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FACULTEIT BIO-INGENIEURSWETENSCHAPPEN

Economic efficient policies for ecological targets

David De Pue

Jeroen Buysse

Three policy areas

- Generic policies
- License policies (targeted)
- Abatement

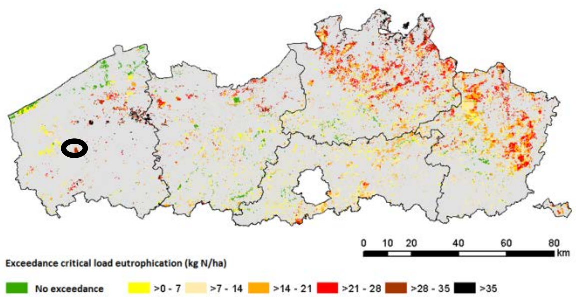
Critical Habitat Cell vs. Total Impact

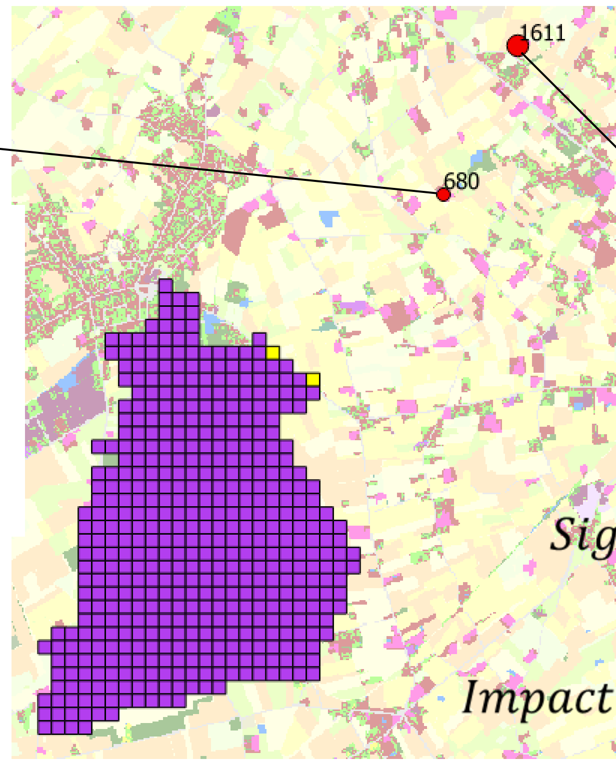
- Deposition in critical habitat cell as indicator of significance
- Used in Flanders
- $Significance_x = \frac{Deposition_{x,y}}{Critical\ Load_y}$

- Indicator of total impact in whole nature area
- Correlates better with total damage costs
- $Impact\ Score_x = \sum_y \frac{Deposition_{x,y}}{Critical\ Load_y}$

Critical Habitat Cell vs. Total Impact

Significance = 3%
Impact Score = 1.04





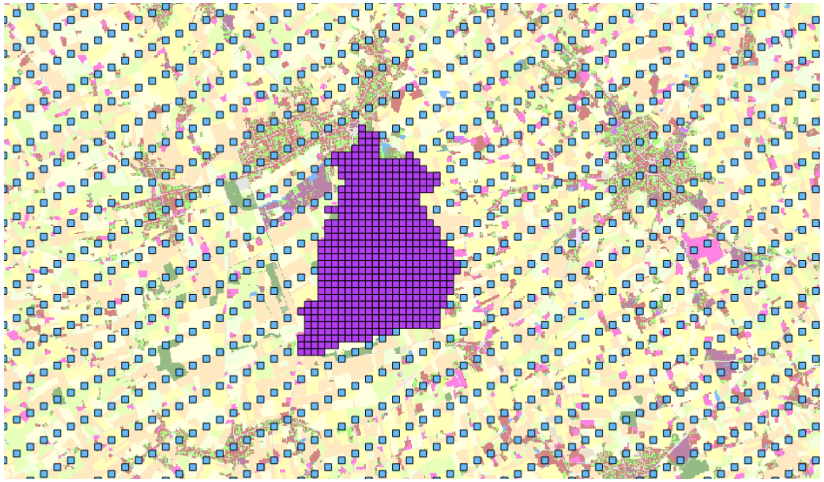
Significance = 3%
Impact Score = 1.43

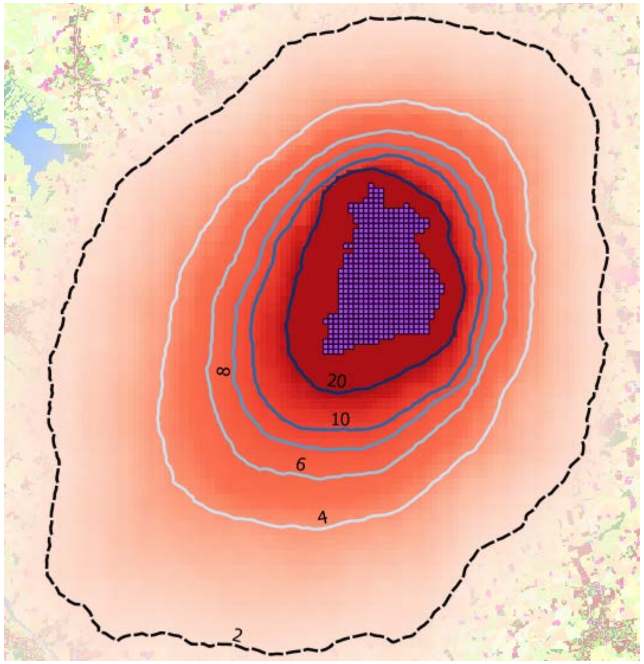
$$Significance_x = \frac{Deposition_{x,y}}{Critical\ Load_y}$$

$$Impact\ Score_x = \sum_y \frac{Deposition_{x,y}}{Critical\ Load_y}$$

Impact map

- Based on bigaussian dispersion modelling
- Maps the impact of hypothetical emission of 5000 kg NH_3-N/year
- $Impact\ Score_x = \sum_y \frac{Deposition_{x,y}}{Critical\ Load_y}$

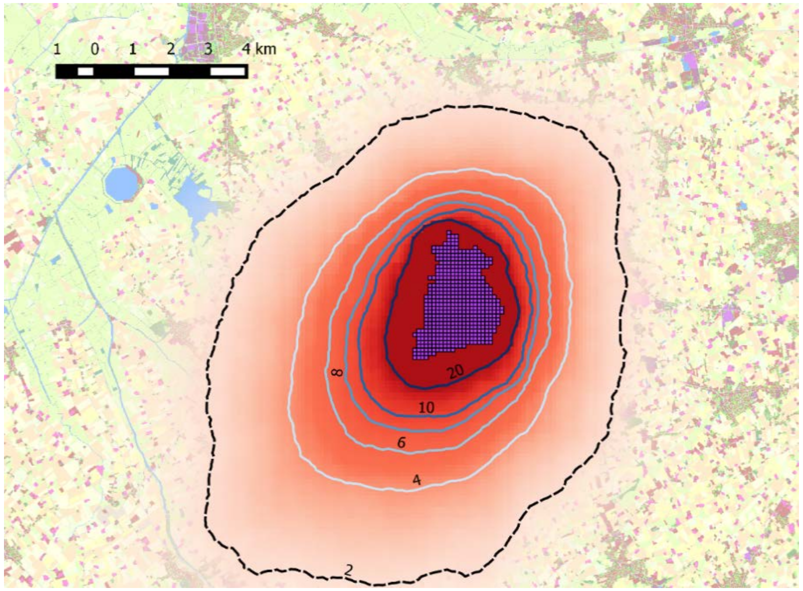




Impact dependend on sensitivity of habitat (~CL)

Vrijbos Houthulst

Habitat 9120: Atlantic acidophilous beech forest (CL 15 kg N/ha.yr)



Zeverenbeekvallei Deinze

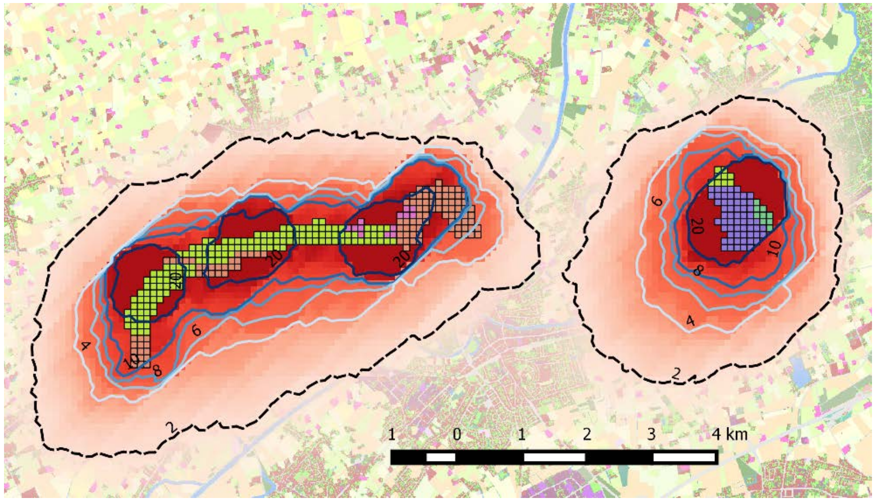
Habitat 9120: Atlantic acidophilous beech forest (CL 15 kg N/ha.yr)

Habitat 3150: Natural eutrophic lake (CL 30 kg N/ha.yr)

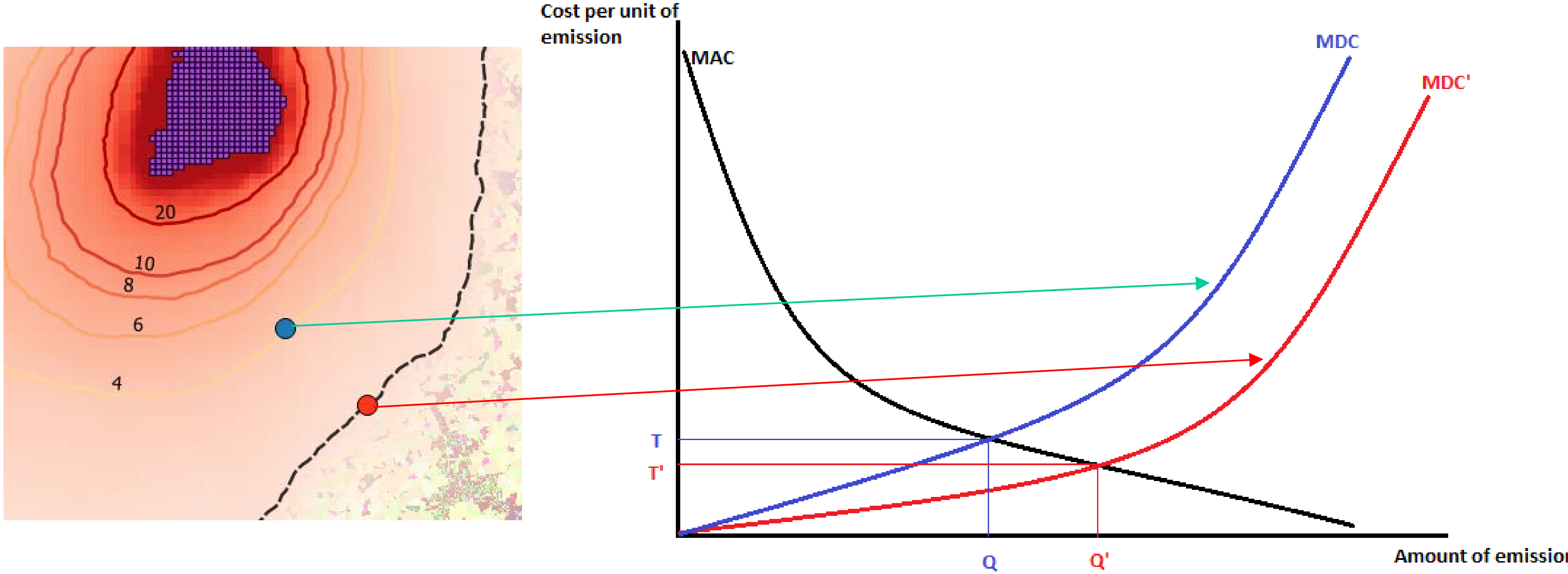
Habitat 6430: Hydrophilous tall herb fringe (CL 30 kg N/ha.yr)

Habitat 9160: Oak-hornbeam forest (CL 20 kg N/ha.yr)

Habitat 91EO: Alluvial forest (CL 29 kg N/ha.yr)



Impact map as tool for spatially differentiated pollution control



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NER: nutriënten emission permits rechten

- permits for animal production
- tradable
- Change to concentration permit (Montgomery, 1972):
  - Emission x impactscore = needed permits
  - Farms decide themselves on relocation or on additional emission reduction measures

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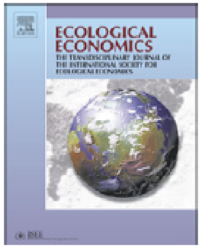

Analysis

Markets of concentration permits: The case of manure policy

Bart Van der Straeten [a,*], Jeroen Buysse [a], Stephan Nolte [a], Ludwig Lauwers [a,b], Dakerlia Claeys [b], Guido Van Huylenbroeck [a]

Conclusion

- Impact map
  - Visualization of ‘emission space’ around protected area
  - Useful for spatially differentiated pollution control
- Impact score is better indicator for environmental damage than deposition in critical habitat cell
- Use of impact score treshold instead of critical habitat cell constraint is more efficient

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Spatial optimization model - Principles

Farm A	Farm D	Forest CL: 15 kgN/ha.yr
Farm B	Grassland CL: 24 kN/ha.yr	Heathland CL: 11 kgN/ha.yr
Farm C	Farm E	Farm F

- ‘Region’ = Grid of 3x3 km²
- Collection of i farms and j nature areas
- Farm = number of animals
- Nature area: zone with characteristic critical load

Spatial optimization model - Principles

- **Objective function**:

  Maximize $\sum_i Animals_i$

  s. t. $Deposition_{i,j} * Animals_i <$
  $0.03 * CL_j$ (**Individual contribution constraint**)

  $\sum_i Deposition_{i,j} * Animals_i + 20 < 2 * CL_j$

  (**Total deposition constraint**)

- $Deposition_{i,j} = \frac{em-(em*e^{-Distance(i,j)*0.01207})}{\pi*Distance(i,j)^2}$ *0.01

  em = 14 kgN/ha.yr

  $Distance_{i,j}$ = from center to center

Farm A 1390	Farm D 841	Forest CL: 15 kgN/ha.yr Dep: 21,75 kgN/ha.yr
Farm B 1241	Grassland CL: 24 kN/ha.yr Dep: 22,86 kgN/ha.yr	Heathland CL: 11 kgN/ha.yr Dep: 21,97 kgN/ha.yr
Farm C 1390	Farm E 874	Farm F 617

Spatial Optimization

- Dispersion modelling: bigaussian with Pasquill-Gifford dispersion parameters (σ_y en σ_z):

$$C(x,y,z;h) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{(z-h)^2}{\sigma_z^2} \right) \right]$$

- Meteo parameters wind direction, wind speed and atmospheric stability from KNMI station Eindhoven (2009-2015)
- Estimation of NH_3 emission per animal category and emission stage: EMEP guidebook (European emission inventory)
- Nature area (location, habitat type and critical load): map with natura 2000 areas and biological valuation map from www.geopunt.be
- Coordinates of industrial livestock farms (big pig and poultry farms) from www.geopunt.be

Spatial optimization: Reference Scenario 3% of CL in CHC

Maximize $\sum_i Emission_i$

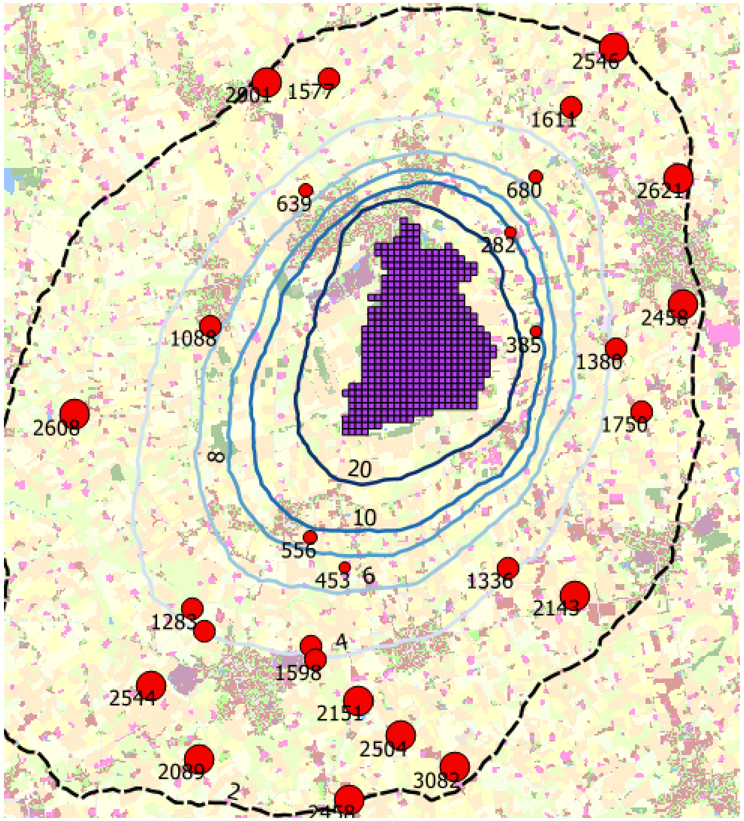
s. t. $Deposition_{i,j} < 0.03 * CL_j$

(Individual contribution constraint)

$$\sum_i Deposition_{i,j} * +20 < 2 * CL_j$$

$$\sum_i Emission \quad 47542\ kgNH$$

$$Average\ deposition = 21.34 \frac{kgN}{ha.yr}$$



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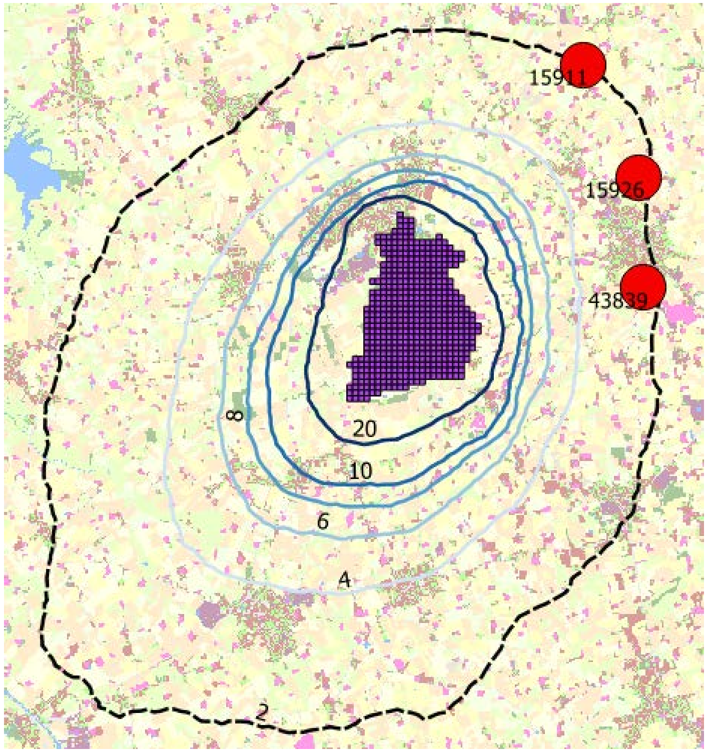
Scenario 2: no individual CL constraint, max. deposition from refererence scenario

Maximize $\sum_i Emission_i$

s. t. $Average\ Deposition < 21.34 \frac{kgN}{ha.yr}$

$\sum_i Deposition_{i,j} * +20 < 2 * CL_j$

$$\sum_i Emission_i = 75676\ kgNH3\ N/yr$$



- 59% more emissions for same environmental quality (average deposition)
- Emissions spread over only 3 farms

What if we would use the total impact as constraint?

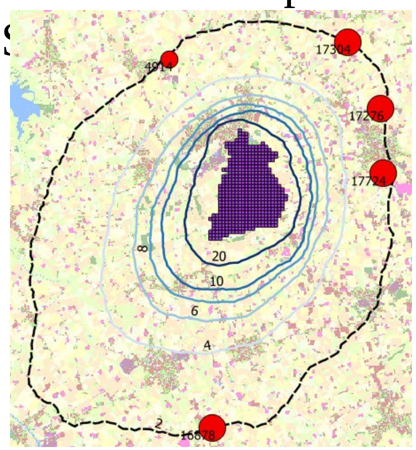
Maximize $\sum_i Emission_i$

s. t. $Impact\ Score_i < Treshold$ **(Individual contribution constraint)**

$\sum_i Deposition_{i,j} * +20 < 2 * CL_j$

$Average\ Deposition < 21.34 \frac{kgN}{ha.yr}$

Scenario 3: Impact

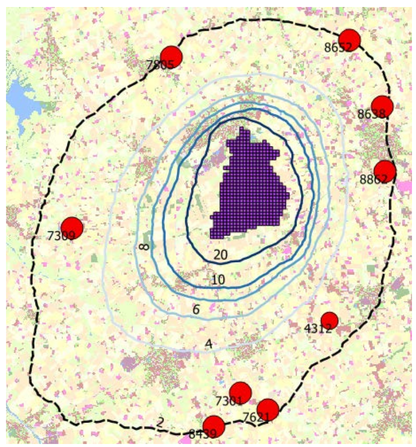


$\sum_i Emission_i = 74095\ kgNH3\ N/yr$

+56%

5 farms

Scenario 4: Impact

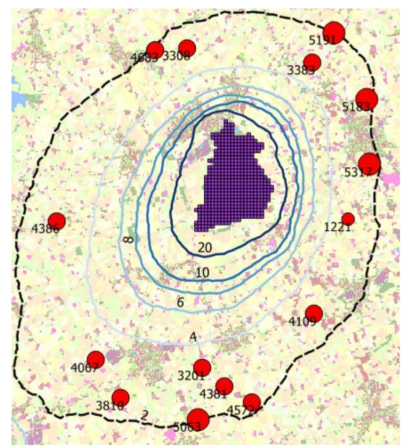


$\sum_i Emission_i = 68938\ kgNH3\ N/yr$

+45%

9 farms

Scenario 5: Impact

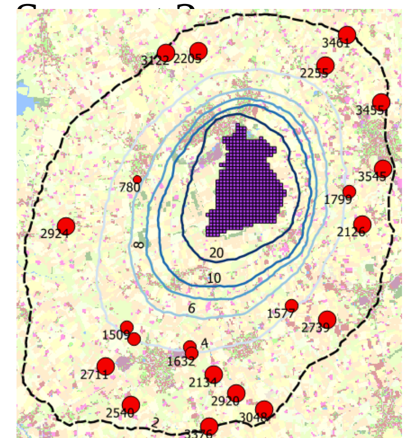


$\sum_i Emission_i = 61873kgNH3\ N/yr$

+ 30%

15 farms

Scenario 6: Impact



$\sum_i Emission_i = 53207kgNH3\ N/yr$

+ 12%

22 farms

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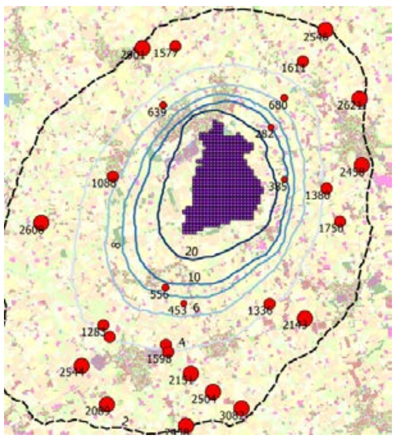
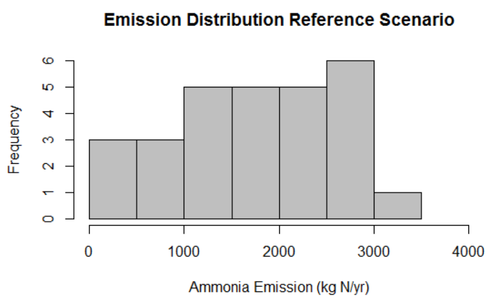
What if we would use the total impact as constraint?

Reference scenario

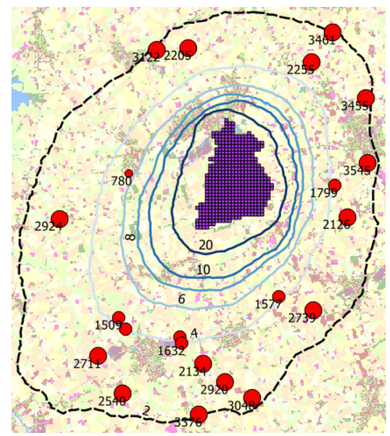
$Deposition_{i,j} < 0.03 * \sum CL_i \quad \sum_i Emission_i = 47542\ kgNH3\ N/yr$

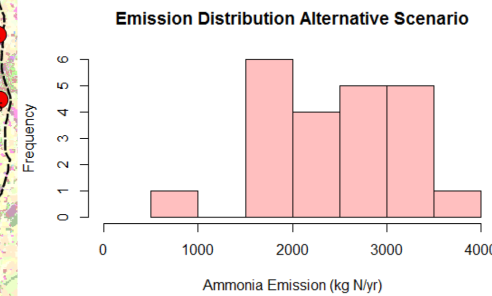




Alternative scenario

$Impact\ Score_i < 2 \quad \sum_i Emission_i = 53207 kgNH3\ N/yr$





- +12 % emissions for same average deposition
- 6 farms with highest impact closed

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