AGRICULTURAL DIFFUSE POLLUTION ABATMENT STRATEGIES IN LOMBARDY (ITALY)

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ABSTRACT

The Lombardy Region of Italy is well known for its agricultural productivity. As realised in other countries, the region has experienced the impacts on water quality of diffuse sources of pollution, such as nutrients lost from agricultural systems. Nutrient management planning is seen to be a crucial element in the control of diffuse agricultural pollution. Consequently, the regional government of Lombardy has used a specialised software package, GIARA, to implement an integrated environmental management system that assists farmers in the preparation and submission of nutrient management plans. The farm nutrient management plans resulting from GIARA are submitted on diskette to a central authority in order to build a regional database of manure utilisation, which is then organised in a geographic information system (GIS). Using GIARA on a regional basis, it is possible to obtain information about the land resources in the region, as well as the distribution of farms and manure therein and manure management practices. The regional database has been used to obtain an environmental risk index related to livestock manure management, and to classify the regional territory. This preliminary application has allowed the regional government to identify the potentiality of adverse consequences in the evaluation of environmental impact of agricultural activities. This, in turn, has allowed the government to focus its resources in an intervention programme, facilitated by the availability of a detailed database having a significant territorial coverage.

Keywords: Animal manure, GIS, Nutrient Management Plan

INTRODUCTION

The Lombardy Region of Italy is well known for its agricultural productivity. As realised in other countries, the region has experienced the impacts on water quality of diffuse sources of pollution, such as nutrients lost from agricultural systems.

The Lombardy region of Italy is characterized, from the agricultural point of view, by high intensity of production and concentration of crops and livestock, mainly in the plain area. In this framework it is obvious the difficulty of the relationship between agricultural activities and environment, due to the high use of technical means. This situation is aggravated also by the fact that, in the last decades, the unbalance between animal breeding activities and land used for animal feed production increased. In fact, in the plain area, grazing is not practiced, and the feed required for animal production is produced only in part (generally roughage) in the region's farms. Consequently, the use of concentrates and protein feedstuffs acquired from markets external to the region is widespread. For this reason, the attention to environmental problems linked to agricultural activity and, in particular, the potential release of nutrients towards waters, has pushed the Lombardy Region government to frame specific rules enforcing the nitrate directive (CEE 91/676). These rules are contained in the Regional Act 37/1993, which was implemented long before national legislation issued to enforce the European nitrate directive (only in 1999). Even now the national legislation does not have operating rules regarding the agronomic use of livestock manure.

The Regional Act 37/93 set up rules for the agronomic use of livestock manure by defining the management options and setting limits on the maximum quantity that can be spread. For purposes of the Act, the limit on manure application is such that the amount of nitrogen contained in the manure spread shall not exceed that required for crop uptake, taking into consideration the nitrogen losses in the different phases of manure management. Moreover, the farm must define a schedule of manure utilisation on a monthly basis, which is used to compute the storage volumes required to hold the manure between subsequent spreading. The operative instrument for implementing this nutrient management procedure is an "Agronomic Utilisation Plan" for livestock manure. This document is the result of three-step procedure:

- an analysis of the farm situation;
- a programming of manure utilisation;
- an evaluation of the storage requirements.

In the first step, all the information of the farm related to the production and management of manure is collected. In particular, the quantity and the nutrient content of manure are evaluated on the basis of the number of animals bred for each growing phase, and on the housing and manure removal system used. Thus, it is possible to obtain an annual estimation of the quantity of manure generated in the farm and the amount of nutrients (nitrogen, phosphorus and potassium) contained in the manure. Furthermore, the way in which the land available to the farm is managed must be defined according to the soil characteristics, designating the crops grown and their uptake of nutrients.

From this information it is possible to obtain a preliminary analysis of the farm nutrient balance by comparing the quantity of nutrients produced in the manure against crop nutrient requirements. If this first balance is not positive (*i.e.*, if the need for nutrients is not larger than the supply), the farm must *either* modify its management approach (*i.e.*, crop rotation, manure production, *etc.*) or acquire more land on which to spread manure. The latter is accomplished by making a formal agreement with another farm which does not breed livestock.

When the farm analysis shows a farm has achieved environmental compatibility, it is possible to progress with programming of the agronomic utilisation of manure. This entails the allocation of manure to the different crops in order to satisfy their nutrient requirements in the time available, finding the best compromise among crop nutrient needs, environmental needs, and farm management constraints. For this purpose the farm is divided into homogenous areas from the pedological and operational point of view in order to define a scheduling of manure utilisation in relation to the crops grown and to the soil characteristics of the field to which the manure is destined.

The scheduling of manure utilisation allows an evaluation of the quantities that have to be spread during the year and, as a consequence, it is possible to calculate the volume of manure that has to be stored. On this basis, considering also cleaning water and rainfall onto manure-soiled surfaces around the farmyard, it is possible to calculate the required manure storage volume. This volume cannot be less than the minimum volume stated by the regulation (180 days for manure of all kinds of livestock except dairy farms, which have a minimum storage period of 120 days). The calculated / regulated value for required manure storage is compared with the actual storage capacity already available in the farm in order to evaluate the necessity of building new storage tanks. The methodology outlined above has been coded into software named GIARA37, which the Lombardy Region has put into free distribution to allow the drafting of Agronomic Utilisation Plans for livestock manure generated on the region's farms.

Under Regional Act 37/93, almost all farmers must obtain authorisation from the regional government to spread livestock manure. To do so, the farm must submit to the government an application with an Agronomic Utilisation Plan included, drafted using the software GIARA37, and presented in both paper and digital formats. It is compulsory that GIARA37 be used to develop Agronomic Utilisation Plans. All livestock farms located in the Lombardy Region must seek authorisation to spread manure, except for small sized farms (8 tonnes of live weight if cattle or pigs, 3 tonnes of live weight if birds or small animals) and farms that produce only solid manure. The applications are submitted to the municipal administration and are evaluated from the agronomic and health security point of view by the provincial offices in charge. When the Plan has received a positive evaluation, the municipal administration gives the farm authorisation for the agronomic utilisation of manure, setting the management and building prescription (*i.e.*, manure storage requirements) that are necessary to assure this. Approved plans (in digital format) are then sent to the government's Regional offices where they are included in a centralised database that is continuously updated.

At present, this database includes plans for more then 5,500 farms representing a livestock population of more then one million cattle (71% of all cattle in the region) and 3.5 million pigs (94% of all pigs in the region). Although coverage of the territory by the database is not completed, farms that have been entered into the database constitute an absolutely representative sample of livestock farms of Lombardy. Thus, the database can be used as a reference dataset to carry out evaluations on the environmental impact caused by this sector of agricultural activity.

METHODS

The information included in the Agronomic Utilisation Plans allows regional environmental officials to know at a detailed level the way that each farm has scheduled the utilisation of manure produced by the livestock, because both manure quantity and time of spreading are reported in the Plans. Various analyses of data in the central database have been undertaken to evaluate the likely environmental impact of practical manure management options.

One such analysis considered the quantity of manure spread in different times of the year. For this evaluation, data related to individual farms have been aggregated at territorial level. In order to have a general view of this parameter the aggregation has been first carried out at provincial level (there are 11 provinces in Lombardy).

The schedule of spreading events has been used also to determine a risk index related to the prevalent manure spreading times during the year. For this purpose, the ratio of the quantity of livestock manure spread during the months from September to February, inclusive, to the total amount spread in the full year has been used. This index, computed at municipal level, gives a theoretical evaluation of the magnitude of nutrient imbalance in the distribution periods and the related potential pollution risk. During the fall and winter periods, the nutrients contained in the spread manure are likely to be released to surface waters and to nitrogen leaching because the crop uptake, if it occurs at all, is very limited and the evapo-transpiration practically null. Thus the soil is often very close to hydraulic saturation.

A second analysis examined the quantity of nutrients that arrive to the land with the manure in relation to the crops grown and their nutrient uptake. This analysis has been carried out on a municipal level by considering the ratio of the amount of nitrogen produced by the animals that actually reaches the soil to the nitrogen uptake of the crops. In some areas the intensity of the crop rotation is such as to require high quantities of nitrogen per unit of surface area farmed. Thus, the same level of nitrogen loading to the landscape may entail different environmental impacts depending on crop production patterns. The index formed as a ratio of nitrogen applied to nitrogen required can be considered an indicator of the equilibrium level of manure produced and the land where the manure is spread.

In addition to the foregoing analysis, the nitrogen load per unit of surface area farmed has been calculated, always at municipal level. This index is used in the Nitrate Directive to set a limit to the organic fertilization in the vulnerable zones. It has to be noted that this index is calculated considering agricultural land associated with livestock farms only, and therefore although it is attributed to a municipality, the index is not applicable to all the agricultural area of the territory. Even so, this index is *not* a direct indicator of pollution risk because, at the same nitrogen loadings, different combinations of crop system and soil characteristics highly influence the nutrient release. Despite these caveats, this index has been used

as a reference also by the regulation that has set as a limit the maximum value of 340 kg $N.ha^{-1}$ outside the nitrate vulnerable zones.

The above described indices have supported a classification of municipalities within the Lombardy Region with reference to the management of livestock manure, dividing the municipalities into three classes of risk (low, medium, high). The different indices have been then combined into a single classification to obtain a comprehensive picture of the potential risk linked to the quantity of nutrients and timing of spreading. To avoid overestimating potential pollution risk due to correlation of indices, the examined parameter has been analysed for independence before combining the effect. Subsequently the municipality has been reclassified as a combination of the indices.

RESULTS AND DISCUSSIONS

Timing of manure spreading during the year

The average amounts of manure spread during the different months of the year, expressed as a percentage of the average total annual quantity spread, is shown at provincial level in Figure 1. As it can be noted, there is always a concentration of manure utilisation in concomitance of the preparation of the sowing season both in springtime and in fall.

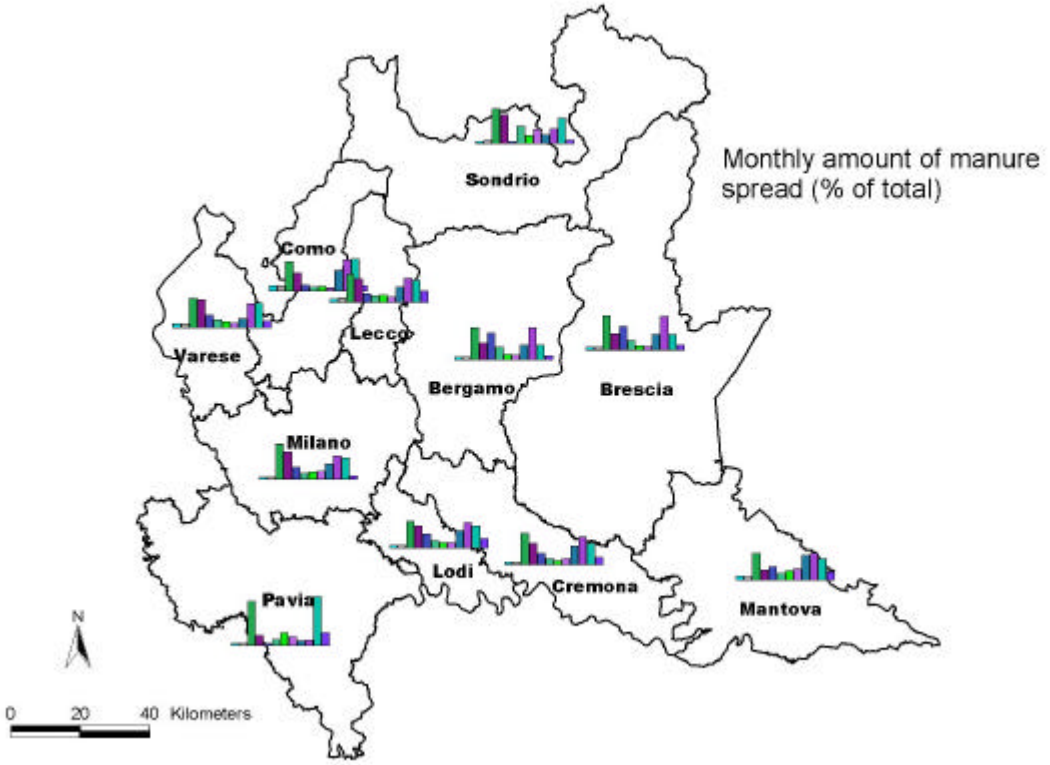

Figure 1 – Amount of manure spread in the different provinces of Lombardy as a percentage of the total yearly quantity. The sequence of bars refers to the months from January to December.

However, it is also clear that the spreading calendar varies for the different provinces, linked to local pedoclimatic conditions, which influence also the cropping system. As an example, in the province of Milano, the manure distribution is concentred in the months of March and April in springtime, is very limited in summertime, and is well proportioned in fall among September, October and November. In this area, the soil has a loamy texture and tillage can be easily performed both in spring and fall. Moving to the Mantua province, where soil are mainly clay soils, the manure spreading is limited in spring almost only in March, and is kept at very low values until the fall when the greater part of organic fertilisation is carried out. In the central provinces (Brescia and Bergamo) the spring distribution is extended until May and spreading in the fall is concentrated in October. Also in this case the pattern is a function of the cropping system: in fact in these areas grassland is diffused and manure is used on it mainly after the first cut, generally in May, and after the last one, in October. These different calendars of manure spreading are well underlined also by the spreading time risk index on a municipal basis. Obviously this risk index is generally higher in the south-eastern area of the Region, although it shows a great variability at municipal level.

Relationship between manure utilisation and crop system

The index defined to evaluate the balance between the nutrients brought to the land and the uptake of the crop grown gives an indication of how critical the manure management is in a certain area. In fact, high values of this index mean that a great part of nitrogen supplied to the crop comes from the livestock manure, leaving to the farmer a very limited flexibility in the fertilisation options. In other words, this index gives an evaluation of the effective nutrient load on the field, taking into account the cropping system used as well as the kind of manure handling system employed.

From the results of this analysis, reported at municipal level in Figure 2, it can be emphasized that the more critical area is again the south-eastern one. This is easily explained by the fact that in this area, together with a very high animal load, it can be noted a lower nutrient uptake by the crop, due to the cited pedo-climatic conditions.

Nitrogen amount

The third index used to evaluate the environmental consequences of manure management in Lombardy refers to the amount of nitrogen applied per hectare, which is shown in Figure 3. It can be noted as, at municipal level, the values of this parameter are in most cases under 170 kg $N.ha^{-1}$, which is the limit mandated by the Nitrate Directive for vulnerable zones, although just a few municipalities are classified as being nitrate vulnerable. The maximum values for this index are not higher, in any case, than 240 kilograms of nitrogen per hectare. From the mapping of this index, the Lombardy region might therefore be considered to be in a situation of low environmental risk for manure utilisation and relatively homogenous.

Environmental risk index

The evaluation of the relationship among the considered indexes has revealed that, while the spreading time risk index does not show any dependence on the other two indexes ($r^2<0.1$), the crop uptake risk index and the nitrogen amount index are strictly correlated (Figure 4).

On the basis of this result, in the subsequent classification of the municipalities, the nitrogen amount index was excluded from further consideration. The choice to exclude this index was also related to the weak linkage to environmental risk of this value, since it is not related to the cropping system to which the nitrogen is destined. The following classification of the municipalities has been carried out on the basis of the combination of risk classes of the two remaining indices. Thus nine different risk classes have been obtained. The result of this processing is reported in Figure 5, where it is possible to outline how, using this classification methodology , two areas are considered at higher risk in the Lombardy plain area. The first one is the situated in the south-eastern area of the region where the high livestock density is associated with a limited flexibility in distribution timing and a cropping system not particularly requiring high nitrogen amounts. The second area refers to the central part of the Region, between the Adda and Oglio rivers where a combination of medium-high values for both indices is reported. The map shows also a certain number of municipalities that are located in areas with a low risk index, but seem to have a more critical situation due to local conditions.

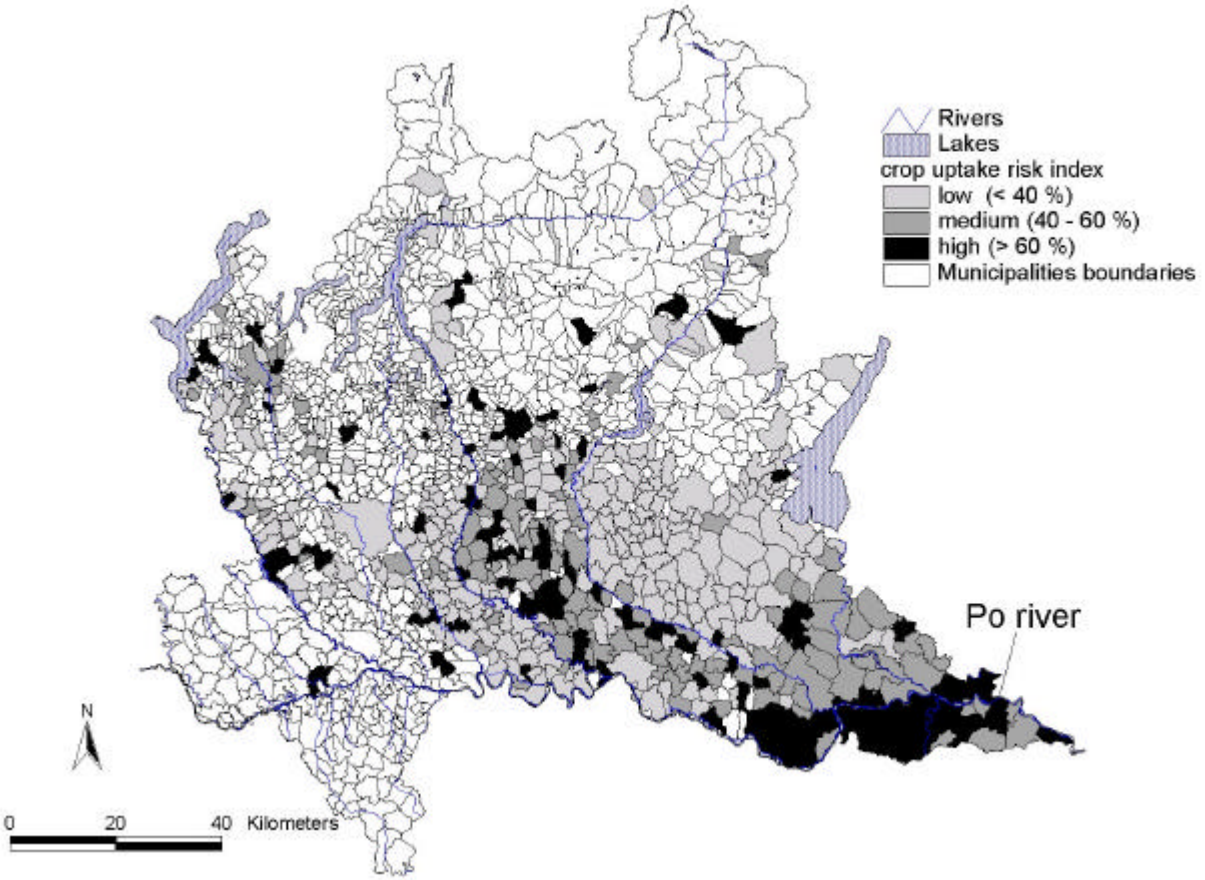

Figure 2 – Classification of municipalities according to the crop nutrient uptake risk index

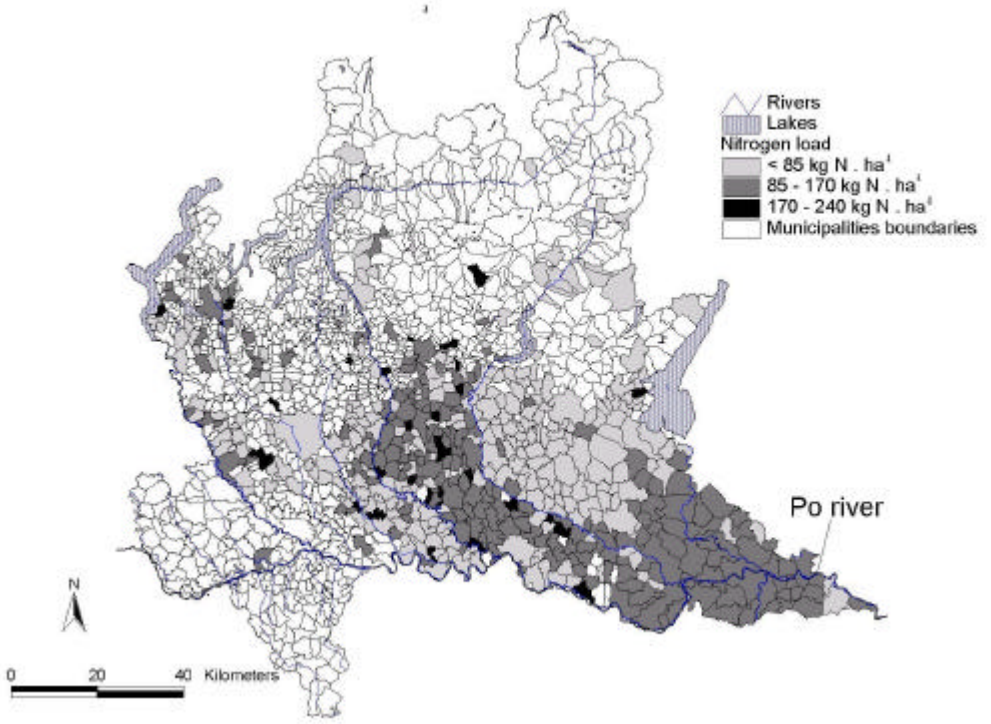

Figure 3 – Classification of the municipalities on the basis of the nitrogen amount per hectare

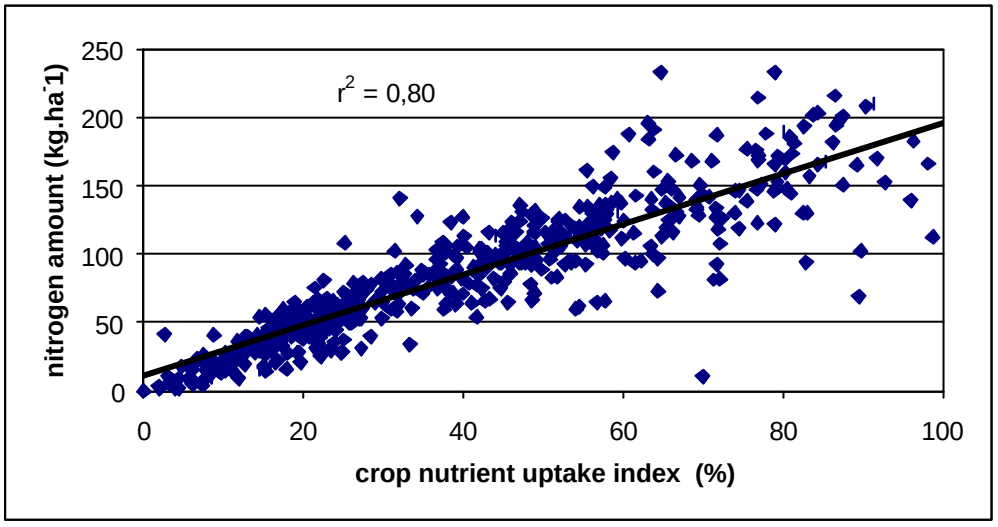

Figure 4 – Correlation of the nitrogen amount and the crop uptake indices based on the values at municipal level

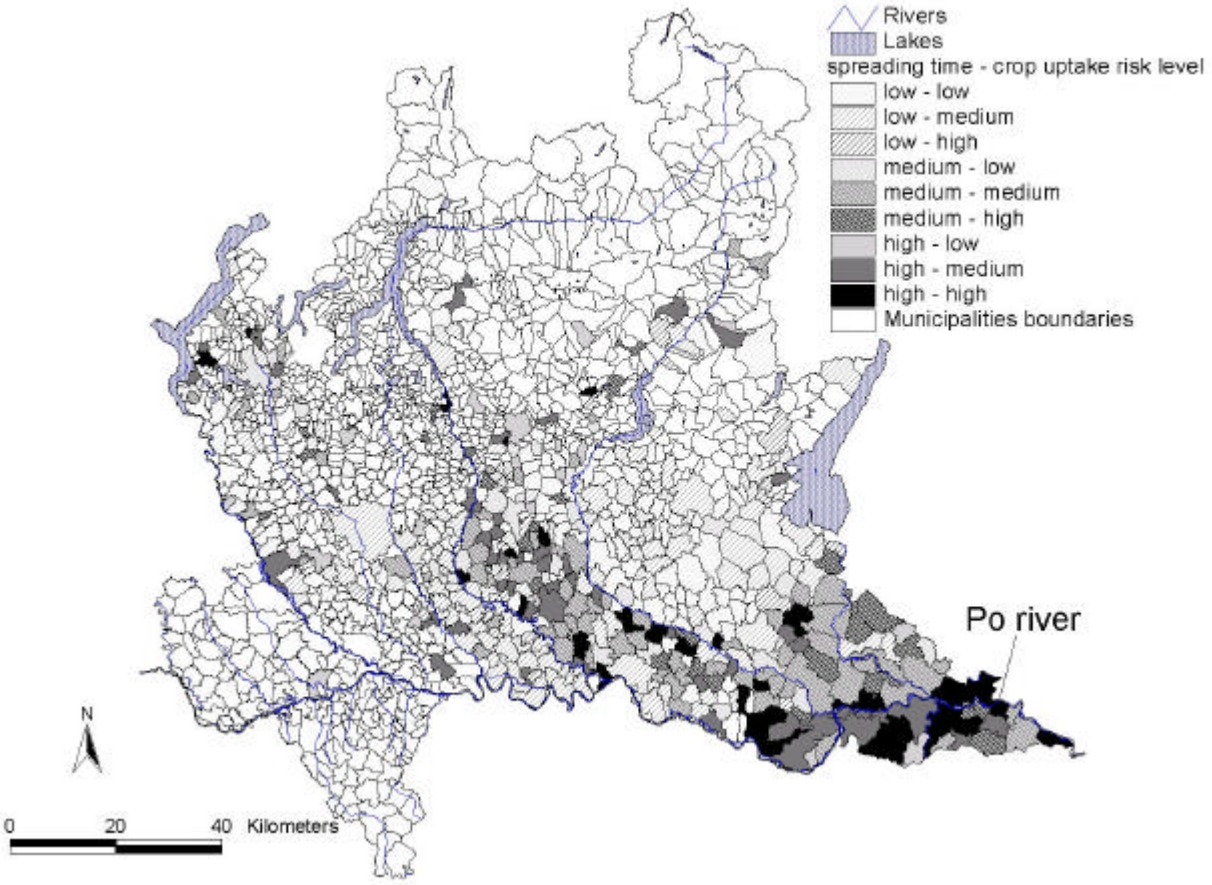

Figure 5 – Classification of the Lombardy municipalities according to the combination of the spreading time index and crop nitrogen uptake index

CONCLUSIONS

The methodology applied for the evaluation of environmental risk linked to livestock manure management in Lombardy has allowed a more exhaustive classification of the territory than ever before, highlighting aspects of environmental risk that some of the commonly used indicators tend to under-estimate. With regard to this point, it seems particularly meaningful that the limited differentiation of the territory resulted from the analysis performed using only the nitrogen amount per hectare. This index considered alone does not seem to be able to give an actual evaluation of the environmental risk linked to livestock manure utilisation. In contrast, the combination of other indicators such as those used in this analysis, bring to light a more detailed picture and identify particular areas within the region that require special attention.

For this purpose the different characteristics of the two areas identified have to be noted. As a consequence, also the possible corrective intervention to reduce the potential environmental risk should consider the different local conditions. In fact, while in the south-eastern area it seems difficult to foresee intervention aimed to modify the manure management system, this solution can be effective in the central area.

The analysis has also pointed out a single municipality that may have some critical situation, where a more focused investigation might be performed.

This methodological approach, even if in its preliminary application, has provided a rational evaluation of the potential environmental impact of agricultural activities and a logical basis for intervention programming, both of which were made possible by the availability of a detailed database that has a significant territorial coverage.

The evolution of this methodology shall foresee the use of more complete analytical systems like meta-models able to estimate through simulation the nutrient release from agricultural activity taking into account the cropping system, the livestock manure management and the pedoclimatic condition of the area. This requires not only the availability of models able to deal with this type of information at a small scale (1:10,000-1:50,000), but also the preparation of suitable databases to support the processing (as, for example, soil characteristics and the meteorological pattern, which at the moment are only partially available).

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