Multiscale analysis of the relationship among land use cover and streams water quality in the Venice lagoon watershed

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Introduction

The Venice lagoon is a fragile habitat threatened by water pollution. A regional plan has been created to reduce nutrients inputs to Venice lagoon to 3000 t yr^{-1} for nitrogen and 300 t yr^{-1} for phosphorus. The analyses of the relationships between the watershed Land Use (LU) and the surface water quality could provide important information for management and planning purposes. The LU patterns can be represented by simple percent values or by metrics that consider the landscape spatial patterns. Together with LU, natural watershed characteristics such as soil texture and permeability can influence water quality. The aims of this study was (1) to analyse the relationship between streams nutrients concentrations and LU patterns; (2) to verify the role of soil properties in this relationship; (3) to analyse the role of landscape spatial pattern; (4) to highlight a scale effect, (5) valuing the rural hedgerow network effect.

Methods

The Venice lagoon watershed covers about 2.124 Km^2 and it is cultivated for the 70%, mainly as grain cereals. It is an alluvial, almost entirely flat plain, with clay loam sediments; it is divided into 8 monitored sub-basins (*ca.* 90% of the total watershed). Three years (2002-2004) of ammonium and nitrate loads at the sub-basins outlets, digitised land use/land cover maps, digitised soil characteristics maps, streams and basins boundaries were obtained from Veneto Regional Agency for the Environment Protection.

LU types were aggregate into 7 classes: urban, agriculture, industrial, tree farming and orchard, natural zones, vineyards, zootechnics. Among soil characteristics, soil texture classes and soil hydrologic groups were used. Landscape metrics were selected from literature studies; in particular, we used the Shannon-Wiener index for heterogeneity (Franco, 2000) and the Effective Mesh Size index for fragmentation (Jaeger, 2000). Landscape proximity analysis was conducted by buffering concentric zones around the streams within each sub-basin. Zone widths (0-50 and 0-100 m from streams) were chosen based on the size of the sub-basins and the literature analysis (e.g. Sliva and Williams, 2001).

The autocorrelation among variables was studied by means of correlation and principal components analysis (PCA). The selected independent set of variables was then regressed against the water quality variables by means of multivariate models. The significance of the obtained models was evaluated first for their ecological relevance and then using the Akaike Information Criterion, corrected for small sample size (AICc, e.g.: Hamer *et al.*, 2006).

Results

The correlation analysis revealed a strong correlation among soil texture and hydrologic groups, which characterized also the first extracted component of PCA and MDS (data not shown). The soil characteristics were thus represented by the PCA first extracted component in the regression analysis (F1), in order to reduce the redundancy among predictors.

The models obtained by the regression analyses, selected for their ecological relevance and their ΔAICc are listed in table 1. The two competing models for ammonium indicated that NH_4 loads were dependent on industrial LU at the whole watershed scale and on urban LU at the 50m buffer scale, and on soil characteristics at both scales. Nitrate loads were dependent on agriculture at the three scales, and on heterogeneity at the whole watershed scale.

The regressions performed using the most significant variables at the three spatial scales were not significant ($p>0.05$, data not shown).

Discussion and conclusions

Ammonium loads were dependent mostly on industrial and urban LU: this may reflect a higher concentration of sewage and waste disposal associated with urban and industrial areas (Jones *et al.*, 2001). The relationship with soil characteristics indicated that finer textured, low permeable sub-basins have a higher NH_4 content. In facts, clay minerals and clay humics have a larger potential for adsorption of nutrients such as ammonia, and the low permeability enhances overland flow that may easily carry particulates with adsorbed nutrients into rivers (Sliva and Williams, 2001). The relationship among nitrate loads and agriculture is frequently reported in literature (e.g. Sliva and Williams, 2001) and represents the contribution of fertilizers to the non-point source pollution. The negative relation with heterogeneity at the watershed scale can be explained by the impact of ecotone density (generally matching with ditches in this ancient reclaimed land) on nitrate dynamic.

Several researchers have addressed the issue of whether LU near rivers is a better predictor of water quality than LU over the whole watershed (e.g. Sliva and Williams, 2001), obtaining contrasting results. Our results show that in the Venice watershed there were not significant differences among spatial scales. This could be due to the highly impacted structure of this landscape, where agriculture was 60-75%, urban LU 9-28% and natural zones were less than 8%, even in the 50m buffer zone.

Table 1. Competing models. AG: agriculture; URB: urban; IND: industrial; F1: PCA factor (soil texture and permeability); Shannon: heterogeneity index; AICc: corrected Akaike Information Criterion. In brackets the sign of the relationship.

Nutrients	Variables	R^2	AICc	ΔAICc	Scale
Ammonium	IND(+), F1(+)	0.83	-60.53	0.00	Watershed
	URB(+), F1(+)	0.81	-58.81	1.72	50m
Nitrate	AG(+)	0.69	-26.85	0.61	Watershed
	Shannon(-)	0.67	-25.70	1.76	Watershed
	AG(+)	0.71	-27.47	0.00	100m
	AG(+)	0.67	-25.69	1.78	50m

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