Land Evaluation and Agri-Environmental Indicators: Exploring Spatial Trends of Nitrogen Balance in Greece

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Abstract - **The development and application of a suitable methodology for establishing agro-environmental indicators was the aim of this study, according to the new approaches of environmental dimension of the Common Agricultural Policy (CAP) of the European Union. Agro-environmental indicator development is illustrated by a concrete case study of Nitrogen balance at detailed spatial scale (NUTS IV or LAU1) administrative level in Greece. The nitrogen balance is an indicator of the risk posed to the environment from the excess of nitrogen due to the agriculture. The LAU1 analysis of the Nitrogen balance was carried-out in order to identify vulnerable areas in terms of soil and water resources.**

To this end an original methodology has been developed, using information from statistical databases and from Geographical Information System (GIS) in an attempt to answer this question. Vulnerable areas, due to high nitrogen surplus, are identified using this methodology achieving that specific policy measures for environmental protection at the national level can be applied.

This study can be considered as a scale tool informing the reorientation of the CAP, which is directed to transfer support from agricultural products to local incomes and encourage environmentally friendly agricultural activities.

Keywords – *Nitrogen; Common Agricultural Policy (CAP); Nitrogen balance; Fertilizer; Agricultural.*

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1. Introduction

Agricultural practices affect in many ways the sustainability of water and soil resources. There are some negative impacts as a result of these practices, which mainly affect crop land where the natural and socioeconomic conditions favour intensive agriculture. It is well known that one of the main harmful impacts in the environment originating from the agricultural practices is caused by the excessive use of fertilizers and pesticides. Excessive and unbalanced fertilization causes environmental pollution and deterioration of the quality of agricultural products. Among fertilizers, the nitrates are soluble to water and therefore are the most responsible for environmental pollution.

The present paper deals with the development of indicators of nitrogen pollution at the municipalities level, based on statistical information on the cultivated land for each kind of crop and each kind of animal bred. The usefulness of the analysis at this geographical level lies in the fact that a more precise detection of the problematic areas arising from the excessive use of fertilizers can be achieved so that the agricultural policy concerning the environment and the quality of the agricultural products will be more effective.

This is the background for adopting policies incorporating environmental objectives in agricultural practices. The Directive of the EU dealing with nitrates (Directive for nitrate pollution 91/676) aims to reduce the quantities of nitrogen compounds in agricultural soils, and to avoid pollution of ground waters. This policy intends to reduce the present and future nitrogen pollution, and to measure the existing surplus nitrogen, by means of a nitrogen excess indicator as it has been established in the documents COM(2000)20 and COM(2001)144. Indicators are indispensable tools for distinguishing sensitive regions regarding nitrogen pollution.

The estimation of Nitrogen balance thus represents an indicator of agricultural sustainability. Although there is no linear relationship between the excess of nitrogen and the nitrate salts in water, the risk of nitrogen diffusion is higher when local nitrogen excesses are high. For this reason, the estimation of nitrogen excess at local level is necessary for any assessment related to soil waters and the protection of natural recourses.

2. Methodology and Data Sources

The aim of this project was to introduce an analytical tool using Geographical Information System and statistical data available from existing surveys (Farm Structure Surveys and the Agricultural Census) in order to measure the impact of agricultural activities to the rural environment. The study focused on the nitrogen balance from agricultural activities, at LAU1 level, as an indicator of the risk posed to the environment from excessive nitrogen. The LAU1 analysis of the Nitrogen balance was carried out with the aim of identifying areas of high surplus and thus where surface and ground water may be at risk of contamination.

2.1. Methodology of nitrogen balance estimation

The nitrogen balance provides useful information regarding the state of nitrogen surpluses.

In the DPSIR (Driving forces, Pressures, State, Impacts, Responses) context, the agricultural surpluses represent an environmental pressure, analogue of raw pollution depended on the yield of the activity. The nitrogen balance at the soil surface is defined as the difference between the total quantity of nitrogen inputs to the soil surface and the quantity of outputs that are released from the soil, annually (1), (Figure 1) :

Nitrogen (N) balance = N input – N output =

N held by the soil + N removal from the soil (1)

The total quality of nitrogen inputs to the soil during the process of agricultural production are those coming from mineral fertilizers and organic manure applied to agricultural land, the fixation by leguminous crops and the wet and dry deposition from the atmosphere. The output (removals) of nitrogen are defined as the nitrogen content of crops removed from the field by harvest or by grazing.

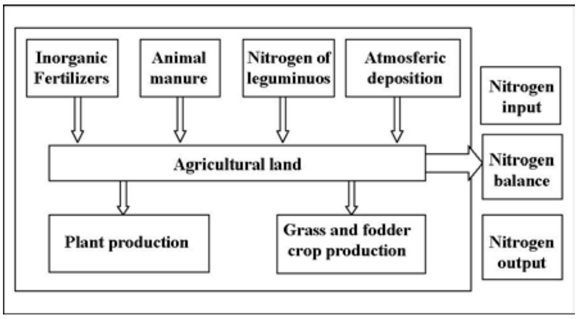


Figure 1. Nitrogen balance in the soil

It is understood that the above estimates are derived by using nitrogen data related only to agricultural practices within the utilized agricultural land. Pollution data referring to industrial wastes, mining activities and urban wastewaters are not considered.

2.2. Data Sources

The data sources used in this study were:

I. Farm Structure Survey: Statistical data on cultivated areas by kind of crop and on number of animals at LAU1 were derived from the Basic Surveys of the year 1991 and 1999/2000 (census of the agriculture);

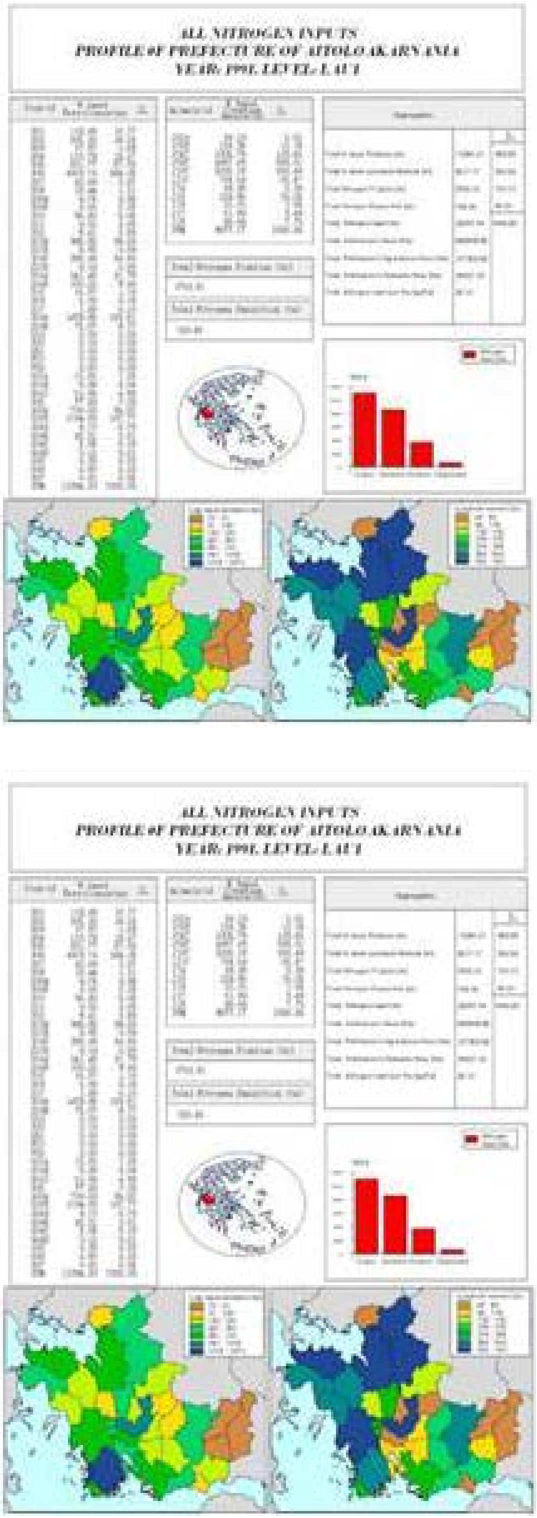
II. Annual Agricultural Statistical Survey: Statistical data on crop yield by kind of crop at LAU1 level were derived from a national survey using administrative sources;

III. Corine Land Cover maps: A data base consisting of 16 land cover classes. These data originated from processing of satellite images and the CORINE program (CLC). This file was used mainly for estimation of nitrogen absorbed by pastures for animal grazing (Crouzet, 2000);

IV. Natura areas: This was a GIS file of Natura 2000 areas which is a complementary one, and allows users to overlay the other information with that of vulnerable areas to nitrogen.

2.3. Data Base Construction

The above files have been organized and processed into a uniform application of GIS with municipalities cluster spatial level Greek. Maps of the reference each prefecture have been produced (Figure 2) for input, output and nitrogen balance of the agricultural areas.



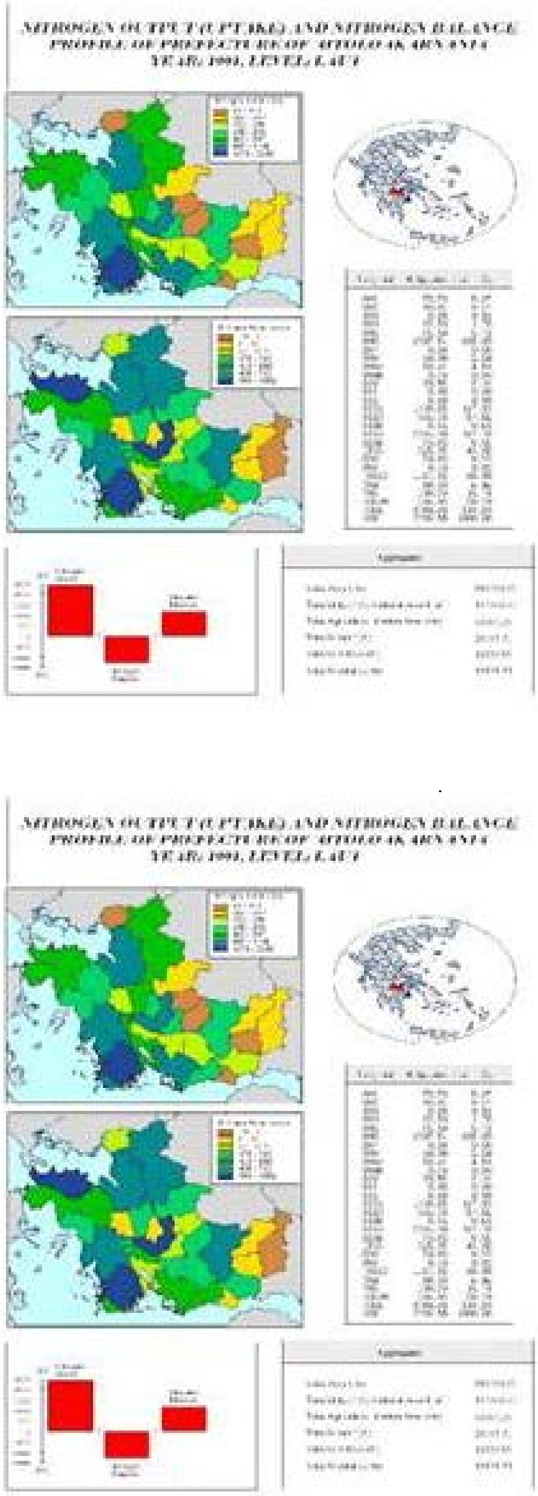


Figure 2. An example of nitrogen input and uptake at the municipal scale in Greece.

3. Results

Nitrogen input due to the consumption of mineral fertilizers is estimated at municipal level using the cultivated areas obtained from the FSS and relevant coefficients of nitrogen inputs from chemical fertilizers. (Figure 3). To estimate the nitrogen input the technical coefficients provided by Eurostat and referred to the 1997standard year have been applied. According to the above estimation about 32% of nitrogen fertilizers are used in winter cereals, 16% in maize, 14% in cotton and 17% in olive trees. Nitrogen input due to livestock manure is calculated as a function of the number of animals present at the reference day of the FSS at municipal 1 level and the appropriate coefficients of nitrogen inputs from livestock manure (Figure 4).

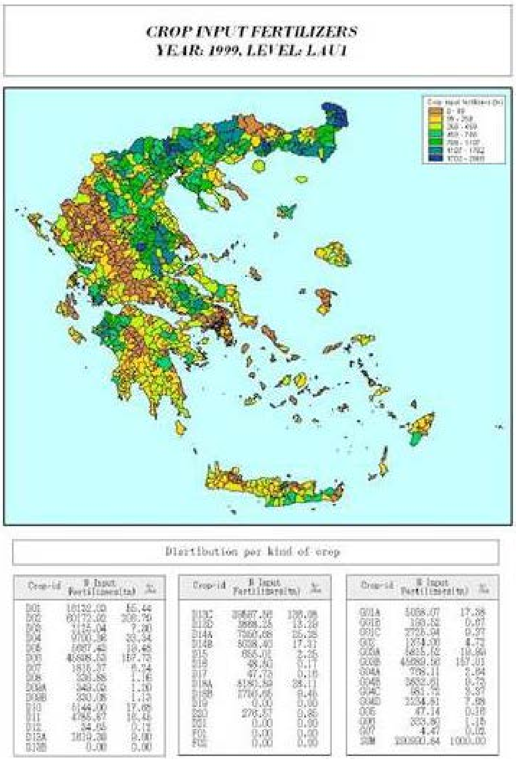


Figure 3. Distribution for kind of crop input fertilizers

According to the above estimation about 44% of the estimated nitrogen charge from manure is due to sheep breeding, 25% to goat breeding and the rest to other categories of animals. It is worth to notice that animal husbandry is of small size in Greece in comparison with other European countries and equally limited are the problems of pollution that it generates. According to the existing National Legislation livestock effluents cannot be applied directly to the land without wastewater treatment. The problem of pollution from this category of pollutants is geographically localized in certain regions of the country where there is concentration of livestock farms of middle or large size. These regions are: Prefecture of Evia (mainly around Artaki and Chalkida), Prefecture of Attiki (mainly in the areas of Megara, Aspropyrgos and Messogia), Prefecture of Thessaloniki (Neochoroutha, Pentalofos), Prefecture of Korinthia, Prefecture of Ioannina (around the lake Pamvotitha), Prefecture of Arta and Preveza (in the watersheds of the rivers Louros and Arachthos), Prefecture of Larissa, Prefecture of Aitoloakarnania (around the lake Trichonis).

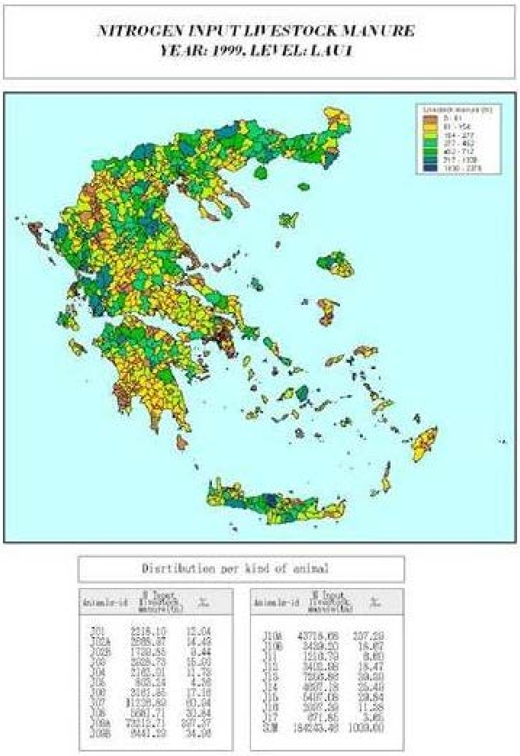


Figure 4. Distribution for kind of animal nitrogen input livestock manure.

Fixation by leguminous crops and clover was estimated using data on cultivated areas as they were collected though the annual agricultural survey that contains more analytical data level and a relevant fixation rate by kind of crop. Data were aggregated at municipal level for all categories of leguminous crops. The total quantity of nitrogen fixation from legumes was estimated at 35,704 tons (Figure 5).

Nitrogen deposition to agricultural land was estimated using data on the utilized agricultural area from the FSS multiplied by a standard coefficient (7 Kg/ha). The outcome is that the estimated total quantity of nitrogen deposition in the utilized agricultural area amounts to 25,082. tons.

The nitrogen absorption from harvested crops (output) is estimated using data of the volume of the production by kind of crop level from Annual Agricultural Statistical Survey and the appropriate coefficients of Nitrogen content of the harvest crops for each kind of crop. From the above data it appears that the bigger absorption is due to the grazing pastures and, in a descending order, to tree crops, cotton, winter cereals and maize. The estimation of the nitrogen absorption from areas under grass was based on the areas classified as pastures for animal grazing in CLC map.

An example for the reference year 1999 is presented in table 1 and Figure 6.

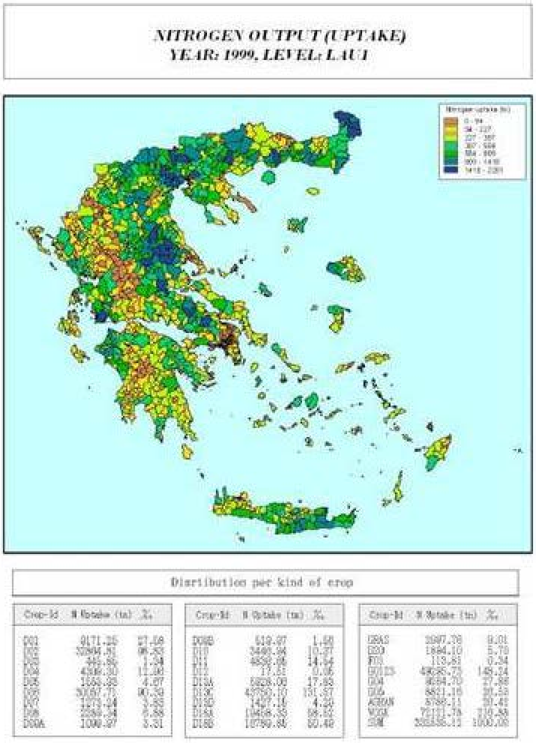


Figure 5. Distribution for kind of crop nitrogen output

Table 1. Nitrogen balance estimations for Greece in 1999

	Tons N
From crops	290,990.84
From animals	184,243.46
Atmospheric deposition	25,082.30
Biological process of legumes	35, 704.22
Total input	535,997.72
Total output	332,535.12
Balance	203,462.60

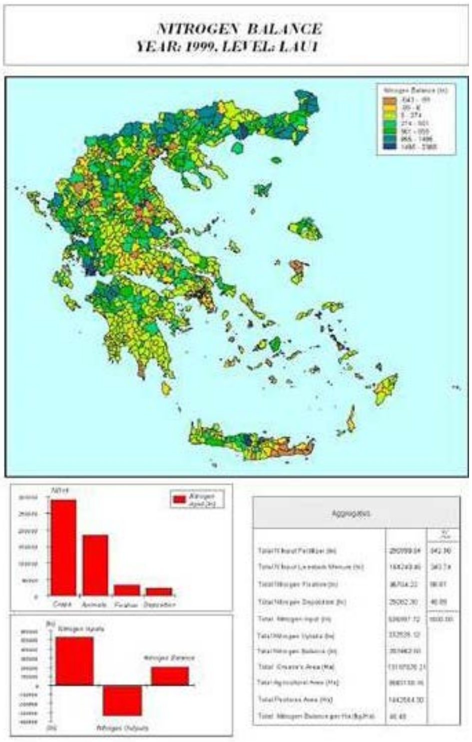


Figure 6. Nitrogen balance **.**

4. Discussion and Conclusion

Similar studies have been made in the past by Terres et. al. (2001) and by Hansen (2000). The first work refers to the EU countries at the prefectural in applying technical coefficients of EUROSTAT. and using data of the Farm Structure Surveys for the years 1990, 1993, 1995, and 1997. According to our point of view the non-adjustment of the technical coefficients by this work has a serious effect on the conclusions concerning the changes in nitrogenous fertilizers use through time. The best approach to this problem is to find an objective procedure for the adjustment of technical coefficients.

The method of adjustment used by Hansen (2000), which is adopted the present study refers to the adjustment of technical coefficients concerning the use of nitrogenous fertilizers according to the changes through time of their total consumption.

Hansen (2000), estimated the nitrogen balance at the prefectural level for the entire European Union. The aggregated results of the above-mentioned works for Greece are presented in Tables 2 and in Table 3:

Table 2. Nitrogen balance for Greece, 1997 according to Hansen (2000)

	Kg/ha	Tons of N
Total agricultural land 3486 th. Ha		
Nitrogenous fertilizers for crops	88	306768
Organic fertilizers (manure)	49	170814
Nitrogen fixation	2	6972
Atmospheric deposition on agricultural	7	24402
Total (input)	146	508956
Nitrogen absorption from crops (F(q))	29	101094
Nitrogen absorption from	69	240534
Nitrogen balance	48	167328

Table 3. Nitrogen balance estimates for Greece, 1991 according Terresa ect al. (2001)

	Kg/ha	Tons of N
Total agricultural land 3486 th. Ha		
Nitrogenous fertilizers for crops	76.94	250703
Organic fertilizers (manure)	12.84	41850
Nitrogen fixation from leguminous crops	-	-
Atmospheric deposition on agricultural land	18.33	59723
Total deposition (input)	-	352276
Nitrogen absorption from crops (F(q))	60.66	197647
Nitrogen balance	47.46	154629

The previously mentioned works are based on the following assumptions:

1. For the estimation of the nitrogenous fertilizers consumption, sampling data about the land area and the number of animals are used, originating from the Farm structure surveys. As a result of the above process, sampling errors are involved in all estimations;
2. Terres etc al. (2001) used constant technical coefficients for the quantities of fertilizers for all years and crop. This treatment ignores changes in farming practices as these are profoundly reflected in the overall consumption of fertilizers;
3. For the quantity of nitrogen absorption from grasslands and pastures, indirect calculations based on animal needs in grass (harvested or not) were used;
4. The nitrogen fixation is underestimated in the case of legumes as many of them, mainly those used for feeding animals are not presented as a separate category in the Farm Structure Survey;
5. Both studies deal with the establishment of nitrogen balance at prefectural level.

The present study uses agricultural census data in order to avoid problems due to sampling errors of the farm structure survey. Also, the technical coefficients provided by EUROSTAT for reference year 1997 are adjusted in the case of the nitrogen fertilizers usage for the years 1991 and 1999, in accordance with their total consumption in the reference years.

The need for more accurate estimation of the quantity of grass was satisfied, because the Annual Agricultural survey includes analytical reference to all relevant crops producing fodder plants for grazing within the utilized agricultural area, which is the object of the research. The same files give detailed data for all kinds of legumes and, as a result, the estimation related to nitrogen fixation in the soil is more accurate.

The estimation of forage produced outside the agricultural land was performed in the present work by using the special survey of National Statistical Service of Greece (NSSG), referring to 16 agricultural land uses. The areas under pastures before deriving from this source are estimated to be about 1.4 million hectares. We assume that this area is used for the grazing of animals.

Comparing to the above mentioned work, it could be concluded that the present results are closer to Hansen's approach. For instance, Nitrogenous fertilizers for crops counts 306,768 tones of Nitrogen in Hansen's work, which is very close to the value in the present study (290,990 tons). Balance of N is estimated equal to 203,463 tons in the present study, value that is closer to Hansen's one (107,328 tons).

The advanced methodology applied in the present study provides accurate estimations of Nitrogen balance. Additional work will be done to extent the estimations and to improve the methodology. Interesting results are extracted for the vulnerable areas of Greece to soil pollution by pollutants category. As a concluding remark, it could be stressed out that a powerful and informative tool a nitrogen believe at municipal land can permanently support in agro-environmental policies at the regional scale in the Mediterranea basin.

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