Nitrate leaching during a 4-year period in a maize monoculture trial in Friuli-Venezia Giulia

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Summary

This paper presents the results of a multi-annual experimental trial carried out in the Friulian plains (N-E Italy), to compare the environmental impact on water and nitrate leaching of the most important crop system of the region (Maize-Maize succession) with a rotation system using cover crop (Maize-Ryegrass). Field lysimeters were used to collect leached water, which was then analysed for evaluating the amount of percolation, the nitrate concentration and the nitrate load of leaching. The results indicate good efficiency of the rotation system to limit nitrate leaching of 5 to10 times compared to maize monoculture, at values of about 20-30 kg/ha per year. The effect of cover crops resulted also when both systems were set-aside for two consecutive years, with a reduction of nitrate leaching of 50-60%. Because of the high temporal and spatial variation of the leaching data, it is anyway stressed that, for monitoring purposes, some other techniques, like diffused suction cups integrated by territorial models, could be more effective.

Introduction

Maize monoculture is the main productive system in Friuli Venezia Giulia. It is characterised by a high environmental impact for two main reasons: the high-impact agricultural activity and the high level of simplification of the productive system. A possibility to moderate this effect is represented by the rotation of maize with a winter cover crop. In order to verify the efficiency of the cover crop in reducing the environmental impact, the maize monoculture system was compared with the maize-cover crop system.

For this reason a multi-annual experiment with field lysimeters was carried out by the Agricultural Service of the Province of Pordenone (SAASD), together with the Regional Agency for Agriculture of Friuli Venezia Giulia (ERSA). This trial was established at Fiume Veneto (Friuli Venezia Giulia, Province of Pordenone), in the experimental farm "F. Ricchieri", in order to study the impact of the most important crop systems of the region on leached water quality, as a consequence of fertilisers application (PARENTE et al., 1996, 1997a, 1997b). This issue is particularly relevant for the Friuli Venezia Giulia plain, where high-impact agricultural activity and environmental characteristics make the whole area very vulnerable (CUCCHI, 2001a, 2001b; PECCOL, 2001; CICOGNA, 2001; MICHELUTTI et al., 2001; BRAGATO and LEITA, 2001). Among these, high annual rainfall, permeable soil with gravels (easily leached by water) in the Northern zone, and the presence of surface ground water in the Southern zone. The objective of the trial was to verify if the best practices in agriculture established by the European Union with the Nitrate Directive 676/91, the Regulations 2078/92 and 1257/99 and included into the recent Regional Development Plan (2000) could result into positive effects on water pollution. With this purpose the field lysimeter stations, established in Fiume Veneto since 1992, were used to collect the leached water from the soil.

Table 1: **Experimental crop systems characteristics during the trial years**

YEAR	Maize-Maize monoculture (MM system)	Maize-Ryegrass rotation (MR system)
1996	Maize cv: DAVIDA (Fao 400) Seeding date : 03.06.96 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 162 - P 96 - K 96	Maize cv: DAVIDA (Fao 400) Seeding date: 03.06.96 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 162 - P 96 - K 96 Ryegrass not seeded
1997	Set-aside, no tillage	
1998	Set-aside, no tillage	Cover crops seed in Autumn Ryegrass cv: ASSO Seeeding date: 17.11.98 Seeding rate: 45 kg ha^{-1}
1999	Maize cv: DK 502 (Fao 500) Seeding date: 02.06.99 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 211 - P 106 - K 100	Maize cv: DK 502 (Fao 500) Seeding date: 02.06.99 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 211 - P 106 - K 100 Ryegrass cv: ASSO Seeding date: 08.10.99 Seeding rate: 45 kg ha^{-1}
2000	Maize cv: CECILIA (Fao 500) Seeding date: 28.04.00 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 211 - P 106 - K 100	Maize cv: CECILIA (Fao 500) Seeding date: 28.04.00 Seeding rate: 7,2 p m^{-2} Fertilisation (kg/ha): N 211 - P 106 - K 100 Ryegrass cv: ASSO Seeding date: 30.10.00 Seeding rate: 45 kg ha^{-1}

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Materials and methods

The trial was carried out at the experimental farm "F. Ricchieri" in Fiume Veneto (Pordenone), 30 m asl, on medium-textured clayey (sand 43%, loam 37%, clay 20%), basic soil (Ph in H_2O 7.9 and Ph in KCl 7.3), with 0.92% of organic C and 0.11% of total N. The annual average rainfall is 1260 mm, mainly distributed in spring and autumn.

Two crop systems were compared:

- a monoculture cash crop with potentially high environmental impact (Maize-Maize succession with no winter soil tillage);
- a cash crop -cover crop rotation (Maize - Ryegrass).

In both systems fertilisation was applied only to Maize, whereas Ryegrass, sown immediately after the Maize harvest, was never fertilised. The total amount of fertilisers was in conformity with the maximum rates indicated by EU Reg. 2078/92 and by the Regional Plan of Rural Development, applied from 1996 and from 1999, respectively.

The crop experimental design during the period 1996-2000 is described in *Table 1*.

The N fertilisation was always provided in 3 rates, i.e. 20% of the total at the Maize seeding, 30% at the stage of 4th - 5th leaf, 30% at the stage of 8th leaf. The crops were established in 1992 and after 4 complete vegetative seasons, the field data collection started. In 1997 and 1998 both systems were set aside with no soil tillage; after wards the crops were re-established.

Experimental data were collected from 2 series of 6 lysimeter ceramic plates of 30 cm diameter, distributed in two 3-plates blocks per each crop, at depths of 70 cm, 100 cm and 140 cm. The samples of leaching water were collected each 15 days on the average, plus / minus one week, depending on the rainfall of the period. The data have been analysed as average values of the 6 plates per crop system at each collection date.

Both systems were provided of irrigation in the hottest periods, 3 times per year on the average, for a total amount of 75 mm. This amount of water was not integrated to the rainfall in the analysis, assuming that it was not relevant with regard to leaching.

The variables analysed are the following:

- Amount of collected water [litre/plate] as indicator of leaching;
- NO_3 concentration in leached water [mg/l];
- Amount of leached nitrates [g/m²].

The analysis was carried out to search for differences in the behaviour of the crop systems during the years of trial, by means of:

- Correlation of the collected leached water with the cumulated rainfall during the season;
- Trend of water NO_3 concentration with time;
- Correlation of water NO_3 concentration with the rainfall of the same period;
- Trend of the amount of leached nitrate with time;
- Correlation with leached nitrate with rainfall, cumulated along the season.

To the aim of this paper, the analysis concerns only the data collected from 1997 to 2000.

Results

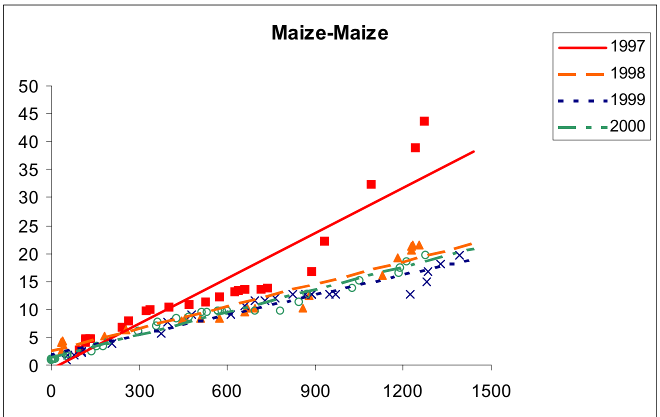
Leached water

The correlation between the cumulated amount of leached water and the corresponding cumulated rainfall is an estimation of the water loss by percolation during the season in each crop system. This correlation is well indicated by linear regressions (*Figure 1 a-b*) that resulted in each case significant at $p<0.01$. In particular, the slope of regression functions (i.e. rate of water loss per rainfall unit received) is given in order to differentiate the crop systems (*Table 2*). It can be remarked that:

- the rate of water loss recorded in the Maize-Ryegrass system is less than the half of the Maize-Maize system in the years of crop re-establishment (1999-2001), and slightly less than the half in the set-aside years (1997-98);

Table 2: **Slope values of the regression curves of *Figure 1*, per year and crop system (MM=maize-maize; MR=maize-ryegrass). Slopes show the water loss rate (l/plate) per mm of rainfall.**

Year	Crop system	Slope
1997	MR	.017
	MM	.027
1998	MR	.009
	MM	.013
1999	MR	.005
	MM	.012
2000	MR	.005
	MM	.013



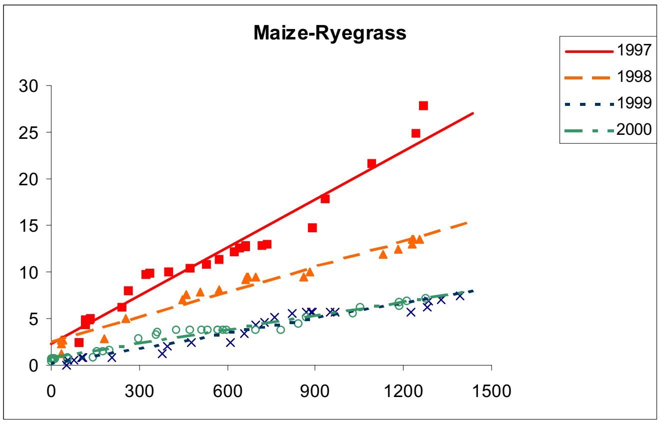


Figure 1a, b: **Seasonal curves of the cumulated water loss through leaching (l/plate) in function of the cumulated rainfall (mm)**

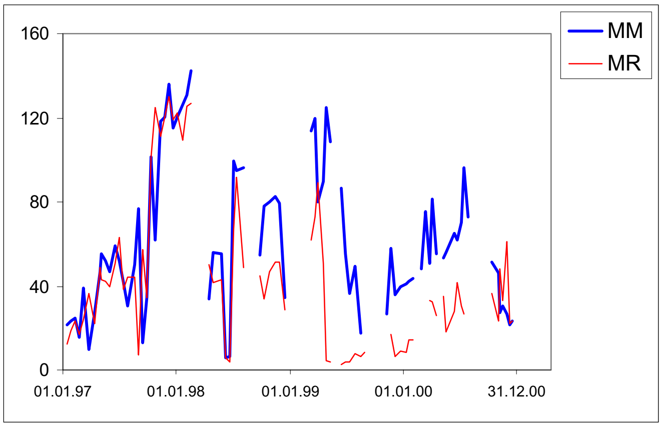


Figure 2: **Time variation of water NO_3 concentration in the experimental seasons.**

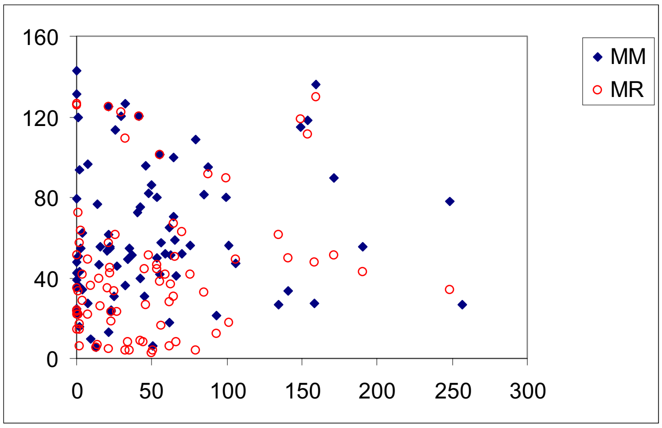


Figure 3: **Diagram of correlation between water NO_3 concentration (mg/l) and rainfall in the corresponding collection period (mm) of the two crop systems, all data gathered over the years.**

- however, the amount of water loss is lower in the Maize-cover system even in the set-aside periods;
- in quantitative terms, the highest water loss is recorded in the MM system at the first set-aside year (about 44 l/plate, equal to 600 mm rainfall, that is about the half of the annual rainfall), whereas the lowest water loss is recorded in the MR system during crops re-establishment (7 l/plate, i.e. about 100 mm rainfall, that is less that 1/10 of the annual rainfall).

Water NO_3 concentration

The trend of NO_3 concentration in leached water is strongly variable along time (*Figure 2*); in many cases it is higher than the limit of 50 mg/l stated by the Dir. EU/676/91, with peaks of about 140 mg/l.

The concentration values are never significantly correlated with rainfall in the corresponding periods of collection (*Figure 3, 4*) in each crop system. A significant statistical difference is found between the average values of crops by gathering all data over the years (MM = 51.2 mg/l, MR = 40.4 mg/l, $p<0.05$). The difference between systems is particularly evident at the restarting of crops (1999-2001), when nitrates concentration in leached water is lower from MR than from MM (*Figure 2*).

Leached nitrates load

The analysis of cumulated leached nitrates per year is more significant than the NO_3 concentration with regard to the behaviour of crop systems. In particular, we must remark:

- the curves of the total load (*Figure 5*) indicate a relevant nitrate loss in the MM system during the first set-aside year (more than 600 kg/ha); such loss is reduced to less than a half in the second set-aside year (263 kg/ha). In the same years, the MR system showed a nitrate loss of less than a half of MM (286 kg/ha and 104 kg/ha respectively);
- at crop restarting after two years, nitrate leaching tends to decrease even in the MM system up to 158 kg/ha in 2000, whereas it dramatically decreases in the maize - cover crop system (18 and 34 kg/ha in 1999 and 2000 respectively);
- in some of the cumulative curves of nitrate load a breaking point can be detected; after that, leaching tends to rapidly increase. This occurs around a cumulated rainfall of 800-900 mm, which happens usually at the end of Summer, when rainfall peaks are recorded and the maize vegetative cycle is ending.

Conclusions

General remarks can be pointed out from the analysis (*Table 3*):

Œ The advantage of using rotation systems with winter cover crops to limit nitrate leaching around 20-30 kg/ha per year in the Friulian plains, is so far confirmed. This practice reduces leaching of 5 to 10 times with respect to a monoculture cash crop succession.

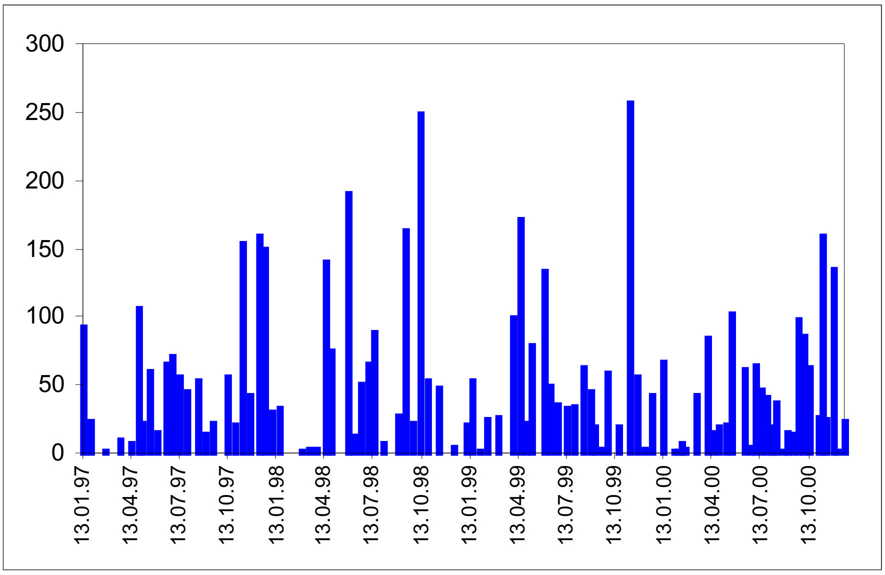
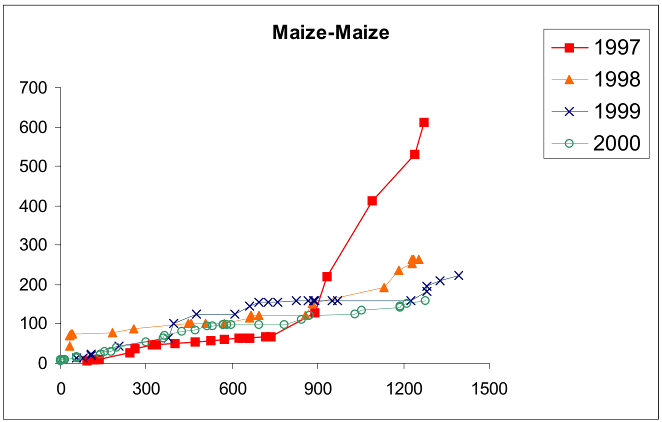


Figure 4: **Time distribution of rainfall (mm) in the experimental seasons. Time periods are of about 15 days.**



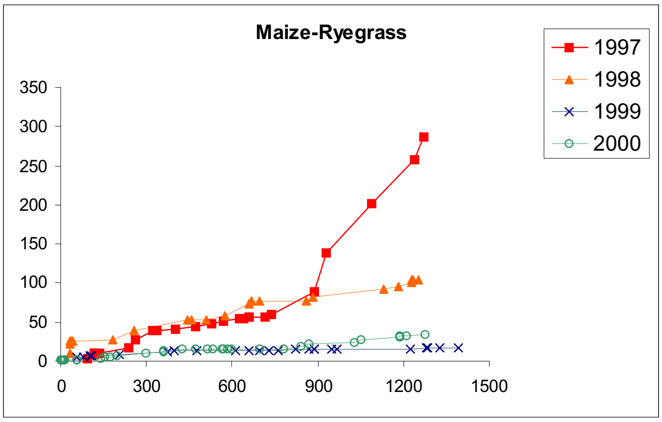


Figure 5a,b: **Seasonal curves of cumulate nitrates loss through leaching (kg/ha) in function of cumulated rainfall (mm).**

Table 3: **Summary of seasonal comparisons between crop systems (MM= maize-maize; MR= maize-ryegrass), total amount of water and nitrate loss through leaching and average water NO_3 concentration.**

Year	Rainfall (mm)	MM water loss (l/plate)	MR water loss (l/plate)	MM nitrate load (kg/ha)	MR nitrate load (kg/ha)	MM water NO_3 (mg/l)	MR water NO_3 (mg/l)
1997	1270	43.6	27.8	612	286	57.4	57.5
1998	1254	21.5	13.6	263	104	72.8	57.4
1999	1392	19.6	7.5	223	18	69.1	24.4
2000	1276	19.6	7.2	158	34	51.0	30.0

- The nitrate leaching in totally undisturbed soil after monoculture systems is relevant, especially during the first year, when almost half of the annual rainfall is lost as well as a nitrate load higher than the previous season fertilisation input rate.
- However, the use of winter cover crops in the years before the set-aside period (1992-1996) is made in order to reduce the water percolation during set-aside periods of some 30-40% with respect to the monoculture, and the nitrate leaching of some 50-60%. This could be attributed to the ability of cover crops to ameliorate soil texture and water retention capacity.
- It is anyway difficult to use this methodological approach as an effective tool for monitoring nitrate leaching, because of the high temporal and spatial variability, mainly due to the intrinsic characteristics of the systems. Probably, techniques of more spatially diffused spot leaching detection (i.e. by suction cups), integrated with precise models of water balance at territorial level, would be more predictive of the nitrate leaching from agricultural practices.

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