (upland: >250 m)	8.5	-	11.8	14.7	**35.3**	11.8

Additionally, our results highlight potential concerns for water quality, with 14.4 % of arable and improved grassland agricultural soils exceeding the trigger point for leaching risk (60 mg/kg). In percentage terms, this issue is most common in arable lands (16.2 %), followed by lowland improved grassland (14.3 %) and upland improved grassland (12 %).

4 Challenges and Opportunities for a Soil Health Alert Indicator for Agricultural Landscapes in Wales

This report presents a first test of a new Soil Health Alert Indicator that could be applied to monitor progress towards the SLM objectives 1 and 3 under the 2023 Agriculture (Wales) Act. The use of a “one-out; all-out” approach allows for multiple properties of soil health to be integrated together into a single, easy-to-communicate indicator to alert stakeholders to soils which require further investigation, and follows the principles underpinning the approach taken by the European Union to assess and monitor soil health (Veerman et al., 2020).

It is important to clarify however, that whilst a soil may be under-performing relative to one or more trigger points, this does not automatically mean that a soil should be seen as “degraded” or “unhealthy” or that immediate remediation action is taken. Whilst some trigger points are based on published limits (Olsen P and most pH limits, with the exception of those for fen, marsh & swamp), many of the trigger points presented in Table 2-1 are based on the most poorly performing 20% percentile thresholds within the habitats according to the GMEP baseline survey. The basic principle being that an increase in the numbers of samples in the more ‘poorly performing’ range over time for either production efficiency or habitat support is not desirable and as a minimum requires investigation and possible remediation. This approach also has the advantage of setting a benchmark to reference against for future assessments, and follows the same principle used in the greenhouse gas inventory, where levels from 1990 are set as the benchmark (UNFCCC, 1997). It should be noted, pH trigger points for arable & horticulture will vary within the range used here with the main crop types that are being produced however insufficient data is available to set these trigger points. New data arising from increased soil testing promoted by the SFS will significantly increase available data for some of these measurements. Finally, it is recognised that not all farms are aiming for optimum (often interpreted as maximum) production due to the many additional costs and resource implications of that (labour, animal housing etc). Immediate application of fertilisers or lime following the soil assessment that suggest of under-performance may risk adding resources that are not needed for supporting production with resulting unnecessary associated environmental consequences with respect to greenhouse gas emissions associated with fertiliser and lime production and spreading, and undesirable nutrient enrichment of soils and waters.

Likewise, while some topsoil properties (particularly SOM and bulk density) appear to be flagged as under-performing less often than for other topsoil properties, this should not be taken to mean that most soils are experiencing no issues in relation to these properties. For instance, the majority of topsoils from agricultural land perform adequately based on bulk density trigger points, but we know there has been an increase in bulk densities of 6-32% across habitats on average between the GMEP and ERAMMP surveys (Emmett et al., 2025). By assessing soils against habitat- and topsoil property-specific trigger points, the one-out; all-out approach is useful for flagging the proportion of soils that currently have extreme soil properties; the national trend analysis (as presented in Bentley et al., 2025 and Emmett et al., 2025) on the other hand reveals the statistically robust trajectory of the population, providing an early warning sign of further instances of under-performance or reliable indications of improvement. Monitoring even where no soils are flagged as under-performing is critical to ensuring soil health remains in good condition to build a more complete picture of soil condition and drivers of change. This is particularly important when external drivers of agricultural soil condition are changing, for example due to climate change.

It should also be emphasised that the NFS monitoring in ERAMMP and GMEP was not designed to monitor and report on individual fields comprehensively but instead takes a more efficient population approach and is representative of the condition of Wales and its habitats as a whole. As such, while the proportion of samples that are flagged as under-performing at a given time (both overall and by broad habitat) is informative, scrutinising individual samples and whether they are under-performing in reference to one or more topsoil properties is not an appropriate use of the indicator presented here. A final issue to note is that monitoring the top 15 cm of soil and for the 5 selected topsoil properties does not provide a complete assessment of soil health. We recognise that whilst we call the indicator a Soil Health Alert Indicator, it currently only assesses the statue of the top 0-15cm. It is hoped that the NFS going forward will have the resources to sample below the current 15cm limit.

Additional considerations include:

a. Assessing soils at depth (>15 cm). Subsoils for instance may be quite compacted even in places where topsoil bulk density would indicate otherwise.
b. Separation of leys from arable and improved grassland would create more refined trigger points and better represent the reality for some soils which switch between habitat. With a push for greater rotations as part of regenerative agriculture practices, this category is likely to increase in size over time.
c. Measurements of heavy metals such as copper, lead, zinc, iron and aluminium, as well as micronutrients such as potassium and selenium. Many of these elements have trigger points of their own reflecting either threats to human health or plant nutrient uptake. Floodplain soils in Welsh catchments with a legacy of metal mining (e.g. the Ystwyth, Conwy and Severn) will likely have several hotspots of very high levels of toxic elements that would be important to monitor going forward.
d. Measurements of other contaminants such as forever chemicals (PFAS), pesticides and microplastics and soil as a reservoir for issues such as anti-microbial resistance (AMR) are also increasingly of interest. Archived samples all provide the potential for these to be completed for both GMEP and ERAMMP.
e. Inclusion of soil organisms is useful, but practically difficult and there is currently disagreement among soil scientists as to appropriate metrics to use. A review on soil biodiversity metrics for national monitoring and an integrated soil health metric is expected in the near future (April 2026) which will help identify the best positive and negative biological metrics for inclusion in an integrated Soil Health Alert Indicator. Again, our archives provide the potential to backtrack and report on change once metrics are agreed.
f. Soil erosion by water may present issues for some soils across Wales, particularly if soil formation rates from parent material weathering are too low to replace losses of topsoil. A scoping study has been undertaken to estimate likely soil formation rates across Wales (0.004-0.193 mm/yr, Tye et al., 2021), which could be combined with model estimates of soil loss rates (see Hooftman et al., 2023 and Feeney et al., 2025). Erosion rates by wind or associated with tillage or harvest are not considered to be a significant issue in Wales although these processes are important locally. Additionally, the degree of connectivity between eroding soils and water bodies should be captured to factor in eutrophication risk, especially in nitrate vulnerable areas.
g. Similar to erosion, it would be useful to undertake some spatial modelling to estimate total nitrogen and phosphorus balances within soils, with some link to catchment processes (e.g. a connectivity index) to estimate risk of contamination of freshwater ecosystems. Recently, high-resolution (25 m) risk maps of phosphorus export rates to stream networks and the degree of phosphorus retention on land have been produced

at full European scale (Hooftman et al., 2025), which could be useful to relate to our assessment.

h. The area of bare soils which is a possible metric to include in time increases the risk of erosion and could be used as an early warning signal of degrading soil health. Data have been captured for 2000 to 2022 at European scale at 10 metre resolution and could be used here, though previous analysis of ERAMMP survey squares indicates higher resolutions (3 metre resolution or finer) would be ideal (Robinson et al., 2021).

i. Soil lost to buildings and paved surfaces (soil sealing) could easily be included although the numbers will be small using Earth Observation.

j. Finally, peats are a very special type of soil which require their own reporting structure and could be included going forward if required by the Welsh Government. New remote sensing tools are currently being tested which could provide a new robust metric for reporting.

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6 ANNEX-1: HABITAT-LEVEL SOIL PROPERTY SUMMARIES

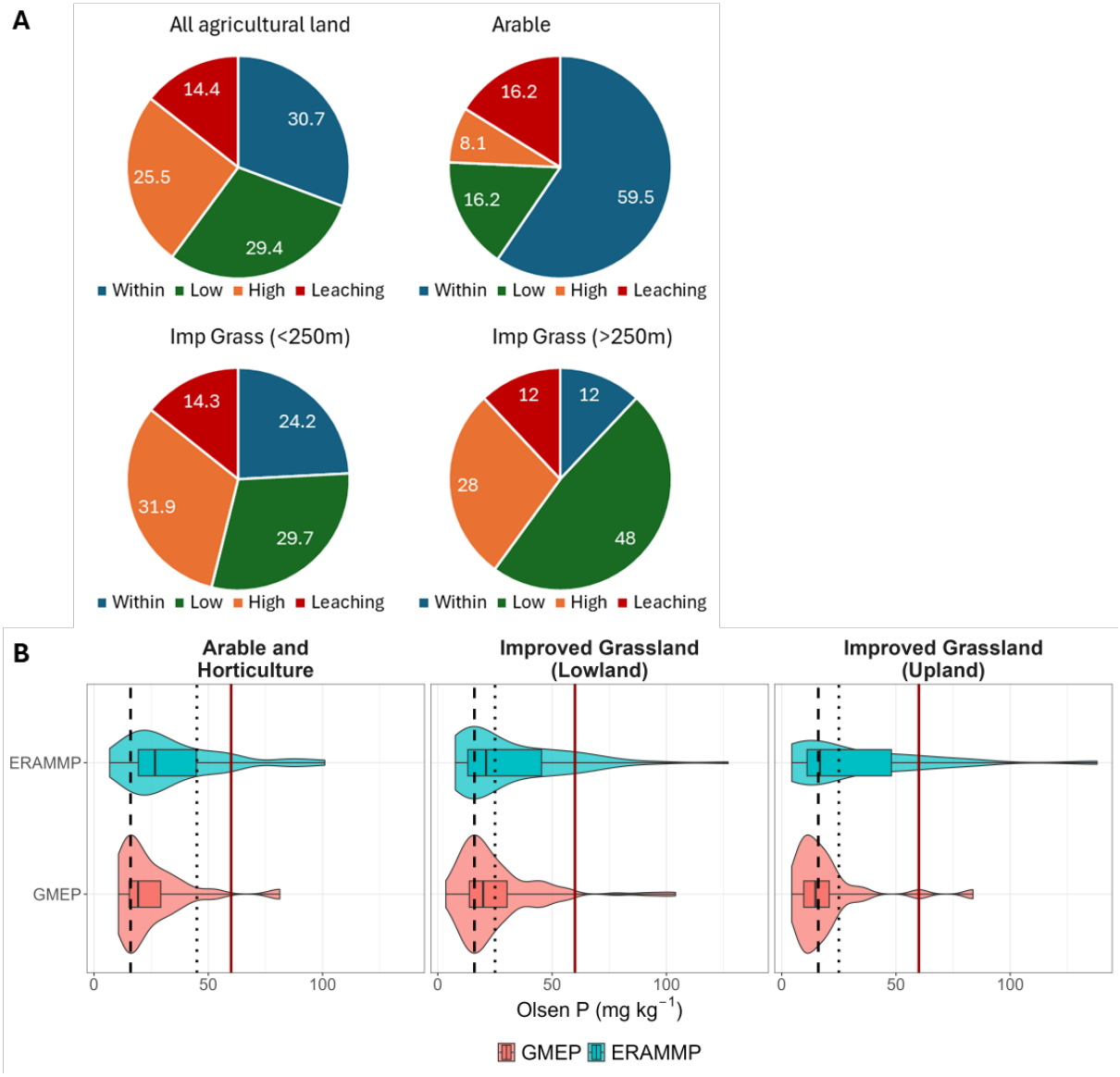

*Figure 6-1 A: Percentages of agricultural soils that either lie within or under-perform (lie outside of) the trigger points for **Olsen P**. Here, soils which under-perform relative to trigger points are divided into those that are "Low" (Olsen P concentration is below the lower trigger) or "High" (Olsen P concentration exceeds the upper trigger). Soils where Olsen P is too high are split between those that are simply higher than the recommended upper trigger for production (25 & 45 mg kg^{-1} for improved grassland and arable & horticulture, respectively) and those that are so high they also exceed the published trigger point for leaching risk (60 mg kg^{-1}). B: Distributions of topsoil Olsen P within agricultural lands split by habitat and survey. Dashed lines indicate the lower trigger points whereby action should be taken if a soil's Olsen P level fall below this level; dotted lines indicate the upper trigger points whereby action should be taken if a soil's Olsen P level exceeds this level; solid red lines mark the trigger point for leaching risk.*

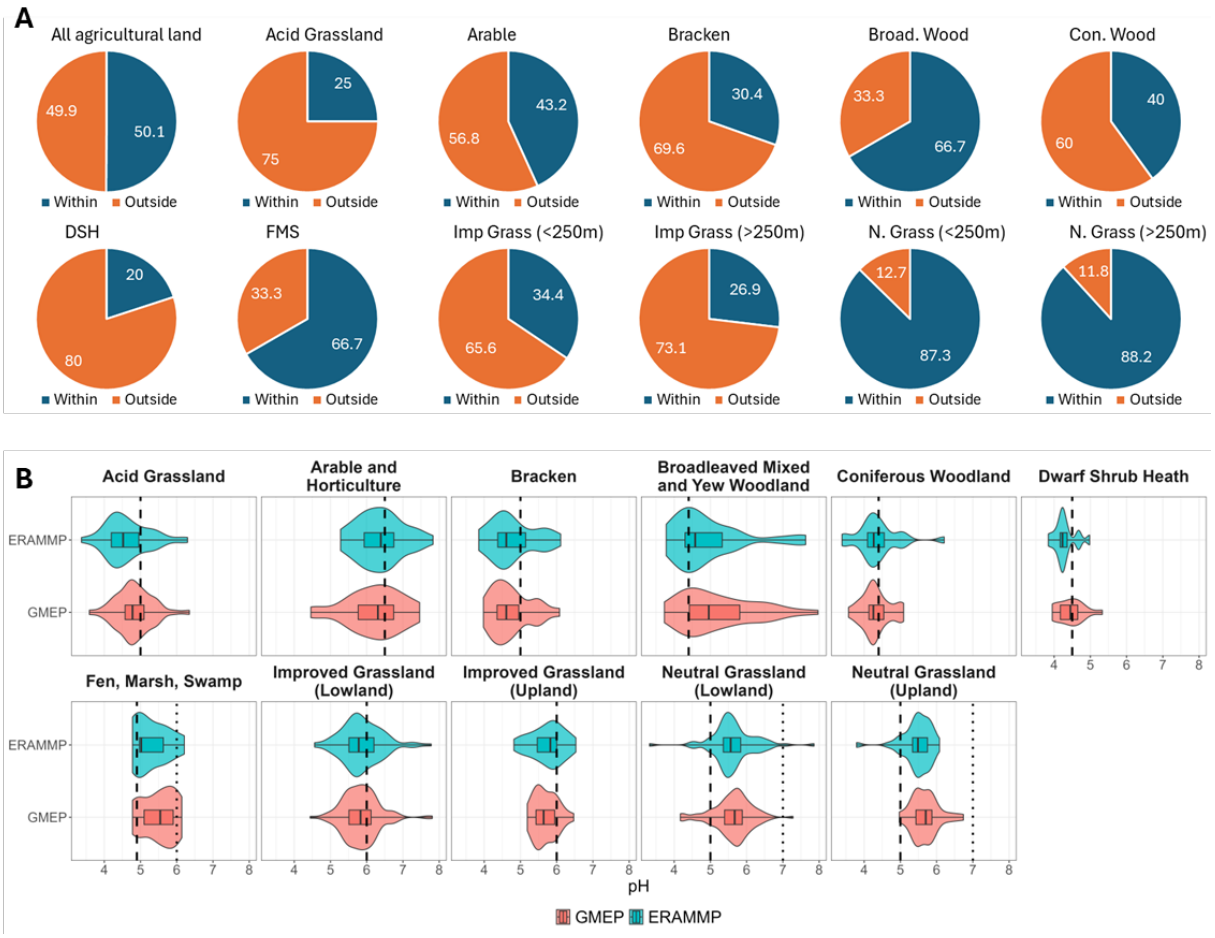

*Figure 6-2 A: Percentages of agricultural soils that either lie within or under-perform relative to the trigger points for **topsoil pH**. B: Distributions of topsoil pH within agricultural lands split by habitat and survey. Dashed lines indicate the lower trigger points whereby action should be taken if a soil's pH level fall below this level; dotted lines indicate the upper trigger points whereby action should be taken if a soil's pH level exceeds this level.*

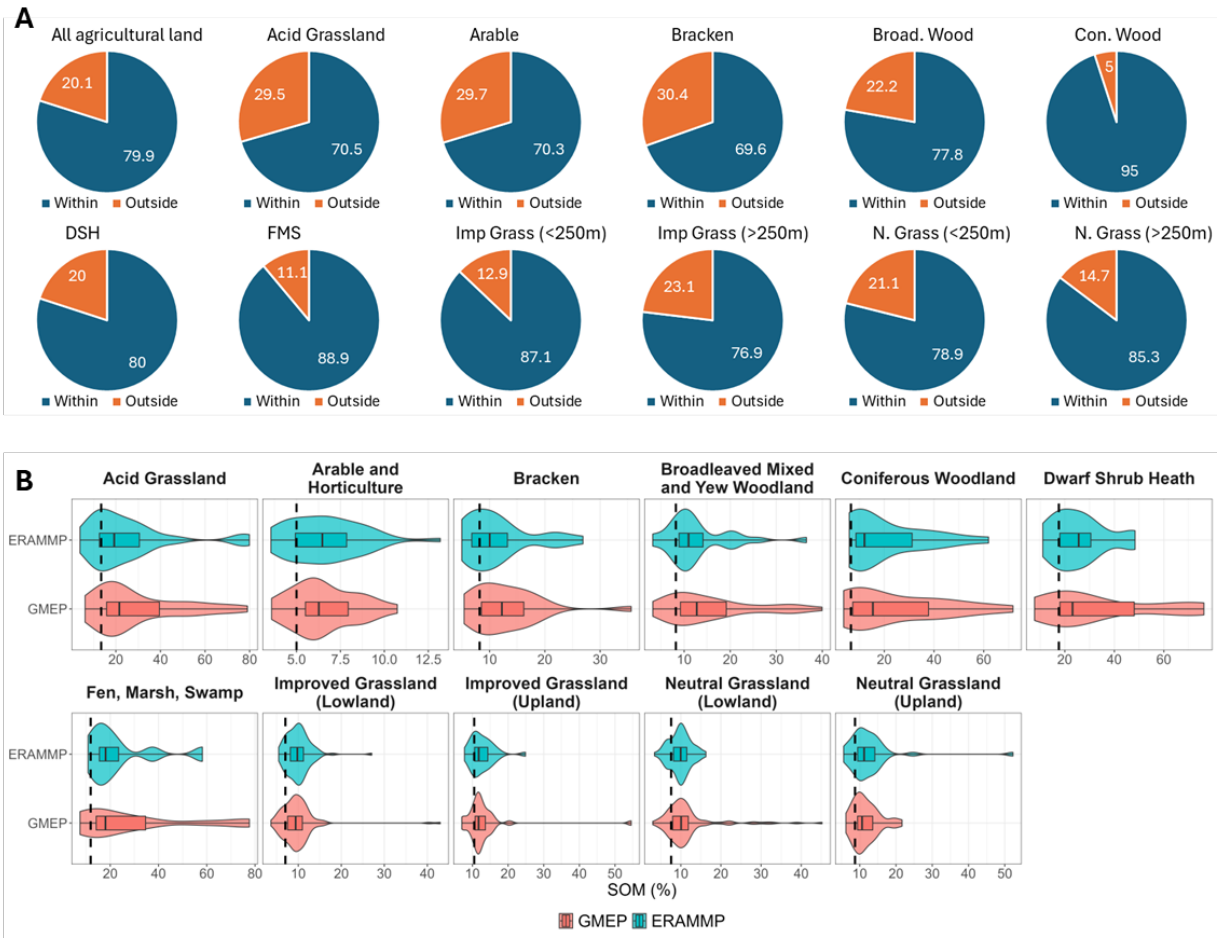

*Figure 6-3 A: Percentages of agricultural soils that either lie within or under-perform relative to the trigger points for **soil organic matter (SOM)**. B: Distributions of topsoil SOM within agricultural lands split by habitat and survey. Dashed lines indicate the lower trigger points whereby action should be taken if a soil's SOM level fall below this level; no upper trigger point is defined for any habitat for this topsoil property.*

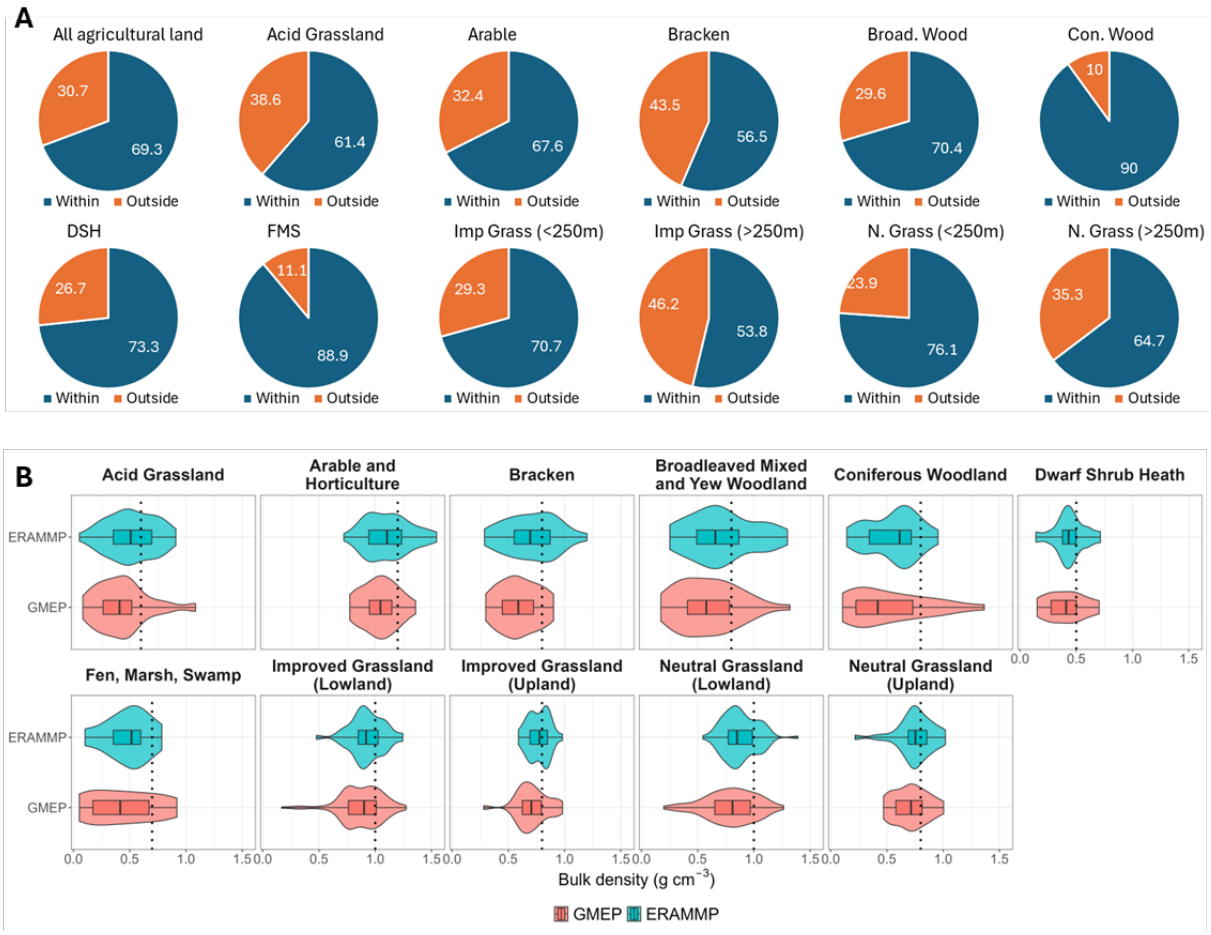

*Figure 6-4 A: Percentages of agricultural soils that either lie within or under-perform relative to the trigger points for **bulk density**. B: Distributions of topsoil bulk density within agricultural lands split by habitat and survey. Dotted lines indicate the upper trigger points whereby action should be taken if a soil's bulk density level exceeds this level; no lower trigger point is defined for any habitat for this topsoil property.*

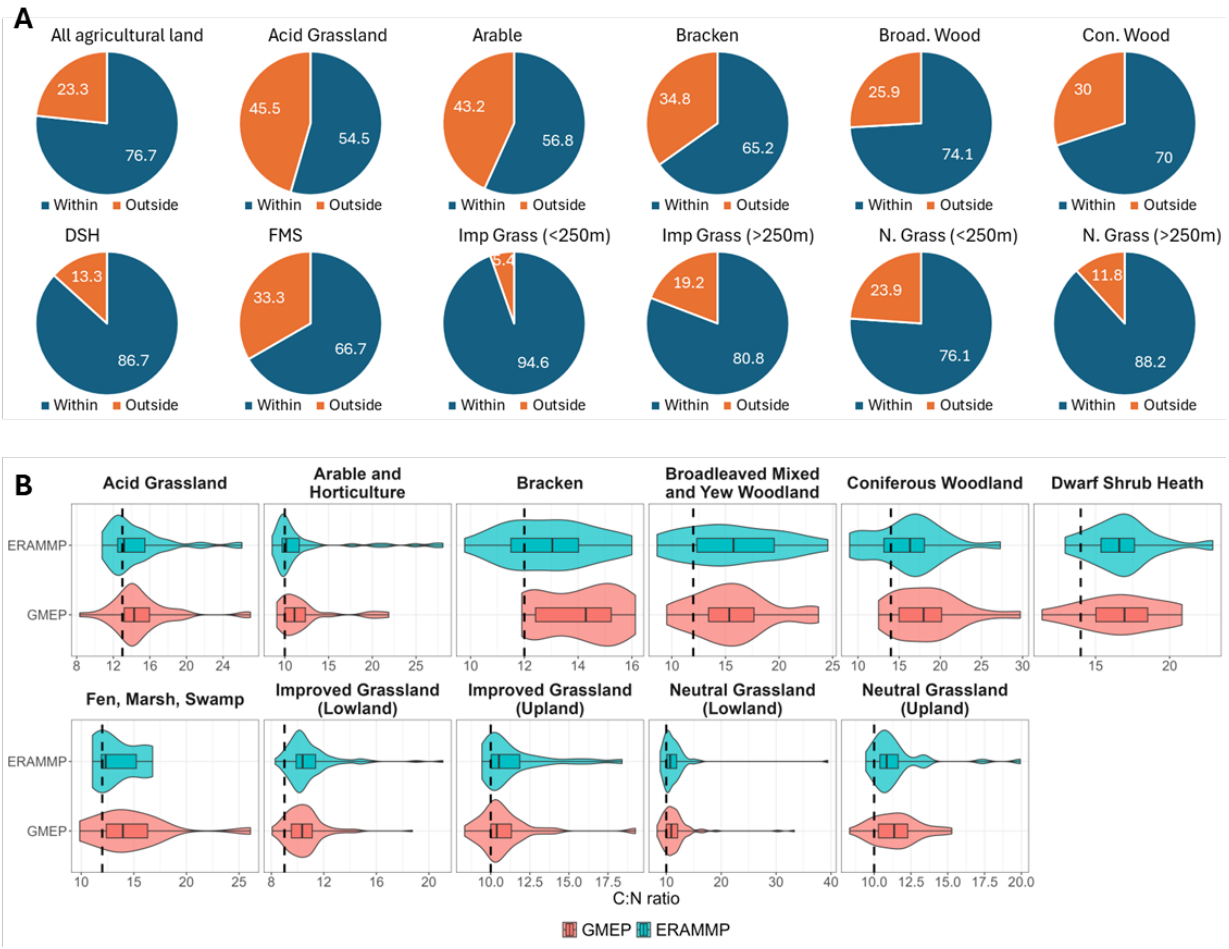

*Figure 6-5 A: Percentages of agricultural soils that either lie within or under-perform relative to the trigger points for Carbon to Nitrogen ratio (**C:N ratio**). B: Distributions of topsoil C:N ratio within agricultural lands split by habitat and survey. Dashed lines indicate the lower trigger points whereby action should be taken if a soil's C:N ratio level fall below this level; no upper trigger point is defined for any habitat for this topsoil property.*

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