Geographical analysis of Agro-Environmental Measures for reduction of chemical inputs in Tuscany

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Abstract

The agro-environmental policies included in rural development plans are acquiring increasing importance in European Community strategies. These policies represent the meeting point between demand and supply of positive externalities. The difficulty of assessing real environmental efficiency is one of the elements characterizing agro-environmental measures. This difficulty is essentially related to the identification of suitable parameters for evaluating farms according to their impact on the territory. This impact is mainly related both to chemical inputs and to the territorial characteristics of the farm. Different types of fertilizers, pesticides and herbicides are currently used in production processes; however, the analysis has focused only on nitrates, as they represent the most critical types of chemicals related to soil pollution.
A case study is provided by the analysis of AE measures in Tuscany for the reduction of nitrates in organic and integrated farms. Using Spatial MultiCriteria Analysis, integrated and organic farms were classified according to their geographical locations and their release of nitrates into the soil. This classification permits the highlighting of farms that make the greatest economic efforts to reduce pollution and therefore it could determine environmental benefits.
Considering that the trend of policy strategies is towards a reduction of monetary resources, this work could help decision makers choose the right allocation of future resources.

Keywords: GIS; Multicriteria analysis; chemical inputs; Rural Development Plan; environmental policies

1 Introduction

By the early 90s of the last century, consumer behaviour had become increasingly oriented towards environmentally friendly products. As a result of this trend, the agro-environmental policies of rural development plans (RDPs) became increasingly important within European Community policy strategies.

One of the targets of RDPs was to encourage reliance on environmentally friendly practices based on organic and integrated farming. Accordingly, by adopting some agro-environmental (AE) measures, funds were distributed to farms that were more efficient from an environmental point of view.

With regard to agricultural activities, the use of fertilizers represents a critical threat to the environment. The use of fertilizers in agricultural activity represents a powerful method of increasing land productivity; however, when not required, fertilizer input can lead to negative effects both on the farmer's income and on the environment. In the context of all chemical inputs used during production processes, nitrates play an important role in environmental contamination because they represent the most critical types of chemicals related to soil pollution. The literature includes some studies on land contamination from nitrates that are considered to raise important issues regarding chemical input into the soil, (e.g., Primdahl et al. 2003; Bahlai et al. 2011). These studies were developed in order to scientifically analyse the relationship between agricultural practices and the dynamics of nitrates concentrations. The authors have proven that the contamination of surface water by nitrates is mainly related to the fact that the most common agronomic systems are characterized by long periods (in fall and spring) during which the principal risk factors from contamination are manifested simultaneously. As argued by Roggero and Toderi (2002), excess soil water with a high concentration of nitrates from the natural decomposition of organic matter is also favoured by soil dehydration due to summer evaporation and the absence of vegetation over most of the arable land.

Nitrates mitigation requires several measures, such as changes in land use, changes in management practices, the use of buffer zones or protected areas and changes in legislation and regulation. The problem of possible water pollution by nitrates from agricultural sources is clarified by the Nitrates Directive 91/676/EEC. Within this directive, it is stated that while the use of organic fertilizers and fertilizers containing nitrogen is necessary for European Community agriculture, excessive use of fertilizers constitutes an environmental risk.

In Tuscany, the Nitrates Directive has been implemented through Legislative Decree 152/99 and Legislative Decree 152 /06, by establishing areas vulnerable to nitrates (ZVN) and protected areas (PA) for the protection of surface water and groundwater for human consumption.

The AE measures introduced by the RDP of Tuscany that mainly contribute to the reduction of nitrates are measure 214a1 "Organic Farming" and measure 214a2 "Integrated Farming". Currently, each farm receives a score based on minimum requirements for the use of fertilizer products: the final score is also influenced by the type of agriculture[1] and by whether the farm belongs to a ZVN or a PA. Locations in all other areas, defined as ordinary areas (ZO), result in no score.

A final ranking gives access to payments[2] that should cover the additional costs related to the method of production and the probable income losses from conversion from conventional agriculture to organic or integrated agriculture.

Considering nitrates as the chemical fertilizers most critical for the environment, the aforementioned legislation does not give a specific reward to those companies whose use of these products may have a greater impact.

[1] For example, orchards, vineyards and olive groves receive the highest amounts.

[2] Vademecum Programma di Sviluppo Rurale (PSR) 2007-2013 della Regione Toscana http://www.regione.toscana.it/documents/10180/70126/testo%20vademecum-2/8ef0d954-b160-4d78-8d6e-50c27f0e2f55 [last access 10th January 2018]

Indeed, payments based on the "binary" definition of areas that give a score (ZVN and PA) and areas that do not give a score (ZO), without providing a classification based on degrees of environmental risk, could be considered a limitation of current policies.
This study aims to improve the current distribution of payments by including in the selection criteria of farms worthy of funding, aspects related to the different impacts that the use of such substances could have, depending on the permeability of the soil and the farm's distance from rivers. This would allow us to overcome the limitation of payments based on a binary definition of a farm's location.
Considering the above-mentioned variables and the chemical inputs, this study provides a farm classification system for whether farms are in areas vulnerable to nitrates or protected areas, or in ordinary areas. Using a spatial multicriteria analysis, all organic and integrated farms that have received funds have been georeferenced and classified by using a multidimensional index called NIV (nitrate impact value).
Considering a potential reduction of funding in the future, this work could provide a useful tool for selecting the farms that contribute most to achieving the objectives linked to AE measures.
The paper is organized as follows: section 2 describes the materials and method, section 3 gives the results, section 4 provides a discussion and section 5 presents the conclusions.

2 Materials and Method

2.1 Case Study

The case study is concerned with the analysis of AE measures in Tuscany for the reduction of nitrates in organic and integrated farms that have received funding (Figure 1). The reference year is 2012 (2007-2013 Rural Development Programme).
The analysis was based on the use of georeferenced companies with agro-environmental commitments (organic and integrated); a database of information on companies that received agro-environmental payments was used for this study. This relied on the extraction of data from the Agenzia Regionale Toscana per le Erogazioni in Agricoltura (ARTEA)[3] (SI) database system, integrated with information on the companies' structures and their technical and economical characteristics.
The population density in Tuscany is approximately 16.3 inhabitants/km^2, i.e., a population of 3,761,616 inhabitants is distributed over an area of approximately 23,000 km^2. The most populated areas are located in the north of Tuscany (in the province of Firenze), with 373,446 inhabitants (ISTAT 2013). The territorial morphology is 90% hilly and includes mountain areas that strongly characterize the landscape. The primary sector occupies 2.7% of the total occupied area in Tuscany and includes approximately 45,000 workers.

a) Tuscany	b) Integrated and organic farms in Tuscany

Figure 1. Case study

According to the ARTEA database, there are 72,686 farms in Tuscany. They are mainly located in the provinces of Arezzo, Grosseto and Siena and the utilized agricultural area is over 754,300 hectares. There are 4,055 organic and integrated farms[4] with a utilized agricultural area of about

[3] ARTEA https://www.artea.toscana.it/sezioni/artea.asp [last access 10th January 2018]

[4] Number based on the activated agro-environmental contracts.

187,534 hectares (Table 1). The areas related to measure 214a1 (organic agriculture) are mainly covered by cereals and forage crops, while the areas related to measure 214a2 (integrated agriculture) are covered by cereals, forage crops and vineyards. Grosseto has the highest area of forage crops related to each measure, followed by Siena, Arezzo and Firenze (cereals, forage crops and vineyards). Wheat, grapes, alfalfa, olives and sunflowers are other crops related to agro-environmental measures.

Table 1. Statistics on organic and integrated farms in 2012 (source: ARTEA database)

2.2 Definition of Model

There are several studies in the literature that analyse agro-environmental policies from different points of view. Padel et al. (1999), Nicholas et al. (2006) and De Maya et al. (2011) underline the complexity of agro-environmental measures at a national scale. Jaraitė e Kažukauskas (2011) perform a regression analysis and panel fixed effects (FE) analysis at a national scale in order to evaluate the cross-compliance effect of the use of fertilizer and pesticides. Ziolkowska (2010) uses a hierarchical analysis to examine the relationship between different agro-environmental measures in Poland. At a regional scale, MiPAAF (Ministero delle Politiche Agricole Alimentari e Forestali)[5] produces an annual report on intermediate evaluation of the RDP. De Blasi and Fucilli (2007) analyse the annual report of MiPAAF from a theoretical point of view. Bartolini et al. (2015) test the impact that new policy measures will have on the provision of bio fuel crops by applying a dynamic mathematical programming model in a sample of farms in the province of Pisa. Marconi et al. (2015) performed a spatial analysis based on a geographical distribution of agro-environmental measures on a municipal scale.

A limit that emerges from these works is the scale of detail, that at most reaches the municipal level. With the aim of overcoming this limit, the present paper is based on spatial multicriteria analysis (able to work with non-monetary variables) with a high level of detail due to the high spatial resolution. Each farm, together with its variables, was georeferenced using a pixel resolution of 75 metres. The flexibility of the approach adopted represents added value, and it can easily be scaled up for use in other territorial contexts. Furthermore, the highly detailed spatialization of agro-environmental measures represents a further development of the existing studies in the literature.

Spatial multicriteria analysis uses the capacities of GIS to solve multicriteria models in order to support decision-making in spatial planning processes and obtain results that are easy to interpret (Malczewski 2006a; 2006b). This methodology is appropriate for territorial analysis, as confirmed by Chen et al. (2010), Cozzi et al. (2015), Riccioli et al. (2016), Gonzalez et al. (2018) and it is widely adopted in the literature, with "over 300 papers published between 2000 and 2009 reporting MCDA applications in the environmental field" (Huang et al. 2011).

In this paper, the spatial multicriteria decision analysis has three main phases: *(i)* choice of evaluation criteria estimated by multidimensional indicators, *(ii)* aggregation of criteria maps and *(iii)* analysis of the results.

The choice of evaluation criteria is based on geographical location and chemical inputs into the soil of organic and integrated farms. A set of evaluation criteria estimated by multidimensional indicators was chosen from the existing literature (Sweeney 1993; Krutz et al. 2005; Borin et. al. 2005; Ormerod et al. 2010). Influenced by the availability of georeferenced data and relying on the indicator scheme developed by Lazarsfeld (1969), the following three indicators were used:

1. run-off index (CK),
2. distance from rivers (D_{rivers}),

[5] http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/5090 [last access 10th January 2018]

3. input of chemical substances (C_{input}).

Each indicator was associated with territorial entities (pixels) and shown in thematic layers called criteria maps (see subsections 3.1, 3.2 and 3.3).
Using these indicators, it is possible to classify the farms according to the type of soil in their location, their distance from rivers and their chemical input into the soil. Only the third indicator depends on the decisions of the farmer, while the first two indices are exclusively related to the location of the farm.
Therefore, the first two indices were aggregated using weighted linear combination (WLC); the result (called the vulnerability index) represents the geographical characteristics of the farm. The final index, called the NIV (nitrate impact value) index, was found by adding the chemical inputs to the vulnerability index using an overlay with multiply operation. A flow chart for the aggregation process is shown in Table 5.

2.2.1 Run-Off Index (CK)

Intensive agriculture has allowed the increase of the crops but has also introduced many environmental problems, such as loss of soil fertility, pollution of groundwater and surface water, increase in energy consumption and loss of biodiversity. The current situation is unsustainable.
Organic and integrated farming systems represent an alternative to conventional techniques because they are potentially more effective in increasing and maintaining the organic matter in the soil. This is essential for maintaining fertility, and is more effective in reducing pollution from fertilizers, pesticides and herbicides. The existing mitigation measures are more stringent in areas where soils are particularly vulnerable due to high risk of leaching and variable weather.
The evaluation of the surface water run-off is exhaustively developed in the literature (Asciuto et al. 1988; Corrado et al. 1988; Guo et al. 2001; Merlo and Croitoru 2005; Baumann et al. 2007). Most authors have studied the soil permeability. Simsek et al. (2006) proposed an approach that takes into account the vulnerability of groundwater to contamination. They consider following factors: the depth of the groundwater, the permeability of the unsaturated zone, the thickness of the impermeable strata and the topographic slope. To calculate the surface run-off index (CK) Kennessey's method was used (Kennessey 1930). Using this method, it is possible to classify surface run-offs using physiographic and climatic data.
From an ecological-environmental point of view, a high value of the run-off index (high CK) indicates high permeability of the land and the possibility of avoiding groundwater contamination from chemicals used for agricultural activity.
Using Kennessey's method with three parameters, it is possible to calculate the average annual run-off coefficient or run-off index (CK) for the case study area, as shown in Equation 1.

$$CK = CA + CP + CV \quad \textit{Equation 1}$$

where
CK = annual run-off coefficient
CA = slope
CP = permeability
CV = land use.

High CK values indicate high surface run-off and low CK values indicate high values of deep infiltration.
In order to calculate the run-off coefficient, the values of the various parameters were standardized and compared with the aridity coefficient (Equation 2).

$$Ia = [P/(T+10) + 12\ p/t]/2 \qquad \textit{Equation 2}$$

where
Ia = aridity index
P = annual average precipitation
T = annual average temperature
p = precipitation of driest month
t = temperature of driest month.

The resulting values were subsequently processed into values between zero and one, as shown in Table 2.

Table 2. Run-off coefficients

2.2.2 Distance from Rivers (D_{rivers})

Considering that agricultural activities (especially if practiced by conventional methods) affect the amount of pollution in watersheds, it can be assumed that companies located far from rivers (watersheds) tend to be minor sources of pollution. This is confirmed by several studies in the literature (Gleick 2003; Ormerod et al. 2010).

Rivers can be subject to anthropogenic pressures. The use of agricultural land represents one of the principal reasons for contamination and habitat deterioration in European rivers (Davies et al. 2009). In this context, agro-environmental measures would reduce the negative effects of the agricultural impact on watersheds (Heathwaite et al. 1998; Borin et al. 2005). However, these effects cannot be eliminated. In accordance with the Nitrates Directive 91/676/EEC and Directive 152/2006, ARPAT (Agenzia regionale per la protezione ambientale della Toscana) has produced a database for monitoring water in nitrate-vulnerable areas. In 2014, the monitoring network was based on around 2,066 sample areas, covering the whole Tuscan region[6]. Poole et al. (2013) propose evaluating the ecological efficiency of agro-environmental measures with respect to the distance between watersheds. In this case, an increased distance between a body of water and the farm would indicate less contamination from the farm.

In accordance with the above, a map of the distance from rivers was created by calculating the fuzzy distance (in metres) from watersheds (map produced by the Region of Tuscany[7]), since "the fuzzy distance decay membership function is used to indicate proximity to a given feature" (Al-Ahmadi et al. 2009). Rather than having a single crisp threshold that denotes distance from a feature, the fuzzy distance decay function is capable of describing the degree of vulnerability of rivers towards chemical inputs, which increases with decreasing distance.

2.2.3 Chemical Input (C_{input})

The objectives of adequate fertilization are the maintenance of a vegetative-productive balance of crops and the improvement of the chemical and physical characteristics of the soil, by avoiding an excessive input of nutrients, thereby protecting the quality of the watersheds (Gomiero et al. 2011).

[6] http://www.arpat.toscana.it/datiemappe/mappe/mappa-del-monitoraggio-delle-acque-delle-zone-vulnerabili-ai-nitrati [last access 10th January 2018]

[7] http://www.regione.toscana.it/-/geoscopio-wms [last access 10th January 2018]

Integrated and organic farms use a lower quantity of fertilizers, pesticides and herbicides and carry out fewer treatments than conventional farms, since chemical inputs are regulated by agronomic technical standards (Annex 2 of Regional Law 25/99)[8]. The amount of chemical input, distinguished by type of agriculture, is based on the difference between conventional farms and integrated or organic farms in the input of nitrogen fertilizers (kg/ha) into the soil.

The amount of nitrate input from conventional farms is revealed by data sheets for technical and agronomic standards (available from the ARTEA database); the amount of nitrate input from integrated farms (nitrate input is not allowed in organic production) is determined by the method of production (R.L. 25/99).

2.2.4 Aggregation of Indicators

As suggested by Malczewski (1999), weighted linear combination is one of the methods allowing compensation and determination of the value of each alternative, defined by pixels, as the average value of each criterion multiplied by the relevant constraint. Due to its simplicity of use, this method has been widely applied in other studies on environmental analysis (De Araújo and Macedo 2002; Comber et al. 2010; Carver et al. 2013; Orsi et al. 2013).

The method is implemented via the following formula.

$$V_{indexj} = \sum_{j=1}^{n} c_{ij} \cdot w_i$$

Equation 3

where

V_{indexj} = index of characteristics of farms based on their location referred to the j-th pixel (vulnerability index)

c_{ij} = value of the i-th indicator of the j-th pixel

w_i = the weight of the i-th indicator ($\sum w_i = 1$)

n = the number of indicators.

In the second phase, the NIV was calculated: chemical inputs were aggregated using the index of characteristics of farms based on their locations (V_{index}) via an overlay with multiply operation (Equation 4).

$$NIV_j = V_{indexj}\ C_{nj} \qquad \text{Equation 4}$$

where

NIV_j = nitrate impact value index of the j-th pixel

V_{indexj} = index of characteristics of farms based on their location referred to the j-th pixel (vulnerability index)

C_{nj} = chemical input of the j-th pixel.

It has been said that "thinking in terms of map algebra can make the overlay process efficient and convenient" (Davis 2001), and indeed this operation allows to emphasize the average values of the vulnerability of farms.

[8] http://www.regione.toscana.it/pan/manuali-di-riferimento [last access 10th January 2018]

3 Results

3.1 Map of Run-Off Index (CK)

The run-off index calculation was performed using a digital elevation model of Tuscany (75-metre spatial resolution), precipitation and lithological maps (scale 1:250,000) and the Corine Land Cover map for 2012, developed within the CLC project as per the European Standard on Geographic Information (ENV 12657).

Figure 2 shows lower permeability for high values of CK (darker colours). Due to a reduced infiltration of polluting chemicals, high values of CK indicate lower pollution of groundwater and of rivers.

Figure 2 shows the areas with the highest run-off index (represented by dark colours, CK = 90): these are mainly located in hilly and mountainous regions, such as the provinces of northern Tuscany (along the Apennines mountains and in the area of Mount Amiata in the province of Grosseto). Dechorgnat et al. (2011) state that “Generally, in soils with high permeability, nitrate predominates and if it is not absorbed by plant roots or utilized by microorganisms, it is available for leaching.” Hence, vulnerable soils are represented by areas with lower values of CK (light colours in Figure 2).

Figure 2. Map of run-off index

3.2 Map of Distance from Rivers (D_{rivers})

The map of distance from rivers was produced using the map of water basins provided by Regione Toscana[9].

The map shows the distance from watersheds, where darker values indicate a greater distance (3,270 metres) from rivers, and consequently lower pollution. These values are evident in the southern part of the province of Arezzo, in the east part of the province of Siena and in the south of the province of Grosseto.

Lighter colours indicate shorter distances from rivers, and consequently show the areas that are most vulnerable to chemical pollutants.

Figure 3. Map of distance from rivers

3.3 Map of Chemical Inputs (C_{input})

The map of chemical inputs is shown in Figure 4, where darker colours indicate the maximum difference in chemical inputs into the soil (between conventional and integrated or organic farms), representing the best results from an environmental impact point of view. This is due to the more stringent and constraining rules applied to integrated and organic farming and is in line with the principles of environmental protection and the reduction of pollution characterizing these principles.

[9] Available at http://www.datiopen.it/it/opendata/Regione_Toscana_Fiumi_torrenti_corsi_d_acqua [last access 16th April 2018]

Areas with higher values (farms with a lower contribution of nitrates) are mainly located in the provinces of Pisa, Siena, Arezzo and Grosseto.

Figure 4. Map of chemical inputs

3.4 Aggregation Process

The three indicators adopted were examined from a statistical point of view. A correlation matrix was calculated in order to produce correlation coefficients (Table 3). Correlation coefficients with high values correspond to indicators that are strongly correlated with others, and therefore redundant (Eastman 2009). The aggregation of indicators was performed with no redundancy.

Table 3. Correlation matrix for indicators

In order to compare values having different units of measurement, a normalization method was used. This was based on fuzzy logic (or the infinite values method) where the logical variable can take on any continuous truth value in the interval [0,1] (Zadeh 1965; Chen and Hwang 1992). Table 5 includes the normalization parameters used for the indicators. Each indicator has a minimum and a maximum value. Through the normalization process, a maximum value was attributed to each of the three previous characteristics, represented by control point *a* for the run-off and distance-from-rivers indices and control point *b* for the chemical inputs index. It is important to underline that control points do not measure the absorption of nitrate in the soil, but rather they measure the degree of impact, e.g., the distance-from-river control point *a* (0 metres) indicates the highest degree of impact, while control point *b* (3,270 metres, shown in Figure 3) indicates the lowest degree of impact.

The absorption of nitrogen in the soil follows a linear function in both horizontal and vertical directions (Goss et al. 1985; Johnsson et al. 1987; Molina and Smith 1998; Morari et al. 2012). The permeability of the soil and the distance from rivers are related to vertical and horizontal movements of nitrates in the soil respectively. Combining both factors, the movements of nitrates maintain a linear trend; this linearity of movement is directly related to the problem of loss of nitrate due to the leaching process. Nitrates are not retained by soils; they move with soil water and have the potential to enter into groundwater. Nitrate leaching occurs because nitrates have a very weak affinity for forming surface complexes with soil minerals, and most soils adsorb cations more strongly than anions (Strahm and Harrison 2006).

In accordance with the above, the normalization process for the indicators was based on a linear function (Table 5).

In order to calculate the NIV index, two types of map algebra aggregations were performed. Run-off and distance-from-rivers indices were aggregated using the WLC method, and the result was denoted V_{index}. The NIV index was obtained by adding chemical inputs (C_{inputs}) to V_{index} through an overlay with multiply operation.

In the first phase, using weighted linear combination, the two indicators related to a farm's location were aggregated. The permeability of the soil and the distance to rivers were weighted using an analytic hierarchy process (Saaty 1980). This process is widely adopted in territorial planning, especially in combination with multicriteria evaluation (Long et al. 2012; Kayastha et al. 2013; Valle Junior et al. 2015; Gdoura et al. 2015).

A matrix of indicator pairs was developed with the aim of pairwise comparison of their relative importances in the evaluation of the vulnerability index. "The comparison is quantified using a number between 1/9 (extremely low importance) and 9/9 (extremely high importance). This number

(n) will populate the lower triangle below the main diagonal of the square matrix, while its reciprocal (1/n) will populate the upper triangle" (Valle Junior et al. 2015). As in previous works (Gdoura et al. 2015; Chaudhary et al. 2016; Petrini et al. 2016), the pairwise comparison process was based on expert opinions: after consulting a focus group including professors of soil chemistry and pedology within our university, the run-off index was considered "moderately more important" (rating scale number = 3) than the distance-from-rivers index. Table 4 shows the comparison matrix.

Table 4 Comparison matrix

The main eigenvector of the matrix was calculated, the components of which are the final weights of the factors (Table 5). The factor weights were found to be consistent, with a consistency ratio of 0.05. "This value indicates the probability that the ratings were randomly assigned. Values less than 0.10 indicate good consistency. When values exceed 0.10, the matrix of weightings should be re-evaluated, and a consistency index matrix will be presented" (Eastman 2009).
The vulnerability index was created by aggregating CK and D_{rivers} using weighted linear combination. The obtained vulnerability index was aggregated with C_{input} using an overlay with multiply operation. The flow chart for the aggregation process is shown in Table 5.

Table 5. Normalization parameters and aggregation of indicators

3.4.1 Map of NIV Index

Figure 5. Map of NIV index

The map of NIV index is shown in Figure 5 where darker (higher) values are related to the deserving organic and integrated companies that are mainly located on more permeable soils, are close to rivers and release smaller amounts of chemical input into the ground (compared to conventional methods of cultivation).
Over 332,000 pixels were examined, representing 4,055 organic and integrated farms and covering about 187,533 hectares. It can be observed that 89% of the area examined is included in NIV classes 50-100 (over 167,500 hectares), 10% belongs to NIV class <50 (about 18,700 hectares) and only 1% is included in NIV classes >100 (about 1,218 hectares). The higher values of NIV index (NIV classes >100) are mainly located in the central areas of the province of Siena and in the south parts of Grosseto and Arezzo. Pisa and Livorno also reveal the presence of high values of NIV (>100). Farms included in these classes of NIV are not present in the provinces of Firenze, Massa, Pistoia, Lucca and Prato. Results are shown in Table 6.

Table 6. Hectares of organic and integrated farms in 2012 sorted by NIV classes

The analysed surfaces of organic and integrated farms represent 24.86% of the total agricultural surface area in Tuscany (754,344 hectares[10]).
NIV class 80-100 represents 7.8% of the total agricultural surface area, NIV class 50-65 represents 7.6% and NIV class 65-80 represents 6.7%. The remaining classes (NIV classes >100 and NIV class < 50) represent 2.65% of the total agricultural surface area in Tuscany.

[10] Source VI ISTAT Agricultural Census database (2010). Online, available at http://dati-censimentoagricoltura.istat.it/Index.aspx [last access 10th January 2018]

Starting from the ARTEA database, it is possible to analyse the payments made as a result of the Rural Development Programme 2007-2013, related to measures 214a1 and 214a2. Their distribution, sorted by NIV classes, is shown in Table 7. The total amount of RDP 2007-2013 payments was about 138 million euros. In 2012, payments amounted to about 35.5 million euros: organic and integrated farms in the province of Siena received over 10.7 million euros, representing 30.2% of the total amount. Farms in Grosseto and Arezzo received over 6.7 million euros (19% and 18.6% of the total respectively). Farms located in the province of Firenze received over 5.7 million euros.

Table 7. Funds by province and NIV class in 2012

The surface areas of organic and integrated farms belonging to areas vulnerable to nitrates or protected areas amount to 36,150 hectares: over 62% (22,600 hectares) relates to farms with NIV > 65, while 27% (9,750 hectares) relates to farms with NIV > 80 (Table 8).

Table 8. Number of hectares for organic and integrated farms in ZVN and protected areas in 2012 sorted by NIV

4 Final Remarks and Conclusions

The general hypothesis is based on the fact that payments should be directed towards companies with higher values of NIV. Indeed, farms located in areas with high permeability, close to rivers, should significantly reduce their use of chemicals to ensure a level of impact similar to that of other farms located in areas with less permeability and far from rivers. The lower income resulting from the reduction of chemical inputs (lower revenues and higher management costs) should be offset by higher payments. This would find a justification in the social benefit that would result from reduced impacts related to the use of chemicals.

Expecting a progressive reduction of monetary resources in future environmental policies, many farms, without funding, could return to conventional agriculture (less expensive than organic and integrated agriculture). Taking into account the last two RDP programmes (2007-2013 and 2014-2020), the reduction in resources related to agro-environmental measures has been estimated at 23.4 million euros (-17%)[11].

This reduction is expected to result in a decrease in the number of farms that will have access to finance and a reduction of the amount per farm. As a result of these reductions, the companies remaining without contributions could be those with the lowest scores in the ranking (see section 1) and farms located in the ordinary zones.

It is important to emphasize that not all the sites located in ZVN and PA are characterized by the same permeability of the soil and/or the same proximity to rivers. Consequently, the impact produced by the nitrates will be different according to the location of the farms within the above-mentioned areas. At the same time, it is possible to hypothesize that some ZO sites may be more sensitive to nitrate impacts, due to the permeability of the soil and the distance from rivers.

The proposed model could improve the choice of companies to be financed, and each farm could be evaluated independently of its location in a specific area (ZVN, PA or ZO).

In 2012, about 35 million euros were allocated. Applying the estimated average reduction rate observed for the entire program (-17%) gives a reduction of six million euros.

Applying the current legislation, only farms outside areas vulnerable to nitrates and protected areas are excluded. Using our model, however, all farms belong to NIV class <50 and almost a quarter of those belong to NIV class 50-65 would be excluded from financing (Table 7).

[11] Source Artea http://www.artea.toscana.it/sezioni/artea/

Considering the farms located in ZVN and PA (Table 8), our model would ensure that funding was maintained only to companies that cultivate areas that are mostly inside these areas (more than two thirds of the total farm area). At the same time financing would also be maintained for farms located in ZO which show a high sensitivity to impact from nitrates.
Agro-environmental measures offer a significant contribution to the maintenance of a territory, but the efficiencies of these measures are difficult to estimate. The evaluation of agro-environmental measures constitutes a key point in the justification of interventions that aim to allocate significant financial resources. Indeed, considering the substantial resources invested, the expected results have not always been achieved. Accordingly, evaluation tools are needed which are more specific.
This study uses information from administrative sources (ARTEA) with a high level of detail. Using a spatial multicriteria analysis, all organic and integrated farms in Tuscany that have received agro-environmental payments were examined.
Generally speaking, chemical inputs, the permeability of the soil and the distance from rivers are important indicators for determining the efficacy of environmental measures. However, it is important to consider other variables.
In order to improve the analysis, a more complete set of indicators should be used. According to the European Commission, "A set of 45 indicators was identified to describe the general context in which policy measures are designed, planned and implemented. They form part of the monitoring and evaluation framework for the CAP 2014-2020 and are used in rural development programmes for a comprehensive overall description of the current situation of the programming area"[12].
These indicators are georeferenced at different scales: agricultural areas, age structure of farm managers and livestock units are available at a regional scale (NUTS 2), population density, age structure and labour productivities are available at a provincial scale (NUTS 3), etc[13].
A future recommendation is to aim at spatialization with a high resolution for these indicators. Indeed, the use of a georeferenced data set with high resolution represents a new frontier in spatial territorial planning (Nelson and Kennedy 2009; Zandersen and Tol 2009; Bernetti et al. 2011; Baerenklau et al. 2010; Bottalico et al. 2016).
Despite the numerous variables that can be implemented in the proposed model, the NIV index represents an important parameter for selecting farms for financing, in order to obtain a more efficient distribution of contributions aimed at reducing the environmental impact related to agricultural activities. Given a reduction in funds, it would be preferable for farms with a lower NIV index to return to conventional techniques, because these farms make the lowest economic efforts to reduce pollution.
In this way, application of the model would guarantee the financing of farms with a high nitrate impact value, even if they are located outside the areas vulnerable to nitrates and protected areas, by considering different impacts of nitrates on the environment related to the permeability of the soil and the distance from rivers.

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[12] http://ec.europa.eu/agriculture/cap-indicators/context/index_en.htm [last access January 10, 2018]
[13] More details are available at http://ec.europa.eu/agriculture/cap-indicators/context/2015/indicator-table_en.pdf [last access 10th January 2018]

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