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Assessing Nutrient Hotspots in Denmark's Agricultural Fields: a Focus on the Livestock sector

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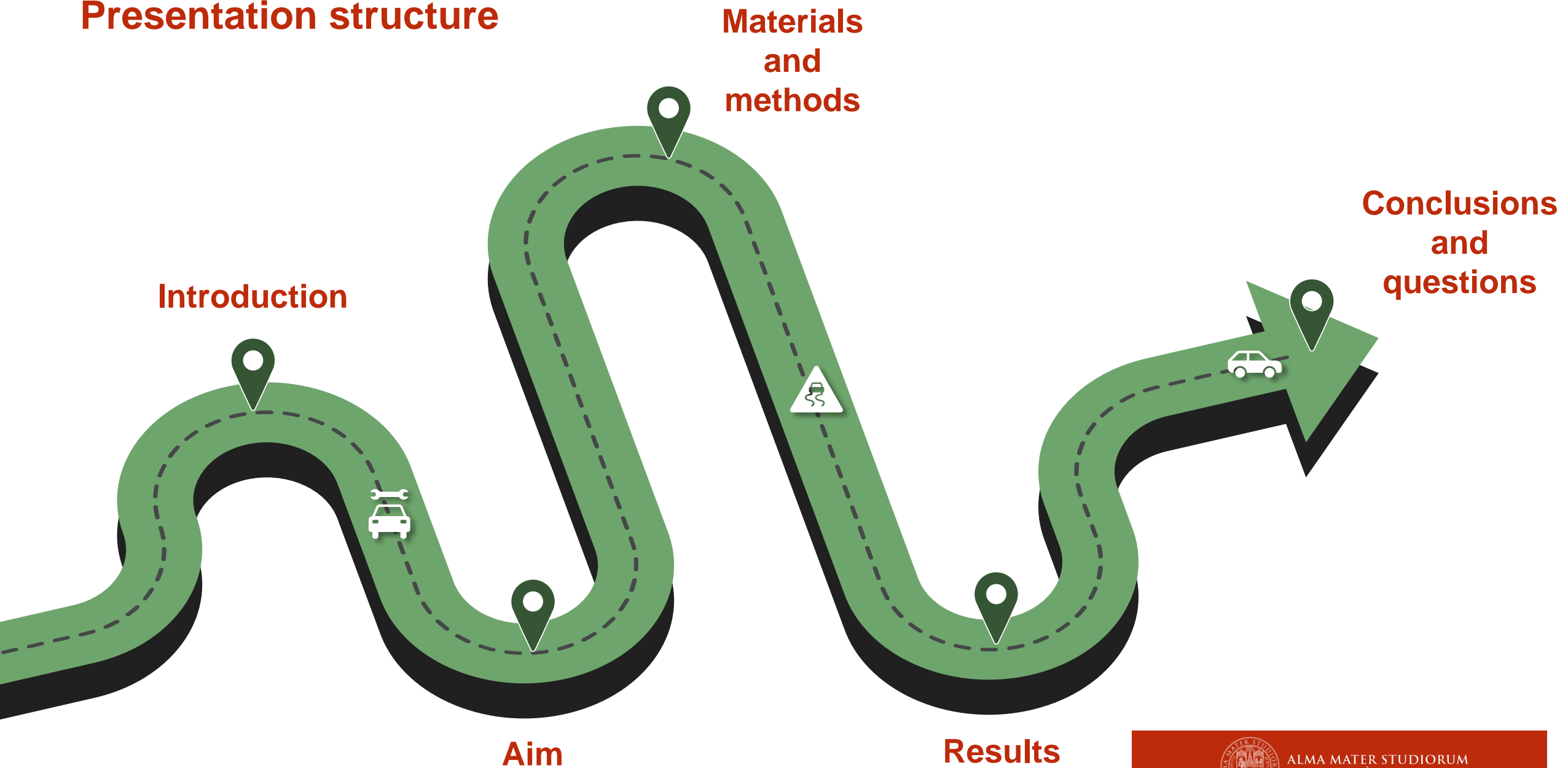
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International Interdisciplinary Conference on Land Use and Water Quality

Agriculture and the Environment - Aarhus, Denmark, 3-6 June 2025



Presentation structure

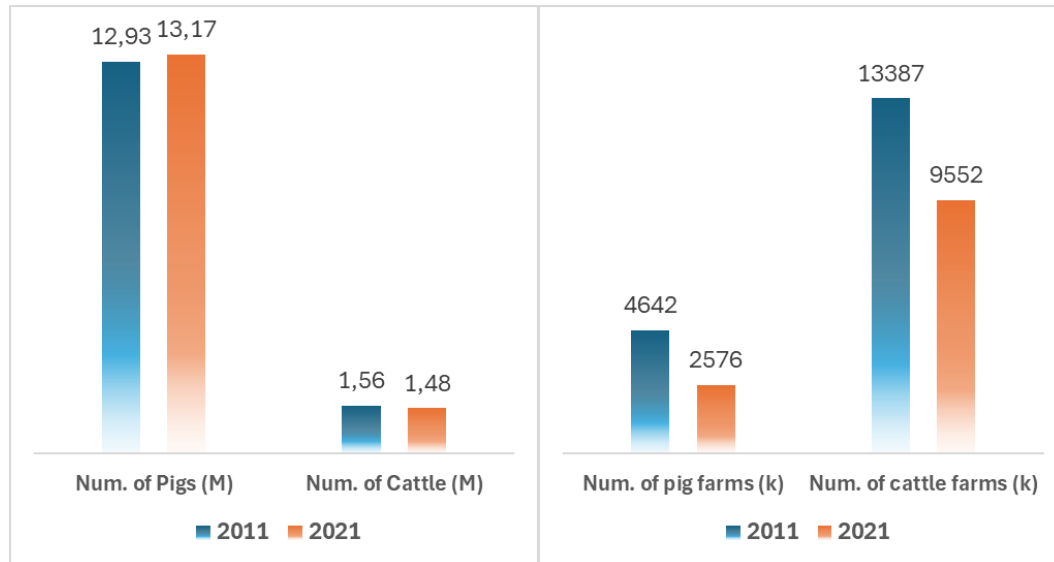


Aim

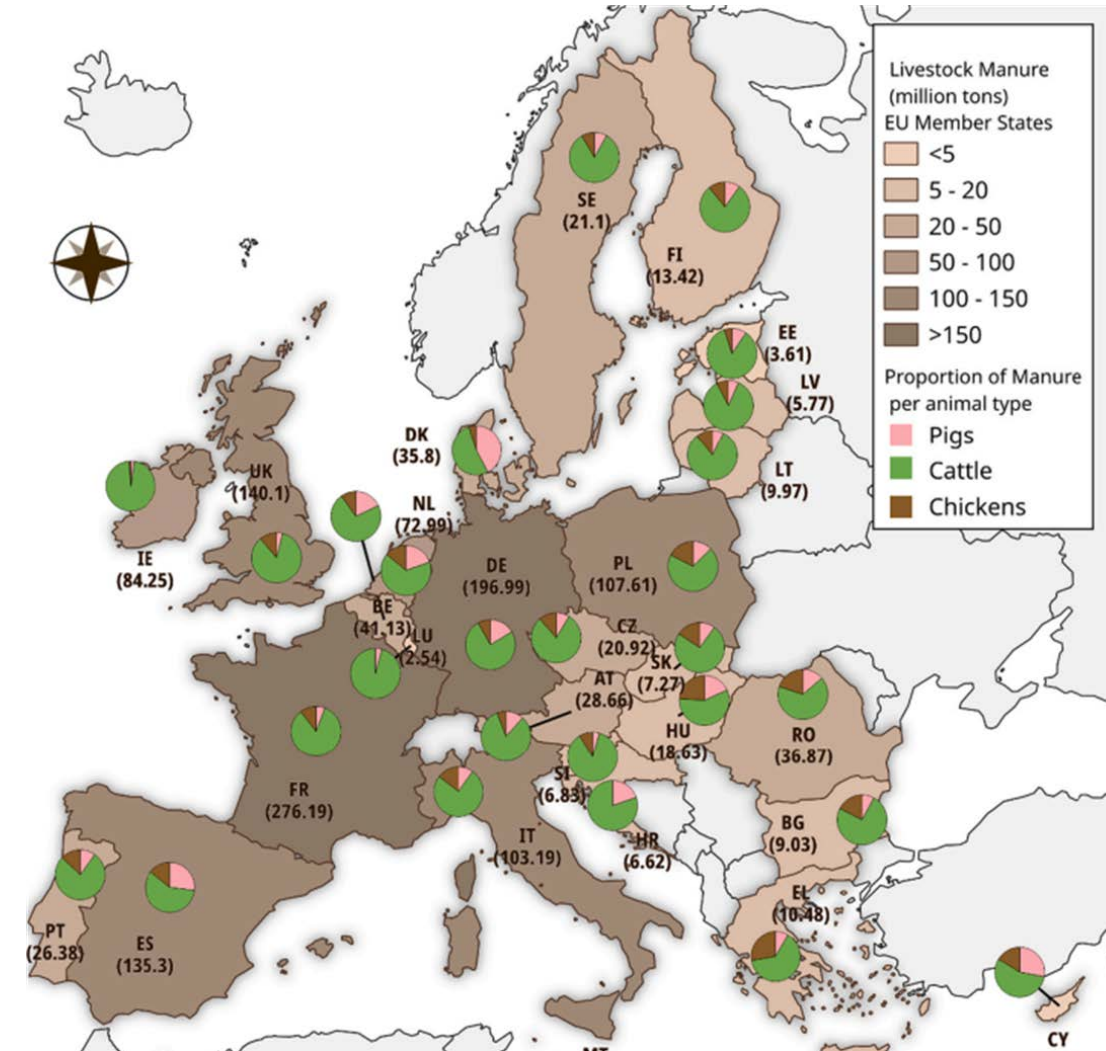
Results

Introduction

Denmark is one of the leading European countries in terms of livestock intensity, with a high concentration of pigs and cattle. This intensive production has significant environmental consequences, particularly in terms of nutrient loadings in water.



Statistics Denmark. 2021. "Farms with Livestock."



* Köninger, E. Lugato, P. Panagos, M. Kochupillai, A. Orgiazzi, and M. J. I. Briones (2021). "Manure management and soil biodiversity: Towards more sustainable food systems in the EU," *Agric Syst*, vol. 194, no. September, p. 103251



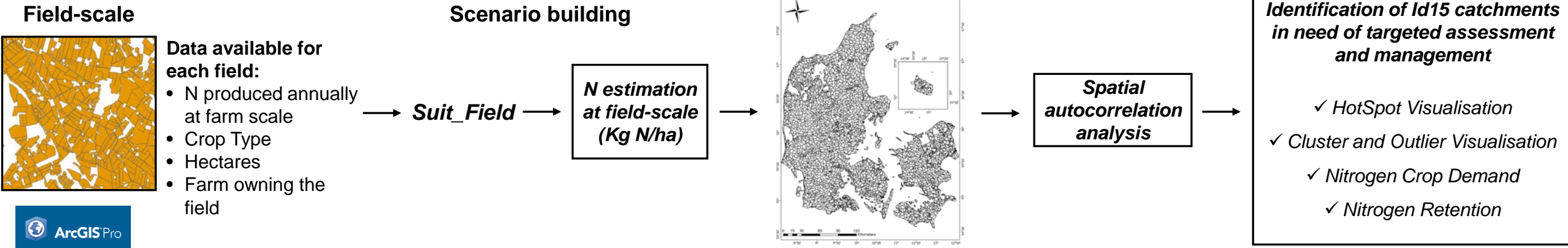
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Aim



- To identify catchments requiring **targeted mitigation measures**
- Produce a detailed spatial overview of **nitrogen (N) hotspots and clusters** caused by livestock manure at the national scale

Materials and methods



Field-scale

Data available for each field:

- N produced annually at farm scale
- Crop Type
- Hectares
- Farm owning the field



Version 3.2.2

Scenario building

Suit_Field → **N estimation at field-scale (Kg N/ha)**

Aggregate the data at the Id15 catchment level



Spatial autocorrelation analysis

Identification of Id15 catchments in need of targeted assessment and management

- ✓ HotSpot Visualisation
- ✓ Cluster and Outlier Visualisation
- ✓ Nitrogen Crop Demand
- ✓ Nitrogen Retention

Data source

Danish farmers with considerable livestock production or usage of manure are compelled to account for this each year to the Danish General Farm Register (GLR)

Geoprocessing

Calculation of the nitrogen applied on each field and subsequent aggregation of the data at the catchment scale Id15

Spatial autocorrelation analysis

Two Local Indicators of Spatial Association (LISA) were used in this study:

- Hot Spot Analysis (Getis-Ord G_i^*)
- Cluster and Outlier analysis (Anselin Local Moran's I)

Identification of targeted Id15 catchments

Visualisation and overlapping



Materials and methods

1. Uploading the Denmark dataset in **ArcGIS Pro**: Join data to respective fields and removal of fields with a nitrogen load of 0;
2. Scenario building: **Suit_Field**, excluding fields unsuitable for manure application.
3. Nitrogen calculation for each field: This was calculated considering that the farms distribute the nitrogen load (kg N ha⁻¹) evenly considering the available hectares.
4. Then the load was calculated as the weighted average kg N ha⁻¹ ha at the **ld15 level** considering the fields falling in each catchment area



Materials and methods

Spatial autocorrelation analysis

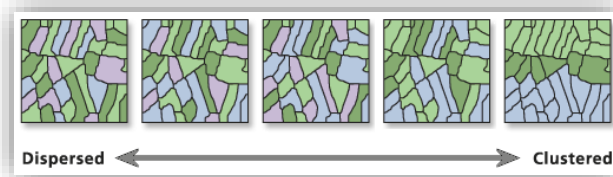
Global Moran's I

Interpretation:

$I > 0$: indicates positive spatial autocorrelation (clustering). Areas with similar values are close to each other.

$I < 0$: indicates negative spatial autocorrelation (dispersion). Areas with dissimilar values are close to each other.

$I \approx 0$: indicates random distribution (no spatial autocorrelation).

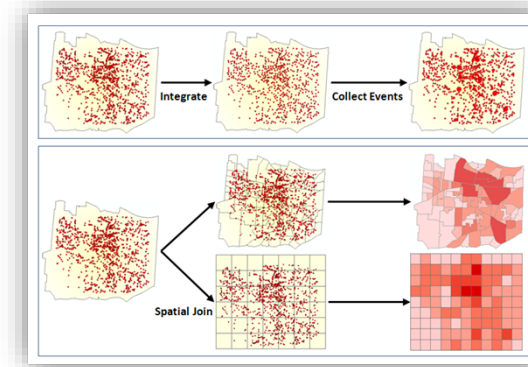


Getis-Ord G_i^*

Interpretation:

G_i^* **high**: indicates a hot spot (an area with significantly high values).

G_i^* **low**: indicates a cold spot (an area with significantly low values).



The option *Contiguity edges corners* was selected for the conceptualization of spatial relationships

Materials and methods

Targeted Id15 catchments

The shapefiles related to N hotspots, crop N demand, and N retention map were used to identify catchments with high N pressure.

The data were filtered using attribute selection to isolate specific areas, and subsequent overlapping:

- ***N hotspots (identified by a Gi index greater than 0)***
- ***Catchments with medium-low and low N retention (less than 60%)***
- ***Areas with medium-high and high crop N demand, classified using the Natural Break classification***

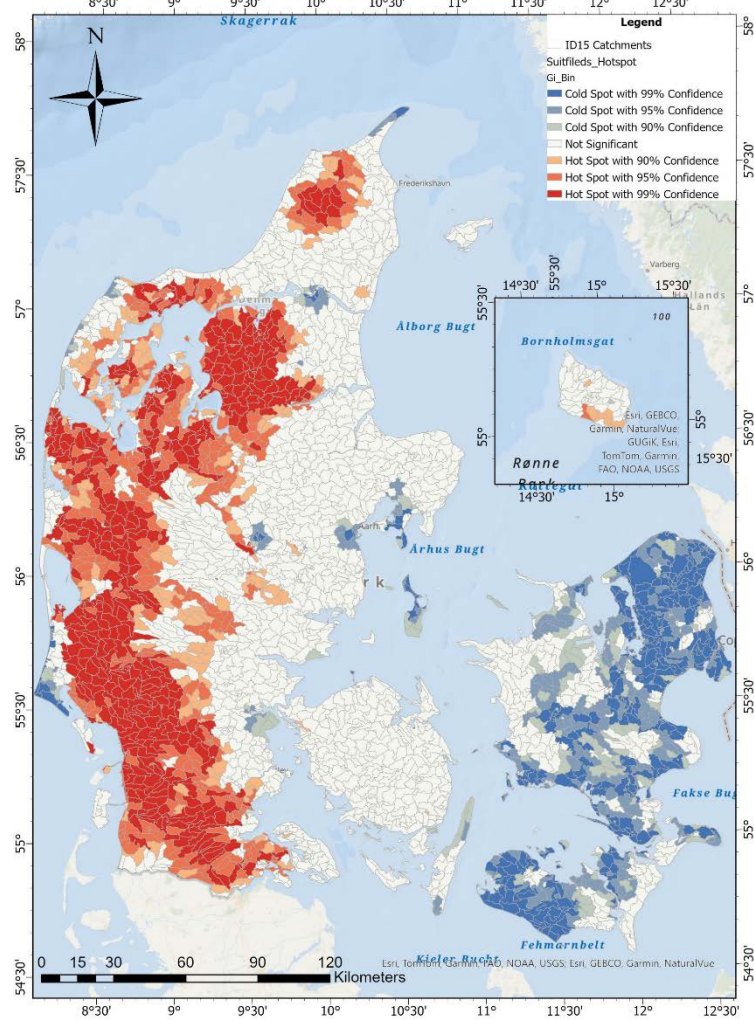
$$A_{n,i} = \sum (P_{r,i} \cdot Q_i \cdot 10^{-2})$$

Where $A_{n,i}$ is the total N requirement of crops i in the catchments (10^3 kg), $P_{r,i}$ is the total production of crop i in the catchments (10^3 kg), and Q_i is the required amount of N to produce 100 kg of dry matter for crop i in the catchment (kg)



Results

Nitrogen - Hot Spot Analysis (Getis-Ord Gi*)



Scenario *Suit_Field*

Nitrogen load in each catchment

| Amount of Nitrogen (kg N/ha) | <i>Suit_Field</i> (Num. of catchments) | <i>Suit_Field</i> (%) |
|------------------------------|--|-----------------------|
| <90 | 1599 | 47,72 |
| 90 - 180 | 1737 | 51,84 |
| 180 - 270 | 15 | 0,45 |

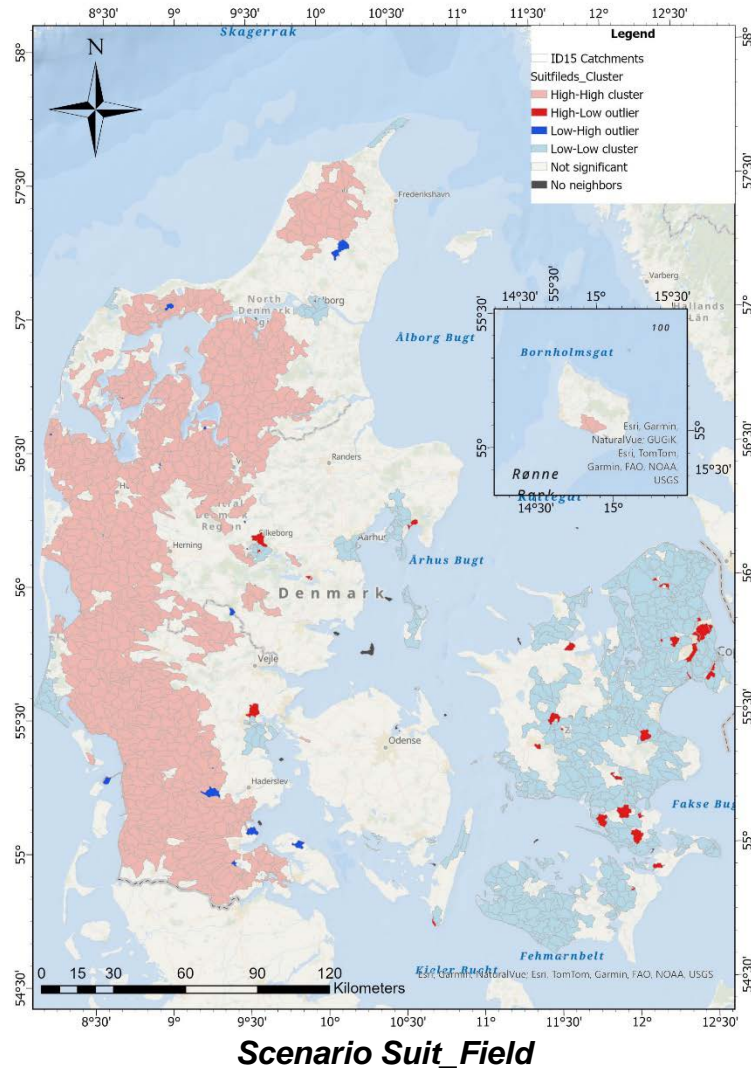
Number of catchments in each Hotspot and Coldspot category

| <i>Gi_Bin</i> | <i>Suit_Field</i> | % of total catchment <i>Id15</i> |
|------------------------------------|-------------------|----------------------------------|
| -3 (Cold Spot with 99% confidence) | 337 | 10,1 |
| -2 (Cold Spot with 95% confidence) | 255 | 7,6 |
| -1 (Cold Spot with 90% confidence) | 153 | 4,6 |
| 0 (Not significant) | 1686 | 50,3 |
| 1 (Hot Spot with 90% confidence) | 180 | 5,4 |
| 2 (Hot Spot with 95% confidence) | 312 | 9,3 |
| 3 (Hot Spot with 99% confidence) | 428 | 12,8 |



Results

Nitrogen - Cluster and Outlier Analysis (Anselin Local Moran's I)

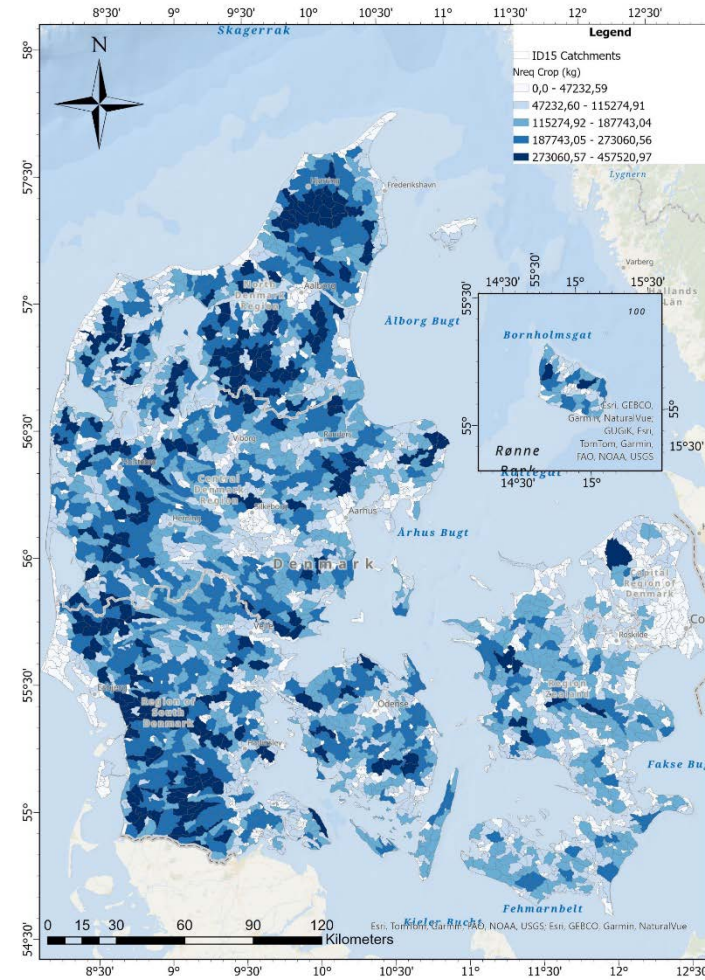


Number of catchments in each Cluster and Outlier category

| Cluster - Outlier | Suit_Field | % of total catchment Id15 |
|-------------------|------------|---------------------------|
| High - High | 828 | 24,7 |
| High - Low | 32 | 1,0 |
| Low - High | 22 | 0,7 |
| Low - Low | 564 | 16,8 |

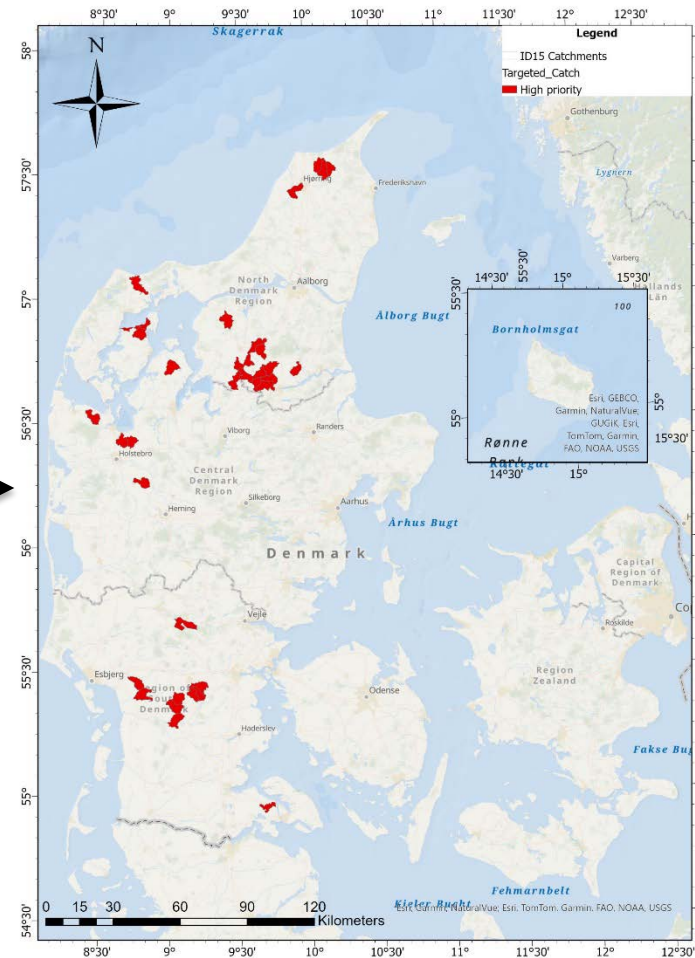
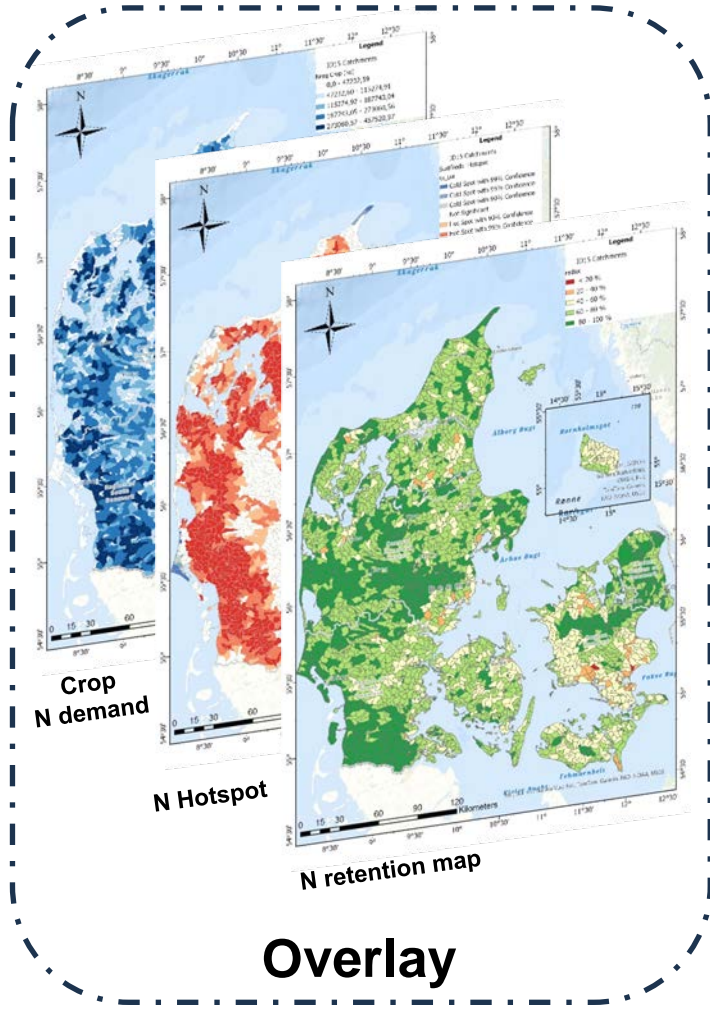
Results

Nitrogen crop demand



Results

Targeted Id15 catchments



- The spatial overlap of the three shapefiles - *N hotspots from livestock sources, areas with high N demand from crops, and areas with low N retention* - resulted in a set of **34** catchments
- These critical areas mainly fall within the areas with high N reduction goals (NRG) set in the Danish water management plans and represent about **1%** of all catchments in the study area

Conclusions

Understanding and visualizing the catchments to be managed is crucial for easily identifying critical areas where environmental mitigation and protection strategies should be implemented

- *Nitrogen and environmental protection* •

In the identified catchment areas, it may be crucial to promote the introduction of mixed farming systems that integrate livestock and crop production

- *Livestock-Crop synergies* •

Understanding the spatial clustering of catchments with high N loads represents a valuable sustainable livestock manure management opportunity

- *Treatment plants and manure management* •



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Thank you for the attention!

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Finanziato
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