End of Grade Work

Trabajo Fin de Grado

Substitution of mineral fertilizer by animal slurry in Aragón

Sustitución de fertilizantes minerales por purines animales en Aragón

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2019

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Título del trabajo: Substitution of mineral fertilizer by animal slurry in Aragón (Sustitución de fertilizantes minerales por purines animales en Aragón)

Titulación: Grado en Administración y Dirección de Empresas. **Mención ADEi**

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Abstract:

The high concentration of industrial pig farms in several areas of Aragon is causing, among other problems, serious nitrate pollution of soils and groundwater. Council Directive 91/676/EEC addresses the problem by proposing adaptation and mitigation measures. In addition, Royal Decree 261/1996 establishes an order to the Autonomous Communities for the territories involved to delimit vulnerable zones and to establish boundaries between vulnerable zones. These regulations require farmers to reduce the volume of manure and slurry, as well as nitrogen and other nutrients generated in farms. In addition, in recent years, researchers have pointed the value of animal excrement as a resource to be considered in a circular bio-economy scheme, and among others, they propose the possibility of exporting slurry outside areas with a high livestock density. The export of surplus nutrients encourages composting and organic fertilization, adjusted to the needs of the crops. This work analyses the most appropriate way of using organic and mineral fertilisers to improve the quality of soils and groundwater in the Autonomous Community of Aragon, while guaranteeing the viability and sustainability of Aragon agricultural and livestock farms. A model of transport of slurry has been carried out, between all the villages of Aragon, from the surplus localities in the by-product to others, which due to their characteristics, can accept the polluting load.

Key Words:

Slurry, CO_2, Nitrogen, gas emissions environmental problems, GHG, Aragon, region providers, demanders villages, linear programming,

Resumen:

La concentración de granjas porcinas industriales en varias zonas de Aragón está ocasionando, entre otros problemas, una grave contaminación por nitratos de los suelos y las aguas subterráneas. La Directiva 91/676/CEE del Consejo aborda el problema proponiendo medidas de adaptación y mitigación. Además, el Real Decreto 261/1996 establece una orden hacia las Comunidades Autónomas para que los territorios implicados delimiten las zonas vulnerables y se establezcan los límites entre las zonas vulnerables. En dichas normativas se impone a los ganaderos reducir el volumen de estiércoles y purines, así como del nitrógeno y otros nutrientes, generados en las granjas. Además, en los últimos años, los investigadores señalan la valorización las deyecciones animales como un recurso a considerar en un esquema de bio-economía circular, y entre otros, plantean la posibilidad de exportar purines fuera de las zonas con alta densidad ganadera. La exportación de los excedentes de nutrientes fomenta el compostaje y la fertilización orgánica, ajustada a las necesidades de los cultivos. En este trabajo se analiza la forma más adecuada de uso de los fertilizantes orgánicos y minerales para mejorar la calidad de los suelos y de las aguas subterráneas de la Comunidad Autónoma de Aragón, a la vez que se garantiza la viabilidad y la sostenibilidad de las explotaciones agrícolas y ganaderas aragonesas. Se ha realizado un modelo de transporte de purines, entre todos los pueblos de Aragón, de las localidades excedentarias en el sub-producto a otras, que por sus características, pueden aceptar la carga contaminante.

Palabras clave

Purines, CO2, Nitrógeno, emisiones de gases, GEI, Aragón, municipios demandantes, municipios oferentes, problema del transporte.

1. ACKNOWLEDGEMENTS

First, we would like to thank to Safa Bac who had the kindness of providing us every village agricultural and farming data. Safa encouraged us to perform this project and showed us the variety of themes that could be interesting to study yet. Thanks to that information the development of this project has been possible.

Secondly, we would like to thank Sergio Monteagudo Latorre, Head of the Territorial Information Systems Section of the Instituto Geográfico de Aragón (IGEAR) attached to the Directorate General for Territorial Planning, for his collaboration. From the Service they have provided the kilometric distances between the towns of Aragon. The computerized treatment of the distances provided has allowed us to elaborate with more rigor the work presented in this document.

Thirdly, we would like to thank Professor Javier Tapia for his help in the handling of information (big-data), the Excel and Gams programs; without whose help we could not have carried out this work, for us of great complexity.

We would like to thank the teacher Elena Calvo, along with Javier Tapia, they have been our tutors during this project. We are grateful to find tutors with the dedication and patience that they have had during this year, since they have been available to solve doubts and advise us how to run the project at all times. We have been able to learn much more about what appears in the project thanks to them.

Finally, I would like to thank the University of Zaragoza for giving the students the opportunity to develop their final project in front of a great variety of topics, giving them the option to focus them towards a topic of personal interest related to what they studied during their studies.

INDEX

1. ACKNOWLEDGEMENTS iii
2. Índex Of Figures iv
3. Index of Tables v
1. Introduction 1
2. Background Literature Survey 4
3. Research Methodology 7
3.1 Data Collection 8
3.2 Variables 8
3.3 GHG Balance 10
3.4 The Modelling 14
4. Results and Empirical Analysis 16
5. Discussion and Implications 22
6. Limitations and Future Research 23
7. References 24
8. Webgrafía 26
9. Annex I 26
10. Annex II 32

2. INDEX OF FIGURES

Figure 2.1. Critical points in Spain 4
Figure 3.1 Main 16 Aragon's villages with lowest GEI balance 11
Figure 3.2. Main 16 Aragon's villages with highest balance 11

3. INDEX OF TABLES

Table 3.1 CH4 Emission by animal 9
Table 3.2 Nitrogen by animal 9
Table 3.3 Postcode of main 16 Aragon's villages demanding slurry 12
Table 3.4 Postcode main 16 Aragon's villages offering slurry 13
Table 3.5 Restrictions 15
Table 4.1 Kilograms of slurry transported in Huesca 17
Table 4.2 Kilograms of slurry transported in Teruel 17
Table 4.3 Kilograms of slurry transported in Zaragoza 18
Table 4.4 Kilograms of slurry transported in Aragon 19

1. INTRODUCTION

The climate change is a problem with unique characteristics, mainly because it harms the whole planet, and to solve a global problem the solution must be harmonized and uniform. Therefore, the Kyoto Protocol was signed by certain countries in November 1997 (P.D.K., 1998) with the objective of reduce the global greenhouse gas (GHG) emissions and mitigate the climate change. But it was in 2015 when a new agreement between countries was set, Paris Protocol, there the policies are extended and updated regarding the present world values (P.D.P, 2015).

Greenhouse gases (GHGs) are gases that form part of the atmosphere, which absorb and emit radiation within the infrared range. The Kyoto Protocol affirms that the main GHGs in the atmosphere are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O) and ozone (O_3). Since 1750, after the Industrial Revolution, the concentration of carbon dioxide in the atmosphere has increased (American Chemical Society, 2007). In 2016, according to the World Meteorological Organization, CO_2 levels exceeded, in some places of the world, the barrier of 400 parts per million signed in the Paris Protocol (WMO, 2016). The increase of CO_2 comes from the combustion of fossil fuels, mainly coal, oil and natural gas. The CH_4 and N_2O are produced in the agriculture, which added to other environmental problems such as deforestation or soil erosion, have produce a negative impact in the environment.

In order to classify the causes of pollution, a distinction is made between pollution from clearly delimited sources, local and non-point pollution (Martínez Sánchez et al., 2005), and that caused by non-point sources (Martínez Sánchez et al., 2005). Local pollution is that which has a direct relationship with the polluting source. The human activities linked to this pollution are mining, landfills, industries, etc. On the other hand, diffuse pollution is linked to the transport of polluting substances far from the source of origin, a very research subject. Obviously, in agricultural areas, the main problem may be non-point pollution (Martínez Sánchez et al., 2005).

According to the European Environment Agency (EEA, 2015), agricultural and livestock activities are the main cause of the deterioration of water quality in more than 40 percent of European rivers and coasts. In northeastern Spain this problem is aggravated by the

greater presence of livestock, especially pigs. Aragon is currently the second autonomous community in Spain in pig breeding and it has more than 3900 farms with more than 6,900,000 animals (Magrama, 2015).

Environmental policies have focused on the mitigation of punctual pollution, due to the complex regulation and identification of diffuse pollution, as it requires controlling a large number of imperfect variables (the economic value of the environmental damage, the damage avoided, the parameters of the company, agents involved, etc.). The difficulty in the study of diffuse pollution has led the European Union to base some of its policies on limiting the use of fertilizers and promoting good practice in the agricultural and livestock sector.

One of the measures adopted by the Spanish Autonomous Communities to reduce pollution is the use of organic fertilizers in agricultural fields, trying to reduce artificial fertilization as much as possible. One of the residues most used as organic fertilizer are the so-called "*reference slurry*", these residues consist of a mixture of solid and liquid excrements, the slurry of pigs are the best known as they are the most polluting. Slurry has different degrees of dilution, and therefore, has different economic potential due to the nutrients it contains and the amount of them. Miller and Donahue (1990) and Carballas et al. 1990, conclude that, slurry weight on dry provide nitrogen (between 2 and 8%), phosphorus (0.2 to 1%) and potassium (from 1% to 3%). Organic matter is fundamental to improve the physical, chemical and biological properties of the soil and, for this reason, its maintenance has so much interest in organic farming, being also an effective method to avoid wasting these nutrients (González V. et al. 2008). According to Ferrer et al. 1983, slurry yields can act like mineral fertilizers do. Therefore, slurry can substitute or complement the use of mineral fertilizers in edaphoclimatic conditions of the Ebro Basin (Ferrer et al., 1983; Daudén and Quílez, 2003; Irañeta et al., 2002; Daudén and Quílez, 2004).

The European Union has adopted a waste strategy (Resolution 7/05/1990) which establishes a hierarchy of management options. It is recommended, firstly, to avoid their generation; secondly, to encourage recycling and reuse, in the soil trophic chain system. However, it must be borne in mind that poor management of organic fertilizers has harmful consequences for agricultural soils. This assertion known to farmers is often

ignored. Excessively mineralized soils show a loss of nutrient retention capacity, which end up in watercourses generating eutrophication and pollution. The level of nutrient loss in cultivated soils depends mainly on soil type, climatic conditions and farming systems. In Mediterranean areas this value varies between 1% and 3% depending on the soil, according to Vida Rural Magazine (2000). The livestock waste to be reused in the form of slurry is valuable as fertilizer due its mineral content. It is necessary to estimate correctly the amount needed in each plot so that these problems do not appear.

In short, intensive agricultural production causes water pollution. This phenomenon can be seen, above all, in the growth of nitrate concentration levels in surface water and groundwater. To solve this problem, Council Directive 91/676/EEC addresses the problem of water protection by proposing adaptation and mitigation measures. In addition, Royal Decree 261/1996 establishes an order towards the Autonomous Communities so that the territories involved delimit the vulnerable zones and the limits between the vulnerable zones are established. In Decree 317/2015 of the Government of Aragon, it defines the zones whose vulnerability due to pollution caused by nitrates of agricultural origin was higher.

For this problem of surplus of pollutant load, known its good quality as mineral fertilizers, it is taken as a possible solution the transfer of slurry to those nearby municipalities that are demanders of this by-product because of their need of fertilizer. Therefore, our work aims to calculate the optimal route, minimizing the transportation costs, for transporting the slurry between villages. Thus, would balance the excess of slurry, and therefore the quantity of nitrogen emission, in the Aragon's villages and the deficit of slurry in others, allowing the lasts a reduction in artificial fertilizer. Thence the mathematical methodology of linear programming is used to achieve the optimal route, taking into consideration the objective of minimizing transport costs and satisfy the supply and demand.

In order to achieve the final goal, the document has been organize following the next guideline: The first part of the paper is focused in past studies related with our topic, later the methodology of investigations and the data collection methodology is described. Then model of optimization is explained, and we provide the optimal solution of the problem.

After the results, the implications are discussed and some limitations that appear in the research are explained.

2. BACKGROUND LITERATURE SURVEY

Nowadays the society has the moral need to identify and assess the factors that influence climate change, thus trying to correct, replace or eliminate them so that we can make a more sustainable place to live (Necpalova et al., 2018). Some environmental groups have concluded that the livestock industry is one of the main responsible of the global warming, as pollutants are dumped into the soil, then water, and finally emitted into the atmosphere. (Gerber, P. J. et al. 2013).

Velasco et al. (2016) conclude that the livestock industry uses 80% of the fields used for agriculture and the 8% of the water consumer globally; it produces 37% of CH_4 from enteric and manure fermentation, 9% of the total CO, 65% of the global emissions of NO and the 64% of the global ammonia. According to Van Damme et al. (2018), in Spain, the critical points identified in the world ranking are mainly caused by pigs: Vic-Manlleu (Barcelona); Cánovas, Lorca-Port Lumbreas (Murcia); but also beef cattle: Mensalbes (Toledo) and Viso-Pozoblanco milk cattle (Córdoba). On a larger geographical scale, the Ebro Valley (Aragon and Catalonia) stands out. In the figure 2.1, regarding the study of Van Damme et al. shows the Spanish geographic zones with highest pollution. Being represented in yellow those with high values and in red the highest levels. Therefore, it is seen that Aragon is one of the most affected places by the pollution in Spain.

Figure 2.1. Critical points in Spain

Source: Van Damme et al. (2018)

Necpalova et al. (2018) based on the Day Cent model which predicts the N_20 emissions, this study decided to analyze the long-term impacts on soil and greenhouse gas management of farming systems in Switzerland. They selected four experimental cities within Switzerland (Therwil, Frick, Changins and Reckenholz), evaluated the model in a way that analyzed the results of crop productivity, soil dynamics carbon and nitrogen emissions. The results they obtained suggest that the implementation of soil management practices in cropping systems has considerable potential for climate change mitigation.

The present organic "farming" movement grew with the publications of Howard (1940), Balfour (1943) and Rodale (1945) which were concern about the problems of soil erosion and the detrimental of this problem. But the origins are in 1924, with a movement known as biodynamic agriculture. (Scofield, 1986).

On the one hand, in order to avoid or reduce this problem, governments should assume the responsibility for periodic monitoring of livestock production system, thanks to that they could control it in the case of excessive discharges of pollutants into the environment and natural resources (Pinos -Rodríguez et al, 2012). On the other hand, regarding the European Union and National Legislation (Spain) the waste produce in the livestock by the animals, could be used as a fuel if its successfully managed. And, therefore, it should be one of the main goals for farmer, the conversion of pig slurry to pellets, because it is a great fertilizer option in order to reduce environmental pollution from slurry accumulation (Pampuro et al, 2017). The European guidelines in the 7th Environment Action Program (European commission) the main objective is to eliminate the waste without contaminating water, soil or atmosphere environment. Thereby, in the case of the slurry, which had traditionally been wrongly thrown in the fields in order to eliminate them, producing contamination in the fields and due to the leaks into the rivers, could be used taking into account their economic value as compost, processing it as required (composting, drying system and similar), having prepared infrastructures, who would process the slurry ensuring the legal constraints, and later, eliminating them as compost in agricultural fields (Lössel et al, 2002).

The natural compost has positive effects by using life cycle assessment (LCA), such as nutrient supply and carbon sequestration, benefits on soil erosion and soil moisture (Martínez-Blanco et al., 2013) It is also seen as a way to improve landscape quality,

reduce the runoff and create high-volume market for those compost produced locally. (Martínez-Blanco et al., 2013).

In Spain, according to the MAPAMA, (2018) we have around 50 million animal's heads, of which almost 7000 are bovine animals, more than 30,000 are pigs and about 16,000 sheep. Therefore, the high volume of residues could be used as compost. But the farmers cannot eliminate the waste in a field in 30% of the situations because of their location or absence of demanders.

In order to solve this problem, the transportation of slurry to close villages requiring compost is a feasible solution. As the slurry has to be cheaper than mineral fertilizer, it cannot be transported long distances (more than 20-30 km) because this would affect the economic profit, increasing the transportation costs and therefore the slurry total costs (Suarez F. et al, 2010). Thanks to the Suarez et al. study, the same constrain has been used as a kilometer limitation for this study.

In Spain, one of the main environmental problems is the high quantity of emissions of CO_2. Therefore, Spanish Government developed in 2011 a program called "Fondo de Carbono para una Economia Sostenible (FES-CO2)", in this program they promote projects with the objective of guide the industry in order to reduce the gas emissions. In Aragón the limited society Green Pig Solution, S.L., who developed a program to reduce the CO_2 emissions in their farms, was chosen. Thanks to Spanish Government grant they bought the pig slurry form other farm in Guallar reducing the emissions (Ministerio Transición Ecologica, Gobierno de España).

Aragon has been focusing of many studies related with the greenhouse gases emissions. Between the years 1990 and 1997, the Aragon Government confirms that the growth in those emissions was higher than the Spanish mean. Hence, the Government decided to introduce some changes, following the guideline of "Estrategia Aragonesa de Cambio Climático y Energías Limpias" (EACCEL), and they achieve the expected percentage between 2012 and 2018.

In Baccour's study (2019) there is made an estimation balance of the GHG (greenhouse gases) of the agricultural sector in Aragon. The results obtained in her study show that emissions from the agricultural sector in Aragon reach 4.1 M_tCO_2 and are concentrated

in the regions of Monegros, Cinco Vilas, La Litera and Hoya de Huesca. Moreover, an economical and environmental analysis regarding the different possible policies that would reduce the GHG can be find. It should be noted that in Baccour's project was considered the long-term evolution perspectives of Aragon's agriculture under those different scenarios of mitigation policies. Our work differs from the last because it is focus on the mitigation the way of transport and on how to reduce those costs for an improvement in distribution.

3. RESEARCH METHODOLOGY

Aragón has a surface of 47.720 km^2, 3.7 of those are used for the primary sector (IAEST, 2018), conforming the 10% of Spain surface (INE, 2017). The pig sector has grown during the last years, in 2014 there were 5.3 million pigs in Aragón and now we reach the 7.76 million animals (Encuesta ganadera del Ministerio 2018). Currently, pig production represents 62% of livestock production and 36.4% of agricultural production (Government of Aragon, 2017). The increase in the number of pigs entails an increase in its wastes and therefore their emissions. The increase has not been homogenous all over Aragón and there are some villages which have suffer a higher increase of pigs and contamination, those villages are known as vulnerable areas.

Because of the society demand to reduce the gas emissions and the negative consequences that produces a vulnerable area to its habitants, the different villages from Zaragoza, Huesca and Teruel, conforming Aragón, are studied. All Aragon villages have been analyzed, but the attention has been focused in those villages with high detrimental emissions, due to the surplus of slurry from the farming sector (farming intense villages), and those with more agricultural fields which needed some slurry in order to compost them, agriculture intense villages.

The reason of choosing this local area is because of the necessity of promoting a sustainable economy in Aragón and reducing its emissions. The emissions of CO_2 have increased in Aragon of 22.74%, upper to the allowed percentage in Protocol de Kyoto, but lower to the average increase of Spain (FEDER, de Aragon 2007). Tapia (2014), points out that Aragón emissions are around 20 million tons of CO2 and 20% of those emissions come from the farming sector.

According to Iguácel Soteras, F. et al. (2007), slurry management incurs to the farmer 15.8% of the total costs of the farm, mostly related to management costs within the method of application and distribution mainly because of the distance from the farm and the fields were the slurry are needed. Therefore, in order to reduce this cost, this paper studies the best combinations between demanding and supplying peoples.

3.1 DATA COLLECTION

In order to carry out the proposed study, it is required the knowledge of the kilometer distances between all the villages in Aragon. Because the study is focused on supplying the slurry demanding villages in the cheapest available way for both members in the exchange. In order to do this, need to know the kilometers and to be supplying depending on the distance between the supplier and the one who needs the slurry, and to be increasing the circle of kilometers as the nearest ones are satisfied first. These data have been obtained from the Instituto Geográfico de Aragón (IGEAR), attached to the department of Vertebración del Territorio, Movilidad y Vivienda.

The classification of supplying and demanding municipalities, regarding the quantity of slurry, is also required to carry out this study. For this reason, the crop data obtained from the 1T questionnaires of the Government of Aragon was needed. In addition, the number of heads of livestock and their typology per municipality has been obtained from Baccour S.'s study (2018).

3.2 VARIABLES

The variables used in this study are obtained from the subtraction of the total nitrogen emissions produce by the farming sector and the total nitrogen absorbed by the agricultural sector. This difference has been calculated for every village placed in Aragon, which has been used in this project to balance the total emissions in side Aragon, transporting the slurry.

Therefore, with the number of animals of each breed and thanks to the Kahill methodology (2011), we can translate the quantity of animals in CH_4 and N_2O emissions, multiplying the animal figures by the emission that each animal produce (information of the European Environment Agency, EEA). These data is summarized in table 3.2.1 and

3.2.2. The database used to quantify the cattle population is obtained from the EEA 2003, 2009, and is divided in pig, cow and sheep cattle.

Table 3.1 CH4 Emission by animal

Animal	**CH_4/animal/year**
Pig	1.5
Dairy cattle	97.92
Beef cattle	54.21
Sheep	8.66

Source: EEA (2009)

Table 3.2 Nitrogen by animal

Animal	**N/animal/year**
Pig	8.38
Dairy cattle	80
Beef cattle	55
Sheep	29.2

Source: EEA (2003)

Once know those figures, they are used the following expression to translate it to CO_2 equivalent tons:

(1) $$CH4\ emissions\ from\ enteric\ fermentation = \sum(j = 1)^{m} = \left(Cj.FEAj.\frac{PC}{1000}\right)$$

Where Cj represents the number of animals' species *j*, FEAj, are the emissions factor of CH_4 from enteric fermentation (from animals´ breed j) and PC is the potential for green house warning.

In order to calculate the N_2O emissions in equivalent units of CO_2, the same process than before is used. The mathematical expression for N_2O emissions follows:

(2) $$N2O\ emission\ from\ purine\ management = \sum(i = 1)^{n} = \left(Cj.Nexj.Fesk.\frac{44}{28}\frac{PCN20}{1000}\right)$$

Where *Cj* represents the number of animals' species *j*, Fesk are the emissions factor of N_2O from slurry management (from animals´ breed *k*), y PC is the potential for green house warning. The figure 44/28 is the ratio from the molecular weight between the N_2O and N.

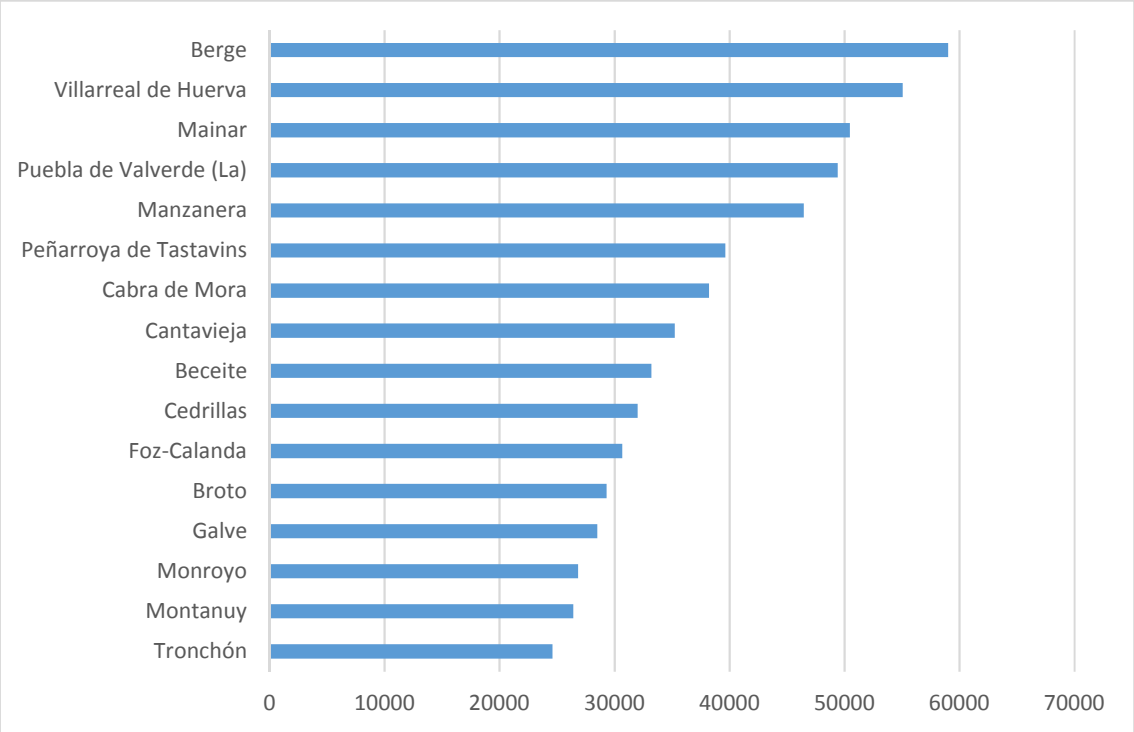
3.3 GHG BALANCE

The study exposes the actual condition of Aragon's primary sector and the influence of the agricultural sector in the environment, it also studies who some changes in the sector would decrease the negative effects that it produces. It begins by examining the balance of greenhouse gas emissions in the Autonomous Community, inspecting in detail the agricultural and livestock subsectors. In the farming activities, the direct emissions of nitrous oxide from fertilizers used in the fertilization of crops are evaluated, as well as the indirect emissions of nitrous oxide from the leaching and runoff of nitrogen. Livestock activities assess direct methane emissions from animal enteric fermentation, and indirect nitrogen oxide and methane emissions from manure management. The GHG balance (subtraction of both magnitudes) indicates the pollution situation of the primary sector in the area. According to the results, the possibilities of transporting manure from one area to another as organic fertilizer will be analysed.

Sector authorities declare an area to be vulnerable when the level of CO2 emissions exceeds 10,000 tonnes. The Government of Aragon has declared vulnerable areas, as for example Montarraña and Jiloca (in Teruel); Albalatillo, Castillonroy, Sena and Vencillón (in Huesca); Mirambel, Monroyo, Peñarroya de Tastavins en Teruel, Mainar and Villarreal de Huerva (in Zaragoza). We intend to contrast our results with those published by the Government of Aragon

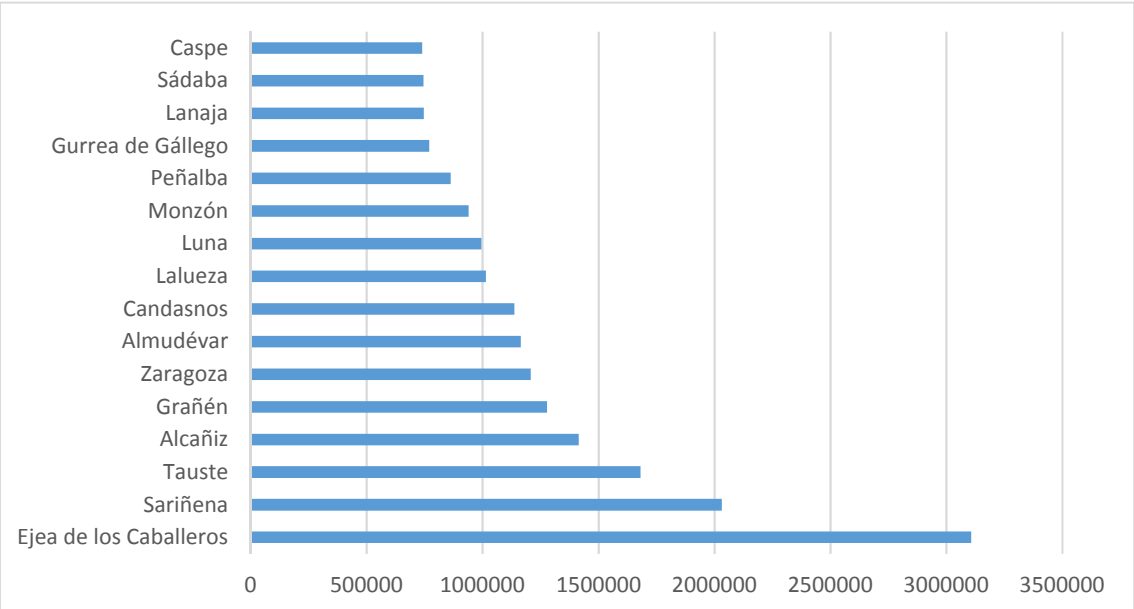
For this study, it is useful to analyze those villages with lowest pollution and highest pollution (Tons). In graph 3.1 we can see the sixteen Aragon's villages with the lowest number of total tons of nitrogen. Virtually all municipalities emit a pollutant load below half of what is considered a critical level.

Figure 3.1 Main 16 Aragon's villages with lowest GEI balance.



In contrast to the previous graph, Figure 3.2 includes the sixteen localities with the highest pollutant load and shows that almost all of them are close to the critical threshold of 10,000 tons.

Figure 3.2. Main 16 Aragon's villages with highest balance



In order to prepare the data of the transport model, it can be said that the villages with the lowest pollutant load will be the possible demanders and those with the highest load will be suppliers. It is important to keep in mind that the figure does not use the 100% of the quantity, it uses the 76% of it. The other 24% becomes from mineral fertilizer, which is preferred by the agricultural people because in this way they are aware of the precise quantity of minerals that they are using in their fields.

To facilitate the reading of the results included in the annex, the postal codes of the previous municipalities are included in tables 3.1 and 3.2

Table 3.3 Postcode of main 16 Aragon's villages demanding slurry

Villages	**Postcode**
Berge	44040
Villareal de Huerva	50292
Mainar	50154
Puebla de Valverde	44192
Manzanera	44143
Peñarrolla de Tastavins	44179
Cabra de Mora	44048
Cantavieja	44059
Beceite	44037
Cedrillas	44074
Foz-Calanda	44107
Broto	22074
Galve	44115
Monroyo	44154
Montanuy	22163
Tronchón	44236

Source: Own elaboration

Some municipalities do not have enough cultivable land to use the manure as fertiliser, also, the limit set for the areas declared vulnerable, 170 kg per hectare per year, must be taken into account.

Table 3.4 Postcode main 16 Aragon's villages offering slurry

Villages	**Postcode**
Caspe	50074
Sádaba	50230
Lanaja	22137
Gurrea de Gállego	22119
Peñalba	22172
Monzón	22158
Luna	50151
Lalueza	22136
Candasnos	22077
Almudévar	22022
Zaragoza	50902
Grañén	22116
Alcañiz	44013
Tauste	50254
Sariñena	22222
Ejea de los Caballeros	50096

Source: Own elaboration

The same applies to the areas of Hoya de Huesca and Somontano de Barbastro in the province of Huesca, which have several municipalities declared vulnerable and a large quantity of pig slurry can be found. In the case of Zaragoza the area with the most contribution of all is Las Cinco Villas, which has some municipalities declared vulnerable areas.

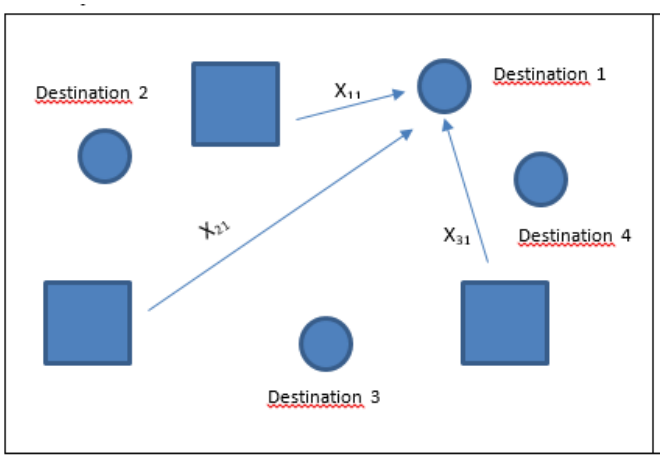
3.4 THE MODELLING

Linear programming has become a widely used method for solving optimization and business planning problems. Advanced operating procedures can be found in the bibliography, including the simplex method and the solution to so-called "transport problems". Its fundamental use is based on the need to take units from a specific, point called source or origin, to another specific point called destination.

The mathematical methodology known as the "Transport Problem" has been widely used both in economics and in other scientific fields (Hitchcock, 1941; Kantorovich, 1942; Koopmans 1947). The problem studies how many units shall be transported from the origin points to the destination points, in order to minimize the cost.

Before formulating the linear problem, you must know the resources, the activities and the relationships between them; then you must follow three steps. The first one, is to define the decisive variables, those are expressed by x_{ij}, and represent the quantity to be transferred from origin i to destination j (see figure 3.4), D_j represent the demand required in the origin, S_i represent the supply required in the origin, and C_{ij} is the cost of transporting one unit from origin i to destination j. The transportation costs, the supply and demand are given data.

Figure 3.5 Graphical representation of movement from offering villages to demanders.



Secondly, on the decision variables, supply (Si) and demand (Dj) restrictions will be established. The mathematical formulation of these is shown in equation 3. Inequality

restrictions are transformed into equality restrictions by adding a "fictitious plaintiff", whose demand is the difference between total supply and the total demand.

Table 3.5 Restrictions

Supply	**Demand**	
$\left.\begin{array}{l} x_{11}+x_{12}+x_{13}+\ldots+x_{1n} \le S_1 \\ x_{21}+x_{22}+x_{23}+\ldots+x_{2n} \le S_2 \\ \vdots \\ x_{m1}+x_{m2}+x_{m3}+\ldots+x_{mn} \le S_m \end{array}\right\}$	$\left.\begin{array}{l} x_{11}+x_{21}+x_{31}+\ldots+x_{m1} \ge D_1 \\ x_{12}+x_{22}+x_{32}+\ldots+x_{m2} \ge D_2 \\ \vdots \\ x_{1m}+x_{2m}+x_{3m}+\ldots+x_{nm} \ge D_m \end{array}\right\}$	(3)

And the last step, we propose the function of objective to minimize, that is to say, to minimize the cost of the transport. The mathematical expression of transport cost is given in equation 4.

$$Z = C_{11}X_{11} + C_{12}X_{12} +\ldots\ldots + C_{1n}X_{1n} + C_{21}X_{21} + C_{22}X_{22} +\ldots\ldots + C_{2n}X_{2n} +\ldots C_{m1}X_{m1} + C_{m2}X_{m2} +\ldots\ldots + C_{mn}X_{mn} \quad (4)$$

From a mathematical point of view, the problem can be expressed as the search for a set *Xi,j* where $i = 1,2,...m$; and $j = 1,2,...,n$ (the quantity to be transferred from origin *i* to destination *j*) in such a way as to minimize the cost of transport, subject to supply and demand restrictions. In the case of this study *m* is referred to the total number of rows, demanding villages, which in this case are 560, and *n* is referred to the number of columns, offering villages, which are 160. This leaves in this research project a total of 720 villages to analyze mostly.

The complexity found in solving the problem has been marked by the size of the matrix (560 rows, 160 columns). The information on distances between supplying and demanding villages could not be treated with the Solver Excel package (due to the magnitude of the problem), so the mathematical optimization was performed with the GAMS program, a specific software able to solve mathematical problems with high number of variables.

4. RESULTS AND EMPIRICAL ANALYSIS

A great achievement of this work is that it has been investigated in the "Repercussion and economic and environmental benefits for the Autonomous Community of Aragon". The research carried out has strengthened cooperation in research and knowledge transfer between the Autonomous Community of Aragon and the University and has contributed to a better understanding of the environmental impacts and economic benefits of the livestock industry in the Autonomous Community of Aragon. We have been able to contribute knowledge to the continuous improvement of the social environment, socio-economic development and the quality of life of the Aragonese population, since the environmental costs of Aragonese agriculture and livestock have been analyzed, examining the contribution to the improvement of manure management for the reduction of atmospheric emissions of greenhouse gases and nitrogenous emissions of greenhouse gases and aquifers in their waters.

As mentioned above, the problem matrix has 560 rows and 160 columns, which makes it impossible to include the results of the transport problem in this section. These results are included in the Annex. However, we proceed to explain some interesting situations.

The results of the mathematical problem of transport will be explained for the sixteen municipalities that were included in Figures 3.1 and 3.2, which, as explained above, make up what are called demanding and supplying municipalities.

We intend to contrast the results of this work with that carried out by the Government of Aragon. Certain differences will be observed mainly due to the fact that in this TFG the total nitrogen per hectare is analysed and that of the Government of Aragon focuses only on the nitrogen produced by the livestock sector.

The rows of the matrix represent the municipalities demanding slurry (i) and the columns the municipalities offering (j). To point out that 560 municipalities demand and only 160 offer polluting loads, that is to say, there are many more demanding towns. The total quantity of slurry that will be send is 1,744,877 t and the total quantity required by the demanding villages is 64,824,935 t. The total figures show the inability to supply totally to the demanding villages.

Once located the village from which you want to obtain the results, you can search manually focusing on the numbers of the corresponding municipal code as they are ordered from less to greater in each case in both axes (rows and column). Another quicker way would be pressing the control button and the letter F, you get the search engine where you can put the municipal code and takes you to its box directly.

Table 4.1 lists in its rows the applicant municipalities in the province of Huesca (postcode beginning with 22). The columns include the municipalities, province to which it belongs (postal code beginning with 44 corresponds to Teruel and postal code beginning with 50, corresponds to Zaragoza) and the optimum tones to be transported from the municipalities in the row to those in the column.

Table 4.1 Kilograms of slurry transported in Huesca.

		Peñarrolla	*Cabra de Mora*	*Broto*	*Tronchón*
		44179	*44048*	*22074*	*44236*
Abiego	*22001*	**2,120**			
Graus	*22117*			**12,320**	
Nueno	*22163*		**14,134**		
Quicena	*22195*				**24,603**

Source: Own elaboration

For example, in the case of Peñarrolla (postcode of 44179) will send 2,120 Kilograms of slurry to the village of Abiego, post code 22001.

Table 4.2 indicates a special situation. In the table one more cell has been added for the case where a village that gives slurry to another village, and satisfies its demand, has more product to continue distributing among other villages.

Table 4.2 Kilograms of slurry transported in Teruel

		Berge	*Cantavieja*	*Cedrillas*	*Foz-Calanda*
		44040	*44059*	*44074*	*44107*
Aguaviva	*44004*		**9,796**		
Alcorisa	*44014*	**59,008**			

Alfambra	*44016*			**21,114**	
Allueva	*44023*		**4,876**		
Calanda	*44051*				**30,677**

Source: Own elaboration

As we can observe in the case of Cantavieja (postcode 44059), send some slurry 9,796 Kilograms to Aguaviva, postcode 44014, and 4,876 Kg to Allueva, postcode 44023.

The table 4.3 shows a different possible case. It occurs when a village that demands the product does not only require one supplier (because is not able to provide all the quantity required) and needs more villages to be able to satisfy the total of its demand, as in the case of Villadoz, code 50283 that needs the slurry of Villareal de Huerva, 50292, and Mainar, 50154.

Table 4.3 Kilograms of slurry transported in Zaragoza

		Villareal de Huerva	*Mainar*	*Manzanera*	*Peñarrolla de Tastavins*
		50292	*50154*	*44143*	*44179*
Pedrosas	*50205*			**4,482**	
Torralbilla	*50258*		**46,330**		
Undués de Lerda	*50268*				**10,567**
Villadoz	*50283*	**55,070**	**4,046**		

Source: Own elaboration

The situations explained in these three tables can be generalized for the rest of the municipalities in the Annex, which collects the results of transport between all plaintiffs and bidders.

The following table contains the information from Tables 4.1, 4.2 and 4.3.

Table 4.4 Kilograms of slurry transported in Aragon

		Berge	Villarreal de Huerva	Mainar	Puebla de Valverde (La)	Manzanera	Peñarroya de Tastavins	Cabra de Mora	Cantavieja	Beceite	Cedrillas	Foz-Calanda	Broto	Galve	Monroyo	Tronchón
		44040	50292	50154	44192	44143	44179	44048	44059	44037	44074	44107	22074	44115	44154	44236
Abiego	22001						2,120									
Graus	22117												12,320.17			
Nueno	22163							14,134								
Quicena	22195															24,603
Aguaviva	44004								9,796							
Alcorisa	44014	59,008.82														
Alfambra	44016										21,114.22					
Allueva	44023								4,876							
Ariño	44029								6,124							
Calanda	44051											30,677.03				
Camarillas	44055										10,903.87					
Cañada Vellida	44062													16,021.66		
Cretas	44086									16,640.66						
Fórnoles	44105														15,572	
Lagueruela	44132					10,438										
Mezquita de Jarque	44148													12,492.04		
Ráfales	44194														11,274	
San Martín del Río	44207							4,278								
Teruel	44216				49,416.24											
Valderrobres	44246									16,561.15						
Villar del Salz	44258						11,642									

		Berge	Villarreal de Huerva	Mainar	Puebla de Valverde (La)	Manzanera	Peñarroya de Tastavins	Cabra de Mora	Cantavieja	Beceite	Cedrillas	Foz-Calanda	Broto	Galve	Monroyo	Tronchón
Alcalá de Moncayo	*50014*								1,495							
Alhama de Aragón	*50020*							4,304								
Anento	*50028*					31,547										
Botorrita	*50056*						15,313	15,514								
Cuarte de Huerva	*50089*								1,372							
Mianos	*50168*								8,667							
Pedrosas (Las)	*50205*					4,482										
Santa Eulalia de Gállego	*50238*								2,916							
Torralbilla	*50258*			46,330.05												
Undués de Lerda	*50268*						10,567									
Villadoz	*50283*		55,070.55	4,046.31												
Villarroya del Campo	*50294*			90.20												

In the figure 4.1 you can see inside the map of Aragon, the municipality of Campo de Daroca and referring to the example mentioned above, the village of Villadoz is marked with a circle and its two suppliers would be Villareal de Huerva and Mainar marked with a square.

Figure 4.1.Movement example.

Source: Own elaboration

Even this project studies the emissions in Aragon, there are other similar studies with the same objective but using different variables. This leads to different results, as in the case of the BOA and BOE.

On the one hand, the BOA, in the ORDENDRS/333/2019, 25th March, considers the villages with over quantity of farming those which quantity of Nitrogen per hectare and year is superior to 220 kilograms. An example of those villages are Albalatillo, Alfántega, Altorricón, Castillonroy, Mirambel, Monroyo, Peñarroya de Tastavins, Sena, Vencillón, Mainar, Villarreal de Huerva…

On the other hand, the BOE list several vulnerable underground waters such as the Aluvial del Ebro, Saso de Bolea – Ayerbe, Arba de Luesia river, Aluvial del Gállego or Somontano del Moncayo. It also higliths some municipies with a high degree of contamination as for example Alcalá del Ebro, Biota, Cadrete or Utebo (Boltein oficial del Estado, BOE, 25/07/2019). Aragon has areas where pig production is very concentrated, which, depending on the cultivated hectares, could produce a surplus of slurry.

5. DISCUSSION AND IMPLICATIONS

We want to point out that the accomplishment of this work end of degree has supposed us a high knowledge of the environmental topic and as summary of the learned thing we indicate the following one:

Nowadays the European Union is adopting different policies in order to reduce gas emissions coming from the farming sector. The main idea is to achieve an application of the slurry through injection systems in the ground or hanging tubes, avoiding the spreading of slurry by means of barrel, fan or plate systems, the most commonly used in Spain. The Agriculture Ministry will penalize those farmers using the conventional Systems.

The CIAM researcher Juan Castro Isua, explained that "there is a series of known and easy-to-apply agricultural practices that allow greater use of the fertilizer value of the slurry, notably reducing nitrogen losses through evaporation in the form of ammonia, and that they are even more efficient, more easily applicable and less costly than the injection of slurry". Those are the proper alimentation of the animals, the increase in the grazing time, create a crust in the slurry fossa in order to avoid the emissions, apply the slurry when it is raining or adjust the quantity of nitrogen fertilization depending on the slurry applied.

Other policies that could be adopted by the government are those related with economic aspects. On the one hand, a solution could be an increase in the percentage of taxes to those villages emitting a quantity of GEI superior to the standard. Or on the other hand, a reward could be given to the villages that keep low levels of emissions. Another option is financing the transportation cost to the farmers, even though the price is low, that could work as an incentive to send their slurry to those villages needing it to fertilize its camps.

Other solutions, that would require a global behavior, is reducing the demand of meat, that would lead to a reduction in the farming sector and consequently in their emissions. This would not reduce the employment of the farmers, because, even though the quantity of animals will be reduced, their standards of living would increase, increasing their grazing time, their space to live, and global conditions. This would increase the price of the meat and would compensate the reduction in the supply.

Another way to solve the problem of exceed of slurry, making any modification in their conventional way of working, is opening its business in another sector. They could sell their slurry, as a natural product, and try to compete to the chemical fertilizer brands. In the case of do not feeling confident in engaging in a new business, the farmer could get an agreement with those brands to sell their natural products and combine those, with the chemical ones to create a hybrid of both.

It is important to be aware of what guidelines is going to implement the new PAC 2021-2027 in order to achieve the objectives. But our research is matching with the current PAC and will match with the next one, because it allows the supplier farmers to reduce their emissions and provides those requiring the slurry reducing the economic cost.

6. LIMITATIONS AND FUTURE RESEARCH

The main problem we have found to develop the work has been the management of the data and its implementation in the Excel program, initial idea in the planning of the TFG. The high number of rows and columns in the transport matrix made it impossible to use the Excel Solver package. To solve the problem, we used the program GAMS (https://www.gams.com/), a very powerful program that helped us solve the problem, but it is not free software.

In addition, although the difficulty of the program exceeds the competencies that must be acquired by an undergraduate student, we opted for this route to acquire the competence of "Learning to learn". Professor Javier Tapia, explained the operation of the program and helped to program the resolution of the problem to solve.

Once the work has been completed, we can confirm that we have learned a great deal from environmental economics and, at this moment, it seems interesting to propose some future lines of research. A case that may be interesting to develop in another project is the issue of whether adding an economic reward would be well accepted by the distributor or receiver and related to this investigate which of the two would be fairer to give such a reward. Since the person who removes rid of the slurry, he should be thankful because it is a problem to have excess product.

But in the case of the person who receives it could also be seen in two ways. The first way could be to give him the reward for dealing with an excess that is harmful to the environment and he gives it a good use, but on the other hand it could look like they are giving him a good that otherwise he should pay to get fertilizin chemical, so it saves him.

Finally, consider the comments of farmers and ranchers, people very interested in this project. We should have participants to the Government of Aragon to know their opinion and that it is easier to know if there is the possibility of making real changes in the system.

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9. ANNEX I

The annex contains the results of the transport problem developed in this work. It is 162 pages long and the first three pages are extracted from them to complement the results already included and explained.

The rows in the matrix represent the municipalities that can receive slurry and the columns include the municipalities that must send slurry to another town to comply with current regulations.

From the bibliography we know that the maximum distance to which it can be transported is about 20-30 km. In this work, a distance of 40 km has been considered in order to have more transport possibilities.

Obviously, most of the cells have a zero coefficient, whose interpretation is that from the municipality of the column there is no transport to the village of the row. It is the non-nil elements that indicate the pollutant load to be transported.

Table AI.1 Kilograms of slurry transported from row municipality i to column municipality j

	22006	22025	22028	22032	22037	22041	22045	22054	22057	22059	22062	22066	22067	22068	22069	22074	22078	22084	22086
22001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	892	0
22009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22024	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22039	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22042	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22043	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22044	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

22046	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22047	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

22006	22025	22028	22032	22037	22041	22045	22054	22057	22059	22062	22066	22067	22068	22069	22074	22078	22084	22086
22048	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22051	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22053	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22058	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22061	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22063	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22064	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22072	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22075	0	0	0	0	0	0	4798	0	0	0	0	0	0	0	0	0	0	0	0
22077	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22080	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22081	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22082	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22083	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22087	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22088	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22089	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22090	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22096	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22113	0	0	0	0	0	0	0	0	0	0	0	2767767	0	0	0	0	0	0	0

2200	22025	2202	2203	2203	2204	2204	2205	2205	2205	2206	2206	2206	2206	2206	22074	22078	22084	2208
22115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22130	691391	0	0	0	0	0	0	0	0	0	0	0	0	3375	0	0	187777	0	3460
22135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22139	0	0	0	0	0	0	0	5459	0	0	0	0	0	0	0	0	0	0	0
22141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22158	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22163	0	0	0	0	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22164	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22172	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10. ANNEX II

To facilitate the reading of the results table, the postal code of the 720 municipalities involved in the analysis is attached in Annex I.

Table A2.1 Postal code of the municipalities

Código	Municipio
22001	Abiego
22002	Abizanda
22003	Adahuesca
22004	Agüero
22907	Aínsa-Sobrarbe
22006	Aisa
22007	Albalate de Cinca
22008	Albalatillo
22009	Albelda
22011	Albero Alto
22012	Albero Bajo
22013	Alberuela de Tubo
22014	Alcalá de Gurrea
22015	Alcalá del Obispo
22016	Alcampell
22017	Alcolea de Cinca
22018	Alcubierre
22019	Alerre
22020	Alfántega
22021	Almudévar
22022	Almunia de San Juan
22023	Almuniente
22024	Alquézar
22025	Altorricón
22027	Angüés
22028	Ansó
22029	Antillón
22032	Aragüés del Puerto
22035	Arén
22036	Argavieso
22037	Arguis
22039	Ayerbe
22040	Azanuy-Alins
22041	Azara
22042	Azlor
22043	Baélls
22044	Bailo
22045	Baldellou
22046	Ballobar
22047	Banastás
22048	Barbastro
22049	Barbués
22050	Barbuñales
22051	Bárcabo
22052	Belver de Cinca
22053	Benabarre
22054	Benasque
22246	Beranuy
22055	Berbegal
22057	Bielsa
22058	Bierge
22059	Biescas
22060	Binaced
22061	Binéfar
22062	Bisaurri
22063	Biscarrués
22064	Blecua y Torres
22066	Boltaña
22067	Bonansa
22068	Borau
22069	Broto
22072	Caldearenas
22074	Campo
22075	Camporrélls
22076	Canal de Berdún
22077	Candasnos
22078	Canfranc
22079	Capdesaso
22080	Capella
22081	Casbas de Huesca
22083	Castejón de Monegros
22084	Castejón de Sos
22082	Castejón del Puente
22085	Castelflorite
22086	Castiello de Jaca
22087	Castigaleu
22088	Castillazuelo
22089	Castillonroy
22094	Chalamera

Código	Municipio
22095	Chía
22096	Chimillas
22090	Colungo
22099	Esplús
22102	Estada
22103	Estadilla
22105	Estopiñán del Castillo
22106	Fago
22107	Fanlo
22109	Fiscal
22110	Fonz
22111	Foradada del Toscar
22112	Fraga
22113	Fueva, La
22114	Gistaín
22115	Grado, El
22116	Grañén
22117	Graus
22119	Gurrea de Gállego
22122	Hoz de Jaca
22908	Hoz y Costean
22124	Huerto
22125	Huesca
22126	Ibieca
22127	Igriés
22128	Ilche
22129	Isábena
22130	Jaca
22131	Jasa
22133	Labuerda
22135	Laluenga
22136	Lalueza

Código	Municipio
22137	Lanaja
22139	Laperdiguera
22141	Lascellas-Ponzano
22142	Lascuarre
22143	Laspaúles
22144	Laspuña
22149	Loarre
22150	Loporzano
22151	Loscorrales
22905	Lupiñén-Ortilla
22155	Monesma y Cajigar
22156	Monflorite-Lascasas
22157	Montanuy
22158	Monzón
22160	Naval
22162	Novales
22163	Nueno
22164	Olvena
22165	Ontiñena
22167	Osso de Cinca
22168	Palo
22170	Panticosa
22172	Peñalba
22173	Peñas de Riglos, Las
22174	Peralta de Alcofea
22175	Peralta de Calasanz
22176	Peraltilla
22177	Perarrúa
22178	Pertusa
22181	Piracés
22182	Plan
22184	Poleñino

Código	Municipio
22186	Pozán de Vero
22187	Puebla de Castro, La
22188	Puente de Montañana
22902	Puente la Reina de Jaca
22189	Puértolas
22190	Pueyo de Araguás, El
22193	Pueyo de Santa Cruz
22195	Quicena
22197	Robres
22199	Sabiñánigo
22200	Sahún
22201	Salas Altas
22202	Salas Bajas
22203	Salillas
22204	Sallent de Gállego
22205	San Esteban de Litera
22207	San Juan de Plan
22903	San Miguel del Cinca
22206	Sangarrén
22208	Santa Cilia
22209	Santa Cruz de la Serós
22906	Santa María de Dulcis
22212	Santaliestra y San Quílez
22213	Sariñena
22214	Secastilla
22215	Seira
22217	Sena
22218	Senés de Alcubierre
22220	Sesa
22221	Sesué
22222	Siétamo
22223	Sopeira

Código	Municipio
22904	Sotonera, La
22225	Tamarite de Litera
22226	Tardienta
22227	Tella-Sin
22228	Tierz
22229	Tolva
22230	Torla-Ordesa
22232	Torralba de Aragón
22233	Torre la Ribera
22234	Torrente de Cinca
22235	Torres de Alcanadre
22236	Torres de Barbués
22239	Tramaced
22242	Valfarta
22243	Valle de Bardají
22901	Valle de Hecho
22244	Valle de Lierp
22245	Velilla de Cinca
22909	Vencillón
22247	Viacamp y Litera
22248	Vicién
22249	Villanova
22250	Villanúa
22251	Villanueva de Sigena
22252	Yebra de Basa
22253	Yésero
22254	Zaidín
44001	Ababuj
44002	Abejuela
44003	Aguatón
44004	Aguaviva
44005	Aguilar del Alfambra

Código	Municipio
44006	Alacón
44007	Alba
44008	Albalate del Arzobispo
44009	Albarracín
44010	Albentosa
44011	Alcaine
44012	Alcalá de la Selva
44013	Alcañiz
44014	Alcorisa
44016	Alfambra
44017	Aliaga
44021	Allepuz
44022	Alloza
44023	Allueva
44018	Almohaja
44019	Alobras
44020	Alpeñés
44024	Anadón
44025	Andorra
44026	Arcos de las Salinas
44027	Arens de Lledó
44028	Argente
44029	Ariño
44031	Azaila
44032	Bádenas
44033	Báguena
44034	Bañón
44035	Barrachina
44036	Bea
44037	Beceite
44039	Bello
44038	Belmonte de San José

Código	Municipio
44040	Berge
44041	Bezas
44042	Blancas
44043	Blesa
44044	Bordón
44045	Bronchales
44046	Bueña
44047	Burbáguena
44048	Cabra de Mora
44049	Calaceite
44050	Calamocha
44051	Calanda
44052	Calomarde
44053	Camañas
44054	Camarena de la Sierra
44055	Camarillas
44056	Caminreal
44059	Cantavieja
44060	Cañada de Benatanduz
44061	Cañada de Verich, La
44062	Cañada Vellida
44063	Cañizar del Olivar
44064	Cascante del Río
44065	Castejón de Tornos
44066	Castel de Cabra
44070	Castellar, El
44071	Castellote
44067	Castelnou
44068	Castelserás
44074	Cedrillas
44075	Celadas
44076	Cella

Código	Municipio
44077	Cerollera, La
44080	Codoñera, La
44082	Corbalán
44084	Cortes de Aragón
44085	Cosa
44086	Cretas
44087	Crivillén
44088	Cuba, La
44089	Cubla
44090	Cucalón
44092	Cuervo, El
44093	Cuevas de Almudén
44094	Cuevas Labradas
44096	Ejulve
44097	Escorihuela
44099	Escucha
44100	Estercuel
44101	Ferreruela de Huerva
44102	Fonfría
44103	Formiche Alto
44105	Fórnoles
44106	Fortanete
44107	Foz-Calanda
44108	Fresneda, La
44109	Frías de Albarracín
44110	Fuenferrada
44111	Fuentes Calientes
44112	Fuentes Claras
44113	Fuentes de Rubielos
44114	Fuentespalda
44115	Galve
44116	Gargallo

Código	Municipio
44117	Gea de Albarracín
44118	Ginebrosa, La
44119	Griegos
44120	Guadalaviar
44121	Gúdar
44122	Híjar
44123	Hinojosa de Jarque
44124	Hoz de la Vieja, La
44125	Huesa del Común
44126	Iglesuela del Cid, La
44127	Jabaloyas
44128	Jarque de la Val
44129	Jatiel
44130	Jorcas
44131	Josa
44132	Lagueruela
44133	Lanzuela
44135	Libros
44136	Lidón
44137	Linares de Mora
44141	Lledó
44138	Loscos
44142	Maicas
44143	Manzanera
44144	Martín del Río
44145	Mas de las Matas
44146	Mata de los Olmos, La
44147	Mazaleón
44148	Mezquita de Jarque
44149	Mirambel
44150	Miravete de la Sierra
44151	Molinos

Código	Municipio
44152	Monforte de Moyuela
44153	Monreal del Campo
44154	Monroyo
44155	Montalbán
44156	Monteagudo del Castillo
44157	Monterde de Albarracín
44158	Mora de Rubielos
44159	Moscardón
44160	Mosqueruela
44161	Muniesa
44163	Noguera de Albarracín
44164	Nogueras
44165	Nogueruelas
44167	Obón
44168	Odón
44169	Ojos Negros
44171	Olba
44172	Oliete
44173	Olmos, Los
44174	Orihuela del Tremedal
44175	Orrios
44176	Palomar de Arroyos
44177	Pancrudo
44178	Parras de Castellote, Las
44179	Peñarroya de Tastavins
44180	Peracense
44181	Peralejos
44182	Perales del Alfambra
44183	Pitarque
44184	Plou
44185	Pobo, El
44187	Portellada, La

Código	Municipio
44189	Pozondón
44190	Pozuel del Campo
44191	Puebla de Híjar, La
44192	Puebla de Valverde, La
44193	Puertomingalvo
44194	Ráfales
44195	Rillo
44196	Riodeva
44197	Ródenas
44198	Royuela
44199	Rubiales
44200	Rubielos de la Cérida
44201	Rubielos de Mora
44203	Salcedillo
44204	Saldón
44205	Samper de Calanda
44206	San Agustín
44207	San Martín del Río
44208	Santa Cruz de Nogueras
44209	Santa Eulalia
44210	Sarrión
44211	Segura de los Baños
44212	Seno
44213	Singra
44215	Terriente
44216	Teruel
44217	Toril y Masegoso
44218	Tormón
44219	Tornos
44220	Torralba de los Sisones
44223	Torre de Arcas
44224	Torre de las Arcas

Código	Municipio
44225	Torre del Compte
44227	Torre los Negros
44221	Torrecilla de Alcañiz
44222	Torrecilla del Rebollar
44226	Torrelacárcel
44228	Torremocha de Jiloca
44229	Torres de Albarracín
44230	Torrevelilla
44231	Torrijas
44232	Torrijo del Campo
44234	Tramacastiel
44235	Tramacastilla
44236	Tronchón
44237	Urrea de Gaén
44238	Utrillas
44239	Valacloche
44240	Valbona
44241	Valdealgorfa
44243	Valdecuenca
44244	Valdelinares
44245	Valdeltormo
44246	Valderrobres
44247	Valjunquera
44249	Vallecillo, El
44250	Veguillas de la Sierra
44251	Villafranca del Campo
44252	Villahermosa del Campo
44256	Villanueva del Rebollar de la Sierra
44257	Villar del Cobo
44258	Villar del Salz
44260	Villarluengo
44261	Villarquemado

Código	Municipio
44262	Villarroya de los Pinares
44263	Villastar
44264	Villel
44265	Vinaceite
44266	Visiedo
44267	Vivel del Río Martín
44268	Zoma, La
50001	Abanto
50002	Acered
50003	Agón
50004	Aguarón
50005	Aguilón
50006	Ainzón
50007	Aladrén
50008	Alagón
50009	Alarba
50010	Alberite de San Juan
50011	Albeta
50012	Alborge
50013	Alcalá de Ebro
50014	Alcalá de Moncayo
50015	Alconchel de Ariza
50016	Aldehuela de Liestos
50017	Alfajarín
50018	Alfamén
50019	Alforque
50020	Alhama de Aragón
50021	Almochuel
50022	Almolda, La
50023	Almonacid de la Cuba
50024	Almonacid de la Sierra
50025	Almunia de Doña Godina, La

Código	Municipio
50026	Alpartir
50027	Ambel
50028	Anento
50029	Aniñón
50030	Añón de Moncayo
50031	Aranda de Moncayo
50032	Arándiga
50033	Ardisa
50034	Ariza
50035	Artieda
50036	Asín
50037	Atea
50038	Ateca
50039	Azuara
50040	Badules
50041	Bagüés
50042	Balconchán
50043	Bárboles
50044	Bardallur
50045	Belchite
50046	Belmonte de Gracián
50047	Berdejo
50048	Berrueco
50901	Biel
50050	Bijuesca
50051	Biota
50052	Bisimbre
50053	Boquiñeni
50054	Bordalba
50055	Borja
50056	Botorrita
50057	Brea de Aragón

Código	Municipio
50058	Bubierca
50059	Bujaraloz
50060	Bulbuente
50061	Bureta
50062	Burgo de Ebro, El
50063	Buste, El
50064	Cabañas de Ebro
50065	Cabolafuente
50066	Cadrete
50067	Calatayud
50068	Calatorao
50069	Calcena
50070	Calmarza
50071	Campillo de Aragón
50072	Carenas
50073	Cariñena
50074	Caspe
50075	Castejón de Alarba
50076	Castejón de las Armas
50077	Castejón de Valdejasa
50078	Castiliscar
50079	Cervera de la Cañada
50080	Cerveruela
50081	Cetina
50092	Chiprana
50093	Chodes
50082	Cimballa
50083	Cinco Olivas
50084	Clarés de Ribota
50085	Codo
50086	Codos
50087	Contamina

Código	Municipio
50088	Cosuenda
50089	Cuarte de Huerva
50090	Cubel
50091	Cuerlas, Las
50094	Daroca
50095	Ejea de los Caballeros
50096	Embid de Ariza
50098	Encinacorba
50099	Épila
50100	Erla
50101	Escatrón
50102	Fabara
50104	Farlete
50105	Fayón
50106	Fayos, Los
50107	Figueruelas
50108	Fombuena
50109	Frago, El
50110	Frasno, El
50111	Fréscano
50113	Fuendejalón
50114	Fuendetodos
50115	Fuentes de Ebro
50116	Fuentes de Jiloca
50117	Gallocanta
50118	Gallur
50119	Gelsa
50120	Godojos
50121	Gotor
50122	Grisel
50123	Grisén
50124	Herrera de los Navarros

Código	Municipio
50125	Ibdes
50126	Illueca
50128	Isuerre
50129	Jaraba
50130	Jarque
50131	Jaulín
50132	Joyosa, La
50133	Lagata
50134	Langa del Castillo
50135	Layana
50136	Lécera
50138	Lechón
50137	Leciñena
50139	Letux
50140	Litago
50141	Lituénigo
50142	Lobera de Onsella
50143	Longares
50144	Longás
50146	Lucena de Jalón
50147	Luceni
50148	Luesia
50149	Luesma
50150	Lumpiaque
50151	Luna
50152	Maella
50153	Magallón
50154	Mainar
50155	Malanquilla
50156	Maleján
50160	Mallén
50157	Malón

Código	Municipio
50159	Maluenda
50161	Manchones
50162	Mara
50163	María de Huerva
50902	Marracos
50164	Mediana de Aragón
50165	Mequinenza
50166	Mesones de Isuela
50167	Mezalocha
50168	Mianos
50169	Miedes de Aragón
50170	Monegrillo
50171	Moneva
50172	Monreal de Ariza
50173	Monterde
50174	Montón
50175	Morata de Jalón
50176	Morata de Jiloca
50177	Morés
50178	Moros
50179	Moyuela
50180	Mozota
50181	Muel
50182	Muela, La
50183	Munébrega
50184	Murero
50185	Murillo de Gállego
50186	Navardún
50187	Nigüella
50188	Nombrevilla
50189	Nonaspe
50190	Novallas

Código	Municipio
50191	Novillas
50192	Nuévalos
50193	Nuez de Ebro
50194	Olvés
50195	Orcajo
50196	Orera
50197	Orés
50198	Oseja
50199	Osera de Ebro
50200	Paniza
50201	Paracuellos de Jiloca
50202	Paracuellos de la Ribera
50203	Pastriz
50204	Pedrola
50205	Pedrosas, Las
50206	Perdiguera
50207	Piedratajada
50208	Pina de Ebro
50209	Pinseque
50210	Pintanos, Los
50211	Plasencia de Jalón
50212	Pleitas
50213	Plenas
50214	Pomer
50215	Pozuel de Ariza
50216	Pozuelo de Aragón
50217	Pradilla de Ebro
50218	Puebla de Albortón
50219	Puebla de Alfindén, La
50220	Puendeluna
50221	Purujosa
50222	Quinto

Código	Municipio
50223	Remolinos
50224	Retascón
50225	Ricla
50227	Romanos
50228	Rueda de Jalón
50229	Ruesca
50241	Sabiñán
50230	Sádaba
50231	Salillas de Jalón
50232	Salvatierra de Esca
50233	Samper del Salz
50234	San Martín de la Virgen de Moncayo
50235	San Mateo de Gállego
50236	Santa Cruz de Grío
50237	Santa Cruz de Moncayo
50238	Santa Eulalia de Gállego
50239	Santed
50240	Sástago
50242	Sediles
50243	Sestrica
50244	Sierra de Luna
50245	Sigüés
50246	Sisamón
50247	Sobradiel
50248	Sos del Rey Católico

Código	Municipio
50249	Tabuenca
50250	Talamantes
50251	Tarazona
50252	Tauste
50253	Terrer
50254	Tierga
50255	Tobed
50256	Torralba de los Frailes
50257	Torralba de Ribota
50258	Torralbilla
50259	Torrehermosa
50260	Torrelapaja
50261	Torrellas
50262	Torres de Berrellén
50263	Torrijo de la Cañada
50264	Tosos
50265	Trasmoz
50266	Trasobares
50267	Uncastillo
50268	Undués de Lerda
50269	Urrea de Jalón
50270	Urriés
50271	Used
50272	Utebo
50274	Val de San Martín
50273	Valdehorna

Código	Municipio
50275	Valmadrid
50276	Valpalmas
50277	Valtorres
50278	Velilla de Ebro
50279	Velilla de Jiloca
50280	Vera de Moncayo
50281	Vierlas
50283	Villadoz
50284	Villafeliche
50285	Villafranca de Ebro
50286	Villalba de Perejil
50287	Villalengua
50903	Villamayor de Gállego
50288	Villanueva de Gállego
50290	Villanueva de Huerva
50289	Villanueva de Jiloca
50291	Villar de los Navarros
50292	Villarreal de Huerva
50293	Villarroya de la Sierra
50294	Villarroya del Campo
50282	Vilueña, La
50295	Vistabella
50296	Zaida, La
50297	Zaragoza
50298	Zuera