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Hedgerows and non point source pollution: field test and landscape planning

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Abstract

Venetian Municipality is developing several actions to control lagoon pollution, including hedgerow network planting. The hedgerow network is reintroduced by means of a GIS supported planning system that takes into account for the needing of local agriculture and the non point source pollution (NPSP) control effect on the farm and landscape scale. To implement the GIS decision support system, a complex multi-years field test was established. The influence of the hedgerow on crop production is negative in the first year and becomes more and more positive in the second and third year, and the same is for the crop quality. Some results in NPSP abatement were expected, given the hydrogeologic settings, and others are somewhat new: very narrow agroforestry multi-functional plantations have a strong effect on NPSP; the abatement capacity quickly grows in few years; the measured abatement efficiency ranged from 75 (first year) to 99% (last year) and mean annual abatement of nitrate loading passed from 37% (1st year) to 62% (3rd year); the runoff control was strongly effective and the average annual control capacity was of 85% for suspended solids, 73% for total N, 70% for total P. NO_3 abatement was extremely patchy on fine scale, low predictable and depending on NO_3 availability; on coarser scale predictability of the process grew up and other variables were selected: water table, flow rate and temperature.

Introduction

Hedgerow and woodlots perform positive functions on agriculture and environment at landscape level if correctly planned and planted. Afforestation planning should consider all the interactions that characterise such a complex system as landscape: the same afforested surface has very different agricultural, environmental, hydrological, economical effects in a rural landscape according to the distribution, localisation and structure of plantations . Landscape ecology is a necessary approach for rural agroforestry network planning because it allows to consider the hierarchical characteristics and scale problems (that are inherent in landscape processes and structures). Venetian Municipality is developing several actions to control lagoon pollution, including hedgerow network planting. The hedgerow network is reintroduced by means of a GIS supported landscape planning system (PLANLAND®©), that takes into account for the needing of local agriculture (Franco, 1997) and the non point source pollution (NPSP) controll effect on farm and landscape scale. To implement the non-point source pollution functionality in the GIS decison support system, a three years filed test was established. This test was a part of a more complex experimentation on non-point pollution in the area of Venice Lagoon, including control of manure utilisation and the implementation of the "Dafne® 1" approach to animal manure utilisation (Perelli & Franco, 1994).

Methods

Grain corn (*Zea mais* L.) was cultivated between1995 and 1997 on a calcareous clay-loam soil. The hydrogeologic settings (Hill, 1996) restrict groundwater to shallow and strong seasonal water table fluctuation. A multistoried one-line windbreak was planted on half length of a field edge (Figure 1), using grown plant material (*e.g.* 2-3 m trees, 1.5 m shrubs).

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Figure 1 Experimental field, the experimental plots (A-D), the piezometers (1-18) and runoff traps distribution (H-K) are represented.

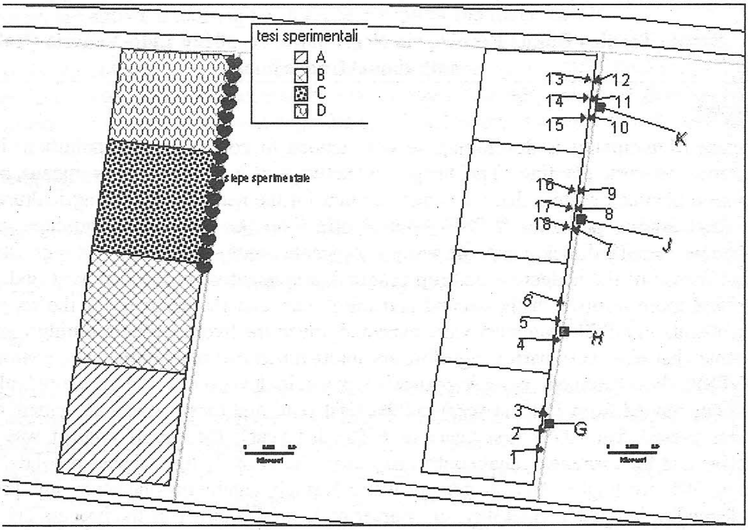
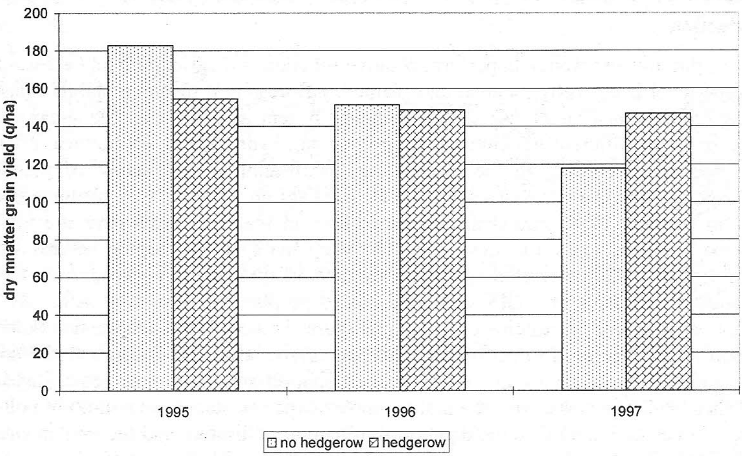


Figure 2 Hedgerow effect on grain yield (dry matter) is reported.



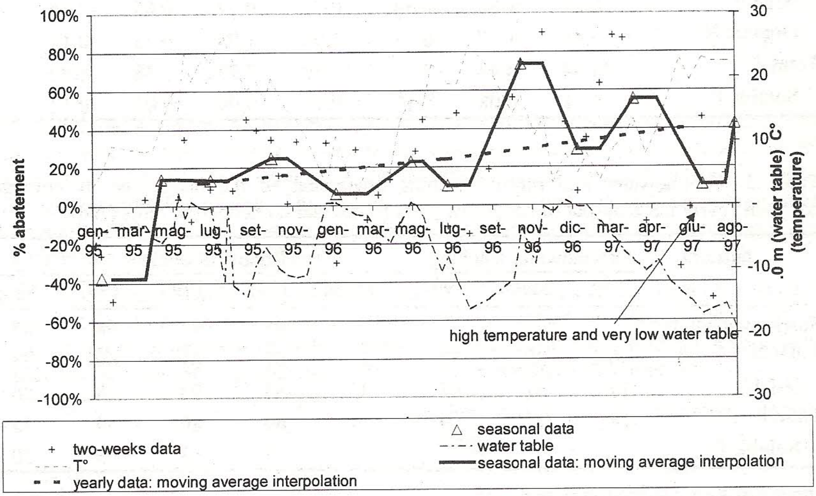
The hedgerow was realised with 2 structural schemes using local species. The nutrient losses and water table level were monitored by means of PVC piezometric wells and traps for run off. Sampling was made every fifteen days for groundwater and after every runoff event for the traps. Mass balance was done either by means of Darcy equation (coupled piezometers 7-18, C-D plots) or field water budget (not coupled piezometers 1-12, A-B-C-D plots) (Figure 1). Fertilisation was made with mineral fertiliser (urea, mono–ammonium phosphate and potassium muriate), compared with liquid animal manure, both to supply 300 kg/ha of

Table 1. Grounwater leachig of nitrogen and phosphorus (kg ha^{-1}). Yearly mean comparison between no hedgerow plots (A-B) and hedgerow plots (C-D).

nutrient	No hedgerow plots				Hedgerow plots			
	1995	1996	1997	Mean	1995	1996	1997	Mean
Total N	34.38	26.62	11.28	24.09	34.30	16.17	5.44	18.64
$N-NH_4$	2.34	3.30	1.09	2.25	1.10	3.02	0.81	1.64
$N-NO_2$	0.19	0.32	0.19	0.23	0.25	0.18	0.09	0.17
$N-NO_3$	22.55	19.53	7.89	16.66	18.78	9.53	2.99	10.43
Organic N	9.28	3.47	2.11	4.95	10.52	3.93	1.55	5.33
Total P	7.25	2.16	5.15	4.85	8.33	1.92	4.67	4.97

nitrogen, 120 kg/ ha of phosphorus (P_2O_5) and 120 kg/ ha of potassium (K_2O). Influence on crop production (quality and quantity) was assessed before each harvest. Pollutant mass balance was obtained by either hydrological budget estimation (whole field) or Darcy law (hedgerow plots).

Figure 3 Mean abatement rate of groundwater Total Nitrogen, estimated by leaching comparison between hedgertow and no-hedgerow plots.



Results

From the agronomic point of view the influence of the hedgerows on crop production is negative in the first year and become more and more positive in the second and third year, and the same is for the crop quality (Figure 2). Some results in NPSP abatement were expected, given the hydrogeologic settings (Hill, 1996):

1. Groundwater abatement process is mainly due to nitrate control (Table 1) and dissimilative processes (ammonification) are not evident;
2. Roots development (species specific) is a key condition for the abatement efficiency;
3. Abatement is ever present and shows seasonal peaks: maximum in spring and autumn, minimum in summer and winter. Spring maximum can be also explained by hedgerow uptake, but autumn maximum is probably linked to optimum environmental condition for denitrification, given that abatement takes place during vegetation rest. Summer and winter minimum are probably related to vegetation rest and bad conditions for denitrification (deep water table or low temperature) (Figure 3).

Table 2. Runoff leaching of nitrogen and phosphorus (kg ha^{-1}). Yearly mean comparison between no hedgerow plots (A-B) and hedgerow plots (C-D).

pollutant	No hedgerow plots				Hedgerow plots			
	1995	1996	1997	Mean	1995	1996	1997	Mean
Suspended solids	12,404	1,422	1,334	5,053	2,052	242	33	776
Total N	6.31	3.09	0.77	3.39	2.06	0.48	0.24	0.93
$N-NH_4$	1.32	0.45	0.16	0.64	0.74	0.17	0.05	0.32
$N-NO_2$	0.08	0.03	0.04	0.05	0.06		0.00	0.02
$N-NO_3$	0.47	1.34	0.34	0.72	0.17	0.09	0.04	0.10
Organic N	4.45	1.27	0.23	1.98	1.09	0.23	0.14	0.49
Total P	24.64	8.44	4.42	12.50	7.73	1.68	1.80	3.74
Soluble P	0.11	0.08	0.13	0.11	0.09	0.04	0.12	0.09

Table 3. Groundwater and runoff leaching abatement of the hedgerow: % comparison between yearly mass output of hedgerow plots (C-D) and no hedgerow plots (A-B).

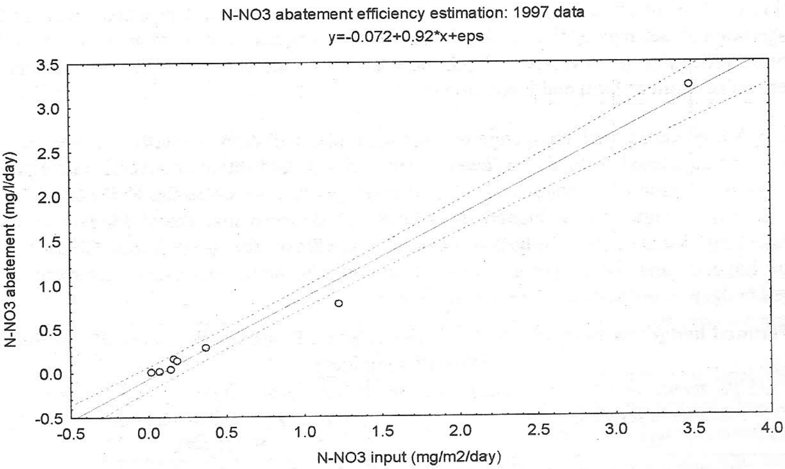
nutrient	Groundwater leaching				Runoff leaching			
	1995	1996	1997	Mean	1995	1996	1997	Mean
Suspended solids					83	83	98	85
Total N	0.2	39	52	23	67	84	69	73
$N-NO_3$	17	51	62	37	64	93	88	86
Total P	-14	11	9	2	69	80	59	70
Soluble P					13	53	5	20

Other results are somewhat news.

1. Very narrow agroforestry multi-functional plantations have a strong effect on NPSP pollution and he abatement capacity quickly grows in few years and seems to reach a steady state;
2. For groundwater leaching the mean abatement of absolute total Nitrogen was of 23% and 52% the last year (Table 3), with strong differences according to the vegetative stress of the different plantation schemes. The mean abatement of absolute nitrate loading was of 37%, and 62% the last year (Table 3).

3. The abatement efficiency (abatement vs input load) of nitrate measured in 1 meter before and after the plantation passed from 75% (first year) to 99% (last year) (Figure 4);
4. The runoff control was strongly effective from the first year given the permanent vegetated bank (Table 2); the 3 years mean annual absolute control capacity was: 85% for suspendend solids, 73% for total N, 70% for total P (Table 3).

Figure 4 D plot: relationship between daily input leaching and output abatement of N-NO_3 through the hedgerow (abatement efficiency).



From the landscape ecology point of view one result was particularly intriguing. NO_3 abatement was extremely patchy on fine scale, scarcely predictable and depending on NO_3 availability, *e.g.* NO_3 mass output was the dominant variable selected in the explorative multivariate regression models. On coarser scale (months and seasonal data aggregation) predictability of the process grew up and other (environmental) variables were selected: water table, flow rate and temperature(Table 4).

Table 4. Explorative multiple regression model for NO_3 abatement rate (dep.var.: estimated by input and output mass comparison before and after hedgerow, sample plot C-D), and chemicals and environmental variables measured/estimated (ind.var.). Multiple determination coefficients (R^2), selected variables and their regression coefficient are reported.

	R^2	Independent variables selected (regression coefficient
		Raw data
Chem fertilisers (D plot)	0.40	N-NO_3 (-0.5); N-NH_4 (-0.7); T° (0.28)
Manure (C plot)	0.25	N-NO_3 (-0.3); water flow (-0.31)
		seasonal data
Chem fertilisers (D plot)	0.5	Water table (-0.58); water flow (-0.58); rain (0.29)
Manure (C plot)	0.3	Water table (-0.27); T° (-0.18)

This suggest a hierarchical organisation of the process, which is related to different variables at the varying of the scale. The available data and the implemented methods utilised did not permit a more precise interpretation, but ongoing measures are coherent with this hypothesis and will give more results in the next 2 years.

Conclusions

The results confirm the strong abatement capacity of agro-forestry plantation designed for economic and environmental purpose even if extremely narrow (one line plantation), the only realistic ones for widespread planning in old, drained cultural landscape. This plantations are studied to give balanced results in the economic (Table 5) and conservation fields. Planning the optimum introduction of this plantation in the landscape needs knowledge about realistic effects of this plantation on several landscape processes and structure. The abatement capacity seems linked to environmental and hydrogeological variables on coarser time scale, and this could support the hypothesis of homogeneous results at landscape level given a hydrogeological settings (Hill, 1996). The results reported are implemented in a GIS supported procedure (PLANLAND®©) that permit to estimate several impacts of the planned hedgerows network at farm and landscape level.

Table 5 Some impacts of the hedgerow network planned with the GIS decision support system. The cultivated surface considered is of 14.5 km^2 and interests several municipalities of the Venice Lagoon Drainage Basin. EU incentives are referred to the Rules 2078/92 and 2080/92. Social values are estimated by comparison between investment for Nitrate NPSP abatement by means of rural hedgerow planting (Masterplan for the Pollution Control of the Venice Lagoon) and the proportional investment for the better estimated abatement of the planned hedgerow network on the same surface.

Planned hedgerow network in the Venice Lagoon Drainage Basin (12.5% of the cultivated surface)	
UE payments for hedgerow reintroduction and/or maintenance (5 years horizon)	
ecu/ha (average)	For the planned surface (ecu.)
705	9,341,441
plantation density -average range in the interested municipalities (m/ha)	
56 - 140	
Nitrogen non point source pollution abatement (range of municipalities' averages)	
Plantation average	Landscape average
40% - 95%	13% - 57%
Estimated social costs (Masterplan for the Pollution Control of the Venice Lagoon) for NPSP control by mean of agroforestry plantation (goal: 10% abatement of Nitrogen outputs)	
ecu/ha	Considered cultivated surface (ecu)
194.15	1,976,410
Estimated social values of agroforestry plantation network planned with PLANLAND©® *in the same surface (mean estimated efficiency: 49% abatement of Nitrogen outputs)*	
ecu/ha	Considered cultivated surface (ecu)
730.84	9,684,409

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