Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-45:
Soil Degradation: Erosion & Compaction Phase-1 Report

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Abbreviations Used in this Report

AI	Artificial Intelligence
BGS	British Geological Survey
DTM	Digital Terrain Model
EO	Earth Observation
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
GAEC	Good Agricultural and Environmental Conditions
GHG	Greenhouse gas
GIS	Geographic Information System
GMEP	Glastir Monitoring and Evaluation Programme
N_2O	Nitrous oxide
NRW	Natural Resources Wales
OS	Ordnance Survey
Poaching	Trampling by animals
Terracettes	Ridges on hill slopes caused by soil wetting and drying
UKCEH	UK Centre for Ecology & Hydrology
VESS	Visual Evaluation of Soil Structure

Abbreviations and some of the technical terms used in this report are expanded on in the programme glossaries: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

Contents

1 SOIL EROSION IN WALES - SUMMARY OF PHASE 1 WORK

This is a brief summary after Phase-1 of the *Soil Degradation, Erosion & Compaction* project within the Environment & Rural Affairs Monitoring and Modelling Programme (ERAMMP)[1]. It outlines what has been done and what will be required for Phase-2.

Identifying the extent of soil erosion and compaction features provides an important first step to assessing soil physical degradation. It provides the basis for a first statistical assessment of the extent of the vulnerability of the soils of Wales to physical degradation and the reduction in the capacity of a soils to undertake their normal function. Not all soil erosion and compaction is considered in this analysis, only that which can be detected from aerial photographs. As a result it is limited to a number of features such as erosion scars, gullies, animal and vehicle compaction around gateways or livestock poaching features. As such it might be considered a lower bound in terms of the extent of damage. We fully recognise that at present features such as rills, or erosion under vegetation can't be detected from the air. Nor, at present, does it consider 'age' so rates of erosion for example are not yet considered.

The aim of the work was to assess the use of aerial photography in identifying areas of soil erosion and compaction (poaching) across 240 x 1km^2 areas of Wales. The objectives were twofold:

A. Obtain an initial measure of the area of soil damage that can be obtained from air photos and ground-truthed at a later stage by surveyors.

B. Create a training data set that can be used to test automation of soil degradation feature detection across Wales.

Areas of soil erosion and compaction were interpreted as GIS polygons from a combination of aerial photography, OS maps, Google Earth, DTM derived landscape characteristics, and importantly analyst knowledge of landscape features. Using the polygon approach will enable approximate areas of erosion or compaction to be calculated.

1) The methodology used aerial images collected mostly over the spring / early summer of 2018. Exact dates of photos will be provided once the dataset is merged with landscape variables.
2) It requires aerial imagery that allows a good image to be obtained at 1:1250 (i.e. 1 cm on the screen represents 1250 cm in real life) – this appeared to be most effective – at any higher resolution the analyst can't see enough of the landscape or it becomes a pixelated blur.
3) Time required - About 2 to 2.5 hours for five 1km squares – however a square with a lot of features, such as a square primarily associated with lowland dairy farming, could be 40 minutes or more (this is far less time than a field visit requires).
4) In time a full analysis of the polygons will be undertaken once landscape variables have been added to polygons, producing a dataset to work on.
5) A range of issues are identified in the appendix.

[1] www.erammp.wales

2 EROSION / COMPACTION IDENTIFIED

Sets of tram lines or animal tracks were not included in the analysis and resolution was too low to pick out certain forms of erosion such as rills. Any erosion under vegetation can't be observed, nor can upland scars that might be covered by an overhang. The following were identified:

1. Gateway damage – this includes both the gateway itself and the associated fan shape of compaction produced as animals or vehicles approach to the point of egress.
2. Hedge gap / wall gap damage – similar to above but through field hedges and walls
3. Poaching around feeding areas
4. Poaching where animals congregate for shelter or socialising (e.g. behind hedges or walls)
5. Poaching in fields, particularly around farm yard access (e.g. where animals are congregated prior or after milking or for animal maintenance)
6. General field poaching, trampling by animals
7. Terracettes, ridges on hill slopes caused by soil wetting and drying and causing soil to move downslope; often exacerbated by animals, see Figure 2-1
8. Areas of soil / peat erosion or where bare peat is evident
9. River bank erosion
10. Silage or straw clamps with associated compaction
11. Erosion - deposition fans indicating erosion in peat or mineral soil

Images of examples of some of these types of features are included in Figure 2-1.

Peat hags

Path erosion in the uplands

Examples of poaching by animals

Mass movement, landscape scars

Example of terracetes in from North Wales

Landslides

Coastal erosion

Riverbank erosion

Figure 2-1: Examples of features detectable to some extent with earth observation systems

3 RESULTS

I. Approximately 2500 features were identified from the analysis and marked using polygons (area within which the feature occurs) in a geographic information system (GIS). These polygons largely related to soil damage, e.g. poaching by animals (~90%). Soil erosion features were identified but were secondary in a grassland dominated country (~10%).

II. Bare soil that is left from poaching indicates soil damage and by itself could be a breach of GAEC[2]. Moreover, these features are important as they are often hotspots for nitrous oxide (N_2O) emissions.

III. The few aerial images taken in early spring show an increase in area of poaching identified as vegetation has not grown back.

Lowland farms, particularly dairy, have the highest numbers of polygons compared to rough grazing areas and the uplands. This is likely to be because of more journeys for animals, especially heavier ones where cattle are present, and tractors (e.g. silage making, milking). In addition the size of fields may affect the number of gateways and journeys, and thus the severity of soil damage.

IV. Arable land was scarce in the squares. Most cultivated land appeared to be recently sown with maize and dry or in full vegetation reflecting the time of the growing season (as expected in May time when most of the photos were taken).

V. The number of soil erosion incidences represented about 10 % (at highest) of the dataset as expected in a largely vegetated landscape.

VI. Terracettes were identified which often followed field boundaries.

Figure 3-1 shows photographs of examples of features found with corresponding GIS polygons marked.

[2] Welsh Government **Good Agricultural and Environmental Conditions** (GAEC) regulations – see also Section 6.

Figure 3-1: Examples of features recorded using polygons and aerial data.

a) gateway soil damage from machinery and livestock and poaching around feeder
b) poaching in fields where livestock access to farm yards is required
c) gateway soil damage
d) area of soil erosion on very steep slope
e) area of terracettes

4 FIELD RECORDING TOOLS: *MYSOIL EROSION*

Work has been undertaken to produce a tool for surveyors to record features and their extent, in the field.

The computer / tablet / phone software is a cross-platform app that will function on Android or iOS devices. The software runs in the ESRI Survey123 architecture, removing the need for the development and upkeep of the base system. The software requires downloading of the standard Survey123 app (which is free) and then the *MySoil Erosion* feature is downloaded using a QR code.

The app works online and offline, but requires online for recording location and accessing base layers. In addition, a citizen science version could be developed and made freely available. Figure 4-1 shows some screen shots - for example the ability to record a polygon around a feature with the help of the base layer.

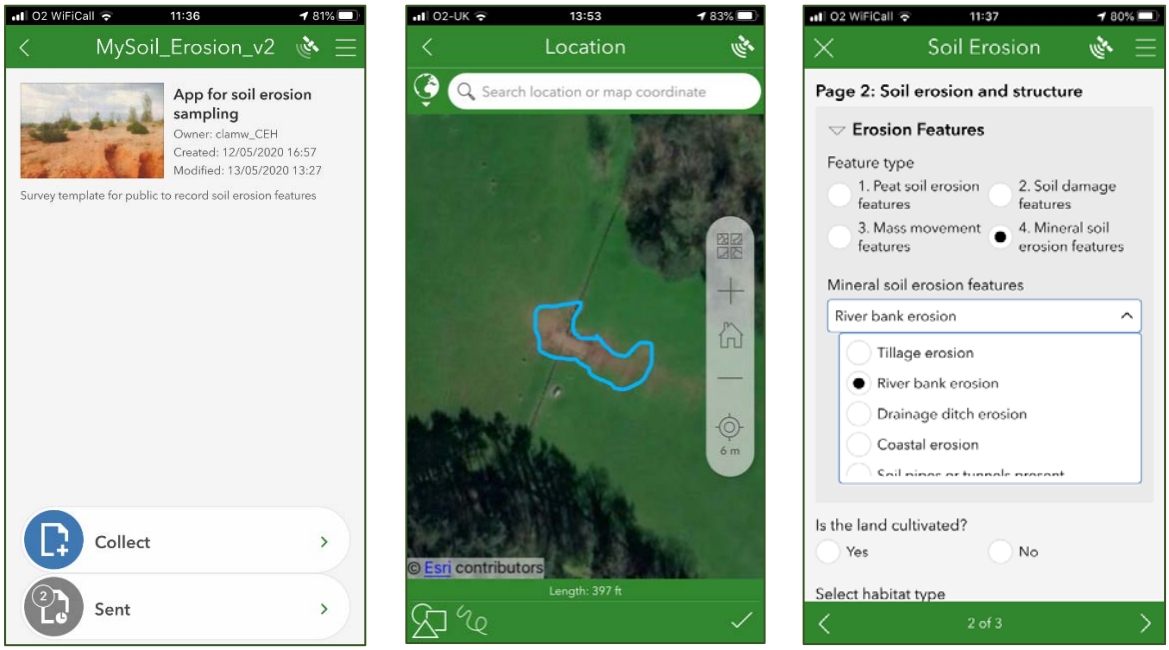

Figure 4-1: Screenshots of MySoil-Erosion that enables surveyors to record the location and extent of soil erosion or compaction features. Other information such as habitat, visual evaluation of soil structure (VESS) scores or peat depth can also be recorded.

In addition we have created a second tool specifically for river surveyors to record river bank features such as river bank erosion and also poaching where animals approach the waterbody to drink.

5 CURRENT WORK-PACKAGE - NEXT STAGES

1. Having generated a GIS set of polygons, work needs to continue to add auxiliary data to the dataset. Polygons are currently being linked with landscape, climate (Chess) and soil variables. The main variables of interest include:

    - Slope that the polygon is in
    - Aspect
    - Altitude (as a proxy for agricultural intensification)
    - UKCEH land cover map
    - Agricultural Land Classification
    - Soil Parent material
    - Precipitation
    - Geology

2. Prepare for the physical survey in 2021; develop training materials for surveyors.

6 OPTIONS FOR FUTURE EXTENSION OF SATELLITE BASED SOIL MONITORING

One potential opportunity going forward is to develop a SOIL-ALERT monitoring system that uses daily, or near-daily, Earth Observation (EO) information combined with modelling for prediction to generate alerts for land-managers and other stakeholders. This could help them avoid practices when conditions are unsuitable and could result in soil degradation. Avoidable activities include cultivating soils that are water logged, leaving soil bare, ploughing too close to boundary features. This alert system could help identify possible breaches of some of the Welsh Government **Good Agricultural and Environmental Conditions** (GAEC)[3] regulations as outlined in Table 6-1 and Table 6-2.

Next steps:

I. The current project has developed a training data set with about 2500 polygons identifying soil erosion and damage features. Work next year will use the field survey to verify this remote observation.

II. Good optical imagery is required for an alert system. Sentinel at ~10m resolution is not optimal. Planet Labs offers products that might work. Therefore, the following needs to be carried out:

    a. conduct an assessment of features easily identifiable against the current air photography.
    b. See if there are any features that can't be resolved.
    c. Determine which of Planet's data sets works offering acceptable, not necessarily the best resolution, 3m, 0.75m or 0.5m.
    d. Determine if using data at different times of year can help identify features of interest.
    e. Develop automatic feature detection using algorithms. Use the obtained polygons as training data to identify features so that the monitoring could be run out nationally and close to real time as data accessibility and processing allows.

III. Explore the use of combining Sentinel radar and Planet imagery to determine soil wetness and inform the system of high risk management conditions, e.g. water logging.

IV. Design and develop an integrated EO and modelling system that can monitor and predict (modelling) high risk areas for erosion or damage and form the basis of weekly / daily alerts. It should be capable of detecting:

    a. Water logging or soils near saturation (optical & radar)
    b. Bare soil (optical) including damage leading to bare soil and potential soil loss, e.g. gateways.
    c. Ploughed soils near boundary features (optical)

V. Explore the feasibility of linking the alert system to river monitoring, identifying areas of risk of bank erosion and sediment discharge, link to NRW river monitoring.

[3] https://gov.wales/sites/default/files/publications/2020-01/cross-compliance-verifiable-standards-2020.pdf

VI. Agree on alert levels and thresholds with stakeholders.

VII. Design and develop an online alert user interface to provide warnings regarding poor conditions for farming / forestry activity.

Table 6-1: Possible breaches of the Good Agricultural and Environmental Conditions (GAEC)[4] that an automated alert system could help identify.

GAEC Standard	Action or Alert that could be Achieved
GEAC-1 WATER – ESTABLISHMENT OF BUFFER STRIPS	
GEAC 1.3 Supplementary feeding carried out within 10 metres of surface water.	Avoiding river bank erosion.
GEAC-4 SOIL AND CARBON STOCK – MINIMUM SOIL COVER	
GEAC 4.0 Failure to maintain a minimum soil cover (e.g. crops, stubbles, residues or other vegetation).	Identification of bare soil areas and duration of bare status.
GEAC-5 SOIL AND CARBON STOCK – MINIMUM LAND MANAGEMENT SITE SPECIFIC CONDITIONS TO LIMIT EROSION	
GEAC 5.1 Mechanical field operations and vehicle activity has taken place on waterlogged soil.	Identifying soils vulnerable to waterlogging or near saturation point
GEAC 5.2 Signs of soil run off down a slope, off site (field) or into watercourses.	Identifying runoff or muddy outwash from fields
GEAC 5.3 Failure to complete an accurate rough surface soil risk assessment and/or notify Welsh Government on or before the day the land is cultivated to leave a rough surface.	Provide evidence of soil erosion, identify areas at risk.
GAEC-7: MAINTENANCE OF LANDSCAPE FEATURES	
GEAC 7.6 The farmer has cultivated or ploughed land within 1 metre of a hedge, earth bank or surface water within a field(s).	Determine distance from feature to ploughed land.

[4] https://gov.wales/sites/default/files/publications/2020-01/cross-compliance-verifiable-standards-2020.pdf

Table 6-2: Other possible breaches of the Good Agricultural and Environmental Conditions (GAEC) that an alert system could help identify if expanded further.

GAEC Standard
GEAC-6 SOIL AND CARBON STOCK – MAINTENANCE OF ORGANIC MATTER
GEAC 6.1 Burning, that contravenes these rules (other than accidental or caused by arson), has been carried out.
GEAC 6.2 Burning has been carried out on land within closed periods.
GEAC 6.3 Burning carried out without or not in accordance with a suitable Burning Management plan.
GEAC 6.4 The farmer has begun or carried out, a) an agricultural intensification land project on semi natural land, or b) a large scale rural restructuring project, without obtaining i) a screening decision, or ii) consent for the project; and/or in the case of obtaining either i) or ii), has not complied with their requirements, including failure to comply with a Stop Notice or Remediation Notice that has been served under the regulations.
GEAC 6.5 The farmer has begun or carried out an afforestation/ deforestation project, without obtaining i) a screening decision, or ii) consent for the project, and/or in the case of obtaining either i) or ii), has not complied with their requirements, including failure to comply with a Stop Notice or Remediation Notice that has been served under the regulations.
GEAC-7 MAINTENANCE OF LANDSCAPE FEATURES
GEAC 7.1 The farmer has not retained pond(s) on the holding (e.g. by drainage, filling in).
GEAC 7.2 The farmer has filled in a ditch on the holding. Note: Any culverting of a ditch or watercourse requires land drainage consent from Natural Resources Wales (under Section 23 of the Land Drainage Act 1991)[5].
GEAC 7.3 Removal of a landscape feature.
GEAC 7.7 A scheduled monument has been damaged, demolished or destroyed.
GEAC 7.9 The farmer has felled a licensable tree or trees without the necessary Felling Licence.
GEAC 7.10 The farmer has failed to comply with the conditions of a Felling Licence or failure to comply with a felling direction.
GEAC 7.11 The farmer has cut down or is destroying a tree covered by a Tree Preservation Order.

[5] https://www.legislation.gov.uk/ukpga/1991/59/section/23

7 APPENDIX: ISSUES IDENTIFIED

A. Erosion pathways: these three examples below constitute possible erosion pathways but are too nebulous and numerous to delineate by hand – might be more possible for AI:

   i. Animal tracks across pastures in uplands were not identified as too numerous as they are everywhere. These could be recorded by surveyors as Yes/No as to presence.

   ii. Vehicle tracks going across fields after gateway fans are too numerous as they are everywhere and not sure about damage. These could be recorded by surveyors as Yes/No as to presence.

   iii. Tram lines

B. Harvested woodland is an area where erosion is likely but resolution is not great enough and surveyors will need to check.

C. Identifying peat erosion / bare peat / upland soil erosion was particularly difficult and required going back through squares with Google Earth. Issues included:

   iv. Whether it is dried bracken or dried soil / peat (all are shades of similar brown)

   v. What the blankets of white on peat squares were (probably a function of reflectance for the photography - as Google Earth images helped to confirm) as couldn't find anything abnormal.

D. Knowledge and familiarity of the landscape and how it changes with season is quite important. This is a key attribute required to undertaking this task. Whereas the team was familiar with lowland landscapes and geomorphology, it was much less aware of upland peat features.

E. Time of year photos taken - vegetation changes with season, which may cover erosion and damage in places e.g. early spring photos may show more signs of poaching. However, most features are likely to be permanent as gateways don't change, animals are habitual in their tracks and shelter/socialising areas. We might expect to identify more damage in winter / spring when soils are soft, animals are in the lowlands and the leaves are not yet obscuring the ground. We note that we did not include the previous years poaching around feeding stations. The outline was apparent but the ground was no longer bare. HWhilst we are marking the physical area of poaching and soil damage, it is expected that a halo effect will extend from the bare soil – how big is this halo?

F. A lot of the steepest slopes are covered in woodland – is there erosion, terracettes in these areas?

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