Comparing High Resolution LiDAR and Conventional Digital Elevation Models for Modelling Phosphorus Transfer Pathways

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Introduction

- Diffuse losses of **phosphorus (P)** from agricultural land to surface waters must be controlled to reduce eutrophication and associated water quality issues. Areas at highest risk, termed **critical source areas (CSAs)**, need to be accurately identified if mitigation measures are to be targeted and cost-effective
- **P Index** tools can identify CSAs at the field scale by estimating the relative risk of P loss using source and transport factors. The transport factor commonly uses the distance-to-stream to account for **variable source area (VSA)** hydrology
- However, VSAs are affected by upslope contributing area, slope and other variables, and surface runoff pathways responsible for the majority of P transport can be influenced by **micro-topography**
- CSAs could be identified with higher precision in catchments with VSA hydrology if a P Index uses a **topographically-based transport factor derived from high resolution Light Detection And Ranging (LiDAR) Digital Elevation Models (DEMs)**

Methodology

Phase 1- Identifying the Optimal Topographic Resolution

- A well drained arable catchment (**Arable A**) and poorly drained grassland catchment (**Grassland B**), located in south-east Ireland and part of the **Teagasc Agricultural Catchments Programme (ACP),** were selected for the study
- Catchment areas prone to surface runoff and hence P transport were modelled using threshold values of the **Topographic Wetness Index (TWI)** at four different grid resolutions **(Fig 2),** derived from 0.25 m, 1 m and 2 m resolution **LiDAR DEMs** and a 5 m DEM
- Predictions were compared to field observations of overland flow during storm events at target sites to determine the **optimal TWI grid resolution**

Phase 2 (Preliminary)- Developing a VSA-Based P Index at the Optimal Topographic Resolution

- A preliminary **VSA-based P Index** was developed by integrating raster datasets of six P source and transport factors (**Fig 1**) within a GIS, including the **TWI** (at the optimal resolution) and the **Network Index** (indicating hydrological connectivity to the stream, calculated)
- Relative risk scores were assigned to data values for each factor. An additive **P loss risk map** was then created by calculating total risk scores for each raster cell **(Fig 4)**
- CSAs were identified at cells with the highest 20% (high risk) and 10% (very high risk) total risk scores (**Fig 5**)

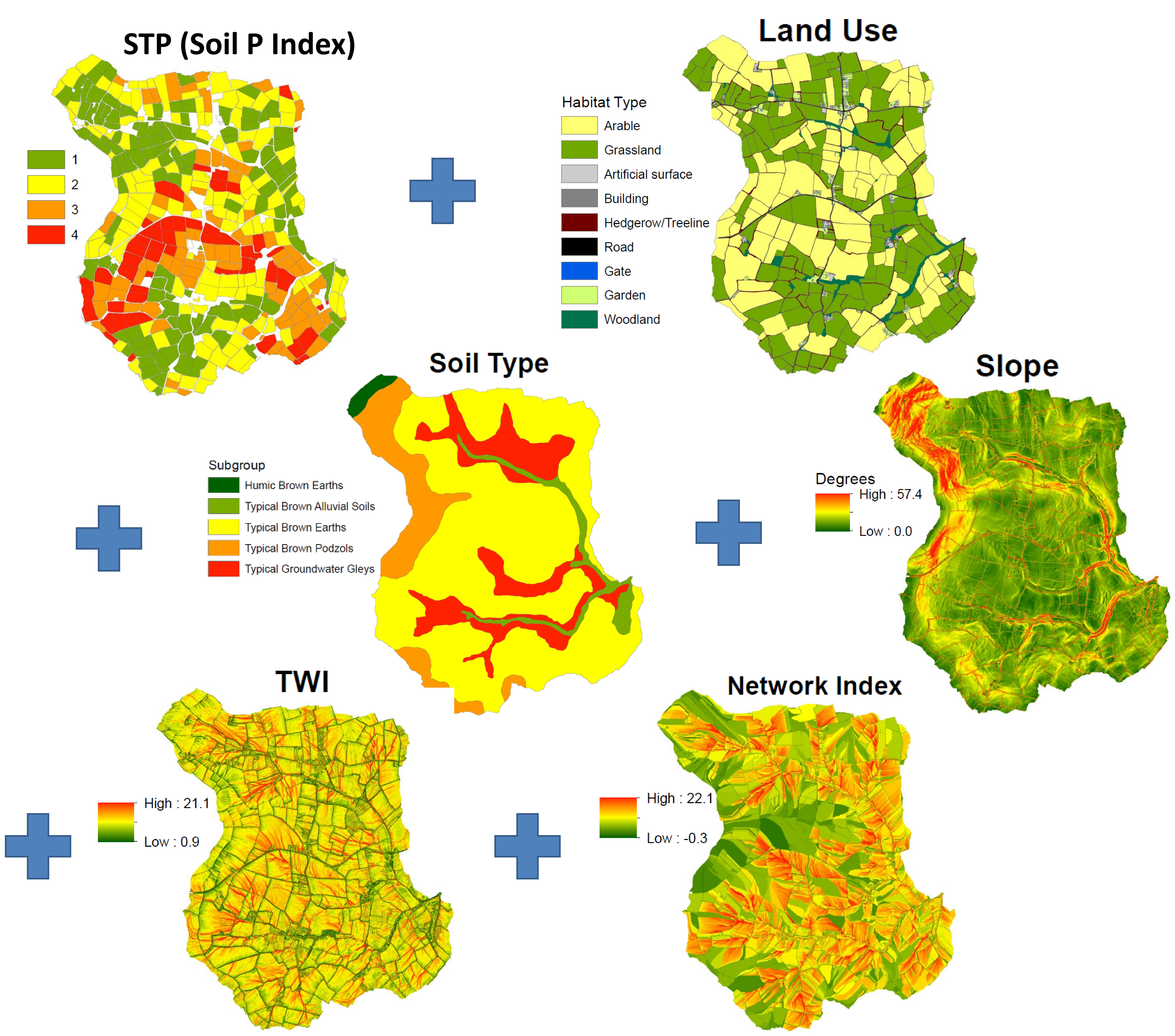

Fig 1. P source and transport factor datasets used within the preliminary VSA-based P Index (for Arable A)

Results

Phase 1:

- Overland flow pathways modelled from LiDAR-derived TWI maps (0.25-2 m resolution) were **diverted** by roads, hedgerow banks and tramlines, and tended to **accumulate** at downslope field boundaries and '**break through**' at hedgerow openings (**Fig 3**). This was not indicated in 5 m maps as the 5 m DEM did not capture such micro-topographic features
- Finer resolution TWI maps thus predicted observed runoff-prone areas with greater accuracy **(Table 1)**
- **The optimal grid resolution** in agricultural catchments with micro-topographic features **was identified as sub-5 m**

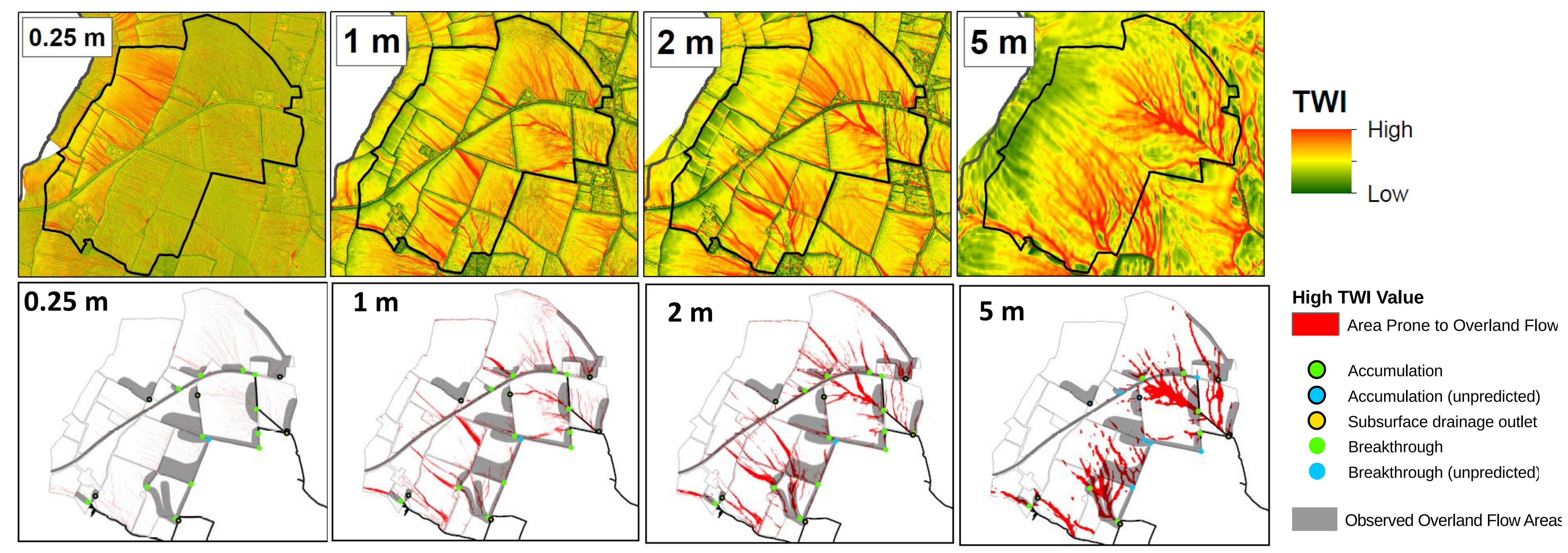

Fig 2. TWI maps derived from 0.25 m, 1 m and 2 m LiDAR DEMs and a conventional 5 m DEM (top row), and highest TWI values overlaid with observed overland flow areas (bottom row) for a target site in Arable A

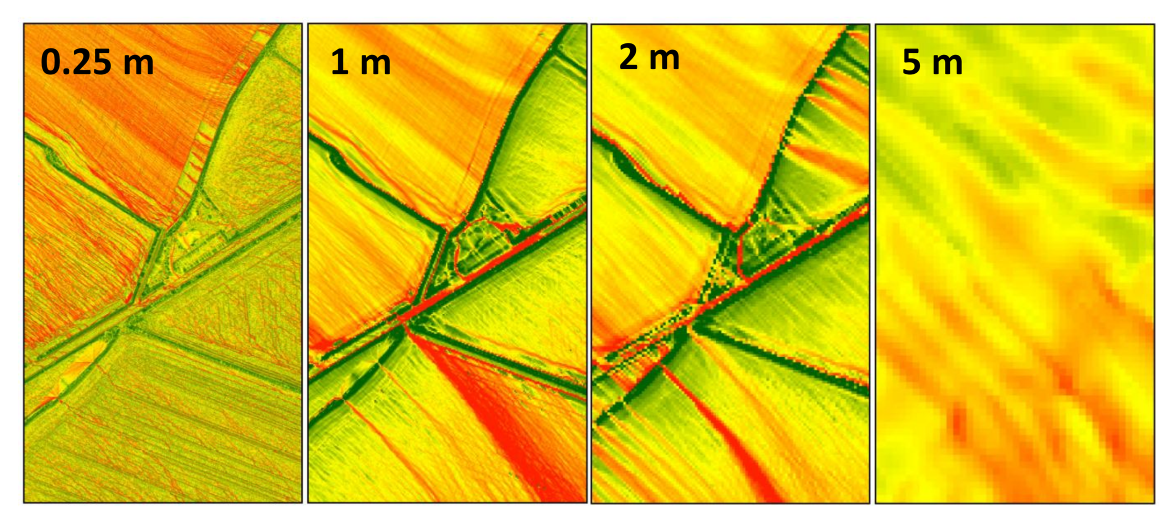

Fig 3. Close-up of TWI maps derived from each DEM resolution, showing the influence of hedgerow banks and a road (centre) on overland flow-prone areas at finer grid resolutions

Table 1. Predictions of observed runoff-prone areas using TWI maps at each grid resolution for upland and lowland target sites of Arable A

	Upland				Lowland			
DEM Resolution	0.25 m	1 m	2 m	5 m	0.25 m	1 m	2 m	5 m
Predicted	19	18	18	11	17	17	14	11
Predicted at or nearby	19	18	18	13	18	18	16	14
Unpredicted	0	1	1	6	3	3	5	7
Total	19				21			
Predicted (%)	100%	95%	95%	58%	81%	81%	67%	52%
Predicted at or nearby (%)	100%	95%	95%	68%	86%	86%	76%	67%
Unpredicted (%)	0%	5%	5%	32%	14%	14%	24%	33%

Phase 2 (Preliminary):

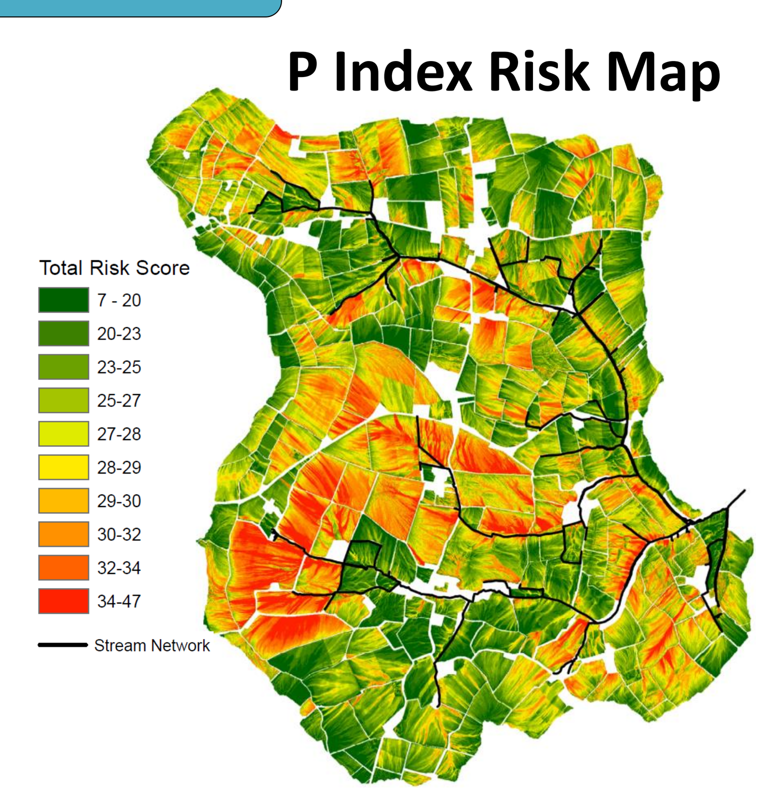

Fig 4. CSA P Index risk map for Arable A

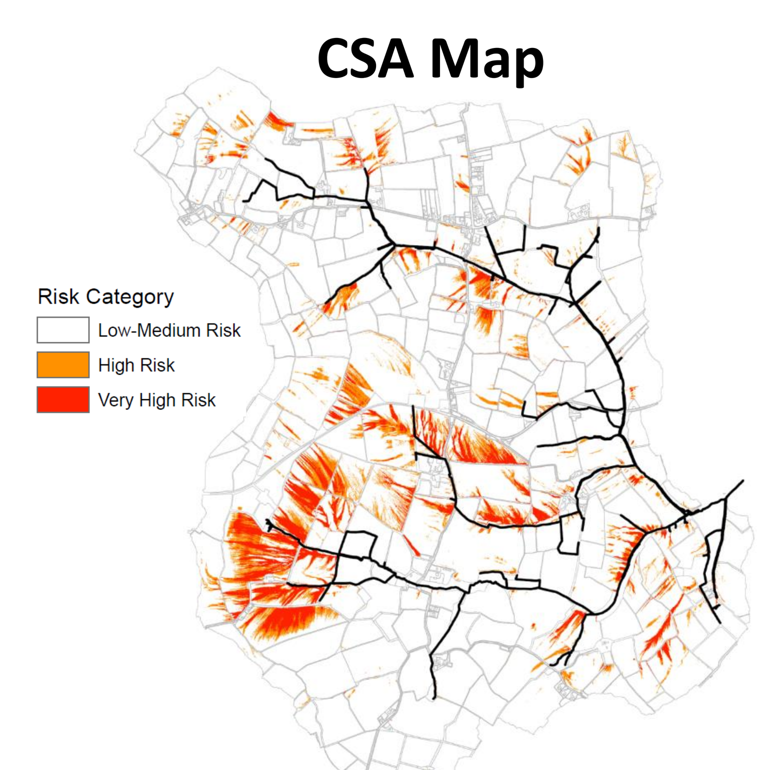

Fig 5. CSAs identified in Arable A

Discussion and Conclusion

- The optimal DEM resolution reflects the scale of the topographic features influencing surface hydrology
- The ability of finer resolution TWI maps to identify **flow breakthrough points** indicates the potential for targeted, sub-field scale mitigation measures to trap P in overland flow close to the source using LiDAR data. These locations are where P is potentially being transported between fields
- **A VSA-based P Index using LiDAR-derived TWI maps may improve CSA identification**
- Refinements and factor weightings will be introduced and the P Index validated using measured and modelled P loads

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