REACTIVE NITROGEN IN THE SPANISH AGRI-FOOD SECTOR: ENVIRONMENTAL IMPACT ON ATMOSPHERE, SOILS, WATER AND RESOURCES

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Introduction

The presence of reactive species of nitrogen (N) in the biosphere might cause environmental impacts at local, regional and global scales (Soler-Rovira et al., 2008). Nowadays the N flows generated by human activities greatly exceed natural processes, thus a necessity exists of identifying and quantifying the current state of environmental N loads (Galloway, 1998). The aim of this work is to quantify the amount of reactive N used in the Spanish agri-food sector, assessing the related potential environmental impacts and potential uses of resources.

Materials and Methods

Data from a previously calculated N flow analysis in the Spanish agricultural and food production system for the 1996-2000 time period were used (Soler-Rovira et al., 2006). Eight economic compartments were identified: fertilizer industry, food and feed industry, agricultural soils, plant production, livestock production, domestic consumption, waste management and wastewater management. The next environmental compartments were considered: atmosphere, water, ecosystems soils and other soils (landfills). Total anthropogenic N inputs to the systems were calculated as: ammonia imports + fertilizers imports + ammonia fixation + feed and food imports + nitrogen in fish products + legume crops biological fixation + NOx emissions. All data came from Soler-Rovira et al. (2006), except NOx data which were taken from INE (2009). Input and output flows were considered in each economic compartment in order to calculate use efficiency (ratio of useful outputs to total inputs), eco-efficiency (ratio of useful outputs to outputs to the environment) and recycling rate (ratio of flow recycled to an earlier life-cycle compartment divided by total outputs). Environmental impacts were assessed by quantifying the N balance between the economic and the environmental subsystems: water, atmosphere, ecosystems soils and other soils. In this case agricultural soils were also considered an environmental compartment, since they are an important intermediate path to the environment. The impact on resources was evaluated considering the net N imports into the system and legume fixing crops, pastures and forages versus feed and fertilizers within the system.

Results

The anthropogenic N inputs in the system were estimated at 2,710 Gg N y^{-1}. This is a large amount but it is lower than 3,980 Gg N y^{-1} reported by Olsthoorn and Fong (1998) for The Netherlands in 1995. The main sources of those inputs were fertilizer synthesis and import (52%), and the import of commodities for the food and feed industry (28%). The resulting balance in the environmental compartments was positive (Tab. 1), because atmosphere and water receive reactive N. Atmospheric deposition on ecosystems and land filling of wastes were other important paths of N inputs to the environment, but the largest quantity of surplus N occurred in agricultural soils. The highest efficiency was achieved in the industrial compartments, whereas it was lowest in the agricultural ones (Tab. 2). Efficiency in soils was lower than the reported value by Bleken and Bakken (1997) for crops at global level (i.e. 50%), but in the livestock compartment it was higher than the global value given by Van der Hoek (1998). If we consider the farm-gate balance (including soil+plant production+

livestock) the efficiency was similar to that of pig farms in Spain (Soler-Rovira et al., 2001) but lower than that calculated for arable, horticultural and dairy farms. In general, eco-efficiency increased with technical efficiency, and it was especially low in waste management compartments, since low quantities of "useful" N were generated in them. The recycling rate within the system was very low, except if we consider the use of manures and slurries or the municipal solid waste (MSW) compost. The problem was that almost the 99.8% of the N was recycled into the soil compartment, and it was probably one of the reasons of the high surplus detected in it. The system was a net importer of reactive N, mainly in fertilizers and raw materials, and then the use of own resources was low: N in pastures and forage crops were 30% of total N in animal feeding (pastures+feed), and N_2 fixed by legume crops was 10% of the soil N input (fixation+fertilizers).

Tab. 1. Reactive nitrogen balance in the environmental compartments (in Gg N $year^{-1}$).

Compartment	Inputs	Outputs	Balance
Atmosphere	426	176	250
Water	321	97	224
Ecosystems soils	-	-	104
Other soils (landfill)	-	-	95
Agricultural soils	2443	1165	1278

Tab. 2. Technical efficiency (in %), eco-efficiency (in kg N kg N^{-1}) and recycling rate (in %) of the eight economic compartments considered in the Spanish agri-food sector (n.a.: not applicable).

Compartment	Efficiency	Eco-efficiency	Recycling rate
Fertilizer industry	100	205	0
Soil	35	2.64	0
Plant production	100	∞	3
Livestock production	15	1.55	75
Food and feed industry	73	20.8	4
Domestic consumption	0	n.a.	0
Waste management	(5)	0.83	46
Wastewater management	(6)	0.07	6
Farm gate	27	1.48	0.15

Conclusions

Anthropogenic N inputs are relatively high in Spain, which is a net importer of nitrogen, mainly in fertilizers and food and feed commodities. Environmental compartments receive relative high amounts of reactive nitrogen, especially soils. Furthermore, there was a relative low use of domestic resources, with a low proportion of N recycled within the system.

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