59th ERSA Congress
Cities, regions and digital transformations: opportunities, risks and challenges
27 – 30 August 2019, Lyon, France

Determinants of Municipal Waste in Poland: Analyses of Spatially Varying Relationships

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The attendance was supported by the National Science Centre (NCN)/ Miniatura 2 [grant number 2018/02/X/HS4/00966]

Waste issues in Poland

- In the context of waste management - reduction of waste is becoming one of the most significant challenges of smart, sustainable, inclusive growth and decoupling theory.
- With an average of below 310 kg per person, Poland has the lowest amount of municipal waste generated in Europe.
- However, the quantities of collected waste are actually greater than statistically reported, with the missing being burned in households or dumped illegally in forests.
- The main factors behind such behaviour are low ecological awareness, low effectiveness of the waste management system and locally varied taxes/fees (Ministry of the Environment, 2017).

Aims

✓identify the determinants of the waste quantity;

✓test , whether the relation between selected socioeconomic determinants and the amount of municipal waste is regionally divergent;

✓examinine spatial aspects (spatial non-stationarity and spatial autocorrelation);

✓examine the extent to which spatial interactions affect the waste quantity at the regional level;

✓use a proper type of geographically weighted regression (GWR) to solve the scientific problem;

Data

- A sample of n=3096 Polish communes (LAU-2).
- Years from 2005 to 2017 (T = 18).
- N = 55728.
- Y (dependent variable): total quantity of municipal waste (mixed and solid) in kg per capita.
- X (independent variables)

Potential determinants (variables in log):

- uncontrolled dumping sites per 100 km^2
- population density
- **share of the population at the working age in %**
- **registrations for permanent residence**
- **nights spent by tourists per 1000 capita**
- **dummy variable indicated urban and rural area**
- **dwellings per 1000 population**
- permanent marketplaces per 100,000 capita
- **entities entered in the REGON register per 10,000 population**
- **graduates per 10,000 population**
- investments in waste municipal management in PLN per capita

Method

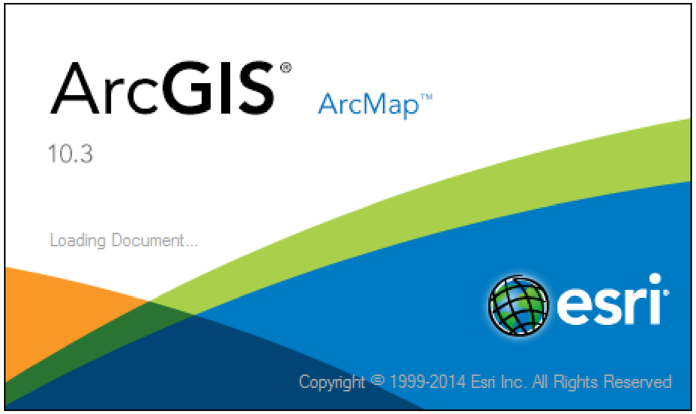
- ESDA to understand waste generation in Poland at the local level and to consider spatial interactions.

- Preliminary analysis, to increase the explained variability of phenomena, and emphasise local differences in the amount of waste.

- Finally, GWR-SEM - as a way to address spatial heterogeneity and spatial dependence between disturbances.

Software

ArcMap (by Esri ArcGis)



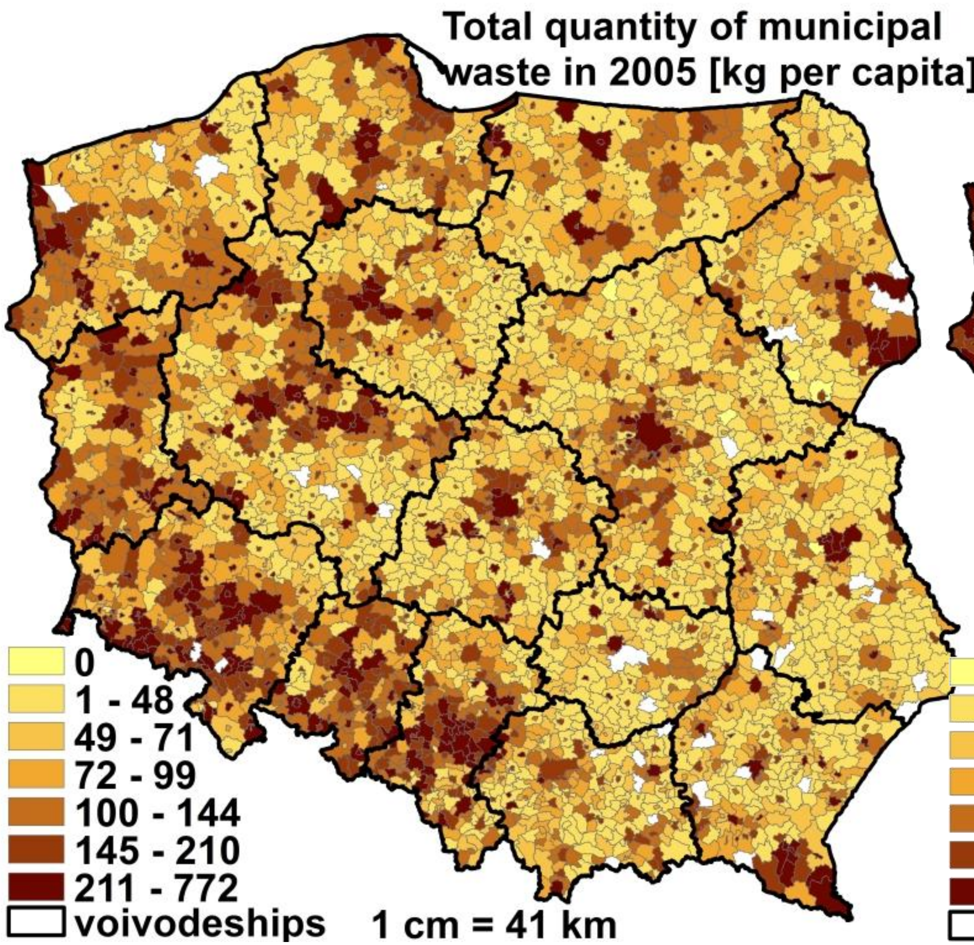
SAM

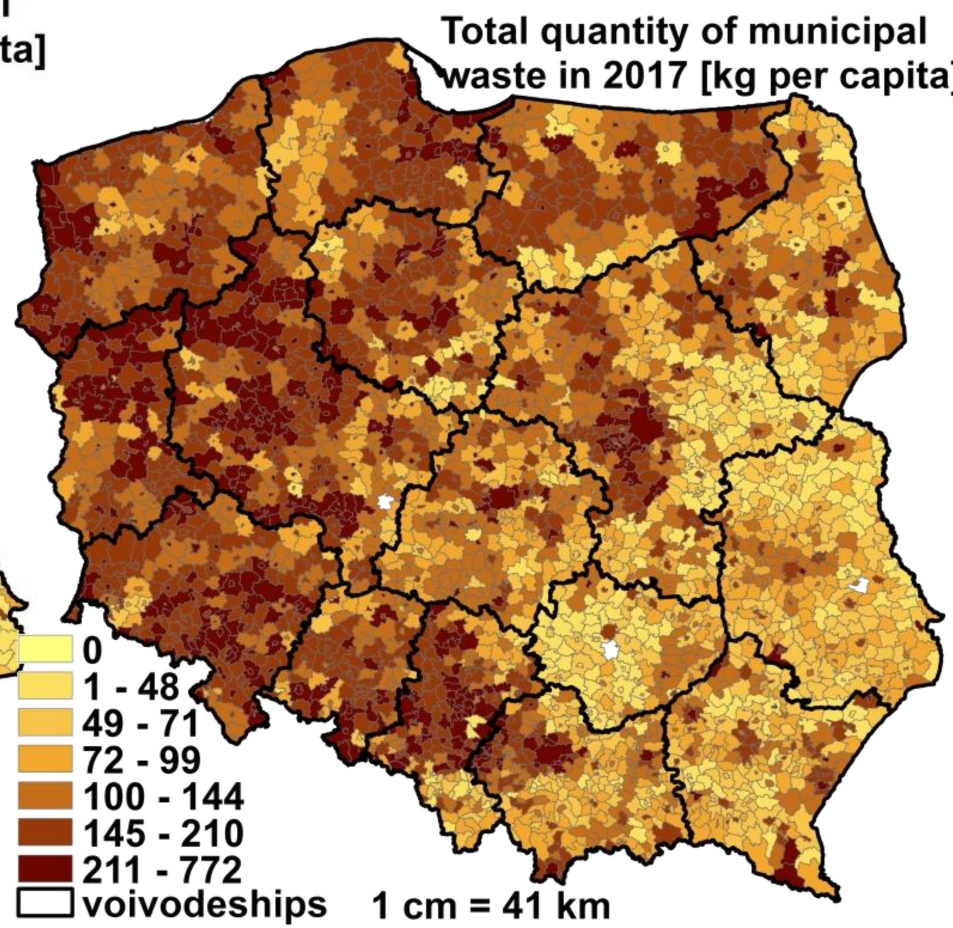
GWR4

Preliminarily data analysis

	2005	2017
Average	104	143
Std.Dev.	85	74

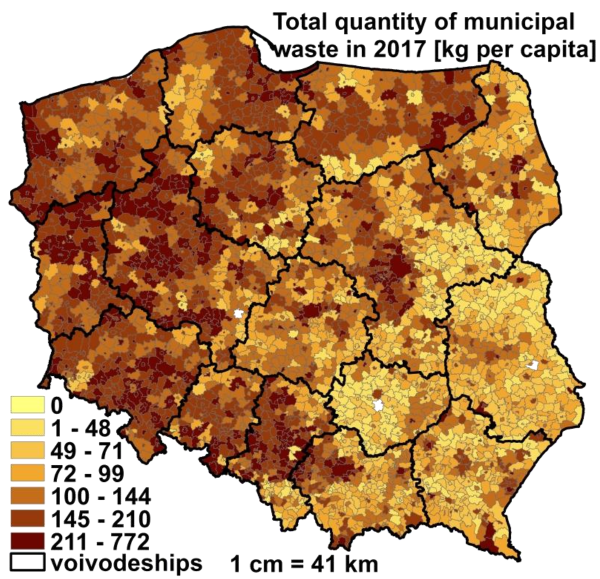
	2005	2017
CV	81%	52%
Median	78	133





CORRELATION BETWEEN AMOUNT OF MUNICIPAL WASTE AND GEOGRAPHICAL DIRECTION (COORDINATES)

	Coor.	2005	2009	2013	2017
LAU-2	X	-0.39***	-0.39***	-0.45***	-0.25**
	Y	0.11	0.19*	0.23**	0.26**



SPATIAL INTERACTIONS

Moran's I	Fixed distance (bandwidth) in kilometres					
Ws	**30**	**60**	**90**	**120**	**150**	**190**
2005	0.33***	0.19***	0.12***	0.07**	0.02*	0.01
2009	0.37***	0.23***	0.13***	0.08**	0.02*	0.01
2013	0.46***	0.35***	0.25***	0.18**	0.05*	0.02
2017	0.45***	0.30***	0.23***	0.19***	0.10**	0.02*

- In the time span only the 300 entities were involved in municipal waste management;
- „Local" companies were able to process just 33% of the total collected waste (Kołsut, 2016);
- Quantity of waste is estimate in RIPOKs (Regional Plant for Processing of Municipal Waste), not in households;
- In such a situation, the transboundary shipment of waste has been, and remains, popular in Poland (export, import or transit over short or long distances) (Cyranka *et al.*, 2016).
- This is one of the determinants of spatial interactions.

METHODS

GWR-SEM

(GWR regression corrected for spatial error autocorrelation)

0) OLS $y_i = \beta_0 + \sum \beta_k x_{ik} + \varepsilon_i$

1) GWR $\hat{\mathbf{y}} = (\mathbf{X}^T \mathbf{W}(u_i, v_i)\mathbf{X})^{-1} \mathbf{X}^T \mathbf{W}(u_i, v_i)\mathbf{Y}$

2) GWR-SEM $\hat{\boldsymbol{\beta}}_k(\mathbf{u}_i, \mathbf{v}_i) = (\tilde{\mathbf{X}}' \tilde{\mathbf{A}}(\mathbf{u}_i, \mathbf{v}_i)\tilde{\mathbf{X}})^{-1} \tilde{\mathbf{X}}' \tilde{\mathbf{A}}(\mathbf{u}_i, \mathbf{v}_i)\tilde{\mathbf{Y}}$

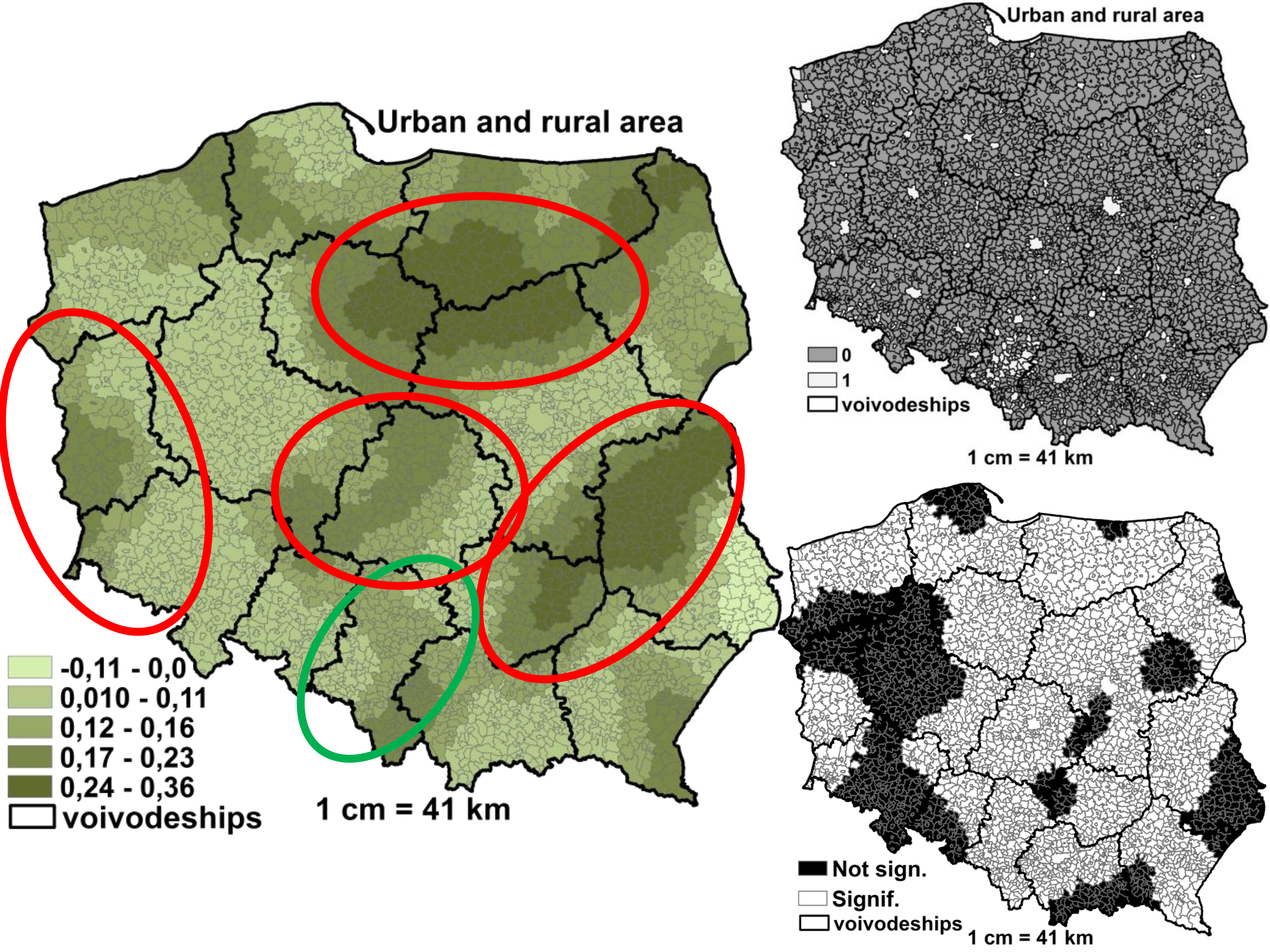
The estimation method for the GWR-SEM was based on the Cochran–Orcutt method of filtering variables, typically divided into four steps (Cho et al., 2010; Kim, Cho, Lambert, & Roberts, 2010):

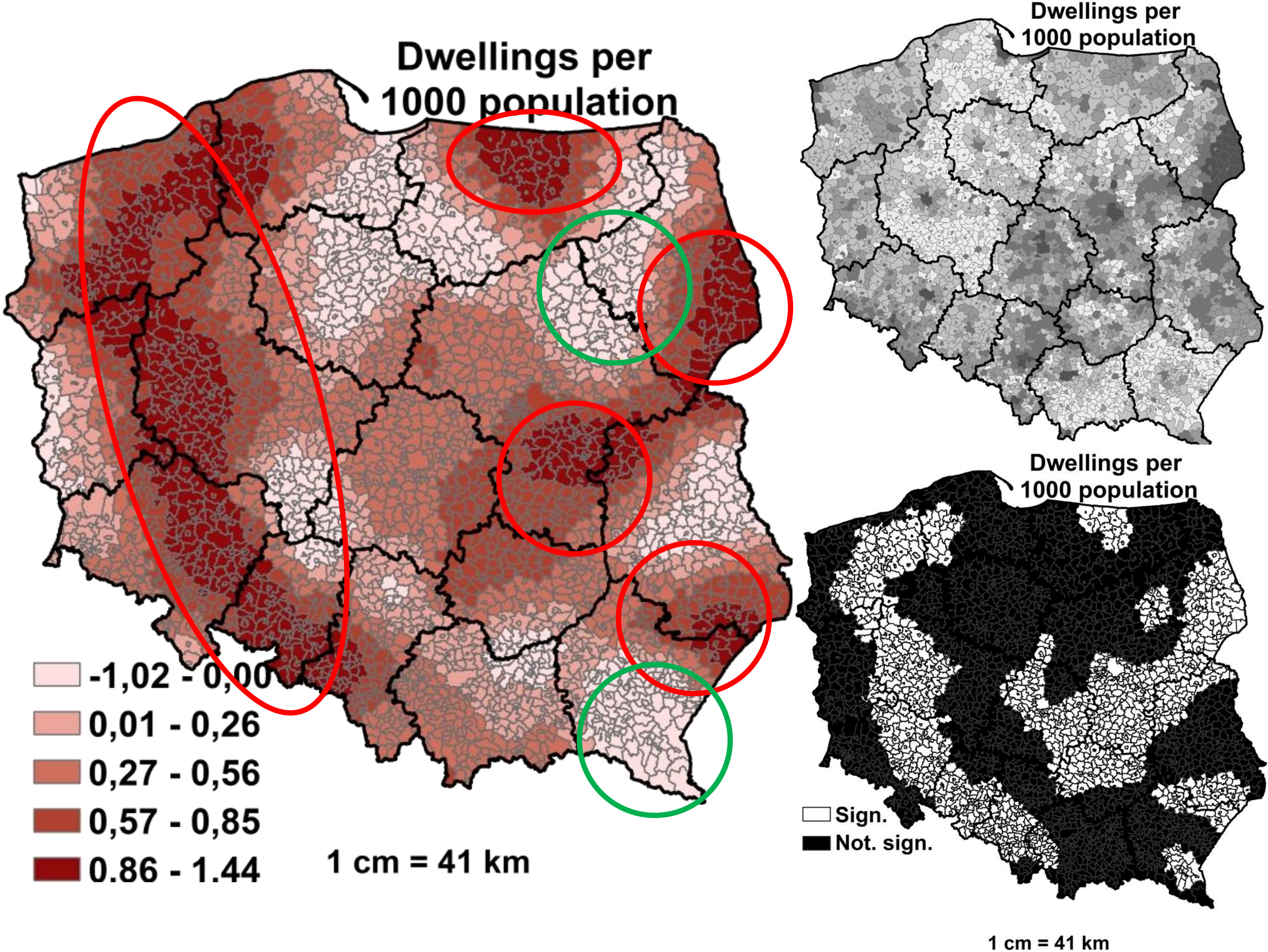
1) estimate parameters of the GWR;
2) use the residuals from the GWR model and based on them estimate the parameter lambda;
3) transform the outcome and explanatory variables using a filtering mechanism [(I – lambdaW)];
4) estimate again the GWR using filtered variables

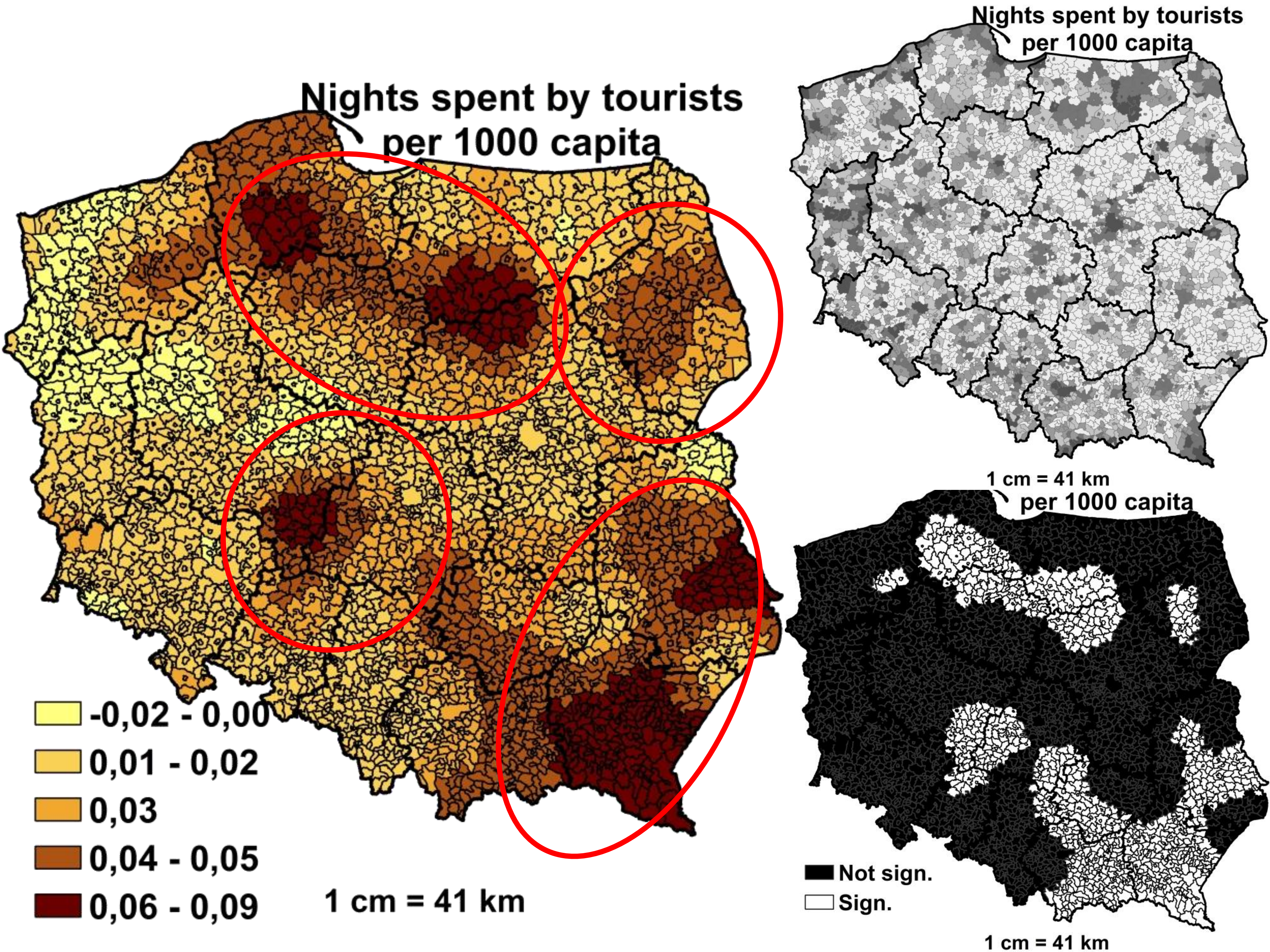
- The residuals of OLS, GWR, and GWR-SEM are tested for spatial error autocorrelation using a Lagrange Multiplier (LM) test (Anselin, 1988).
- Akaike Information Criterion and residual sum of square are compared to measure goodness of fit for each model as next model selection criteria.

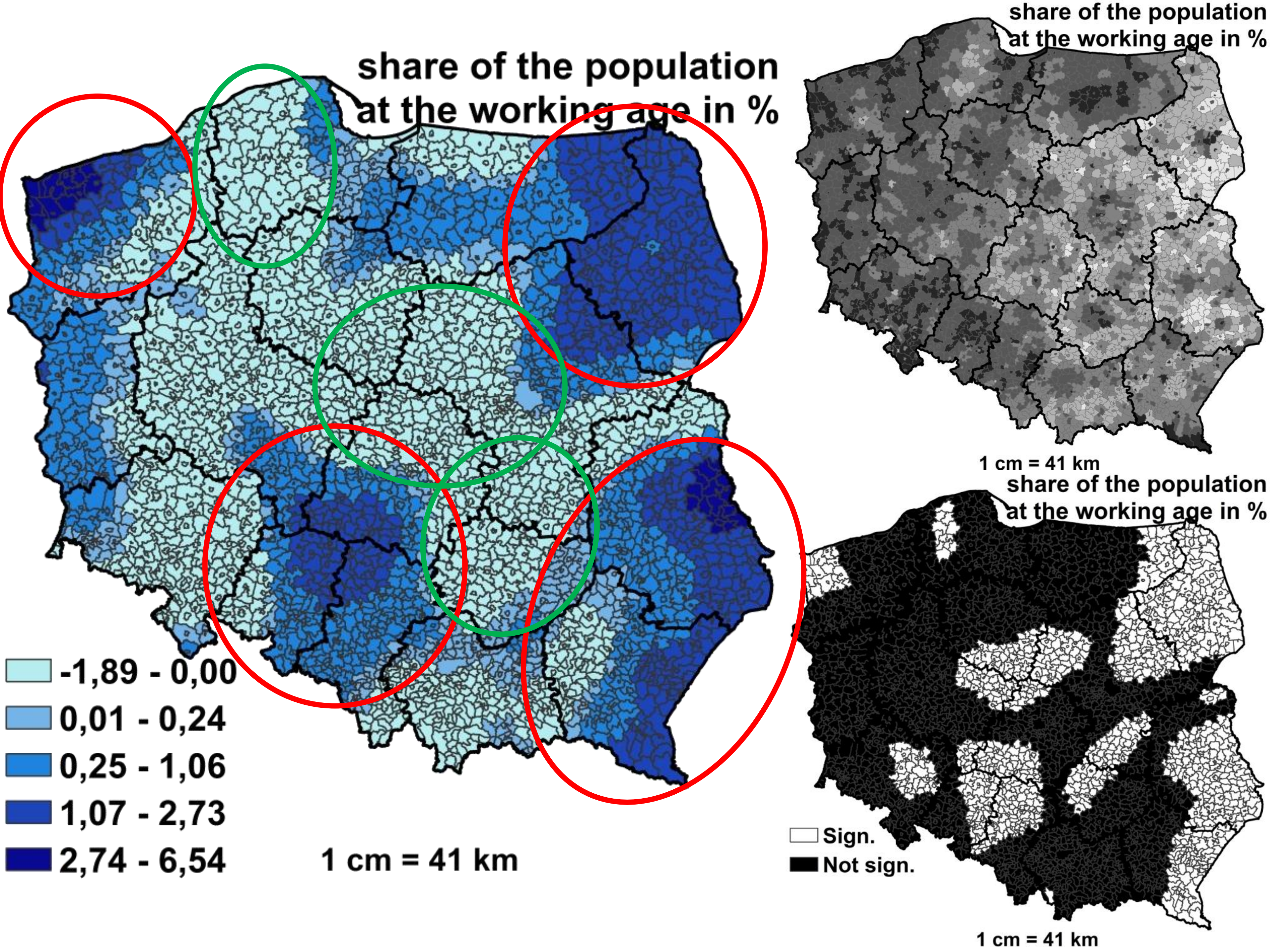
	Moran's I	Rsq.	AIC	RSS
OLS	0.39***	0.96	-1625.2	107
GWR	0.09***	0.97	-1746.7	103
GWR-SEM	0.005	0.98	-2923	58

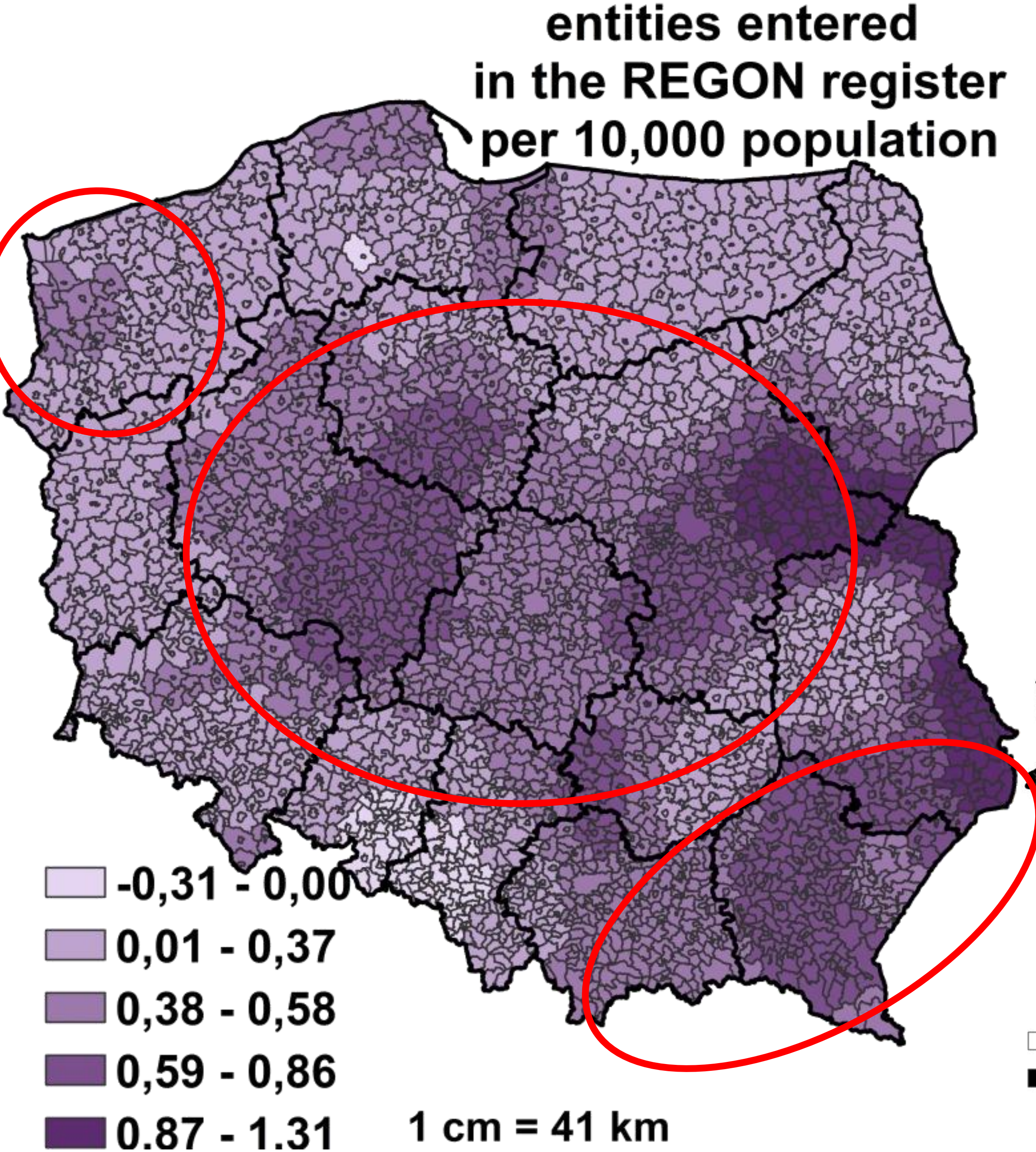

RESULTS

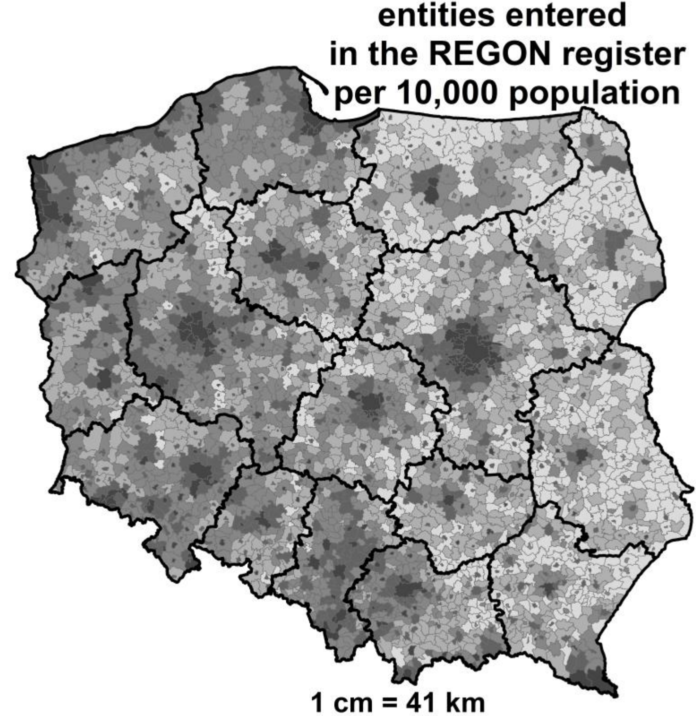

Urban and rural area
-0,11 - 0,0
0,010 - 0,11
0,12 - 0,16
0,17 - 0,23
0,24 - 0,36
voivodeships
1 cm = 41 km
Urban and rural area
0
1
voivodeships
1 cm = 41 km
Not sign.
Signif.
voivodeships
1 cm = 41 km

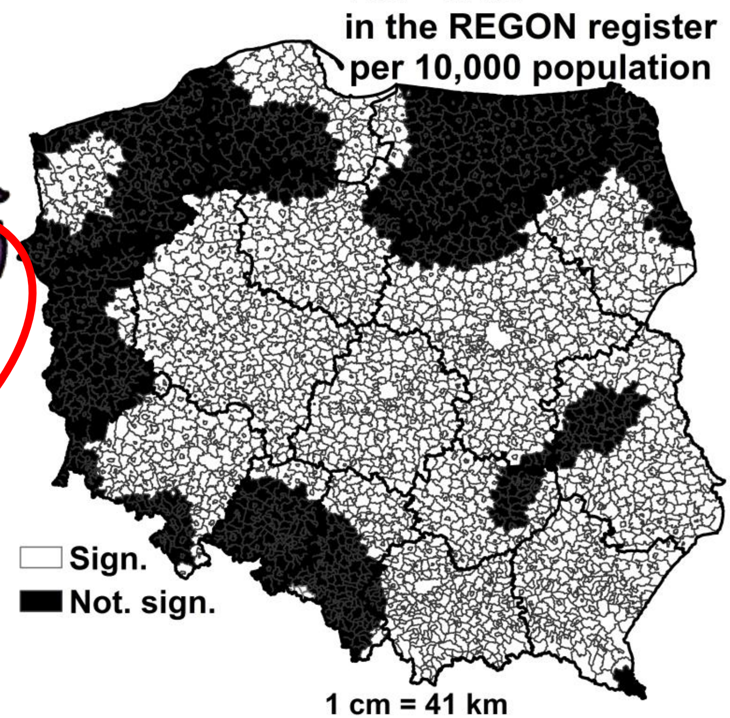

Dwellings per
1000 population
-1,02 - 0,00
0,01 - 0,26
0,27 - 0,56
0,57 - 0,85
0.86 - 1.44
1 cm = 41 km
Dwellings per
1000 population
Dwellings per
1000 population
Sign.
Not. sign.
1 cm = 41 km

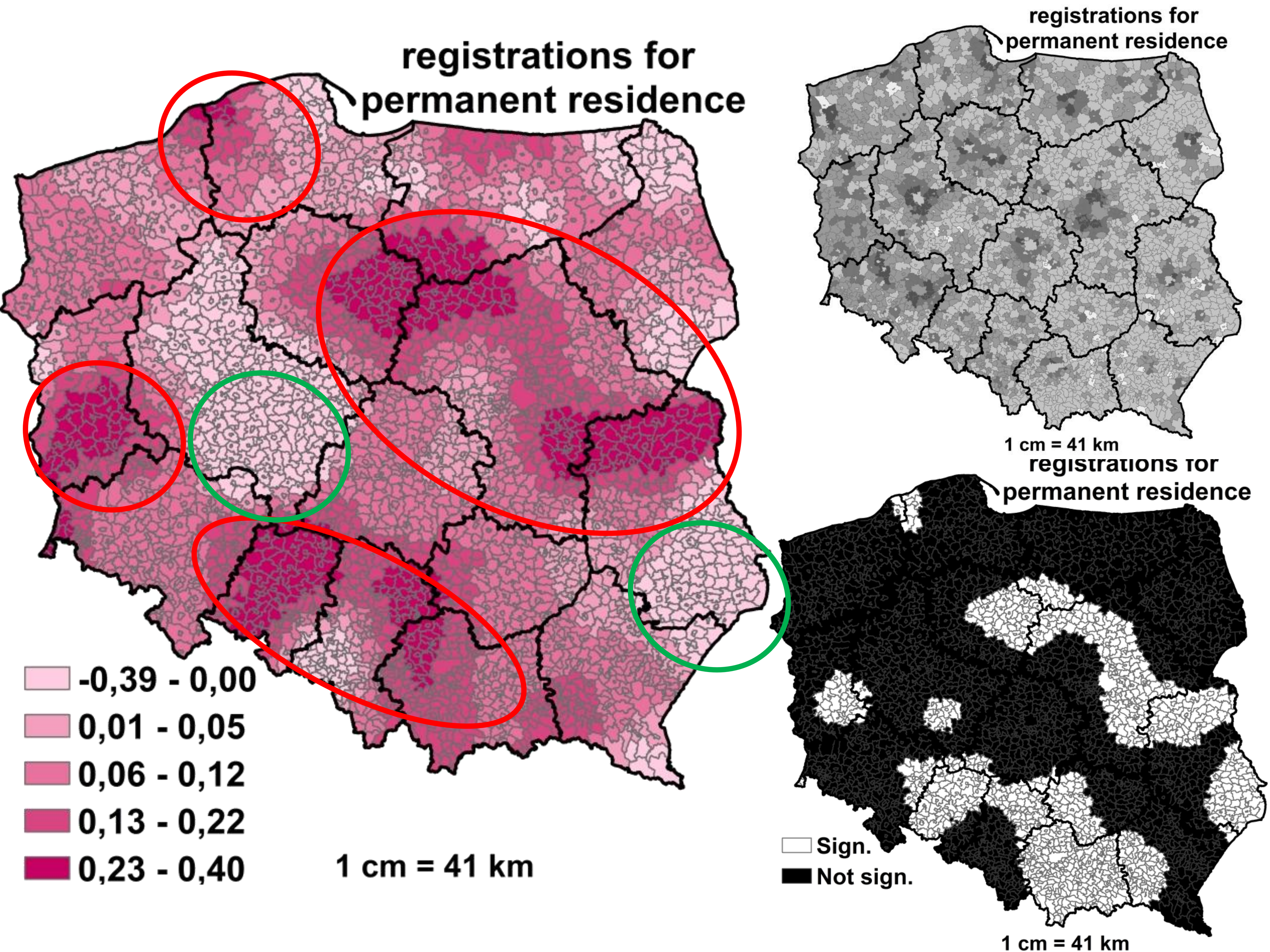

Nights spent by tourists per 1000 capita
-0,02 - 0,00
0,01 - 0,02
0,03
0,04 - 0,05
0,06 - 0,09
1 cm = 41 km
Nights spent by tourists per 1000 capita
1 cm = 41 km
per 1000 capita
Not sign.
Sign.
1 cm = 41 km

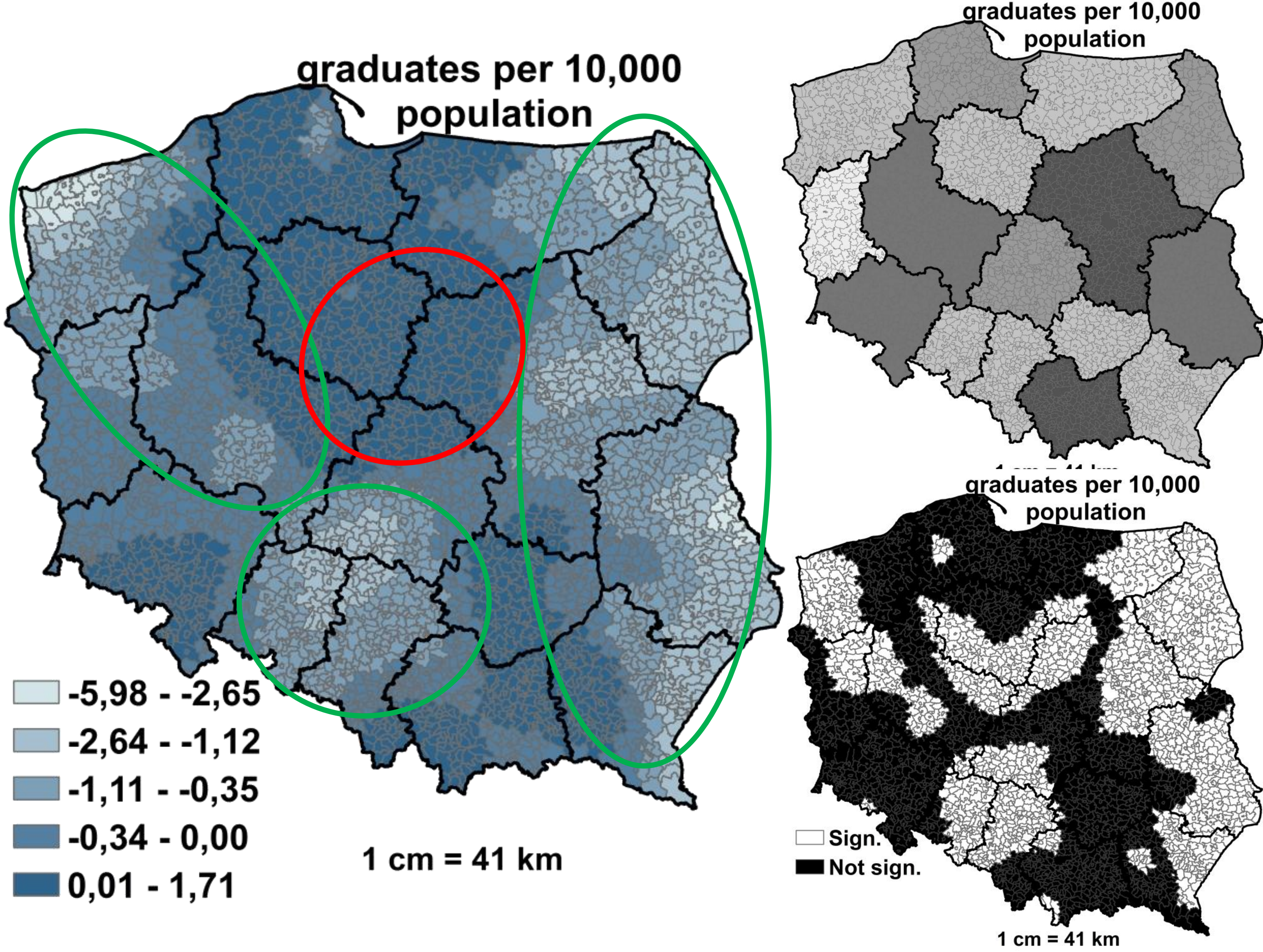

share of the population
at the working age in %
-1,89 - 0,00
0,01 - 0,24
0,25 - 1,06
1,07 - 2,73
2,74 - 6,54
1 cm = 41 km
share of the population
at the working age in %
1 cm = 41 km
share of the population
at the working age in %
Sign.
Not sign.
1 cm = 41 km

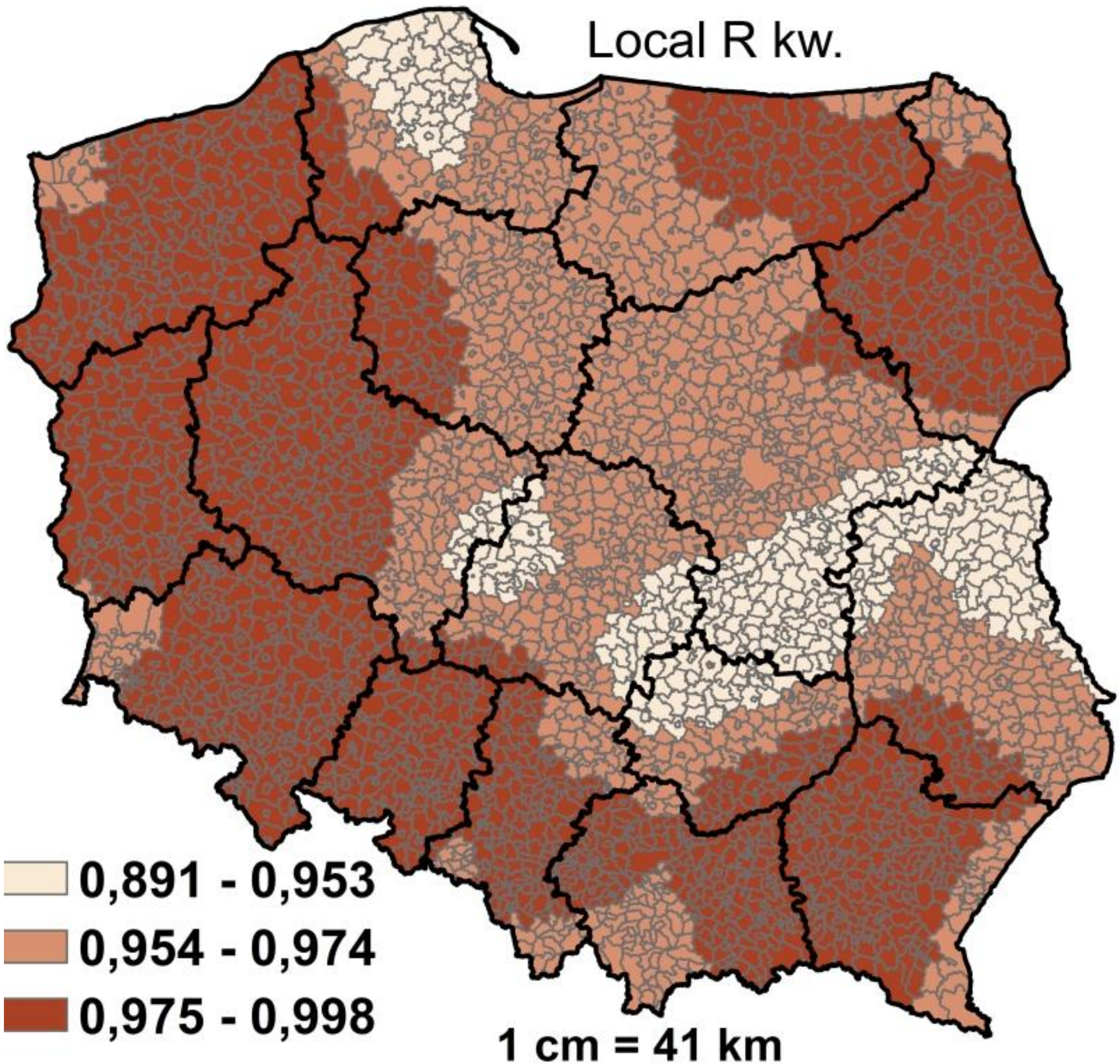

entities entered
in the REGON register
per 10,000 population
-0,31 - 0,00
0,01 - 0,37
0,38 - 0,58
0,59 - 0,86
0.87 - 1.31
1 cm = 41 km


entities entered
in the REGON register
per 10,000 population
1 cm = 41 km


in the REGON register
per 10,000 population
Sign.
Not. sign.
1 cm = 41 km


registrations for permanent residence
-0,39 - 0,00
0,01 - 0,05
0,06 - 0,12
0,13 - 0,22
0,23 - 0,40
1 cm = 41 km
registrations for permanent residence
1 cm = 41 km
registrations for permanent residence
Sign.
Not sign.
1 cm = 41 km


graduates per 10,000
population
-5,98 - -2,65
-2,64 - -1,12
-1,11 - -0,35
-0,34 - 0,00
0,01 - 1,71
1 cm = 41 km
graduates per 10,000
population
graduates per 10,000
population
Sign.
Not sign.
1 cm = 41 km


Local R kw.
0,891 - 0,953
0,954 - 0,974
0,975 - 0,998
1 cm = 41 km

Conclusions

- waste collection might be local and global in nature;
- variables explained the quantity of waste in about 80% of the counties;
- spatial autocorrelation reached more than 150 km;
- these variables were, in order of the most influential to the least: share of individuals of working age, dwellings, entities, graduates;
- GWR-SEM proved to be an effective instrument for identifying and modeling spatially-varying relationship between waste and its determinants;
- this study provides useful data for the relevant decision-makers and local governments in terms of urban planning;

Questions & Problems

- accounting for the determinants of municipal waste by taking into account their structures;
- examining the directions of waste transport by constructing different (nonlinear or asymmetrical) spatial weights matrices;
- consider more information, such as housing characteristics, the average income of households, environmental values, the psychological factors that influence the behaviour of the inhabitants, and the location of the municipality regarding metropolises and regional peripheries.

Thank You for Your attention!

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The attendance was supported by the National Science Centre (NCN)/ Miniatura 2 [grant number 2018/02/X/HS4/00966]