Pesticide leaching under climate change – a regional perspective

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Background

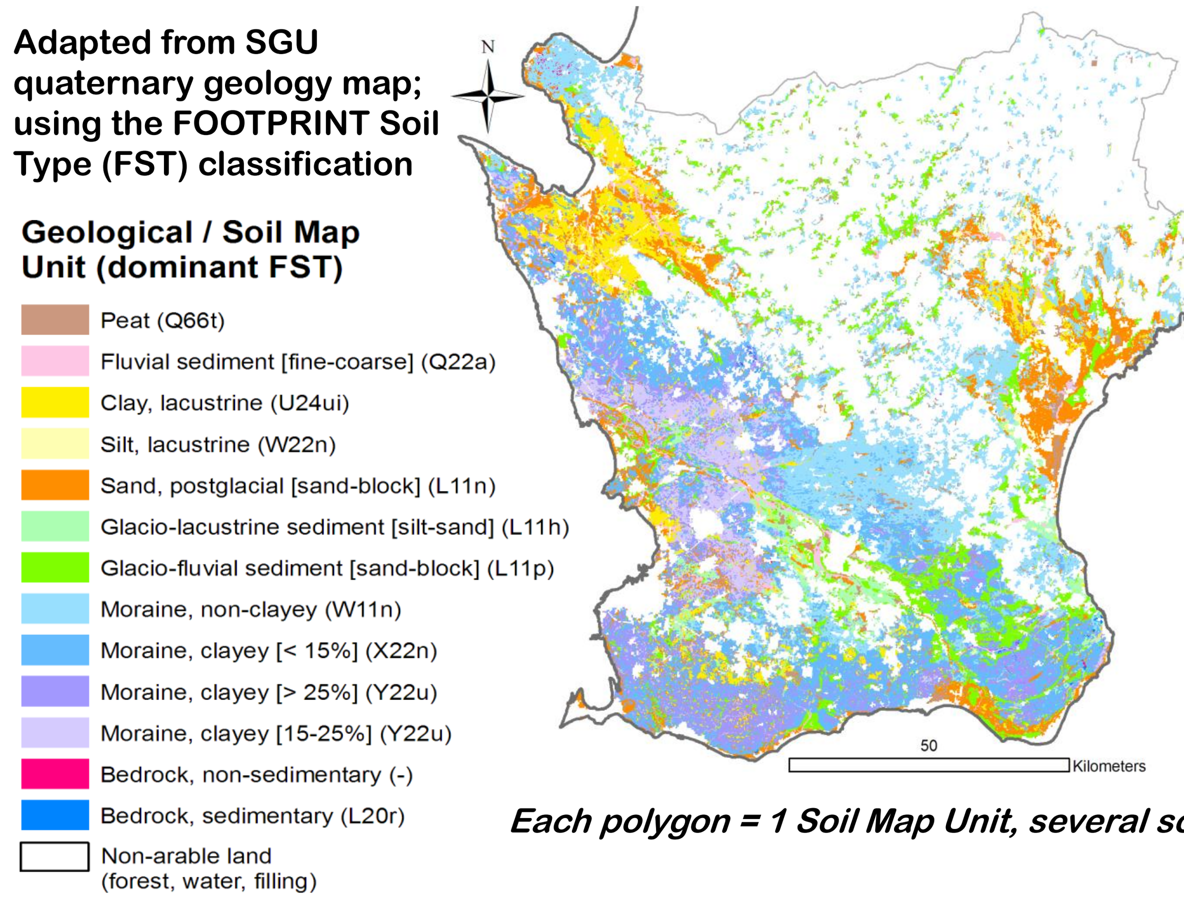
- Future climate scenarios for Scandinavia indicate changes which are likely to affect pesticide leaching from arable land in contrasting ways:
  - Higher temperatures: faster degradation → leaching ↓
  - Higher precipitation: more macropore flow → leaching ↑
- Indirect effects of climate change (changes in land use and agricultural practices) may also be significant.

Aims

- To assess the potential risks of pesticide leaching to surface and groundwater under present and future climate conditions at the regional scale, accounting for different soil types, typical pesticides and application timings.
- To test MACRO-SE, a newly-developed tool for scenario-based parameterizations of the MACRO model.

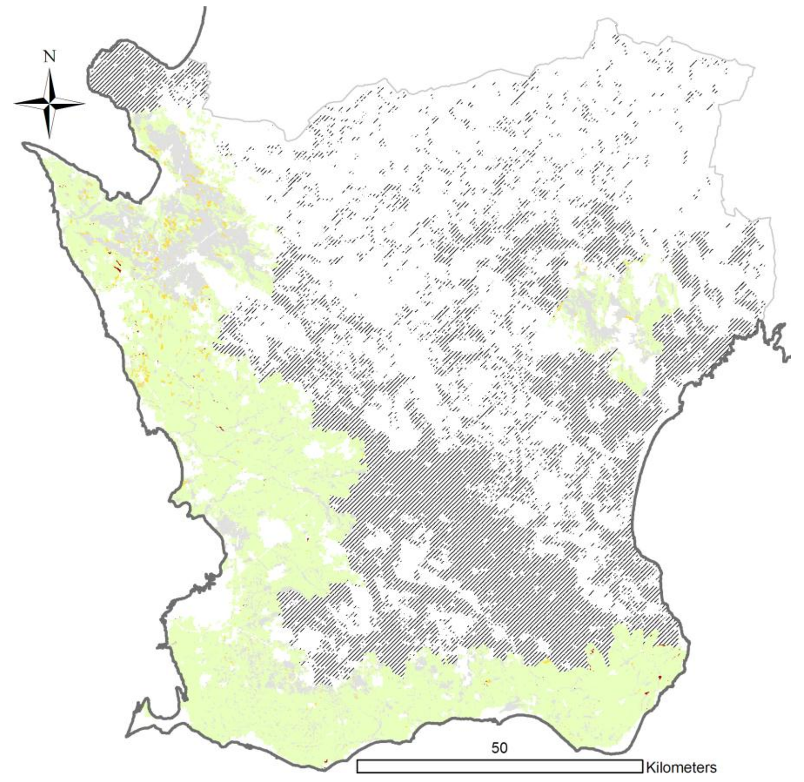
Soil map of Scania (south Sweden)

Adapted from SGU quaternary geology map; using the FOOTPRINT Soil Type (FST) classification

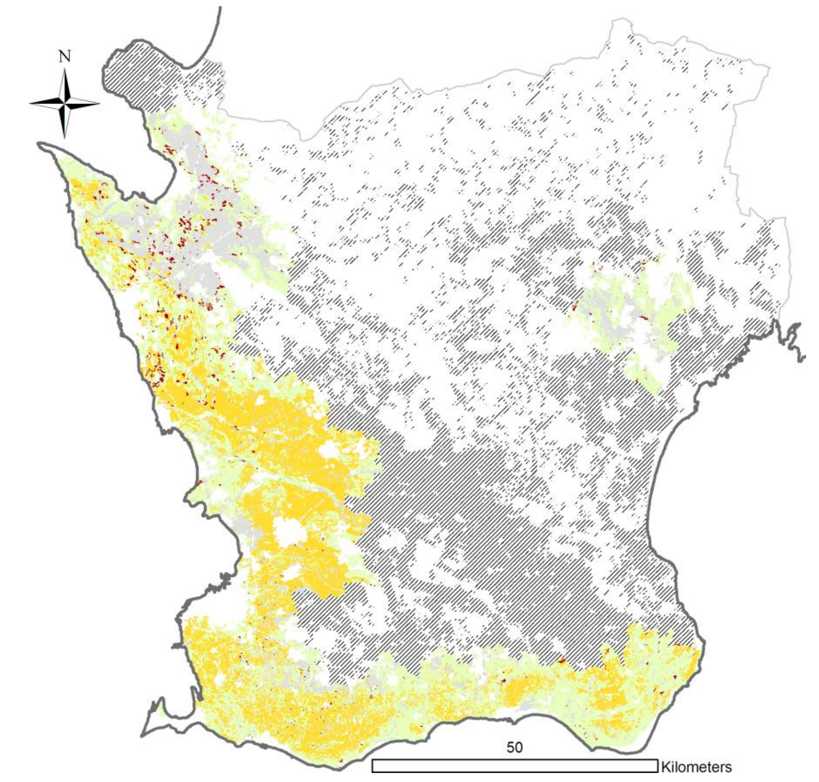


Each polygon = 1 Soil Map Unit, several soil types

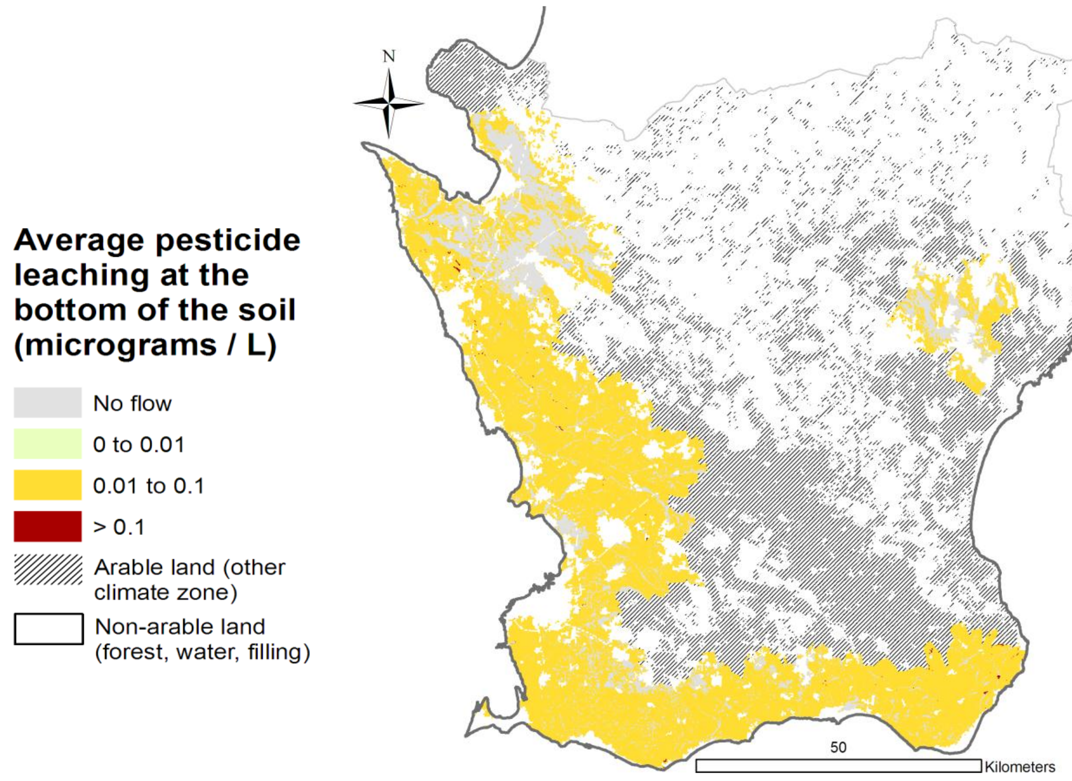
Vulnerability maps: average pesticide concentration in leachate (bottom of the soil)



Autumn application – present climate – P1



Autumn application – future climate – P1

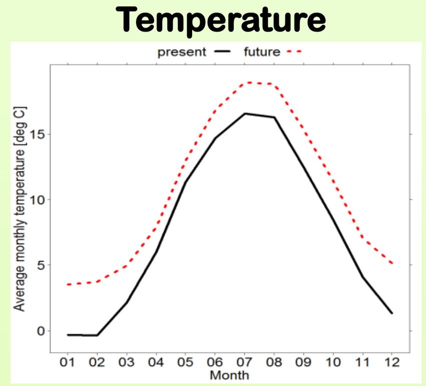


Autumn application – present climate – P3
Future climate: no significant changes

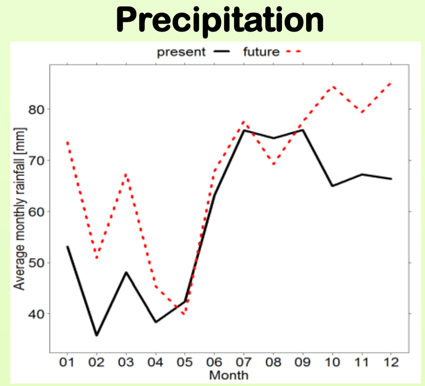
Climate Data

A 30-year climate data set, identified as representative for the studied region, was used as reference period (1970-1999). The future climate data set (2070-2099) was generated with a **delta change approach**, based on monthly values calculated from projections of the ECHAM5-GCM, forced by the A2-emission scenario and downscaled by the RCA3-model (Rossby Center, SMHI, Sweden). Wind speed and relative humidity were assumed unchanged in the future.

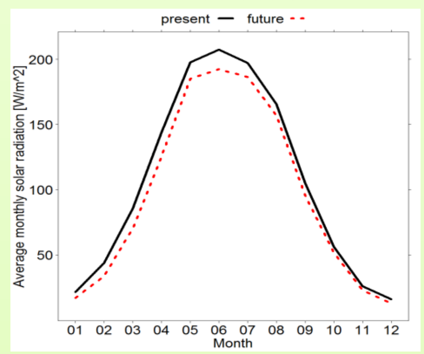
Temperature



Precipitation



Solar radiation

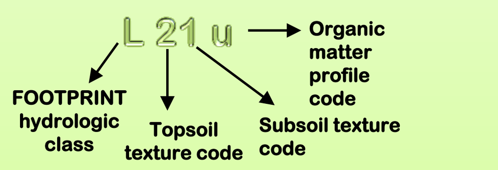


Pesticide leaching calculations

Losses by percolation at the bottom of the profile to **groundwater** were calculated as the **average pesticide flux concentration**. Further dilution in groundwater was neglected. Losses by tile drains to **surface waters** were estimated as the **99th-percentile** of the daily pesticide loads converted to a concentration with the correspoding daily drainage flow. This percentile represents a return period of 100 days.

The FOOTPRINT Soil Type (FST) classification

Recharge or discharge area?	Classes	MACRO bottom boundary condition	Description
Recharge to groundwater	L, M, N	Unit hydraulic gradient	Permeable substrate, groundwater > 2m depth
Discharge to surface water	O, P, Q	Zero flow	Low-lying topography, groundwater depth (O, P > Q)
	R, S, T, U, V		Impermeable substrate
Both recharge and discharge	W, X, Y	Percolation as function of water table height	Slowly permeable substrate Recharge: W>X>Y

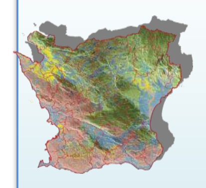


Pesticides: Properties & Application time

Pesticide Name	Koc [ml/g]	DT50 [day]	Application rate [kg/ha]	Freundlich Exponent [-]
P1 - Isoproturon	120	15	0.4	0.8
P2 - Diflufenican	3000	120	0.04	0.92
P3 - Tribenuron-methyl	30	12	0.004	0.98

Application period	First possible day	Last possible day
Autumn	12 Oct	22 Oct
Spring	15 Apr	25 Apr

MACRO-SE : (R package)



Maps: Soil + Climate + Land use

Lookup databases (soil, climate, crop) + parameter estimation functions

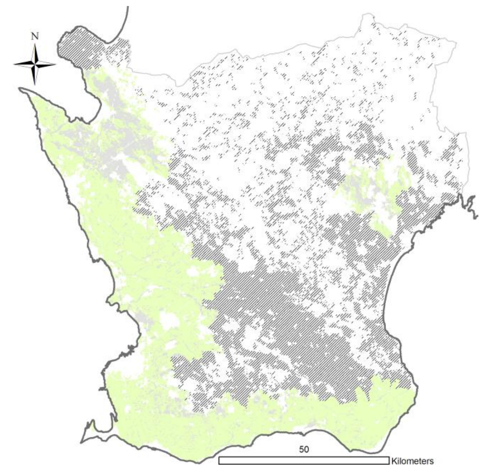
Parameter sets & driving data

Run MACRO pesticide fate model (mechanistic)

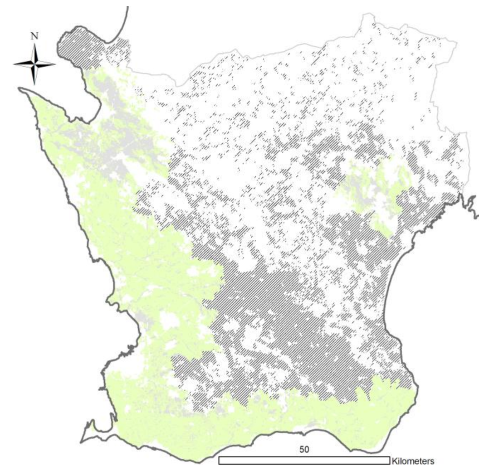
Results

SQLite

Aggregate results, spatial averaging

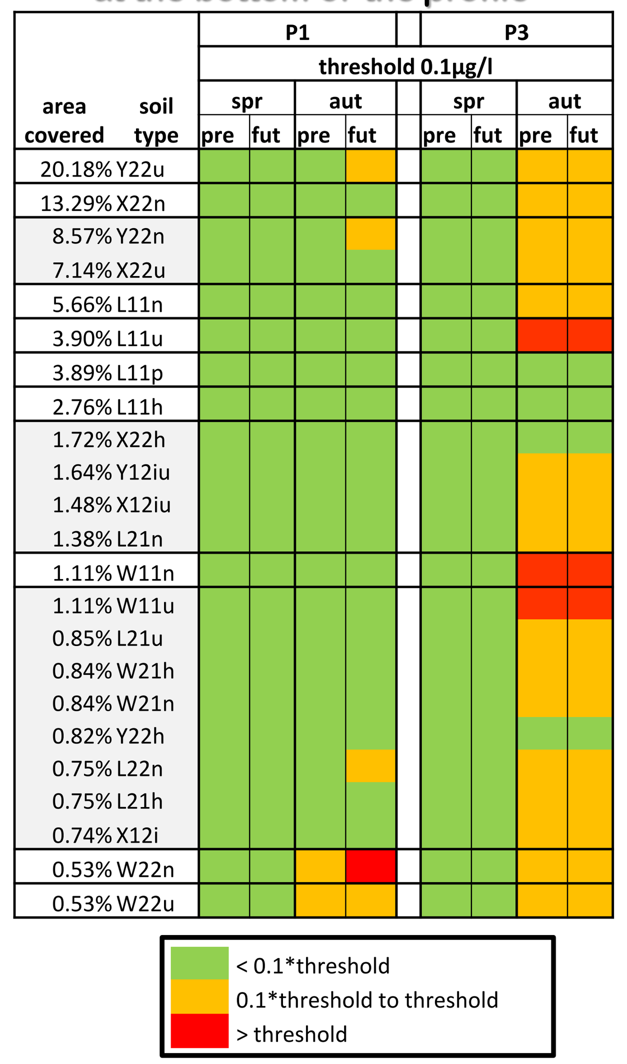


Spring application – present climate – P1
Future climate: no significant changes

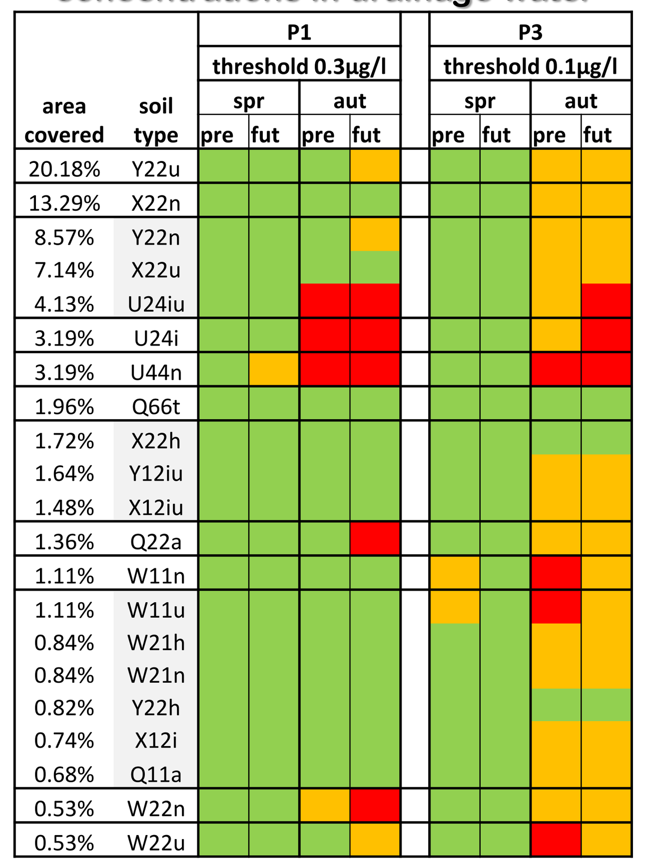


Spring application – present climate – P3
Future climate: no significant changes

Average concentration of pesticides lost at the bottom of the profile



99th-percentile of pesticide concentrations in drainage water



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References

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- Kjellström et al. 2011: 21st century changes in the European climate: uncertainties derived from an ensemble of regional climate model simulations. Tellus 63 (1), Jan. 2011.
- Jarvis N J et al. 2007: Algorithm to completely parameterise MACRO from basic soil property data. Report DL21 of the FP6 EU-funded FOOTPRINT project, 18p.

Conclusion & Outlook

- **Direct effects** of climate change on pesticide leaching depend on soil type, compound properties and application time.
  - No change in leaching after spring application.
  - Higher leaching after autumn application of compounds prone to macropore flow (P1), since increase in rainfall is the dominant driver.
  - For more mobile compounds (P3), faster degradation due to higher temperatures balances the increased rainfall, resulting in negligible changes in the future.
  - The very strongly sorbed pesticide (P2) did not show any leaching at all.
- **Indirect effects of climate change** might have a stronger effect on the overall pesticide leaching than direct effects: e.g. An increase in the area of winter sown crops very likely increases the frequency of pesticide application in autumn and the total leaching.
- **MACRO-SE** is suitable for large-scale screening of vulnerability & susceptibility to pesticide leaching.
- **Next steps**: calculations for all of Scania, including cropping statistics and dilution for surface waters for actual risk rather than vulnerability assessment.
- **Further exploration** of impacts of changes in the frequency of high rainfall events as well as changes in land-use and agricultural practices.