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Survey and Optimization of Nitrogen Management in Farming and Cropping Systems

M. Fumagalli[1], L. Bechini[1], F. Mazzetto[2], P. Sacco[2], F. Vidotto[3], G. Sali[4], C. Bulgheroni[4], M. Pastori[5], M. Acutis[1]

[1] Di.Pro.Ve., University of Milano, Via Celoria 2, 20133 Milano, Italy, mattia.fumagalli@unimi.it
[2] Institute of Agricultural Engineering, University of Milano, Via Celoria 2, 20133 Milano, Italy
[3] Agroselviter, University of Torino, Via L. Da Vinci, 44 10095 Grugliasco (TO), Italy
[4] DEPAAA, University of Milano, Via Celoria 2, 20133 Milano, Italy
[5]ERSAF, Via Copernico 38, 20125 Milano, Italy

In the last decades, the demand for an integrated evaluation of agricultural systems has increased. In our project, that we have started in order to survey and optimise representative farming and cropping systems, and to provide recommendations for improved nitrogen (N) management, we calculated a set of indicators about nitrogen and energy use, economic performance and weed control.

Methodology

We have first identified, in Lombardy region (northern Italy), six farms (arable and dairy), representative of different soil and climate types, different crop and animal production systems, and different management types. We conducted a survey in each farm with periodic visits to collect data about average management, using a structured questionnaire.

Data included annual input and output N flows at the farm level (purchase of mineral fertilisers, feed and bedding materials; sales of animals and vegetable products), and the average crop management at the scale of each single field: tillage (date and type), sowing (date, dose, species, variety and cost) fertiliser and manure application (date, dose, nutrients concentration and cost), pesticide application (date, dose, active ingredients concentration and cost), irrigation (date, type and volume of water application), harvest (date, yield, humidity, type of harvested product and selling price). A list of machinery available on farm was compiled (indicating size and expected workrate), and the several tractor-implement combinations were detected and recorded for each individual crop operations. We also monitored livestock management by collecting data about distribution of the animals in different age categories, their average weight and daily fodder ration.

To simplify data management, fields were aggregated into homogeneous areas. Soil type and agronomic practices were equal within each homogeneous area. Using these data, we have calculated a number of indicators at field scale. As nitrogen indicator, we have calculated the soil surface balance (the difference between N that enters the soil via surface and N that leaves the soil via crop uptake, Fumagalli et al., 2008). To evaluate energy use we have considered only the consumption of non-renewable fossil energy resources, using specific coefficients to convert mass fluxes into energy fluxes. The energy use efficiency was calculated as energy output / energy input (Fumagalli et al., 2008). As economic indicators, we calculated the total costs (variable + fixed). The sum of variable costs includes the costs for plant protection agents (fungicides, herbicides, insecticides, pesticides, adjuvants), fertilisers, seeds, fuel and lubricants. To describe weed management and control, we have defined a weed control indicator that evaluates the impact of cultivation system on weed development probability (WDP). It provides a value from 1 (worst case) to 5 (best case). A value of 3 represents the achievement of a minimum level. The potential toxicity of plant protection agents was described using the Load Index (LI) (OECD, 2005; application rate of active ingredient / LD50 or LC50). All the indicators were calculated for each homogeneous area and will be preliminarily presented here for one farm only (a non-irrigated dairy farm).

Results

The farm is representative of an area with silt-clay soil types and elevated annual precipitation (1150 mm). The cultivated crops are silage maize, Italian ryegrass and permanent meadows. Due to the lack of irrigation water, yields of silage maize are moderate: ~16 t DM/ha for early sowing maize (April), and ~12 t DM/ha for sowing after a winter forage crop (May). They correspond to crop uptake of less than 200 kg N/ha. Yields of meadows are approximately of 9 t DM/ha, with N uptake of 172 kg N/ha.

The calculated indicators are presented in Table 1. For all maize crops there is an important N surplus, ranging from 162 to 255 kg N/ha. This is due to excessive use of mineral fertilisers (211 and 156 kg N/ha for first and second-sowing maize, respectively). The nutrient value of manure (200 and 110 kg N/ha are applied with solid and liquid manure, respectively on area #1, 2 and 3, 4, 5) is not fully taken into account. Double-crop systems (areas #4 and 5) have lower surpluses. N balance for meadows is extremely diversified, ranging from –81 to 58 kg N/ha. This is due to the heterogeneity of the application rate of animal manure. The farmer uses large amounts of solid manure on fields close to the village (to minimise odour problems: 200 kg N/ha; area #7), while liquid manure, being preferentially employed on maize, is scarce for meadows (only 61 kg N/ha; area #6). Finally, on area #8 meadows are fertilised with inorganic N only, with a moderate deficit. Maize-based systems have higher energy inputs compared to meadows, due to tillage operations and pesticide application. Double-crop systems (areas #4 and 5) have much higher inputs compared to continuous maize (areas #1, 2 and 3). Despite being at a similar distance from farm compared to area #3, area #2 has higher energy consumptions due to the use of a small solid manure spreader, that requires many displacements.

There is a higher probability of weed development for continuous maize compared to the double-crop system (silage maize 2nd sowing + Italian ryegrass). Best results in reducing weed development probability should be achieved in meadows.

Economic costs are much lower for meadows compared to maize. For maize-based systems, the addition of the winter fodder crop (Italian ryegrass) does not increase much the total costs.

Table 1. Values of all indicators for each homogeneous area.

Hom. area	Crop	Fertilisers applied	Distance from farm (km)	Surplus (kg N/ha)	Energy inputs (GJ/ha)	Total costs (€/ha)	WDP
1	csm1	s + mn	2.1	255	36.7	1,259	1
2	csm1	s + mn	1.6	255	37.1	1,215	1
3	csm1	l + mn	1.5	165	29.2	785	1
4	sm2 + irg	l + mn	1.0	162	45.3	1,375	2
5	sm2 + irg	l + mn	0.4	162	43.6	1,222	2
6	m	l	1.0	-81	8.9	582	5
7	m	s	1.0	58	14.3	822	5
8	m	mn	1.0	-33	12.0	554	5

irg = Italian ryegrass , csm1 = continuous silage maize , sowing in April , sm2 = silage maize , sowing in May , m = meadows ; s = solid manure , l = liquid manure , mn = mineral fertilizers.

Conclusions

This methodology made it possible to provide an integrated assessment of various aspects of agriculture sustainability. A similar analysis is on going in six other dairy and arable farms.

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