Spatial GHG inventory in the Agriculture sector and uncertainty analysis: A case study for Poland

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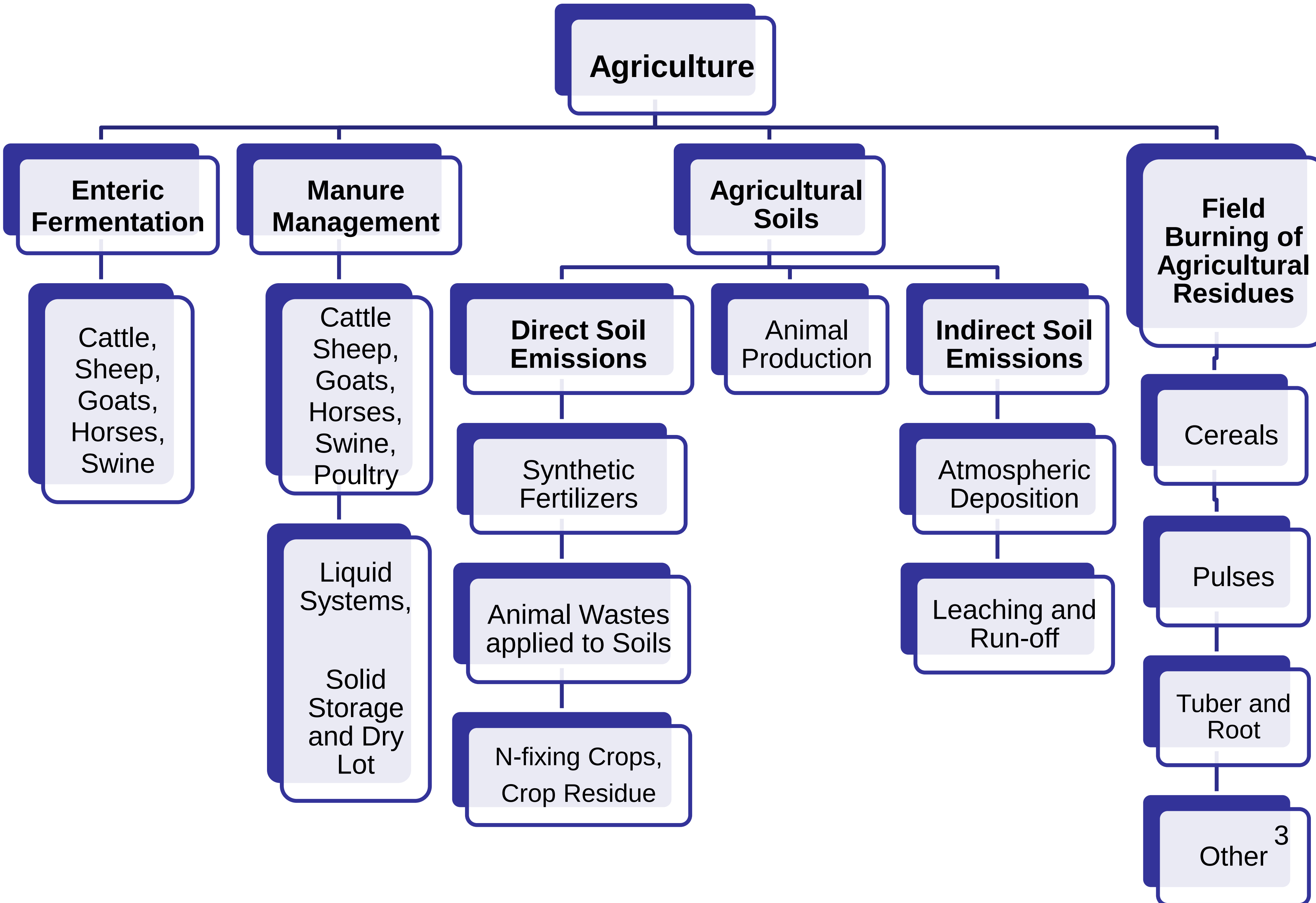
Investigations

- Agriculture
  - Animal sector
  - Agricultural Soils

- Waste
  - Solid waste
  - Wastewater
  - Incineration

Structure of GHG inventory reporting due to IPCC Agriculture sector



Agriculture sector

Sources of input data

1. Animal, crop production by type of ownership

- ✓ Central Statistical Office, Local Data Bank - http://stat.gov.pl;
- ✓ annual reports on GHG inventory (NIR);
- ✓ Statistical Yearbooks on Agriculture.

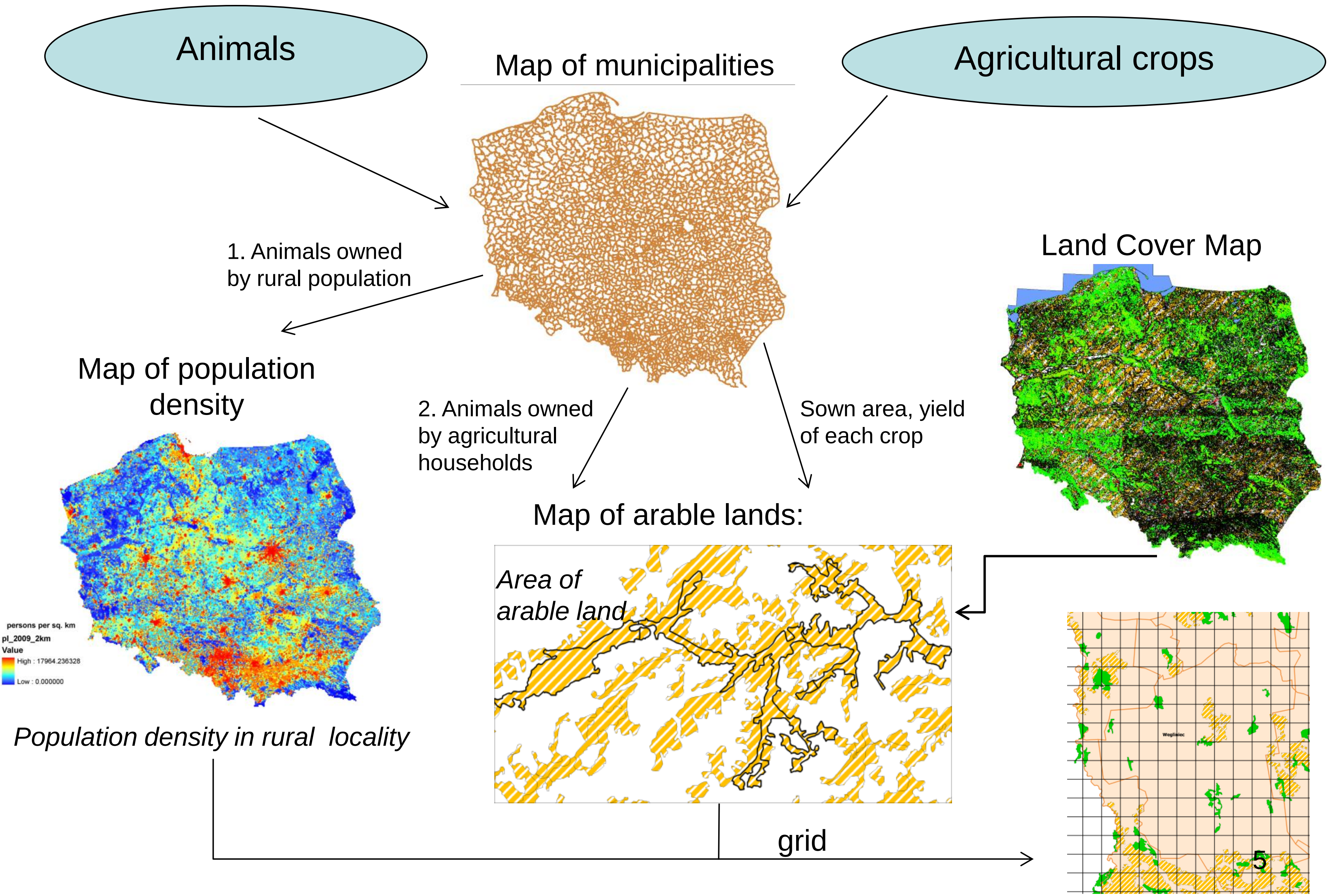
2. Emission factors

- ✓ NIR 2010-2013;
- ✓ IPCC 1996/2006 methodology.

3. Digital maps

- ✓ Corine Land Cover 2000 - > arable lands map;
- ✓ GDP 2009 map -> population density map 2 x 2 km;
- ✓ Map of municipalities + grid 2 x2 km -> map of elementary areas.

Area-type sources:



Formulas for spatial inventory of GHG emissions: enteric fermentation of animals

$$E_{EntFerm}^{\mathrm{CH}_4}(\delta_n) = \sum_{t=1}^{T}\left[A_t^{ind}\left(R_{3,n_3}\right)\cdot V(\delta) + A_t^{agr}\left(R_{3,n_3}\right)\cdot S(\delta_n)\right]\cdot K_t^{\mathrm{CH}_4}(\delta_n),$$

- ✓ *rural population density*

$$V(\delta_n) = \frac{p(\delta_n)\cdot area\left(R_{3,n_3} \cap \delta_n\right)}{P\left(R_{3,n_3}\right)},$$

- ✓ *areas of agricultural lands*

$$S(\delta_n) = \frac{\sum\limits_{f_i \in F} area(f_i \cap \delta_n)}{\sum\limits_{f_j \in F} area\left(f_j \cap R_{3,n_3}\right)}, \quad \forall f_i \cap \delta_n \neq 0, f_j \cap R_{3,n_3} \neq 0,$$

Formulas for spatial inventory of GHG emissions: manure management

$$E^{N_2O}_{ManureSystems}(\delta_n) = \frac{44}{28} \sum_{s=1}^{S} K_s^{N_2O}(\delta_n) \cdot \sum_{t=1}^{T} K_t^{N} \cdot K_{t,s} \cdot \left[V(\delta_n) \cdot A_t^{ind}(R_{3,n_3}) + S(\delta_n) \cdot A_t^{agr}(R_{3,n_3}) \right],$$

- ✓Liquid systems
- ✓Solid storage
- ✓Pastures

- ✓ *rural population density*

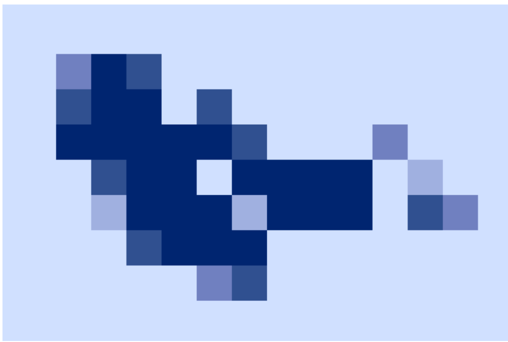
$$V(\delta_n) = \frac{p(\delta_n) \cdot area(R_{3,n_3} \cap \delta_n)}{P(R_{3,n_3})},$$

- ✓ *areas of agricultural lands*

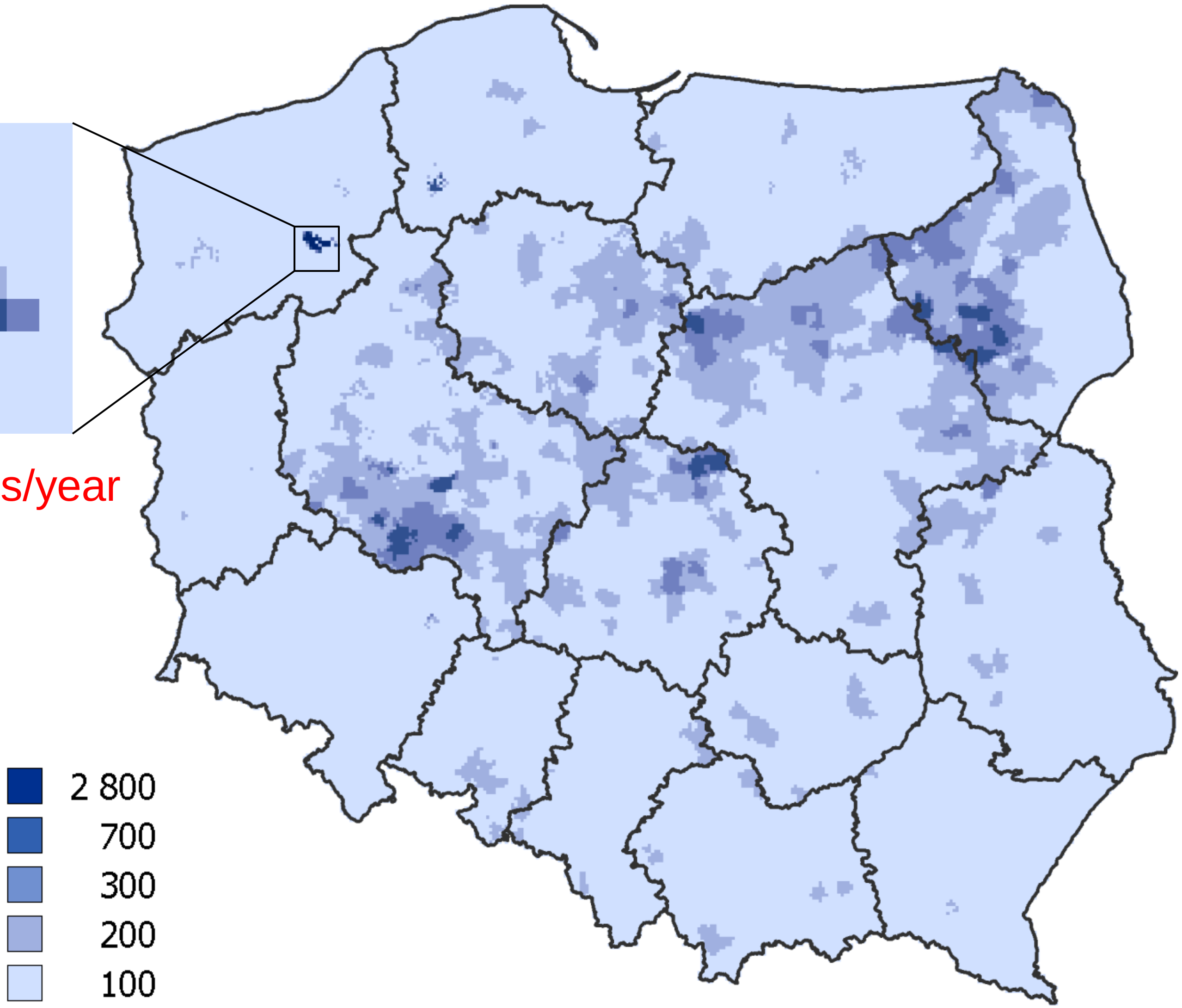
$$S(\delta_n) = \frac{\sum_{f_i \in F} area(f_i \cap \delta_n)}{\sum_{f_j \in F} area(f_j \cap R_{3,n_3})}, \quad \forall f_i \cap \delta_n \neq 0, f_j \cap R_{3,n_3} \neq 0,$$

Results of GHG inventory: animal sector

Gmina Węgliniec

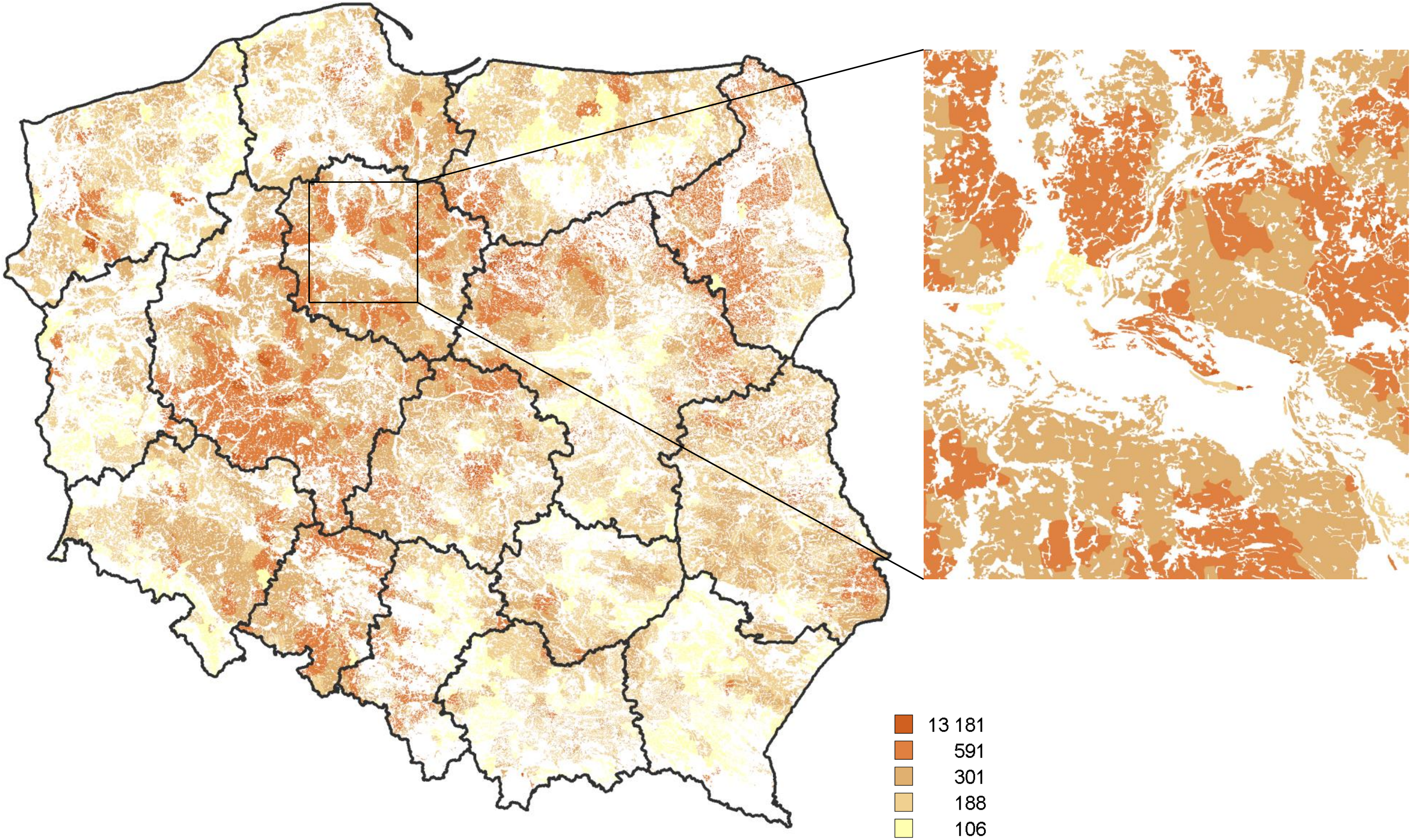


!!! 800 thousand swines/year



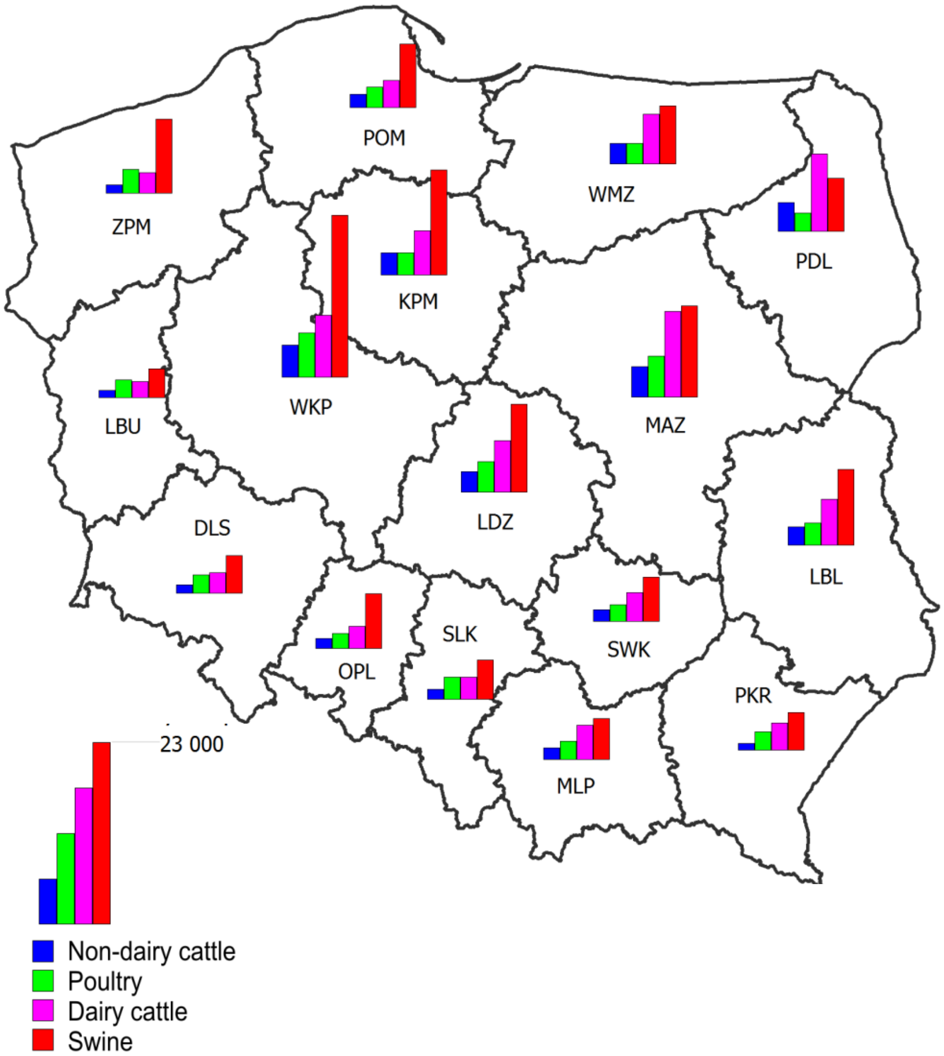
Specific emissions from animal sector (elementary areas 2 x 2 km, Mg/km^2, CO_2 eqv., 2010)

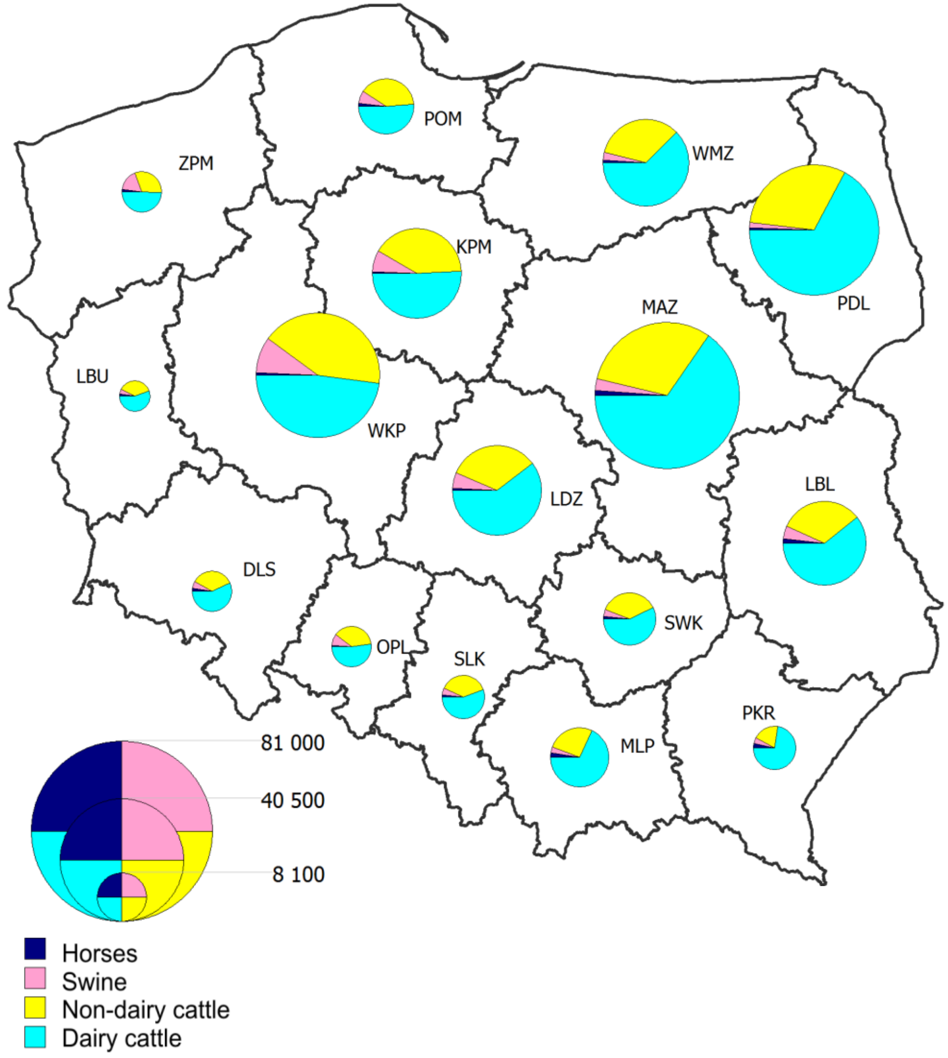
Results of GHG inventory: agricultural areas



Specific N_2O emissions from fertilization of arable lands (kg/km^2, 2010)

Results of GHG inventory: animal sector

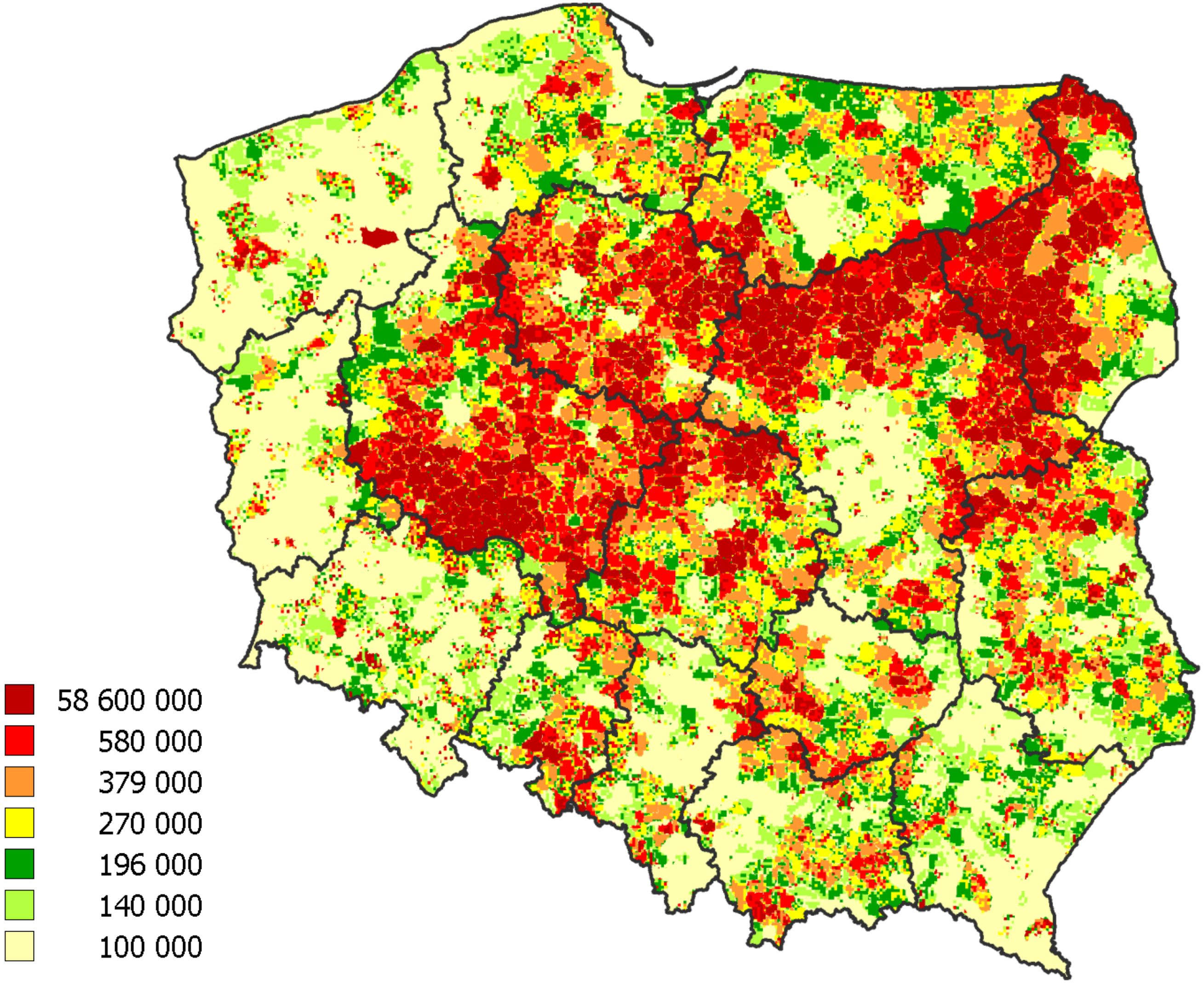




CH4 emissions (Mg, 2010):

a) animal manure management, b) from enteric fermentation

Spatial GHG inventory in Agriculture sector



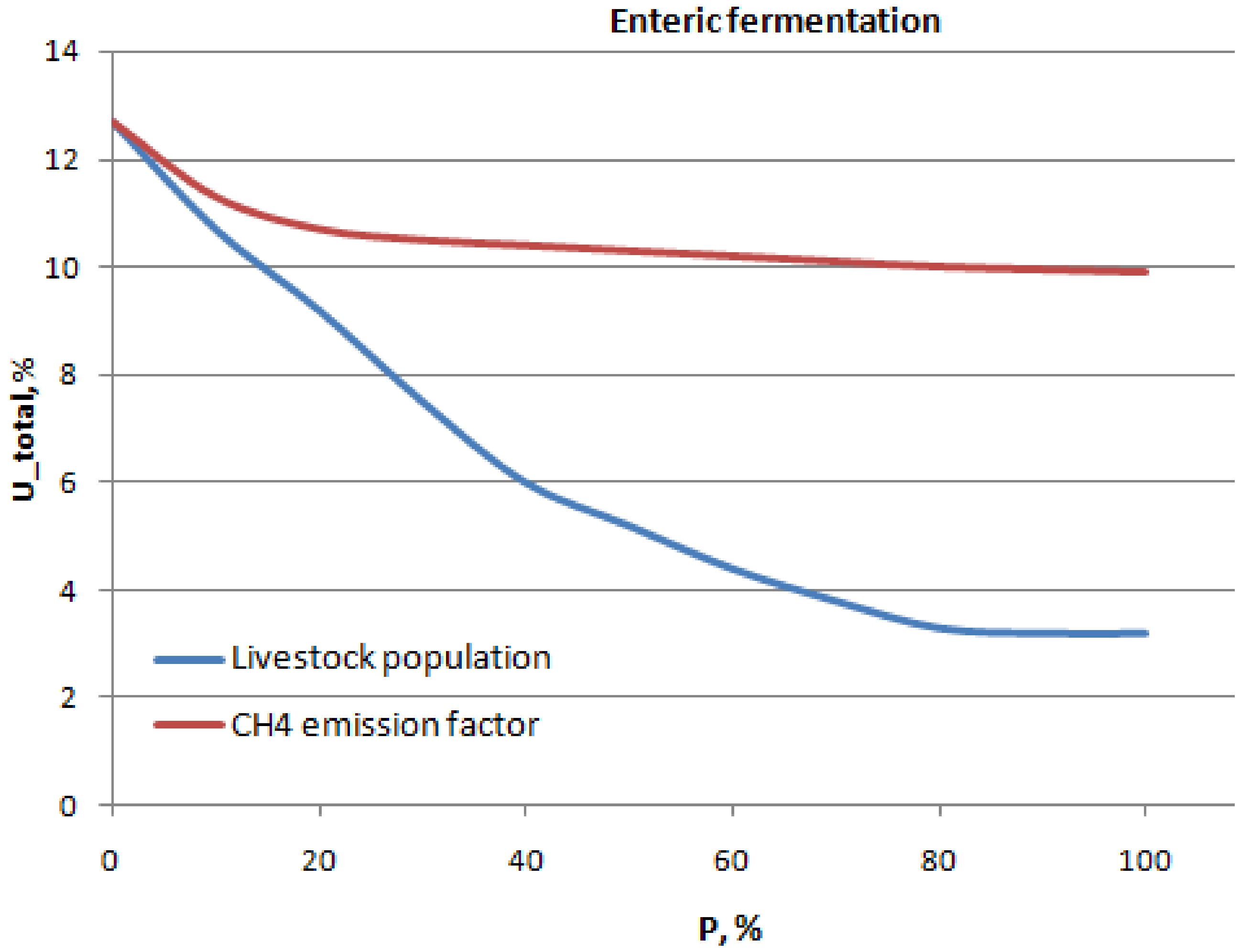
Total CO_2 eqv. emissions from agriculture sector at elementary areas 2 x 2 km (kg, 2010)

Input data for uncertainty analysis and results: enteric fermentation

Statistical data (5%, normal) Emission coefficients (50%, normal)

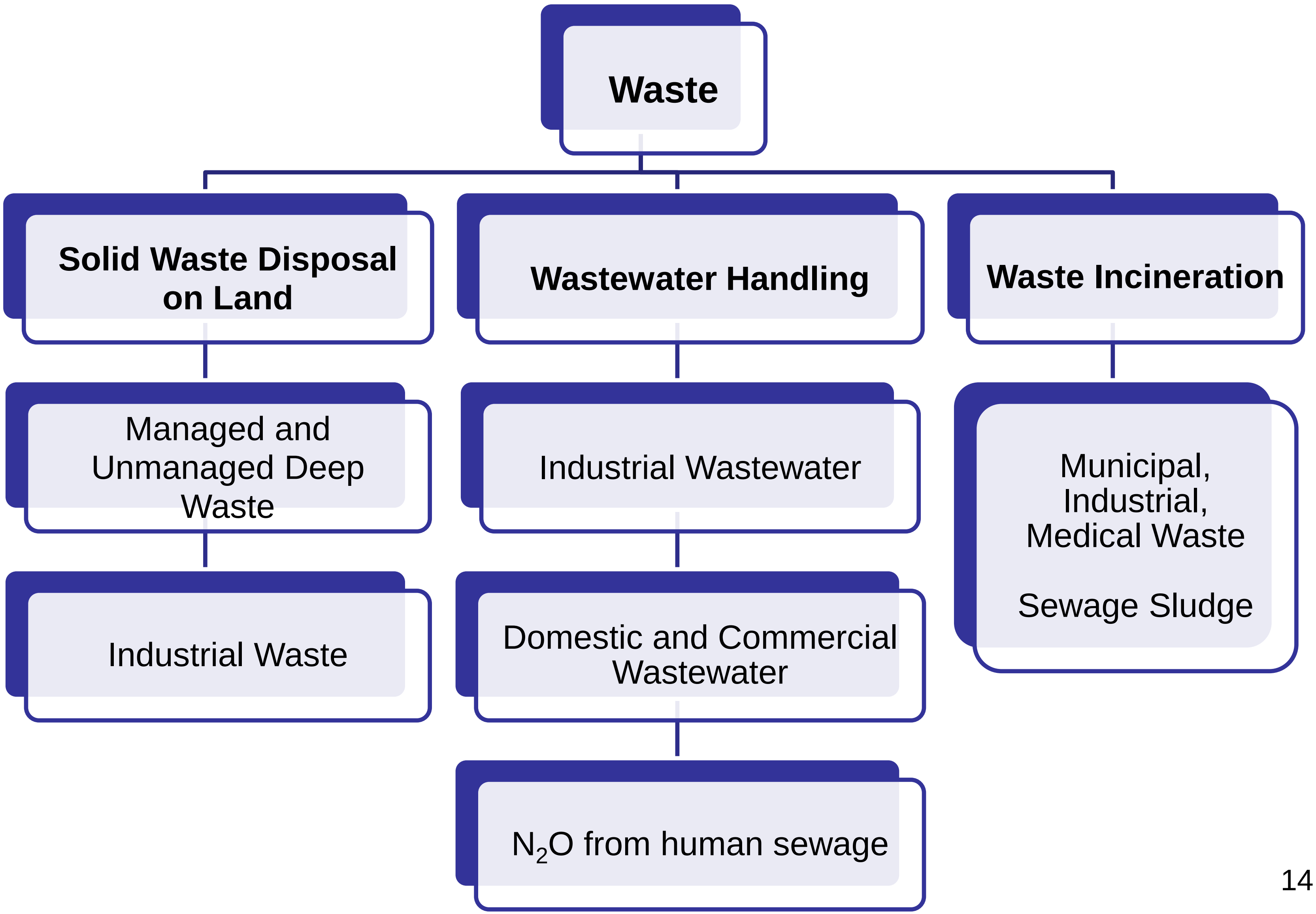
	CH_4 emissions, tons The limits of uncertainty range, %					
Voivodeship	Dairy cattle	Non-dairy cattle	Pigs	Horses	Sheep	Goats
Lower Silesian	4674,4 ±50,3	3186,1 ±50,1	419,7 ±50,2	203,1 ±50,2	102,6 ±50,2	32,3 ±50,3
Kuyavian-Pomeranian	17143,3 ±50,3	14177,9 ±50,2	2684,2 ±50,2	172,1 ±50,3	111,4 ±50,2	15,0 ±50,2
Lublin	18223,2 ±50,4	14156,3 ±50,2	1510,1 ±50,3	546,6 ±50,3	133,5 ±50,3	62,5 ±50,3
Lubusz	2879,5 ±50,3	2114,8 ±50,4	300,6 ±50,2	107,2 ±50,3	33,6 ±50,2	9,6 ±50,2
Łódż	21064,7 ±50,3	11696,9 ±50,4	1959,4 ±50,1	271,5 ±50,3	120,7 ±50,2	25,6 ±50,2
Lesser Poland	10986,5 ±50,3	4371,4 ±50,3	541,2 ±50,2	385,1 ±50,2	575,4 ±50,3	89,5 ±50,2
Masovian	52734,1 ±50,4	25303,7 ±50,2	2115,5 ±50,1	856,4 ±50,2	72,9 ±50,3	31,6 ±50,2
Opole	4698,3 ±50,3	3674,8 ±50,2	901,3 ±50,2	72,9 ±50,3	23,6 ±50,2	14,1 ±50,3
Subcarpathian	7266,6 ±50,3	2081,6 ±50,3	448,7 ±50,2	318,1 ±50,3	152,8 ±50,3	76,2 ±50,3
Podlaskie	44430,2 ±50,3	20639,0 ±50,3	827,5 ±50,3	363,2 ±50,2	173,0 ±50,2	15,8 ±50,2
Pomeranian	7428,6 ±50,3	5941,1 ±50,2	1262,6 ±50,1	257,4 ±50,3	133,6 ±50,3	14,8 ±50,2
Silesian	5230,6 ±50,2	3670,7 ±50,1	524,8 ±50,2	155,4 ±50,3	110,9 ±50,2	42,6 ±50,2
Świętokrzyskie	7761,7 ±50,4	5056,4 ±50,2	603,4 ±50,2	213,6 ±50,3	33,1 ±50,2	26,3 ±50,3
Warmian-Masurian	20538,9 ±50,4	11384,5 ±50,3	1025,1 ±50,1	300,3 ±50,2	84,5 ±50,2	19,6 ±50,2
Greater Poland	29543,7 ±50,3	26487,1 ±50,2	5879,3 ±50,2	376,8 ±50,2	196,0 ±50,2	92,0 ±50,2
West Pomeranian	4225,2 ±50,4	3042,0 ±50,1	1815,9 ±50,1	159,5 ±50,2	103,8 ±50,2	15,8 ±50,2

Sensitivity analysis



Dependence of uncertainty of CH_4 emissions in enteric fermentation of livestock during decreasing uncertainty of input data into ***P*** percent

Structure of GHG inventory reporting due to IPCC Waste sector



Waste sector

Input data

1. Activity data

- GUS, BDL:
  - ✓ municipal and industrial waste collected;
  - ✓ industrial, domestic and commercial wastewater produced;
  - ✓ municipal, industrial and medical waste incinerated.

2. Emission factors

- NIR
- IPCC

3. Digital maps

- CLC 2000 (industrial areas);
- population density map;
- gminas, elementary areas.

Assumptions

1. Types of emission sources

- area-type:
  - ✓ landfills,
  - ✓ industrial areas;
  - ✓ urban localities.

2. Approach to disaggregation

- powiat -> urban locality (for municipal solid waste);
- country -> woj -> industrial areas (for industrial wastewater);
- gmina -> population (for human sewage).

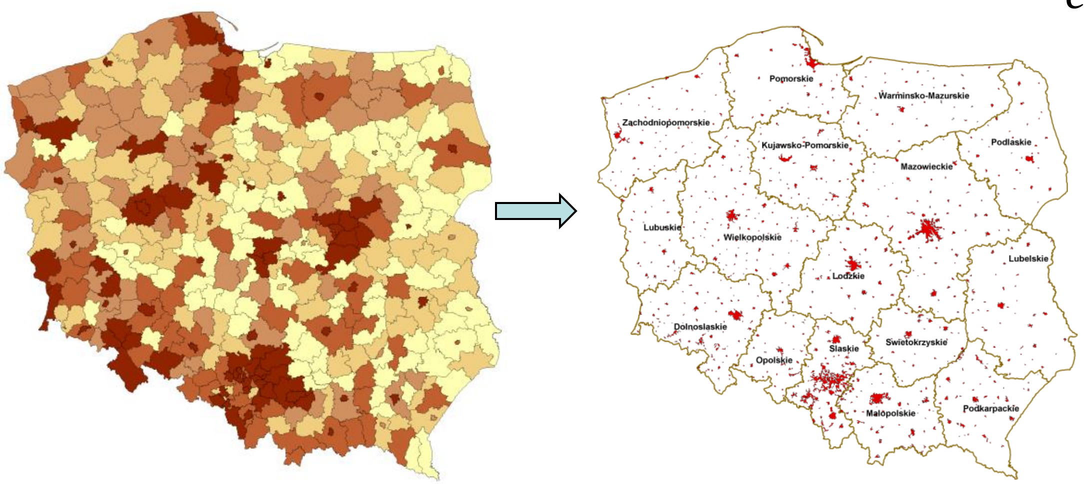
Formulas for disaggregation: solid waste disposal on lands

- ✓ the municipal solid waste collected in powiat;

$$D\left(S_{n_{urb,s}}^{urb}\right)=\frac{D\left(R_{2,n_2}\right)\cdot P\left(S_{n_{urb,s}}^{urb}\right)}{P\left(R_{2,n_2}\right)},$$

- ✓ fraction of urban population in the elementary area of the city

$$c\left(\delta_m,S_{n_{urb,s}}^{urb}\right)=\frac{d(\delta_m)\cdot area\left(S_{n_{urb,s}}^{urb}\cap\delta_m\right)}{P\left(S_{n_{urb,s}}^{urb}\right)},$$

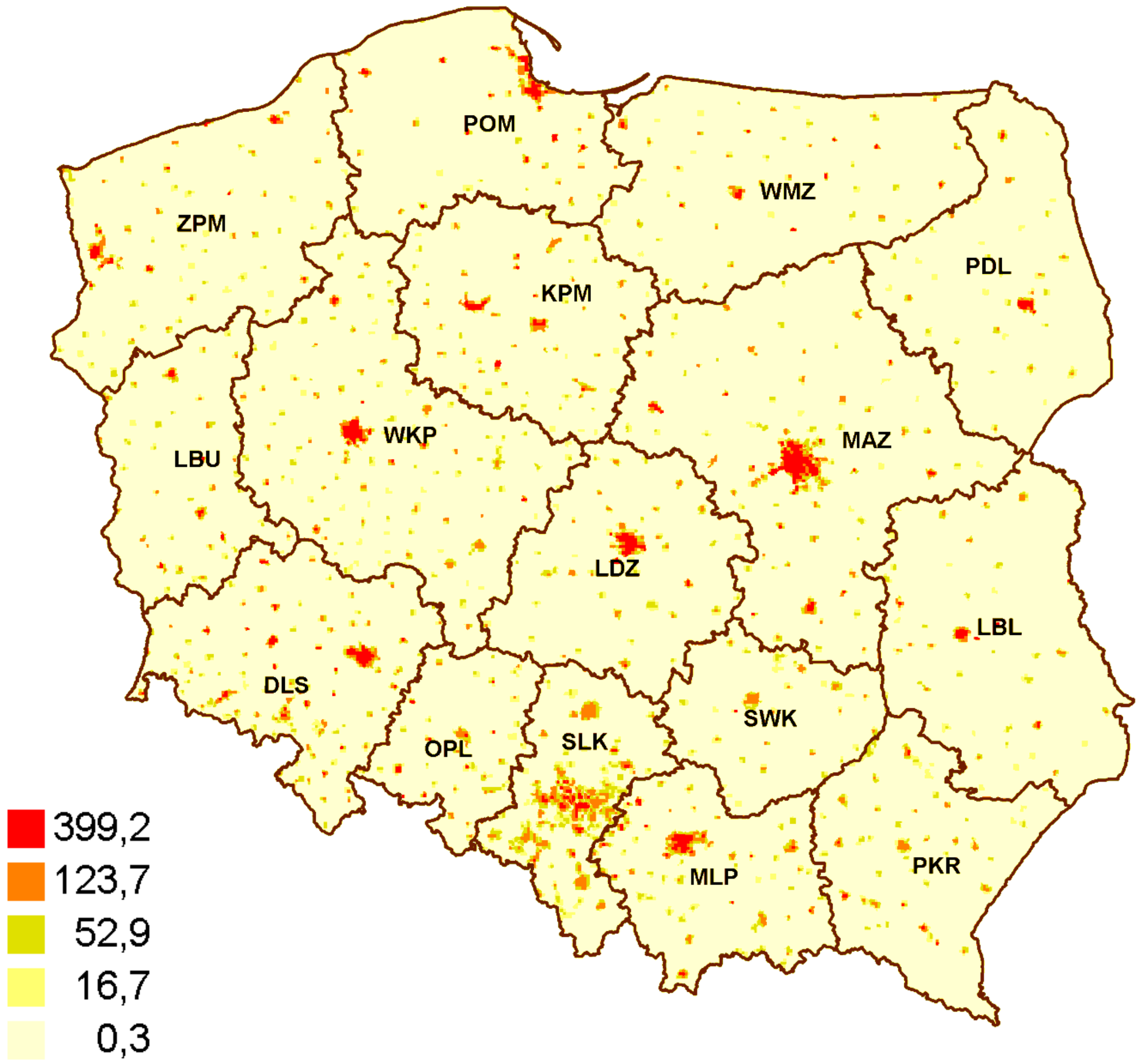


Emission estimation:

$$E_{MSW}^{CH_4}(\delta_n)=\frac{16}{12}\times\left\{\left[D_{MSW}\left(S_{n_{urb,s}}^{urb}\right)\times c\left(\delta_n,S_{n_{urb,s}}^{urb}\right)\times K_{MSW_f}\left(S_{n_{urb,s}}^{urb}\right)\times K_{MCF}\times K_{DOC}\times\right.\right.$$

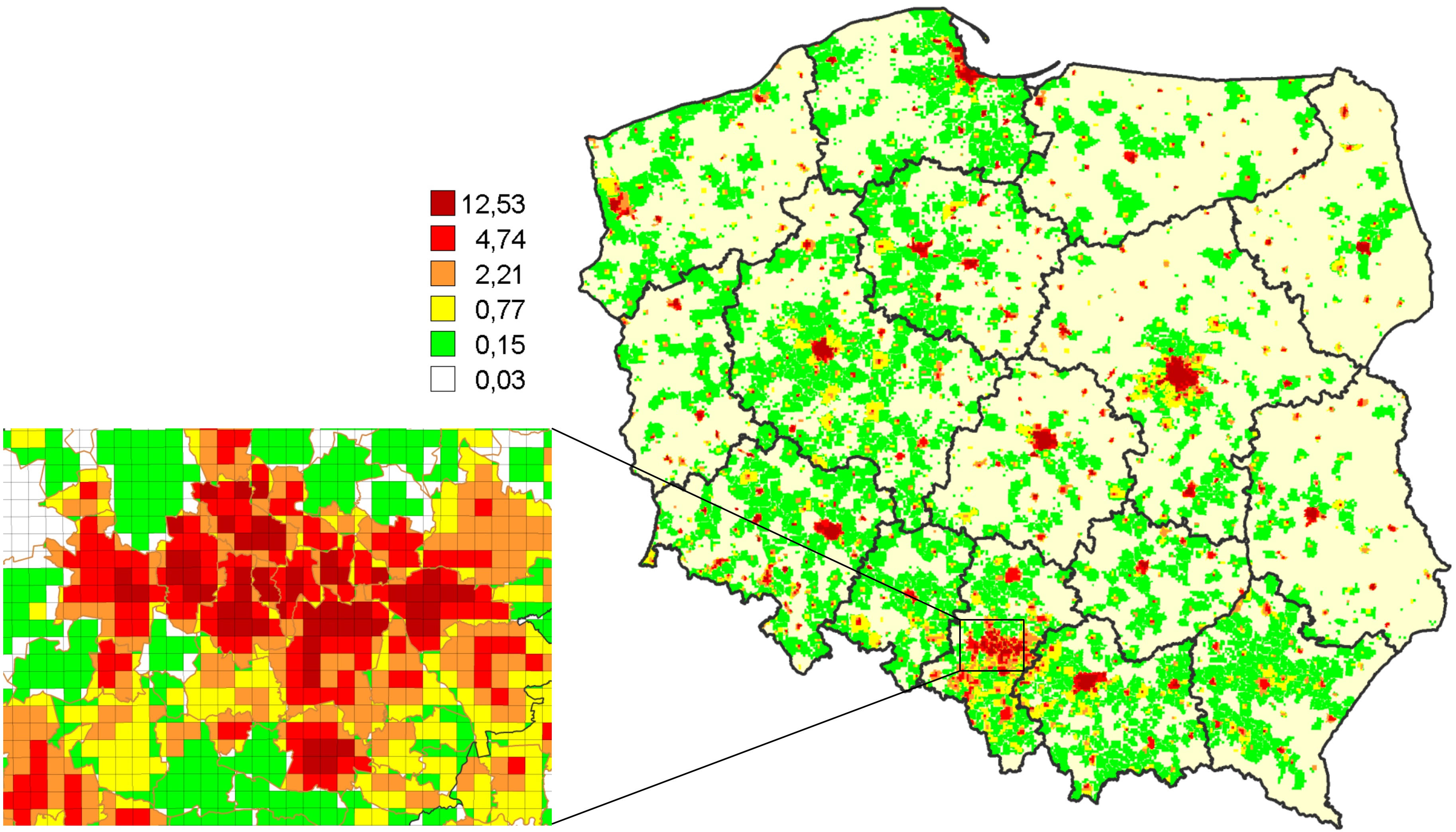
$$\left.\left.\times K_{DOC_f}\times K_F\right]-R^{CH_4}(\delta_n)\right\}\times(1-K_O)$$

Spatial GHG inventory
solid waste disposal on lands



Emissions (elementary areas 2 x 2 km, Mg, CH4, 2010)

Spatial GHG inventory in Waste sector



Total emissions from waste sector (elementary areas 2 x 2 km, Gg, CO_2 eqv., 2010)

Verification of results

	Gg, 2010														
	NIR							**Spatial inventory**							
	CO2	CH4	N2O	HFCs, CO2 eqv	PFCs, CO2 eqv	SF6	CO2 eqv	CO2	CH4	N2O	HFCs, CO2 eqv	PFCs, CO2 eqv	SF6	CO2 eqv	%
Agriculture		**581,2**	**72,1**				**34560,6**		**580,4**	**57,8**				**35628,2**	**3,1**
A. Enteric Fermentation		439,4					9227,2		434,8					10870,0	1,1
B. Manure Management		140,9	16,8				8165,4		145,0	12,3				7284,7	10,8
D. Agricultural Soils			55,3				17140,2			45,6				13576,9	17,5
F. Field Burning of Agricultural Residues		0,85	0,03				27,8		0,6	8E-04				15,24	44,9
Waste	**221,8**	**632,8**	**3,60**				**14629,0**	**208,2**	**542,4**	**3,57**				**14832,1**	**1,4**
A. Solid Waste Disposal on Land		364,8					7660,9		276,8					6920,0	9,7
B. Wastewater Handling		268,0	3,57				6737,0		265,6	3,54				7694,9	14,2
C. Waste Incineration	221,8		0,03				231,1	208,2		0,03				217,1	1919

Thank You for Attention!