Field-Scale Run-off Vulnerability Mapping Using GIS Modelling to Support Precision Agriculture

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BACKGROUND & RATIONALE

Diffuse agricultural pollution from surface runoff is a leading driver of pesticide loading to surface water in the EU, yet regulatory risk assessment and farm management typically treat entire fields as uniform management units, ignoring substantial spatial variability in runoff connectivity.

Spatially explicit vulnerability frameworks identifying which fields and catchments, and where within them, runoff risk is highest, are essential for targeting buffer zones, application restrictions, and higher-tier risk assessment.

Objective: To develop a national screening index that identifies which fields are at the highest risk based on landscape, soil, groundwater, and crop pressure. This work focused on creating a Tier 1 screening framework that identifies priority parcels for pesticide runoff risk assessment in the Netherlands. This approach could aid in replacing blanket worst-case assumptions with spatially explicit, field-level risk rankings across 1.3 million agricultural parcels.

MATERIALS & METHODS

Dataset	Variable	Res.
AHN4 (PDOK)	HAND index, slope	0.5 m
BRP 2025 (RVO)	Field bounds + crop	Parcel
TOP10NL (Kadaster)	Waterway proximity	1:10k
BOFEK2020 (WEnR)	Ksat (cm/day)	1:50k
BRO GWM (WEnR)	Groundwater depth	Point

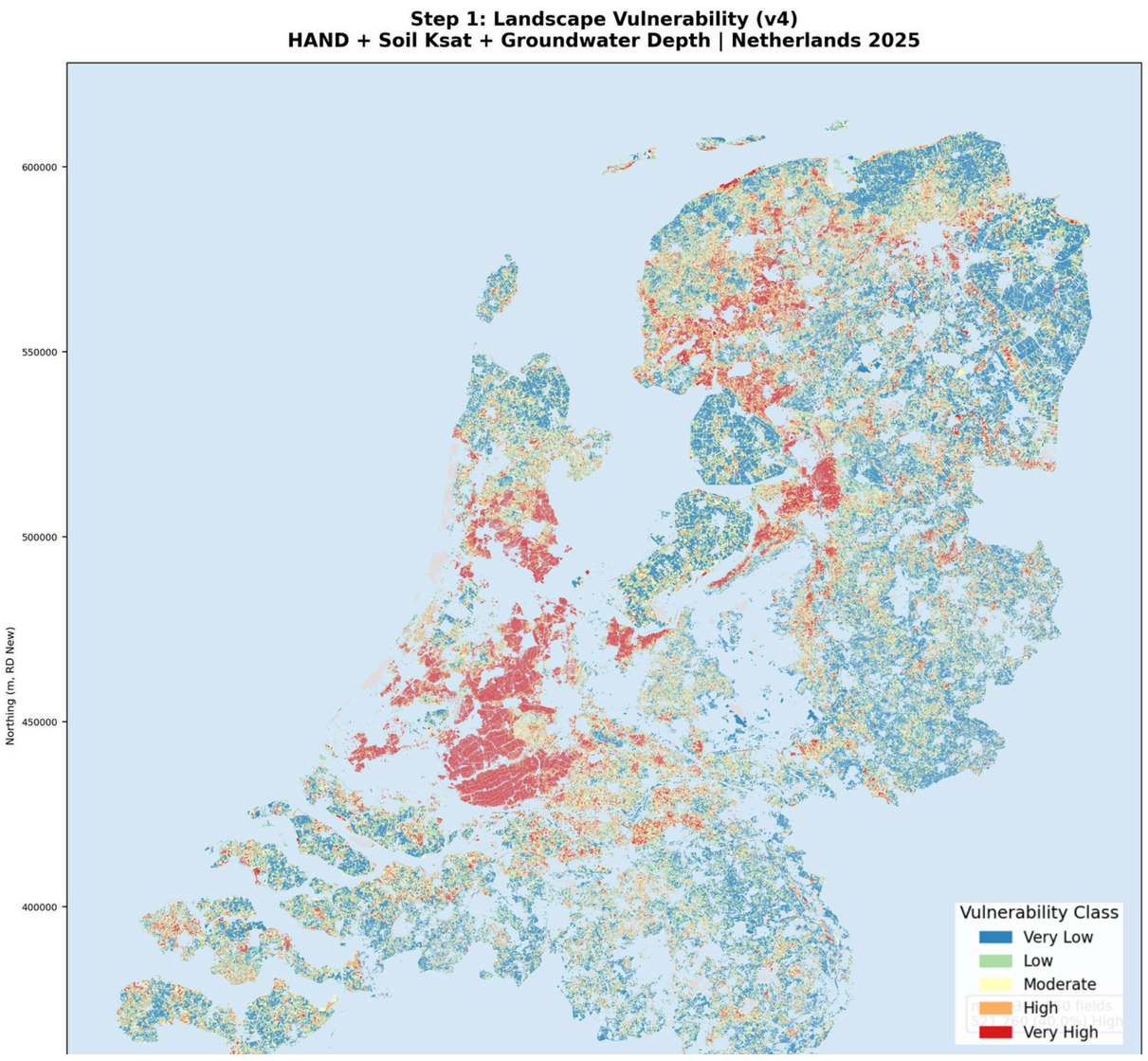
STEP 1 — LANDSCAPE VULNERABILITY
HAND + Ksat + Groundwater Depth → PCA-weighted score
Intrinsic landscape risk, independent of land use

Crop Pressure

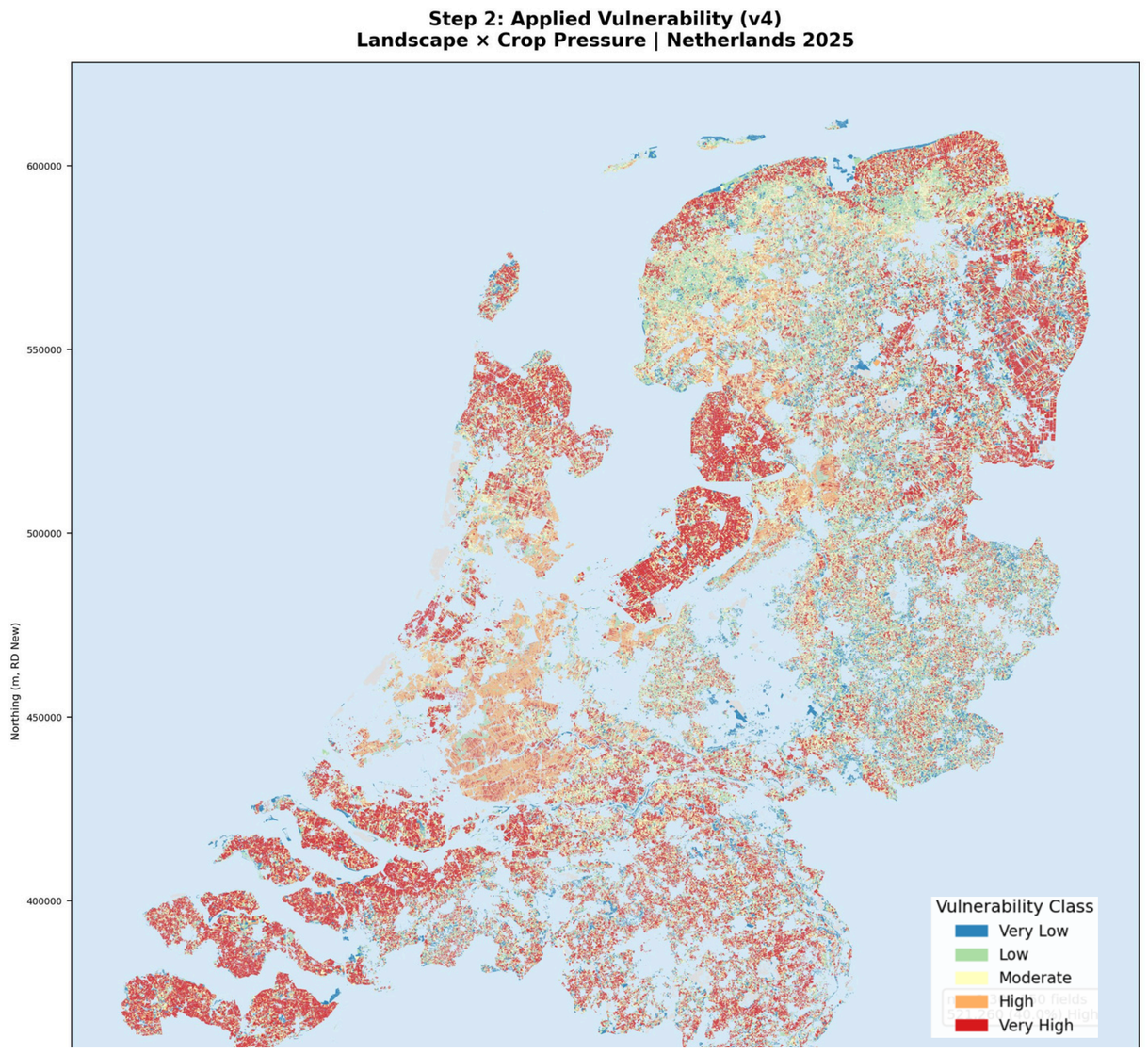
STEP 2 — APPLIED VULNERABILITY
Landscape × Crop pressure (29 crop types; RIVM, CBS, EFSA, Ctgb). Realised risk under current land use.

PCA-derived pillar weights (PC1 loadings): Step 1 Topography 50.0% | Soil+GW 50.0% Step 2 Topography 35.5% | Soil+GW 27.7% | Crop 36.8%
Weights are data-driven; no subjective parameter assignment

STEP 1 — LANDSCAPE VULNERABILITY

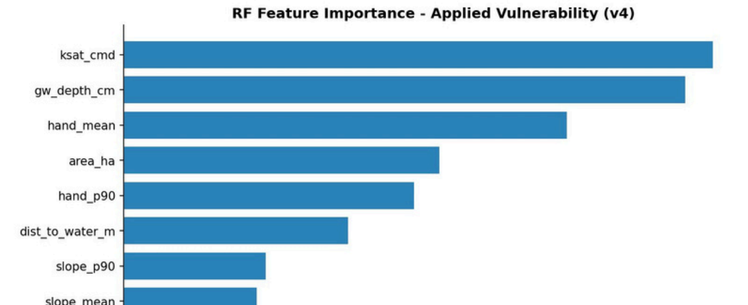


STEP 2 — APPLIED VULNERABILITY

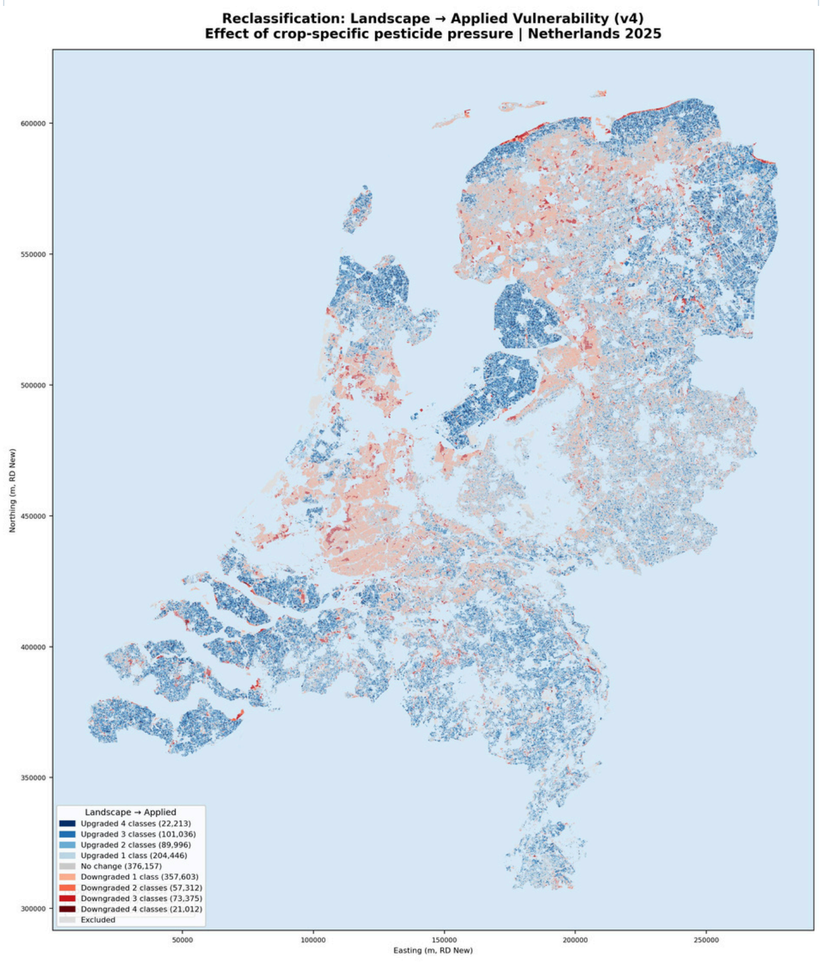


KEY FINDINGS

- 63% of arable fields (640,023 ha) classified High or Very High applied vulnerability — concentrated in Groningen, Flevoland, and Zeeland potato/sugar beet zones.
- Grassland de-risked: permanent grassland (Ksat 20–35 cm/day, pressure 0.30) reduces applied class by 1–2 steps across the peat belt, correctly reflecting lower pesticide loading.
- Groundwater depth and Ksat dominate risk prediction (RF importance ~0.21 each), confirming that saturation-excess runoff mechanisms outweigh slope in flat NL terrain.
- 39% of fields downgraded, 32% upgraded by crop pressure — symmetric reshuffling confirms crop layer adds information beyond landscape risk alone.
- RF spatial holdout accuracy: ~65% (northern NL withheld). Confusion at class extremes reflects geographic transferability constraints.



RECLASSIFICATION:



The two-step framework reveals that the highest-risk landscape locations are not always the highest-risk fields. A peat soil field with a shallow water table adjacent to a ditch carries high intrinsic landscape risk; planted with permanent grassland, it is substantially lower than an equivalent field under a root vegetable crop.

Dominance of Ksat and groundwater depth over slope in the RF (importance ~0.21 each vs ~0.05 for slope) challenges the elevation-centric framing common in runoff literature. In low-relief catchments, soil hydraulic class and groundwater proximity are more mechanistically defensible predictors.

Limitations: Crop pressure scores are generalised use-intensity values and do not account for compound-specific physicochemical properties. RF accuracy of ~65% on a geographic holdout reflects genuine transferability constraints. A model that accounts for regional hydrological, soil and agronomic context cannot accurately predict PPP losses, however it can be a useful screening tool to identify at-risk regions and refine standard low-resolution modelling approaches to account for regional real-world use scenarios. Coupled with spatial dilution modelling it can serve as a higher-tier refinement option.

CONCLUSION

✓ National-scale risk screening based on a field-level vulnerability mapping is feasible at parcel resolution using open data and open-source tools.
✓ Separating landscape from applied vulnerability shows 63% of arable fields exceed High/Very High threshold.
✓ In flat agricultural landscapes, groundwater depth and Ksat outperform slope as runoff predictors.