A spatial econometric approach to assess the impact of RDPs agri-environmental measures on the use of Nitrogen in agriculture: the case study of Emilia-Romagna (Italy)

Marconi V.[1], Raggi M.[2] and Viaggi D.[1]

[1] Department of Agricultural Sciences, University of Bologna, Bologna, Italy
[2] Department of Statistical Science, University of Bologna, Bologna, Italy

v.marconi@unibo.it

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Summary

Agriculture is the main source of nitrogen loading (EEA, 2012) and is the sector with the largest remaining emission reduction potential (Sutton et al., 2011). Furthermore, surpluses of nitrogen are forecast to grow in the next decade (FAO, 2008).

The objective of this study is to evaluate the determinants of the use of nitrogen inputs in agriculture, and the effects of RDP implementation in Emilia-Romagna on preventing nitrate pollution through a spatial econometric regression model.

Firstly, we carried out an estimation of both inorganic and organic nitrogen input in agriculture at the municipality scale for year 2000 and 2010..Secondly, we performed a Moran's statistics and a LISA (Local Indicators of Spatial Association; Anselin, 1995) analysis in order test the data for local spatial autocorrelation. Finally, in order to provide a quantitative evaluation of the application of the agri-environmental measures on the impact of farming systems on water quality, we constructed two spatial regression models: INORGANIC AND ORGANIC. Spatial dependence was included to the regressions (OLS) through spatial lag and spatial error.

The INORGANIC model explains more than 70% of the dependent variable and suggest that participation to the measure 214 is not likely to be important for explaining the reduction of the Inorganic Nitrogen in the municipalities of Emilia Romagna. Significant variables are farm's size, population density, location in NVZs and share of certified organic surface on the UAA. The same regressors could not explain the dependent variable in the case of the ORGANIC model.

The availability of better estimation of changes in nitrogen inputs, such as the calculation at the farm scale, would be an important component to allow for a more robust use of spatial econometrics in RDP evaluation related to Nitrogen reduction.

Keywords: agri-environmental scheme, nitrogen, policy analysis, spatial econometric, rural development plans.

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v.marconi@unibo.it

1. Introduction

Addressing the issue of preventing nitrogen release into water is important due to the amplitude of consequences of its accumulation into the environment. Compared to other pollutants, the impacts of reactive Nitrogen is, in fact, characterized by having consequential effects on environment and human health (Galloway et al. 2004).

Agriculture is the main source of nitrogen loading in water (EEA, 2012) and is the sector with the largest remaining emission reduction potential with respect to other sources, such as wastewater from industry and households (Sutton et al., 2011). Agriculture in Europe contributes, on average, to about 40%–60% of the reactive Nitrogen released to surface waters (Oenema *et al*., 2009). Agricultural deriving Nitrogen originates mainly from animal manure in stables (Oenema, 2011). Together with the others regions located in the Po plain (Veneto, Lombardia and Piemonte), Emilia-Romagna owns 70% of the national livestock.

Mineral fertilizers is the other main source of nitrogen deriving from agricultural systems. Emilia-Romagna represents the third topmost national area for fertilizer distribution (12% of the total fertilizer sale in Italy). In spite of the increasing prices, surpluses of nitrogen and phosphate based fertilizers are forecast to grow in the next decade, while those of potash are likely to remain more or less stable (FAO, 2008).

The Common Agricultural Policy contributes to the mitigation of pollution of waters by nitrates through Rural Development Programs (RDPs): agri-environmental schemes, support for investments in storage of manure, and training. The intervention strategy is based on direct support to farmers who will voluntary implement agri-environmental measures in order to reduce nitrates pollution.

This study focuses on the Agri Environmental Schemes of RDPs 2007-2013 in an Italian case study represented by the Emilia-Romagna Region. The main purpose is to assess if specific actions of measure 214 are effective in reducing the nitrate surplus in agriculture.

Firstly, we carried out a calculation of the two main sources of agricultural nitrogen (inorganic fertilizers and livestock manure) at the municipality scale in Emilia-Romagna for year 2000 and 2010. Inorganic fertilizers and livestock manure are given as weight unit (in kg) of nitrogen per hectares of UUA, values are estimated according to the OECD method for calculation of the Gross Nitrogen Balance (baseline indicator 20, CMEF 2006).

Secondly, in order to provide a quantitative evaluation of the impact of the agro-environmental measures on the reduction of agricultural inputs, we applied a spatial regression model. Nitrogen-based inorganic fertilizers and livestock manure are included as dependent variables in two distinct regression models, which will be called, respectively, INORGANIC MODEL and ORGANIC MODEL from hereafter. Both models are based on Ordinary Least Square estimation. If spatial autocorrelation of the dependent variable occurs, then spatial dependence is added to the regression model through spatial lag and spatial error estimations.

Both the dependent variables are given as a difference between the values calculated in year 2010 and in year 2000, for each municipalities of Emilia-Romagna region.

Analysis focuses on the AES (measure 214) actions that may have a direct influence on the Gross Nitrogen Balance: 214/1 (integrated farming), 2 (organic farming: restrains the use of nitrogen based fertilizers), 8 (extensive meadows: conversion of intensive crops into pasture, fodder crops and grasslands), 9 (protection of natural, semi-natural and agricultural landscape: restrains the extension of intensive cultivation), 10 (set aside of arable crops for environmental purpose: reduces the extension of intensive cultivation). For all these sub-measures, farmers are the direct beneficiaries of the payments.

The paper is structured as follows: section 2 describes background and study area, section 3 sets the methodology, results are presented in section 4 and discussed in section 5.

2. BACKGROUND AND STUDY AREA

The percentage of Utilised Agricultural Area (UAA) on the total extension of the region decreased from 50% in year 2000 to 47% in year 2010. In the same period, the number of farms decreased by 33%, while the average size of farms has increased in considered decade from 11 ha to 22 ha.

In the study area, about 20% of the farms is smaller than 5 ha and 40 % of the farms has an extension greater than 50 ha. According to the last two Agricultural Census, in year 2000, 41% of the farms in Emilia-Romagna included livestock, this percentage has increased up to 71% in 10 years.

Organic farming represented only 2.4% of the Utilized Agricultural Areas in year 2000 and slightly increased up to 3.3% in year 2010.

A detailed dataset of cropping pattern and livestock amounts for years 2000 and 2010, at the municipality scale, is available from the Italian Statistical Institute (ISTAT).

The cropping pattern of Emilia-Romagna is dominated by arable production (about 75% of the agricultural land), while fruit tree (orchards, vineyards and olive groves) and grassland (including permanent grazing) constitute about 15% and 10% of the UAA, respectively. On the whole, the variations in percent UAA per crop between year 2000 and 2010 are negligible. However, it is worth to mention that the share of areas cultivated at arable on the total UAA has increased of 4% over the considered decade, whereas areas dedicated to grassland have decreased of 1% over the same time period.

With respect to the geographical distribution of cultivations, orchards and vegetables are commonly cultivated in the eastern part of the region (especially Ravenna and Forlì-Cesena provinces in Figure 1), whereas the central provinces of Bologna and Ferrara (Figure 1) are mostly cultivated at cereals. Fodder crops and grasslands are widespread in the northern part of Emilia-Romagna (Piacenza, Reggio-Emilia, Parma and Modena in Figure 1). Consistently with the geographical distribution of cultivations, the livestock density is higher in the northern part of the region. In this area, the most common livestock categories are cows and swine, which represent 21% and 25% of the total Livestock Units in Emilia-Romagna. Poultry livestock (50% of the total LUs) are widespread in the southern provinces of Rimini and Forlì-Cesena.

The average livestock density, expressed as LUs per hectare of UAA, in Emilia-Romagna was equal to 1.5 in year 2000 and has decreased by 5% in 2010. On the whole, the variations in shares of the livestock categories between year 2000 and 2010 are negligible. The average number of LUs in livestock has also decreased from 39.21 in year 2000 to 30.51 in year 2010.

Figure 1 – Geographical map of Emilia-Romagna region, red lines indicate provinces' (listed in the figures) borders

Information about the uptake to the single actions of measure 214 was provided by the regional government for each municipality. Data are referred to the whole measure (214) and to the considered actions (n. 1,2,8,9,10) in terms of share of involved agricultural areas on the total extension of each municipality. The uptake refers to the cumulated frequency of years 2007-2010. On detail, participation rate to action 1 (integrated production) is greater in areas characterized by large share of fruit production (eastern part of the region). On the contrary, organic production (action 2) is much more contracted in hill-mountain areas, where more extensive systems and easies plant protection are common. This is true with the exception of the Ferrara Province, which is a completely flat area dedicated to arable production that recorded a high participation rate to action 2. Uptake of action 8 (meadow and grazing conservation) is greater in the hill and mountain areas and in the plain area of the Parma and Reggio Emilia provinces. Finally, actions 9 (protection of natural, semi-natural and agricultural landscape) and 10 (set aside of arable crops for environmental purpose) are mainly contracted in the plain area.

It is worthy to point out that the regional budget for measure 214 exceeded the applications' requirements, therefore all the regular applications for measure 214 were funded by the RDP 2007-2013. Sub-measures 1 could be applied only in preferential areas, whereas the applications for the remaining actions were given absolute priority if belonging to a preferential area. Preferential areas include the Nitrate Vulnerable Zones (NVZs) and protected areas at local and national level (e.g. Natura 2000).

In the study area, 29.9% of the land is classified as NVZs, which are located along the plain-hill boundary across the whole region and in the province of Ferrara (the whole province was included in the NVZs in 2006). The establishment of action programmes to be implemented by farmers within NVZs on a compulsory basis occurred in 2007 and overlaps the last RDPs intervention

3. METHODS

The amount (in kg per ha of UAA) of inorganic fertilizers distributed in each municipality has been estimated taking into account local application rates for 8 cropping pattern elements: cereals (excluding wheat), wheat, vegetables, fruits, vineyards, olive grove, fodder crops, grassland. According to the OECD method (OECD, 2007), the estimated inorganic fertilizers must be referred to the amount of inorganic fertilizers sold at regional level), through the application of an "adjustment factor". The amount of N fertilizers (and the Nitrogen content of these products) distributed yearly in Emilia-Romagna is available from ISTAT at the province scale only since year 2003. Thus, the adjustment factor for year 2000 can be calculated based on the 2003 data. Local fertilization rates were provided by the regional institutions dealing with agricultural (RER) and environmental issues (ARPA).

The calculation of Nitrogen deriving from livestock manure requires the quantity of nitrogen potentially available from local livestock. Based on ISTAT dataset, for each livestock category, the nitrogen quantity in the manure was estimated multiplying the number of heads by a specific manure coefficient. Technical coefficients were taken from APAT reports (National Environmental agency).

As stated in the introduction, both N in inorganic fertilizers and organic nitrogen were calculated for year 2000 and 2010, at the municipality scale, and given as weight unit per hectares of UAA. The variations of these quantities in the considered time shift are the dependent variables explained the two regression models:

1) D N fertilizers (kg) / UAA (ha) = inorganic fertilizers (2010) – inorganic fertilizers (2000), INORGANIC MODEL
2) D N_Livestock (kg) / UAA (ha) = organic nitrogen (2010) – organic nitrogen (2000), in ORGANIC MODEL

The selected explanatory variables can be grouped in three main categories:

1. Policy-related variables: uptake of the AES (extension of the agricultural areas involved in measure 214), location in priority areas, such as Less Favored Areas and NVZs.
2. Structural variables: farm's size, geographical location, farm management (individual company vs limited company), etc…
3. Farmers' characteristics variables: age and education.

All these categories of regressors are likely to influence the optimal fertilization rate adopted by farmers as well as the livestock density distribution.

In order to determine if there is a spatial dependence, the variables must be geo-coded for location and related to a spatial weight matrix ($w_{ij,}$), which provides the structure of the spatial relationship among observations. According to the available dataset, data and spatial weight matrix were geo-coded at the municipality scale.

Three spatial weight matrixes were calculated with the software GEODA based on queen contiguity criterion: municipalities are neighbours if they share a common edge. The three matrix, named queen 1, queen 2 and queen 3 hereafter, are respectively characterized by increasing level of contiguity. In the first order the neighbours of a municipality are only the adjoining ones, in the second order the adjoining of the adjoining are included, in the third level the adjoining of the adjoining of the adjoining are included. In the case of Emilia-Romagna, where the municipalities sizes are homogeneous and the shape of the region is regular, the third order of municipalities will include a very large part of the total land.

We applied the Moran's *I* test statistic as spatial dependence test (Moran, 1950):

$$I = e'We / e'e$$

where e=(y-y)/sd(y). Global Moran's *I* is the slope of line fit to scatter of We, e. This index is a measure of autocorrelation at the scale of all the study area.

We performed a LISA (Local Indicators of Spatial Association; Anselin, 1995) analysis in order test the data for local spatial autocorrelation, which is a measure of the local clustering of the data. LISA analysis lead to the construction of cluster maps, which are tested for significance. Spatial dependence is added to a regression (Ordinary Least Square) in two ways: spatial lag and spatial error.

The following Equations outline the general version of the econometric model (Anselin, 1988; LeSage, 1999) that we used for our estimations.

The spatial lag model is a spatial autoregressive model that includes a spatially lagged dependent variable (Wy). The dependent variable is a weighted average of its neighbors' values. The spatial lag model reduced form equation is:

$$(I - \rho W)y = x\beta + e$$

The independent variables are explaining the variation in the dependent variable that is not explained by the neighbors' values. The spatial dependence parameter ρ is also estimated.

The spatial error model considers spatially correlated errors due to unobservable features or omitted variables associated with location. In this case the spatial dependence parameter λ is estimated.

The spatial error regression reduced form equation is:

$$(I - \lambda W)y = (I - \lambda W)x\beta + u$$

The multipliers in front of the dependent and independent variables are the variations that cannot be explained by the neighbors' values.

4. RESULTS

4.1. Descriptive statistics

As already stated, information about the sale of fertilizers are available for the case study area since year 2003, which will be taken as reference year for the sales in year 2000. The total amount of N-based inorganic fertilizers sold in year 2003 equals 2,023,178 q. Until year 2008, the amount of N-based fertilizers sold in the region stays in the range of 2,000,000 – 2,500,000 q/years. Since year 2009, sales of inorganic fertilizers decreased remarkably: in year 2009 the sale of N-based inorganic fertilizers has decreased of 31% with respect to the reference year (2003), in year 2010, 1,235,438 q of N-based inorganic fertilizers were sold, which means -39% in the regional sales compared to year 2003.

The content of nitrogen (in weight) of the N-based inorganic fertilizers is also available from the Italian Statistics Institute. Values indicates that the amount of nitrogen sold as inorganic fertilizers has decreased of 34% in the considered time shift. These quantities, available at the province scale, were used for the estimation of the N inorganic fertilizers at the municipalities scale in year 2000 and 2010, which was made according to the methodology described in the previous section.

N deriving from livestock manure was also estimated at the municipality scale based on the available datasets on livestock categories (see methodology section for details). The estimated regional amount of organic N has decreased of -14% from year 2000 (645,005 q) to 2010 (556,040 q).

The average value of inorganic nitrogen distributed per hectare of UAA in each municipality is equal to 78 kg/ha in year 2000 and to 55 kg/ha in year 2010 (Table 1). The average values of organic nitrogen (deriving from livestock manure) available in each municipality has also decreased from 62 kg per hectare of UAA in year 2000 to 55 kg/ha in year 2010.

Table 1 – Descriptive statistics of N deriving from inorganic fertilizers and livestock manure, estimated at the municipality scale for year 2000 and 2010

	mean	**st dev**	**min**	**max**
N INORGANIC FERTILIZERS (kg) / UUA (ha) 2000	77.94	24.79	30.88	53.72
N INORGANIC FERTILIZERS (kg) / UUA (ha) 2010	55.21	22.39	19.71	130.08
ORGANIC N LIVESTOCK (kg) / UUA (ha) 2000	61.85	66.50	0.17	458.61
ORGANIC N LIVESTOCK (kg) / UUA (ha) 2010	55.30	84.30	0.00	1070.45

If we compare the standard deviations of the means (Table 1), it is possible to observe that organic N has a much more heterogeneous distribution, especially in year 2010. Minimum values of organic N are about zero kg/ha in both the considered years, but maximum values ranges from 459 kg/ha in year 2000 to 1070 kg/ha in 2010 (Table 1). The highest quantity of nitrogen deriving from livestock in year 2010 were recorded in two small municipalities: Vezzano sul Crostolo and Formigine, respectively located in the northern provinces of Reggio Emilia and Modena.

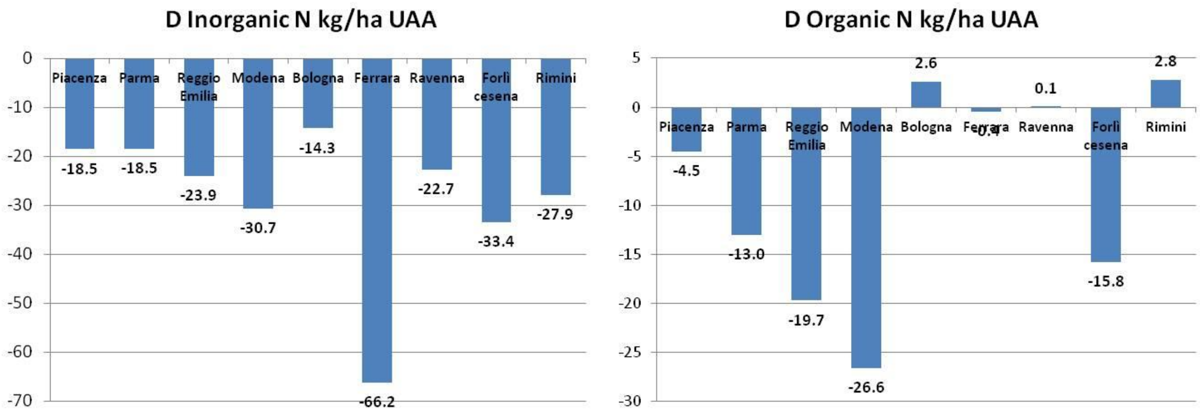
Average differences in agricultural nitrogen input calculated at the municipalities scale indicate an overall decreasing of both inorganic fertilizers and organic nitrogen deriving from livestock manure from year 2000 to 2010, results are reported in Table 2. The average difference of inorganic N (D N Inorganic) equals -22.73 kg/ha UAA, this value is greater than the average difference of N deriving from livestock manure (D N Organic) in the same time shift, which correspond to – 6.55 kg/ha. Consistently to what observed in Table 1, the distribution of D N Organic is much more heterogeneous than the distribution of D N Inorganic as it is indicated by the standard deviation reported in Table 2: 70.92 and 15.72, respectively. The highest increase of organic N (about 1000 kg/ha) from year 2000 to 2010 is recorded in the previously mentioned municipality of Vezzano sul Crostolo, whereas the highest increase of inorganic is of 8.95 kg/ha (municipality of Sant'Agata sul Santerno, in the province of Bologna). The highest decrease of organic N is of -256.04 and belongs to the municipality of Bastiglia (Reggio-Emilia province), the highest decrease or inorganic N is of -92.17 kg/ha (municipality of Mesola, Ferrara province).

We also calculated average values of the two variables (D N Inorganic and D N Organic) at the province scale. Results show that decrease form year 2000 to 2010 of Inorganic N are recorded in all the provinces and that the highest average decrease of Inorganic N is recorded in Ferrara province (-66 kg/ha in the left chart of Figure 2. From year 2000 to 2010, Organic N has decreased in almost all provinces (highest decrease is recorded in Modena province, -27 kg/ha in the right chart of Figure 2, with the exception of Rimini, Bologna, and Ravenna provinces, where it slightly increased.

Table 2 – Descriptive statistics of the difference between year 2010 and 2000 of the N deriving from inorganic fertilizers and livestock manure, estimated at the municipality scale

	mean	dev st	min	max
D N INORGANIC (kg) / UUA (ha) 2000-2010	-22.73	15.72	-92.17	8.95
D N ORGANIC (kg) / UUA (ha) 2000-2010	-6.55	70.92	-256.04	1009.89

Figure 2 – Province scale average values of D Inorganic N (difference between year 2010 and 2000 of the distribution of N-based inorganic fertilizers per ha of UAA) and D Organic N (difference between 2010 and 2000 of the potentially available organic nitrogen deriving from livestock per ha of UAA).



4.2. Spatial analysis

In this part of the chapter the calculations of global Moran's I and the results of LISA cluster maps are presented.

The global Moran's I values for the three variables are listed in 3. The Moran's I values were calculated increasing the order of contiguity of the same queen contiguity matrix from 1 to 3 (queen 1, queen 2 and queen 3, in Table 3).

In all the three spatial weight hypothesis, the global Moran's I value for the variable D N Inorganic (difference of inorganic nitrogen distributed yearly at the municipality scale between year 2010 and 2000) is greater than zero, showing that there is a positive spatial autocorrelation in the variable distribution.

Increasing the order of queen contiguity the autocorrelation is reduced form 0.656 (queen 1) to 0.238 (queen 3).

In the case of the variable D N Organic (difference of organic nitrogen distributed yearly at the municipality scale between year 2010 and 2000), the global Moran's I values are close to zero in all the three spatial weight hypothesis (Table 3), which indicates that there is no spatial autocorrelation of this variable.

Table 3: Global Moran's I of D N Inorganic and D N Organic, calculated using three spatial weight matrix (queen 1, queen 2 and queen 3).

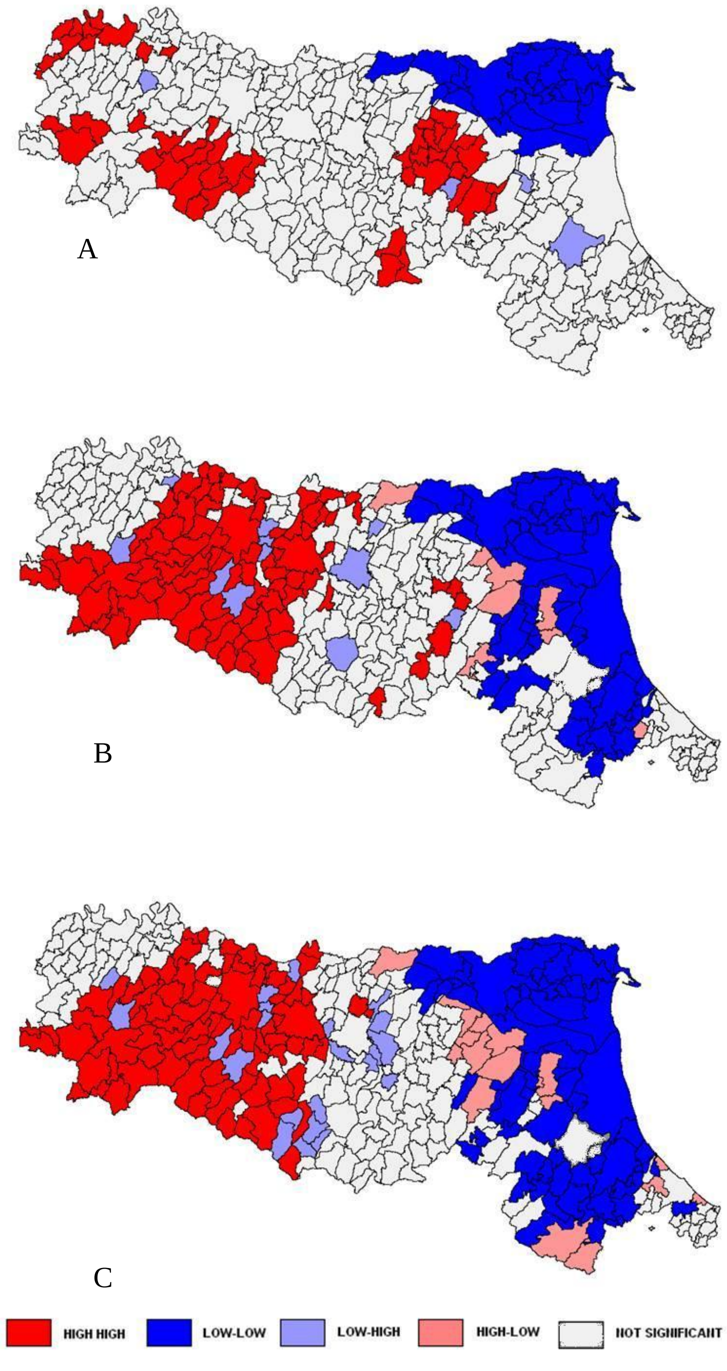
	I moran Queen 1	**I moran Queen 2**	**I moran Queen 3**
D N INORGANIC (kg) / UUA (ha)	0.656	0.497	0.238
D N ORGANIC (kg) / UUA (ha)	-0.004	-0-003	0.013

Positive global spatial association indicates the presence of clustering: positive autocorrelation correspond to hot spot clustering (high-high correlations) and cold spot clustering (low-low correlations).

The results of local spatial association analysis are displayed through LISA cluster maps for both variables: D N Inorganic (Figure 3) and D N Organic (Figure 4). The red colors represent a hot spot clustering (high-high correlation), while the blue indicates the cold spot clustering (low-low correlation). Spatial outliers are represented in pink (high-low correlations) and sky-blue (low-high correlations). All the painted municipalities are those municipalities which are significant at least at 0.05, white municipalities correspond to not significant cluster.

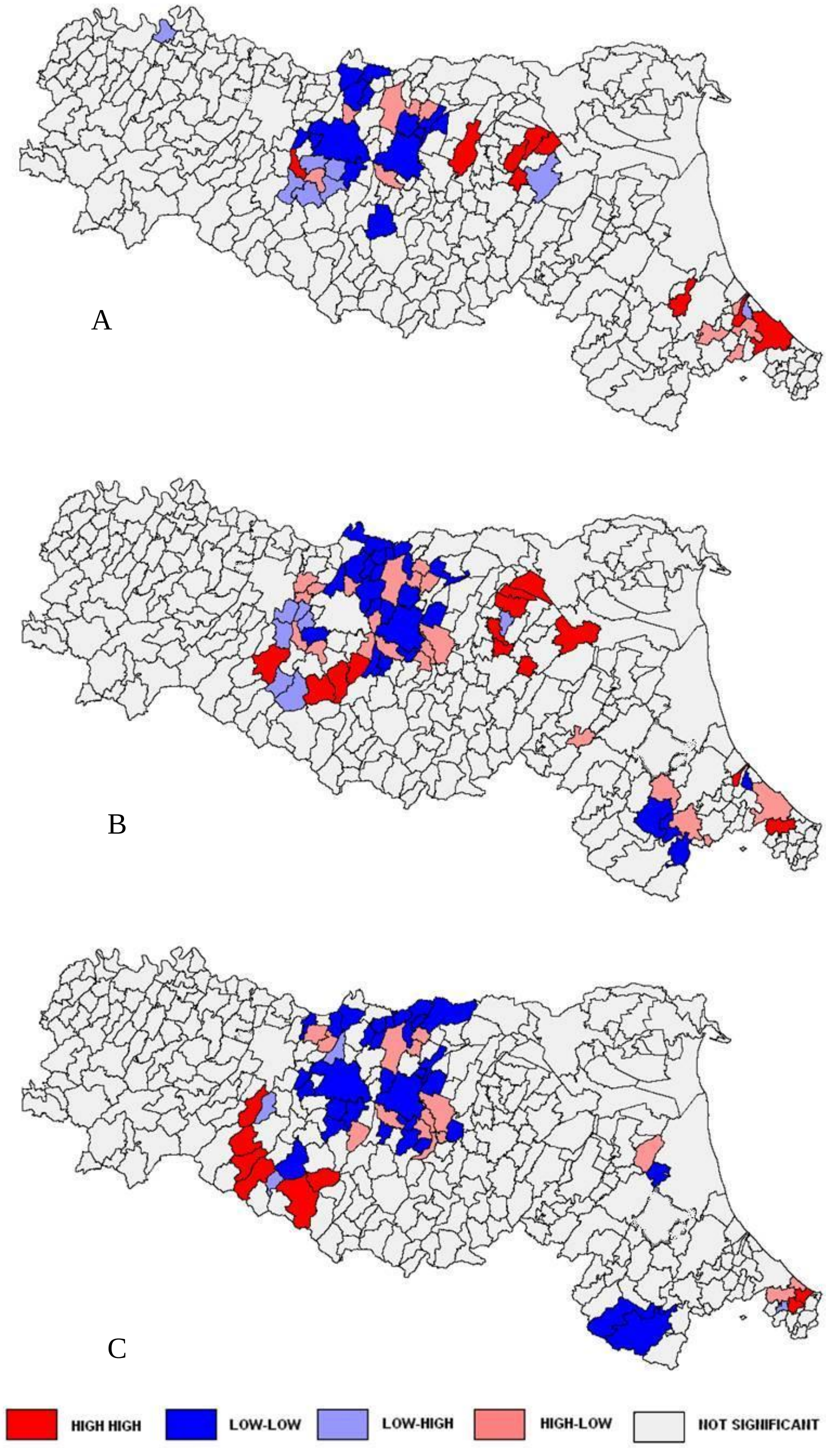
The LISA maps of the variable D N Inorganic are displayed in Figure 3: from map A to C the order of queen contiguity increases from 1 to 3. At the lowest order of contiguity, it is possible to observe that hot spot clustering is located in small areas belonging to the Bologna, Parma and Piacenza provinces, while cold spot clustering is entirely located in Ferrara province (Figure 3A). The number of significant clusters increases with increasing level of contiguity (Figure 3B and 3C): hot spot clustering cover a large area in the western part of the region (especially, Parma and Reggio-Emilia provinces), while cold spot clustering correspond to the eastern side of Emilia-Romagna (Ferrara, Ravenna and Forlì-Cesena provinces).

Figure 3: LISA of D N Inorganic using queen contiguity matrix of the first (A), second (B) and third (C) level



The LISA maps of the variable D N Organic are displayed in Figure 4: from map A to C the order of queen contiguity increases from 1 to 3. Hot spot clustering is limited to a few municipalities at all the levels of contiguity; cold spot clustering slightly increase with increasing order of contiguity and correspond mainly to a discontinuous areas between the provinces of Modena and Reggio-Emilia (Figure 4A-C).

Figure 4: LISA of D N Organic using queen contiguity matrix of the first (A), second (B) and third (C) level



4.3. Regression models

In this section we present the results of the regression models INORGANIC FERTILIZERS and ORGANIC NITROGEN (Table 4-6): the dependent variables are D N Inorganic and D N Organic, respectively. In both models, all the variables are calculated at the municipalities scale. Based on the results of the spatial analysis, we included in the INORGANIC FERTILIZERS model both OLS and spatial (spatial lag and error) estimations, whereas the ORGANIC NITROGEN model consists only of OLS estimation. In the case of the INORGANIC FERTLIZERS model, all the regressions were run under the hypothesis of the first order of contiguity (queen 1).

In the INORGANIC FERTILIZER MODEL, the R-squared is 0.43 in the OLS estimation and increases up to 0.7 and 0.74 in the spatial lag and spatial error models, respectively (Table 4). Spatial dependence is indicated in the spatial lag model by the rho coefficient (Table 4) of the lagged dependent variable (W D N_FERT/ UUA, in Table 5), and by the coefficient lambda in the spatial error model (Table 4 and 5). Both the rho and lambda coefficient are highly significant ($p < 0.000$, Table 5).

All the included independent variables are listed in Table 5, where the coefficients and their statistical significance are given for each estimation: OLS, spatial lag and spatial error. Significant variables are highlighted in bold characters.

The uptake of agri-environmental action n. 214-1 (integrated production) and 214-10 (set-aside) is significant in any of the performed models (both variable show $p<0.01$ in OLS and spatial lag estimations, $p<0.05$ in spatial error, Table 5). Action 214-1 has negative correlation coefficient, action 214-10 shows a negative correlation with the independent variable. Action 214-9 (protection of natural, semi-natural and agricultural landscape) is significant only in the OLS estimation ($p<0.05$) and show negative coefficient.

Significant variables with negative coefficient are also: Y NVZ MUNICIPALITIES (municipalities belonging to NVZs, expressed as dummy variable), which is highly significant in all the estimations 8p<0.001 in Table 5); FARM < 5 ha (percentage of farms with extension lower than 5 ha on the total number of farms), which is significant only in the OLS and spatial lag model; N_FERTILIZERS/ UUA 2000 (ratio of the inorganic nitrogen on the UAA of the municipality, expressed as kg/ha), which is significant in all the estimations; CERTIFIED ORGANIC LAND 2000 (ratio of certified organic cultivated land on the total UAA of the municipality expressed in ha, referred to year 2000), which is significant only in the spatial models. The only other significant variable with positive coefficient is POPULATION DENSITY (ratio of inhabitants on the extension of the municipality in kmq), which results highly significant ($p<0.001$, Table 5) in all the estimations.

Table 4: Summary of the model INORGANIC FERTILIZERS: OLS and spatial estimations

MODEL: INORGANIC FERTILIZERS: Dependent Variable D N_FERTILIZERS/ UUA			
	ORDINARY LEAST SQUARE	SPATIAL LAG MODEL	SPATIAL ERROR MODEL
R-squared	0.430794	0.699616	0.743329
Adjusted R-squared	0.393323		
S.E of regression	12.24770	8.63182	7.97907
Lag coeff. (Lambda)			0.804359
Lag coeff. (Rho)		0.663482	

Table 5: Coefficients and p-values of all the independent variables included in the INORGANIC FERTILIZERS MODEL, for OLS and spatial estimations (spatial lag and spatial error)

MODEL: INORGANIC FERTILIZERS	OLS		SPATIAL LAG		SPATIAL ERROR	
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Variable	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
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W D N_FERT/ UUA (kg / ha)			**0.663482**	**0.000**		
LAMBDA					**0.804359**	**0.000**
CONSTANT	3.979607	0.769343	10.04014	0.211254	6.870828	0.36904
214-1 EXTENSION / UUA	**-0.87632**	**0.004057**	**-0.55621**	**0.009892**	**-0.46575**	**0.044727**
214-2 EXTENSION / UUA	-0.2162	0.076922	-0.04186	0.628853	-0.02556	0.770985
214-8 EXTENSION / UUA	-0.0726	0.517007	-0.07806	0.347252	-0.00759	0.930104
214-9 EXTENSION / UUA	**-4.60342**	**0.042989**	0.879905	0.585501	1.330568	0.389464
214-10 EXTENSION / UUA	**2.765486**	**0.00047**	**1.565455**	**0.004759**	**1.263754**	**0.03159**
Y NVZ MUNICIPALITIES	**-8.36227**	**1.59E-07**	**-4.52371**	**5.05E-05**	**-4.1175**	**0.002117**
DIFFERENCE OF AVERAGE FARM SIZE 2000-2010 (ha)	-0.06234	0.200762	-0.03567	0.296268	-0.01374	0.66386
HIGH SCHOOL DIPLOMA	-0.34667	0.140191	-0.2171	0.174805	-0.05781	0.680615
UNIVERSITY DEGREE	0.019576	0.626081	0.002479	0.929352	0.013606	0.581672
FARM < 5 (ha)	**-0.22262**	**0.011073**	**-0.12842**	**0.021244**	-0.01883	0.705704
FARM BETWEEN 5-30 (HA)	-0.20382	0.064679	-0.09552	0.158887	0.014218	0.814994
AGE BETWEEN 40-54	0.105817	0.481262	-0.02615	0.795499	-0.00098	0.991153
AGE > 55	0.084543	0.380346	-0.00539	0.931394	0.025966	0.640359
INDIPENDENT COMPANIES / TOT COMPANIES	0.155883	0.059174	0.096895	0.106949	-0.0109	0.842528
Y LFA MUNICIPALITIES	1.06742	0.490843	-0.1696	0.876745	-0.13161	0.898758
POPULATION DENSITY	**0.009711**	**9.02E-05**	**0.006373**	**0.000259**	**0.00474**	**0.008857**
DIFFERENCE UAA / TAA 2000-2010	-0.21535	0.874225	0.843535	0.88599	-6.9074	0.194293
LIVESTOCK UNIT / UUA (LSU / ha)	0.053521	0.783539	-0.07224	0.597377	-0.08907	0.466529
N_FERTILIZERS/ UUA 2000 (kg / ha)	**-0.30485**	**4.28E-17**	**-0.16568**	**0.000**	**-0.36545**	**0.000**
CERTIFIED ORGANIC LAND 2000 (ha)	-5.0579	0.105409	**-5.79877**	**0.00843**	**-4.49868**	**0.023515**
ALTITUDE (m)	-0.00331	0.396378	-0.00282	0.31296	-0.00214	0.61183

In the case of the ORGANIC NITROGEN MODEL, the R-squared of the OLS regression is 0.100. All the included independent variables are listed in Table 6, where the coefficients and their statistical significance are listed. Significant variables are highlighted in bold characters.

The uptake of agri-environmental actions is not significant. The only significant variables is D LUs / LIVESTOCK (difference between the ratio of Livestock Units on the total number of livestock for each municipality between year 2000 and 2010), which has a p-value< 0.01 (Table 6).

Table 6: Coefficients and p-values of all the independent variables included in the ORGANIC NITROGEN MODEL, for aspatial (OLS) estimations

MODEL : ORGANIC NITROGEN	OLS	
Variable	Coefficient	p-value
CONSTANT	10.80367	0.888984
D LIVESTOCK / TOT FARMS	0.451776	0.452571
D LIVESTOCK UNITS / LIVESTOCK	**-4.8E-06**	**-0.0079**
D ARABLE / UUA	-84.3721	-1.18313
D FODDER CROP AND GRASS / UUA	-74.3342	-0.98356
214-1 EXTENSION / UUA	0.451776	0.651169
214-2 EXTENSION / UUA	-4.8E-06	0.9937
214-8 EXTENSION / UUA	-84.3721	0.237648
214-9 EXTENSION / UUA	-74.3342	0.326089
214-10 EXTENSION / UUA	-1.04136	0.561128
Y NVZ MUNICIPALITIES	1.133132	0.105386
D AVERAGE FARM SIZE (ha)	-0.00354	0.995633
HIGH SCHOOL DIPLOMA	8.484621	0.523484
UNIVERSITY DEGREE	-0.98758	0.83086
UUA > 5 (ha)	5.778647	0.537562
UUA BETWEEN 5-30 (HA)	0.096198	0.732088
AGE BETWEEN 40-54	-0.89409	0.506246
AGE > 55	0.064938	0.78262
IND. COMP. / TOT COMP.	0.300291	0.551971
Y LFA MUNICIPALITIES	-0.20916	0.743687
POPULATION DENSITY	0.529812	0.544097
D UUA / TTA	0.39922	0.395987
D N_FERTILIZERS/ UUA (kg/ha)	-0.70213	0.207765
N_LIVESTOCK/ UUA 2000 (kg / ha)	-1.27896	0.887182
CERTIFIED ORG 2000 (ha)	-0.00399	0.77899
ALTITUDE (m)	0.304186	0.296529

5. DISCUSSION AND CONCLUSIONS

Results indicates that both inorganic and organic nitrogen deriving from agricultural systems has overall decreased from year 2000 to 2010.

For what concern the inorganic input, this trend is expected as the price of nitrogen-based fertilizers has almost doubled from year 2000 to 2010, when the yearly increase was on average equal to 10% in the US (USDA, 2012). The greatest reductions have been recorded at Ferrara (-66 kg/ha) and Forlì-Cesena (-33 kg/ha) provinces, located in the easternmost side of the region, where orchards are widespread. Within the intensive crops, the extension of orchards shows the greatest reduction (-25%) in the decade. The remaining provinces show a quite homogeneous reduction of N inorganic input.

The outcome of the spatial analysis allows a formal and more precise identification of the significant clustering. Moran's statistics indicate a positive spatial autocorrelation of the variable D N Inorganic, meaning that there is a significant spatial association: hot spot clustering and cold spot clustering. As we expected, the spatial dependence decreases at increasing orders of contiguity. LISA cluster maps point out that the cold-spot clustering is located in the province of Ferrara and is statistically significant at all levels of contiguity. Furthermore, at increasing orders of contiguity, cold spot clustering extends in the easternmost side of the region. LISA maps also allow the identification of hot spots clustering, which are mainly located in the western provinces of Parma and Reggio-Emilia. The occurrence of high-high correlation indicate that in this area the reductions of inorganic N fertilizers at the municipality scale are homogeneously low, although the average reduction at the province scale is aligned with the surrounding provinces.

When considering the uptake of agri-environmental actions, the location of the cold spot clustering overlaps the area where integrated farming (action 1) was most contracted. The location of the hot spot correspond to the provinces (Reggio-Emilia and Parma) where the uptake of action 8 (meadow and grazing conservation) was greater. However, the location of significant cluster (both hot- and cold-spot) partly overlaps also the areas where actions 2, 9 and 10 were mainly contracted.

In the INORGANIC FERTILIZERS MODEL, the relation between the dependent variable D N Inorganic and the uptake of the AES schemes were investigated. The spatial models (spatial lag and spatial error) are more effective in explain the variability of the difference in inorganic nitrogen input between 2000 and 210 with respect to OLS regression. The spatial dependence parameters are significant in both the spatial error model (lambda) and the spatial lag model (rho), which reveals the presence of significant spatial effects due to unobservable features or omitted variables associated with location.

The uptake of actions 1 and 10 is significant in all the regression models. Integrated production (action 1) has a negative coefficient meaning that an increase in the ratio of the extension of the land involved in this action cause a decrease in the input of inorganic nitrogen in the decade. The magnitude of the coefficient indicates that involving all the UAA of a municipality would reduce inorganic nitrogen would of 0.8 kg per ha according to the OLS model and of about 0.5 kg/ha according to the spatial models Voluntary set aside has a positive coefficient, which suggest that lower reductions of the inorganic nitrogen are recorded in the municipalities where the uptake of action 10 was higher. As already mentioned, action 10 was mainly contracted in plain areas, which are characterized by intensive farming systems. Furthermore, in the considered time shift the whole extension of arable has slightly increased (+4%). Spatial distribution of action 214-10 and the occurrence of factors not captured by model (e.g. slippage) should also be further investigate.

Action 9 is significant (with negative sign) only in the OLS model. On the contrary, the ratio of certified organic land on the UAA is significant (with negative coefficient) only in the spatial models. The estimated coefficient is relatively high (about 5) and indicates that there is a significant reduction of inorganic nitrogen in the municipalities where the share of certified organic land was higher before the implementation of RDPs.

The model shows that the reduction of inorganic nitrogen was greater in municipalities belonging to NVZs, mainly located in hilly areas and in the Ferrara province, which is consistent to what expected.

The inorganic nitrogen has decreased less where the population density is higher, the vicinity to cities probably enhances intensive farming systems. The share of small farms (<5 ha) is also a significant variable and has a negative coefficient, which suggest that the reduction of inorganic nitrogen is favored by the occurrence of small farms with respect to middle size and large farms (>30 ha).

For what concern the organic input, the reduction links directly to the decrease of the livestock density in the considered time shift (-9 %). Spatial association is not significant for the variable D N Organic, suggesting that the decrease in the indicator in one municipality does not affect its variation in the neighbouring municipalities. Therefore, only the ordinary least square model has been applied to this variable. However the results indicate that the selected variables do not explain the D N Organic and the test F do not validate the model.

While this study proofs the interest for using spatial econometrics in the context of the evaluation of the effects of AEMs, it also suggest caution in interpretation of the results. Primarily this is motivated by the fact that the dependent variables are not observed data but are rather derived through calculation, which can bring some bias due to the hypotheses adopted in the process.

What is more important, the spatial dimension of the dependent variable cannot be interpreted in a straightforward way as a result of spillover effects in the variable itself, but most likely as an effect of spillovers in its determinants or similar production conditions in neighbouring areas. This work can hence realistically be interpreted as a screening study on the spatial dimensions of RDPs effects, amenable of further improvements. Further research is hence needed, though its feasibility and improvement potential with respect of the current work will be largely dependent on data availability. In particular, access to farm level information and genuinely measured impact parameters are key needs ensure a better exploitation the potential of spatial econometrics.

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