Nitrogen cycling in artificial ponds within agricultural watersheds: urgent need of best management practices to favor denitrification over N_2 fixation

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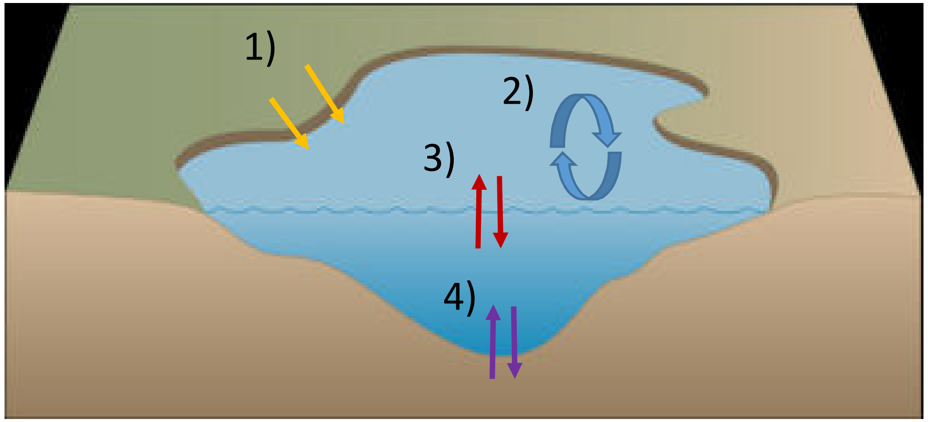
Seasonal characterization of pelagic and benthic processes



1) The Maceri are polluted by point and diffuse sources of nutrients. By means of a GIS approach it is possible to evaluate the potentially generated loads.
2) By means of light and dark bottle incubation we analyzed water column metabolism in order to perform an oxygen budget.
3) We also analyzed dissolved gas (O_2, CH_4, CO_2 and N_2) saturation in order to infer whether these shallow systems are net autotrophic or heterotrophic
4) Intact sediment cores were collected in order to analyze oxygen and nutrient exchange between the surface sediments and the water column

All analysed maceri lay within heavily simplified/impacted areas

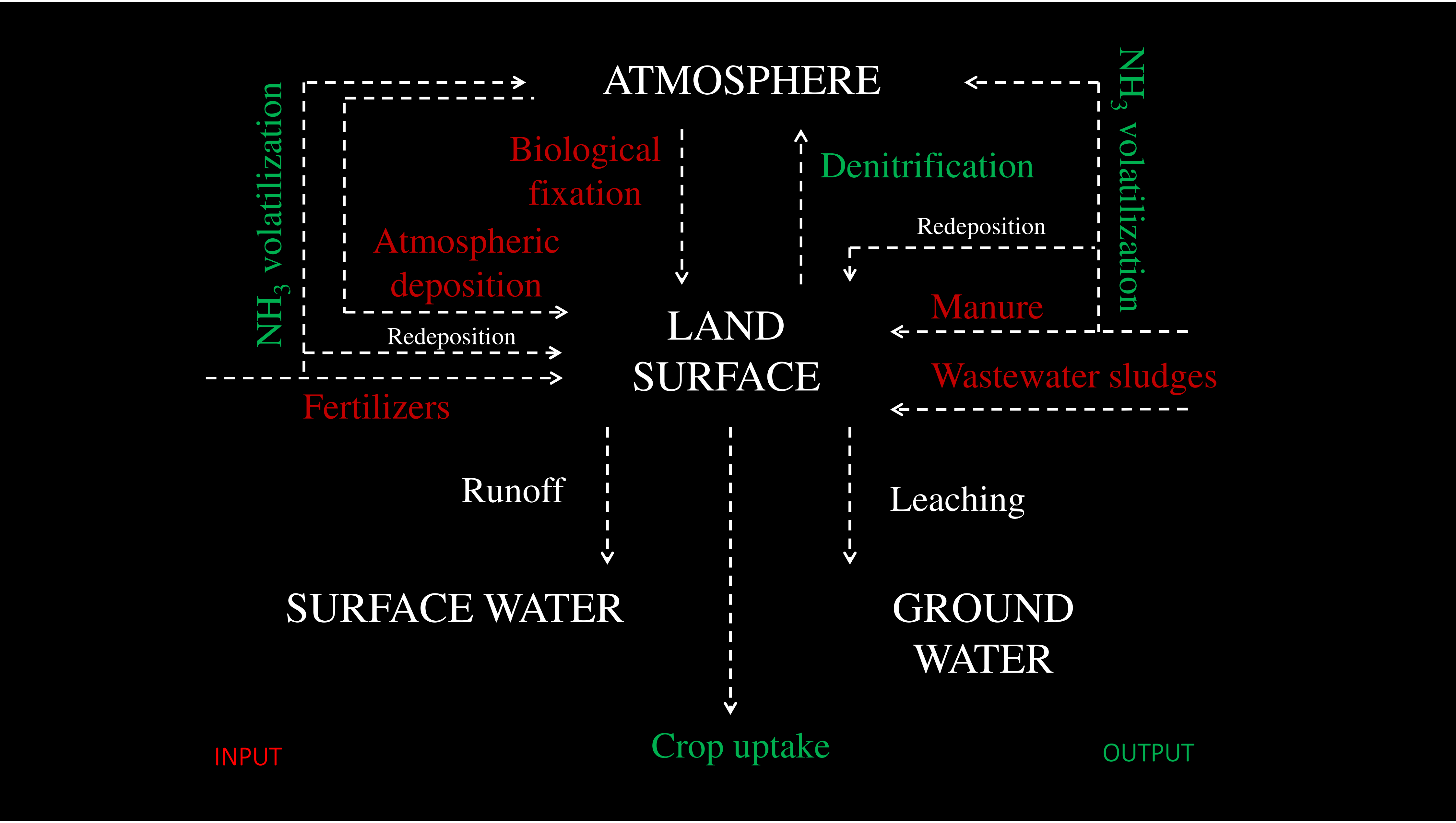
Land use in the 100m and 300m buffer areas of the six ponds.

*Urban area includes also road and rail networks and associated land.

Surface (%)	Quarto		Granarolo		Sala		B3		E17		NE81	
	100 m	300 m	100 m	300 m	100 m	300 m	100 m	300 m	100 m	300 m	100 m	300 m
Arable land	87	87	10	52	100	100	20	39	12	24	100	80
Permanent crops (fruit trees)	0	0	0	0	0	0	0	0	0	0	0	20
Permanent crops (ornamental tree nurseries)	0	0	90	35	0	0	0	0	0	0	0	0
Urban area*	13	10	0	2	0	0	20	23	73	52	0	0
Artificial vegetated area (urban parks)	0	0	0	11	0	0	0	0	15	24	0	0
Industrial area and construction sites	0	3	0	0	0	0	60	38	0	0	0	0

GIS-based approaches may allow to quantify the potential sources of pollution to these aquatic bodies

E. Soana



ATMOSPHERE
NH3 volatilization
Biological fixation
Denitrification
NH3 volatilization
Redeposition
Atmospheric deposition
Redeposition
LAND SURFACE
Manure
Wastewater sludges
Fertilizers
Runoff
Leaching
SURFACE WATER
GROUND WATER
Crop uptake
INPUT
OUTPUT

Macrophyte characterization

	site					
	QI	**GR**	**SB**	**NE81**	**E17**	**B3**
Species						
Hydrophytes						
Lemna gibba					x	
Lemna minor	x				x(d)	
Lemna minuta	x(d)					
Ranunculus (??)			x			
Helophytes/Amphibian						
Bolboschoenus maritimus (group)			x			
Butomus umbellatus		x				
Carex acutiformis			x			
Cyperus longus		x	x			
Eleocharis palustris		x				
Equisetum palustre		x				
Lycopus europeaus				x	x	x
Mentha aquatica		x				
Paspalum distichum		x(d)		x	x	
Phalaris arundinacea s.str.					x	
Phragmites australis	x	x	x		x	
Ranunculus sceleratus						x
Rorippa amphibia	x	x		x		
Stachys palustris				x		
Sparganium erectum s.str.				x		
Typha latifolia		x(d)		x(d)		

All the investigated maceri are characterized by extremely simplified aquatic or riparian plant communities; they appeared as phytoplankton-dominated water bodies.

Only two of the six macery showed a well developed hydrophytes community, dominated by annual eutrophic free-floating species belonging to Lemna genus (Lemna gibba, L. minor, and L. minuta); at the site B3 exclusively few individuals of *Ranunculus* were recorded at the beginning of the investigation period.

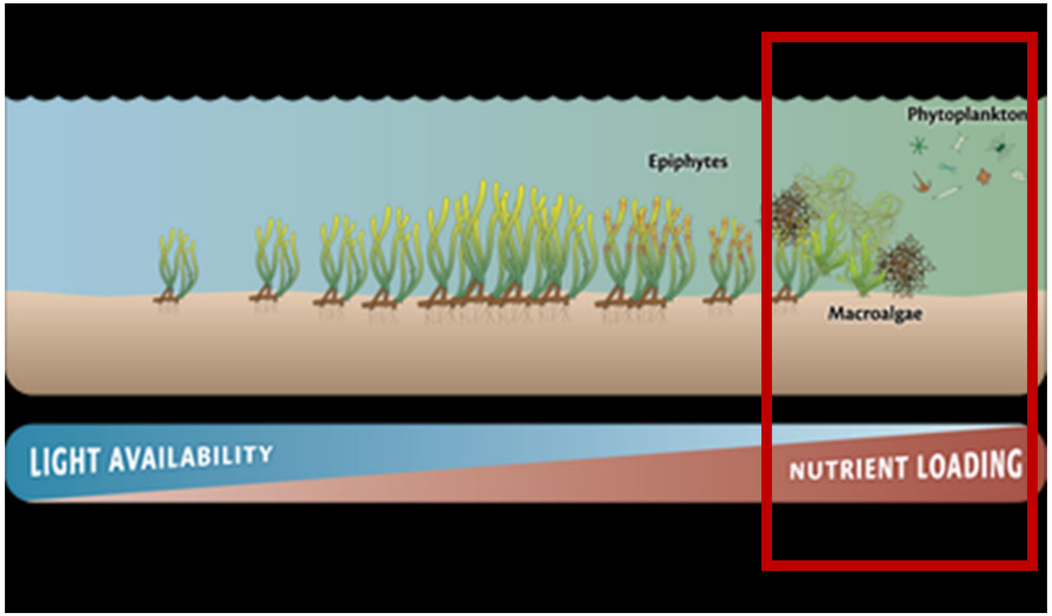
The riparian sectors were characterized by discontinuous helophytic belts – generally dominated by Typha latifolia or Paspalum distichum – frequently coupled with isolated individuals or, more or less continuous fringes dominated by *Salix alba*.

R. Bolpagni

Phytoplankton community

Taxa	Ponds					
	Quarto	Granarolo	Sala	B3	E17	NE-81
Cyanobacteria (blue-green algae)						
Anabaena sp.	-	+	+	+	-	+
Merismopedia sp.	-	-	-	+	-	-
Microcystis sp.	-	+	+	+	-	-
Oscillatoria sp.	-	-	+	+	-	+
Chlorophyta (green-algae)						
Ankistrodesmus sp.	+	-	-	-	-	-
Ankyra sp.	-	-	-	-	+	-
Chlorella sp.	+	+	+	+	+	+
Closterium sp.	+	-	-	-	-	-
Crucigenia sp.	+	+	-	-	-	-
Chlamydomonas sp.	-	-	-	-	+	+
Golenkinia	+	+	-	-	-	-
Kirchneriella	+	-	+	+	+	-
Monoraphidium	+	+	+	+	+	+
Quadrigula	-	+	-	-	-	-
Scenedesmus	+	+	+	-	-	-
Tetraspora	-	-	+	+	-	-
Mougeotia	-	+	+	+	-	-
Zygnema	+	-	-	+	-	+
Crisophita (gold brown algae)						
Dinobryon	-	+	-	-	-	-
Bacillariophita (diatoms)						
Fragilaria	+	-	+	-	-	-
Navicula	+	+	+	+	+	+
Nitzschia	+	-	+	-	+	+
Synedra	+	-	+	+	+	+
Euglenophita (euglenoids)						
Euglena	-	-	-	-	-	+
Number of genera/total	13/24	11/24	13/24	12/24	8/24	10/24

	Quarto	Granarolo	Sala	B3	E17	NE-81
Chl a max	169.5	161.6	45.1	317.2	74.0	281.0
Chl a min	0.9	40.7	2.3	58.1	13.9	0.3
Chl a M	32.4	97.0	17.3	144.8	46.0	74.5



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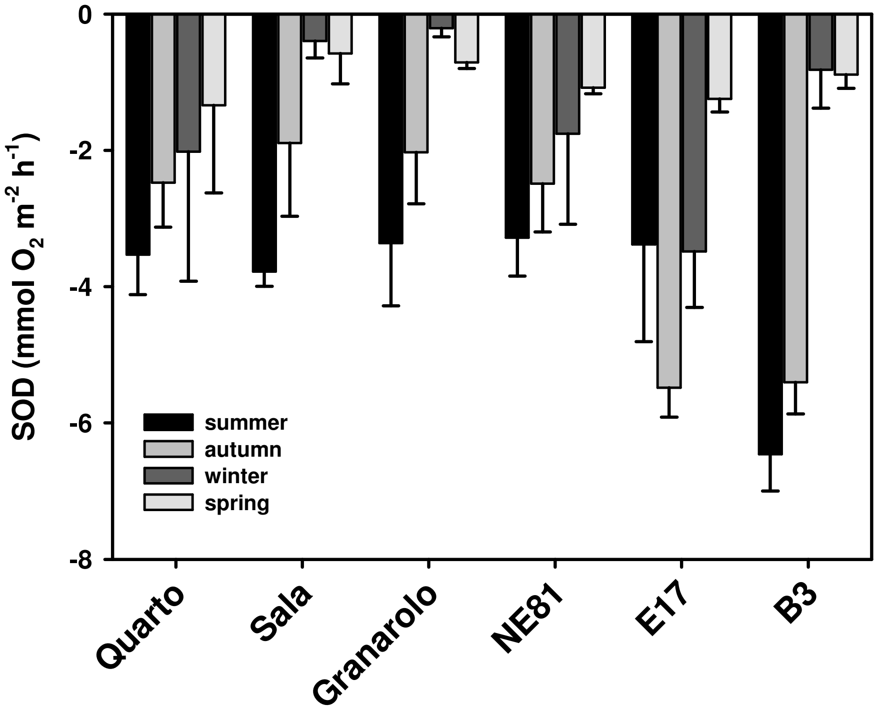
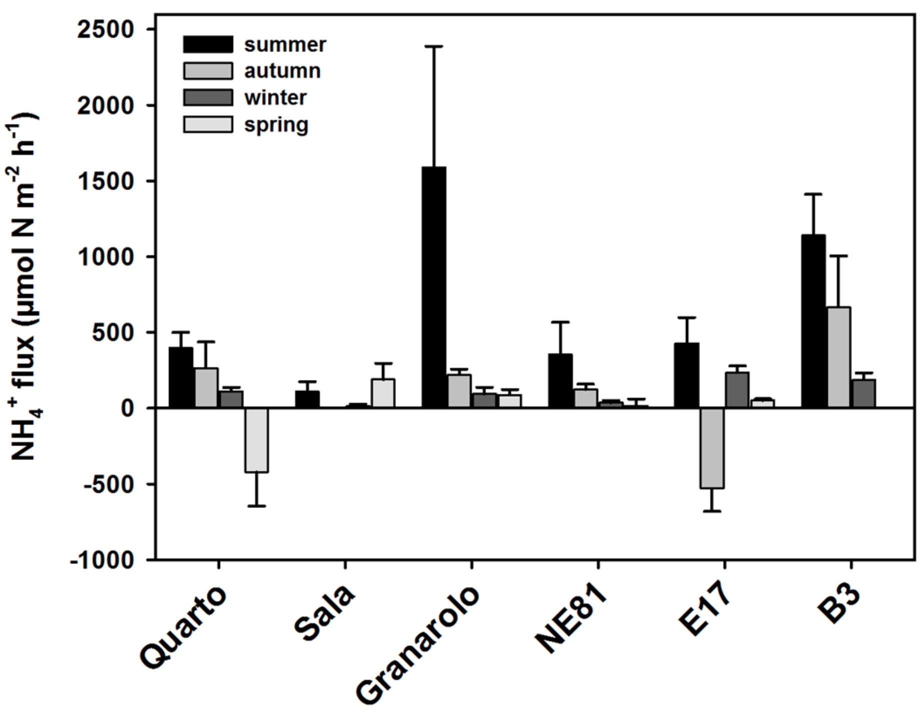
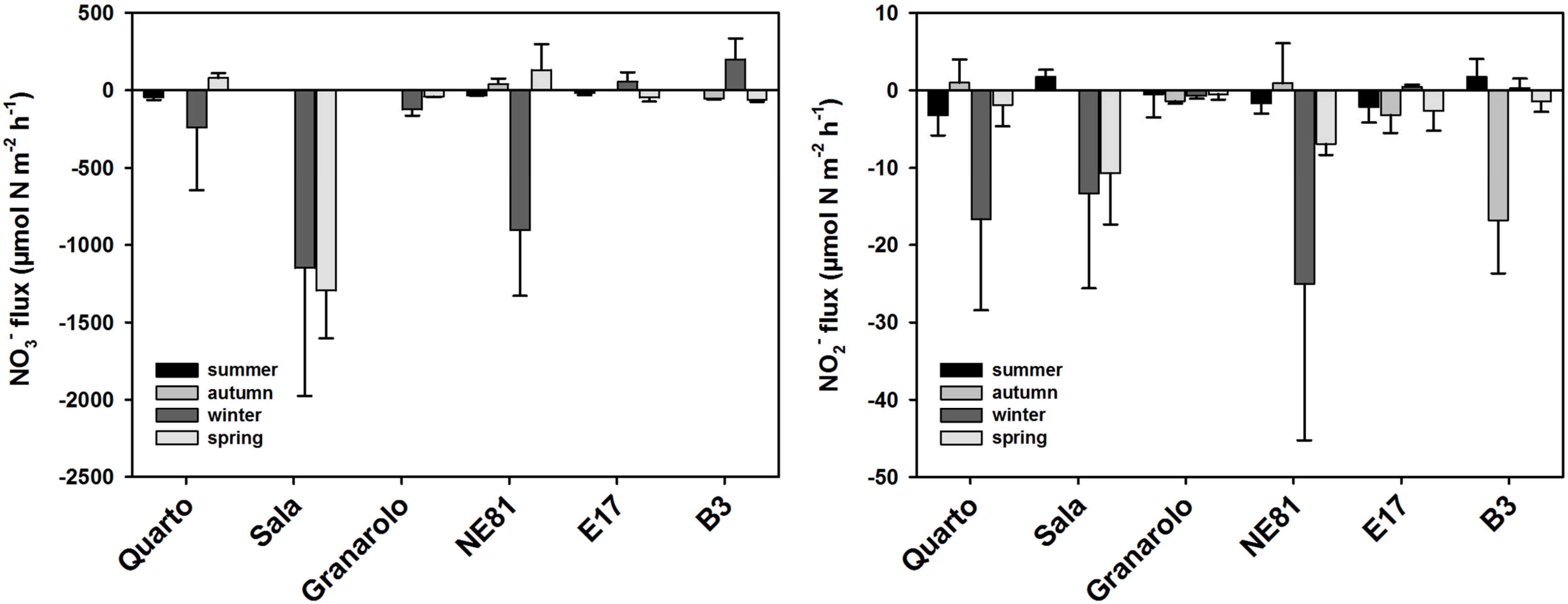
Benthic respiration and nutrient cycling





Organic sediments results in elevated oxygen consumption and high regeneration of ammonium

When present, oxidized forms of reactive nitrogen are consumed, likely via denitrification



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Nitrogen Budget in a Lowland Coastal Area Within the Po River Basin (Northern Italy): Multiple Evidences of Equilibrium Between Sources and Internal Sinks

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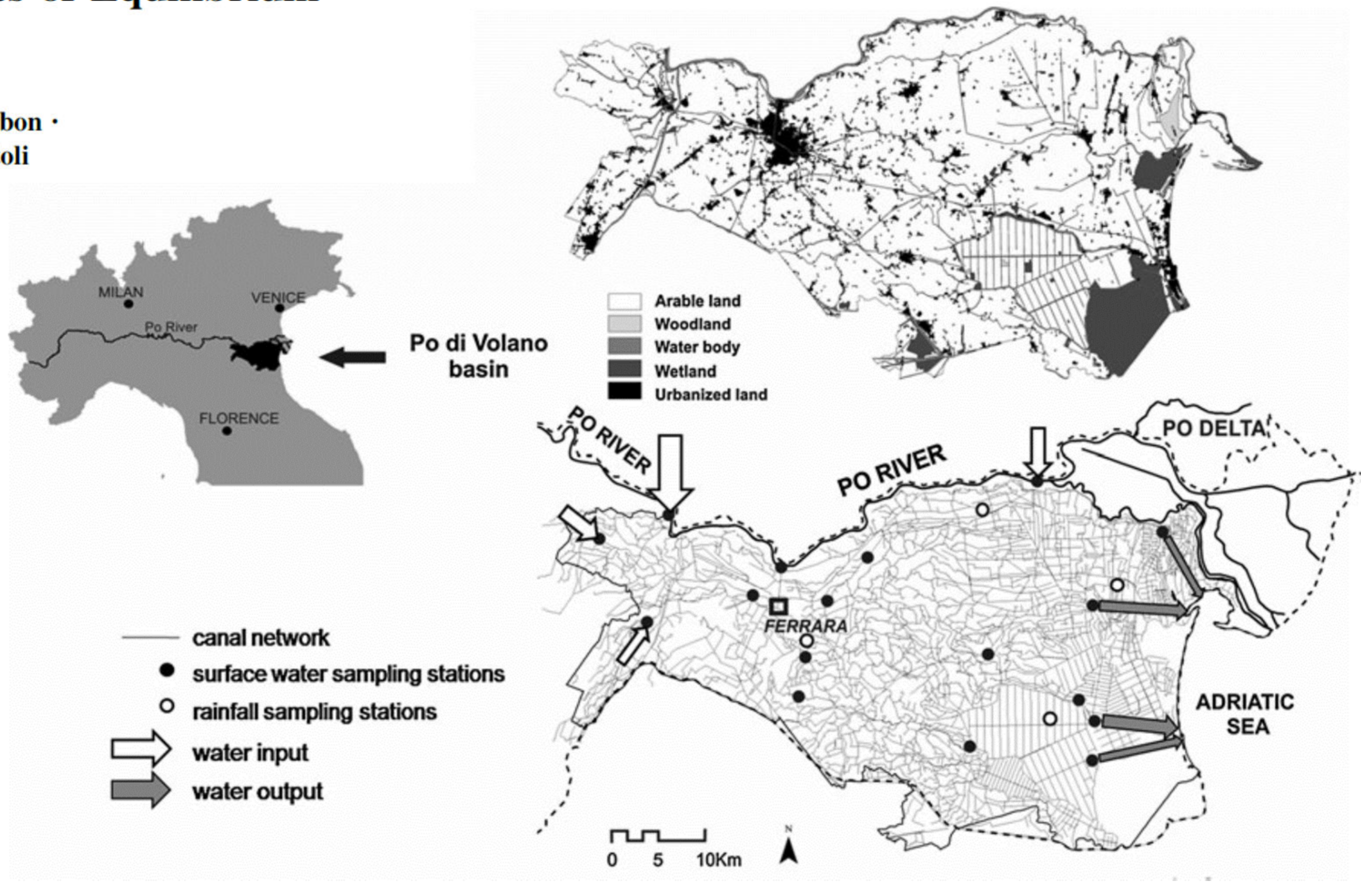


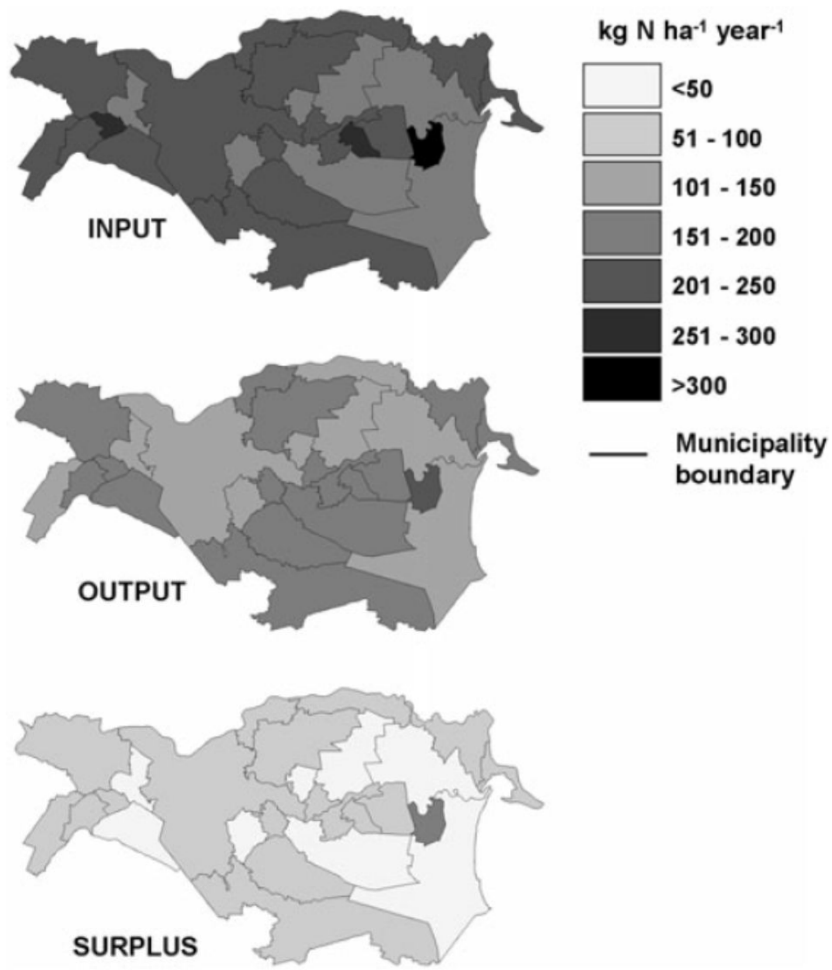


Fig. 2 Spatial distribution of nitrogen input, output, and surplus in each municipality of the Po di Volano watershed (average values of the 3-year period 2006–2008)

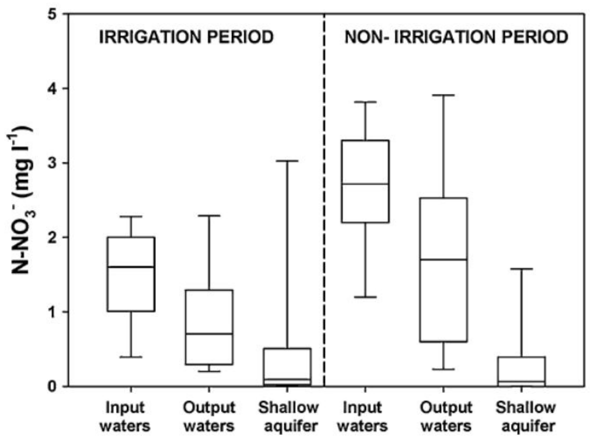


Fig. 3 Boxplot reporting the nitrate concentrations in water imported and exported by the hydrological network of the Po di Volano watershed (17 sampling stations) and in the shallow aquifer (56 sampling stations). Median, 25th, 75th percentiles are indicated

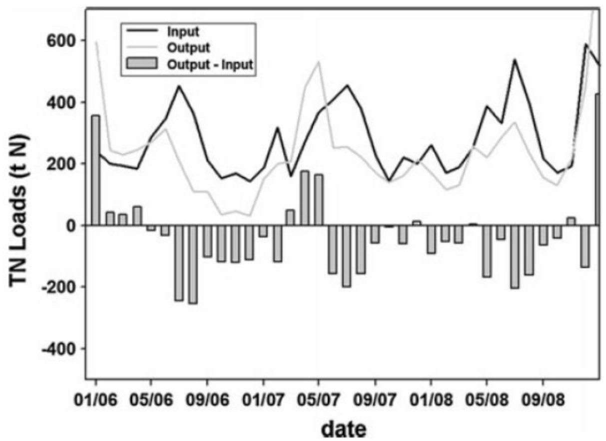


Fig. 4 Temporal pattern of total N loads, reported as input, output and their monthly difference in the hydrological network along the 3-year period 2006–2008

Table 1 Soil system budget for the Po di Volano watershed

	t N year^{-1}	kg N ha^{-1} year^{-1}	% of total
Input			
Synthetic fertilization (N_{SF})	26,225 (2,360)	143 (10)	66.6
Animal farming (N_{AF})	2,162	12	5.5
Biological fixation (N_{BF})	8,450 (921)	46 (6)	21.5
Atmospheric deposition (N_{AD})	2,399	13	6.1
Wastewater sludge (N_{WS})	115	1	0.3
$\sum$Input	39,350 (1,514)	214 (4)	100
Output			
Crop uptake (N_U)	21,574 (2,177)	117 (9)	76.3
Ammonia volatilization (N_V)	4,451 (352)	21 (1)	15.7
Denitrification in soil (N_D)	2,254 (182)	12 (1)	8.0
$\sum$Output	28,279 (2,606)	154 (11)	100
$\sum$Input − $\sum$output	11,071 (1,330)	60 (8)	

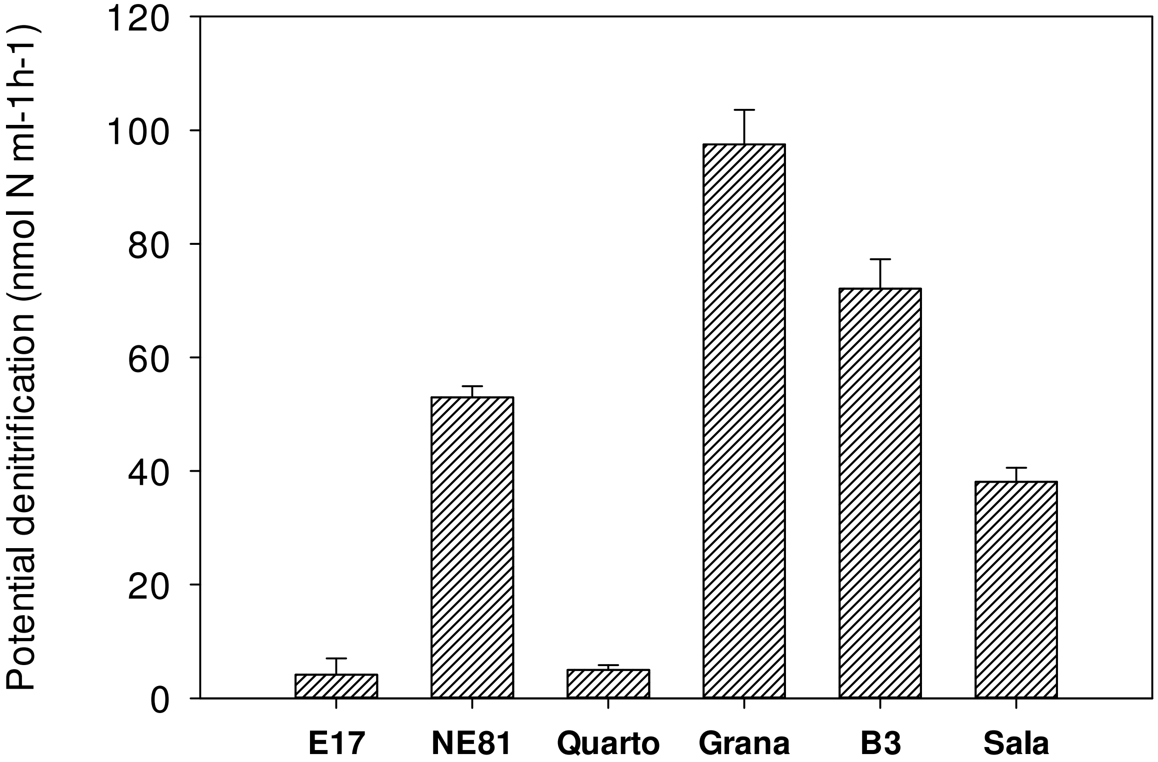
Balance terms (with the exception of N_{AF}, N_{AD} and N_{WS}) are reported as average ± standard deviation for the 3-year period 2006–2008

In this geographical area the average N excess is 60 kg ha^{-1}

This is a small amount if compared to most river basins in the Po River Plain, further reduced by the metabolic activity of bacteria and macrophytes within the secondary drainage basin

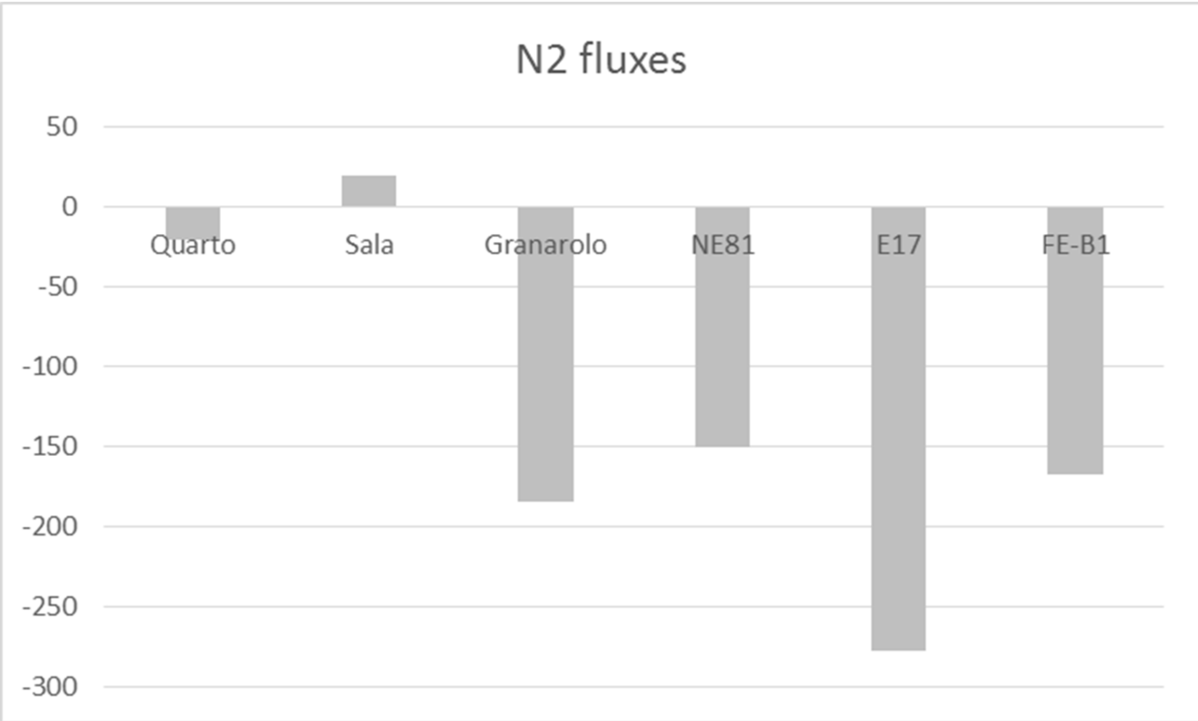
Potential denitrification rates

$NO_3^- \rightarrow NO_2^- \rightarrow N_2$



On a hectar annual basis, the highest rates of potential denitrification measured in this study corresponds to nearly **1200 kg N** removed per ha per year, which is among the highest reported rate of denitrification. As the average nitrogen surplus in the Ferrara Province is in the order of 60 kg N per ha per year, a pond with such capacity could remove the N excess equivalent of **20 ha** of agricultural land.

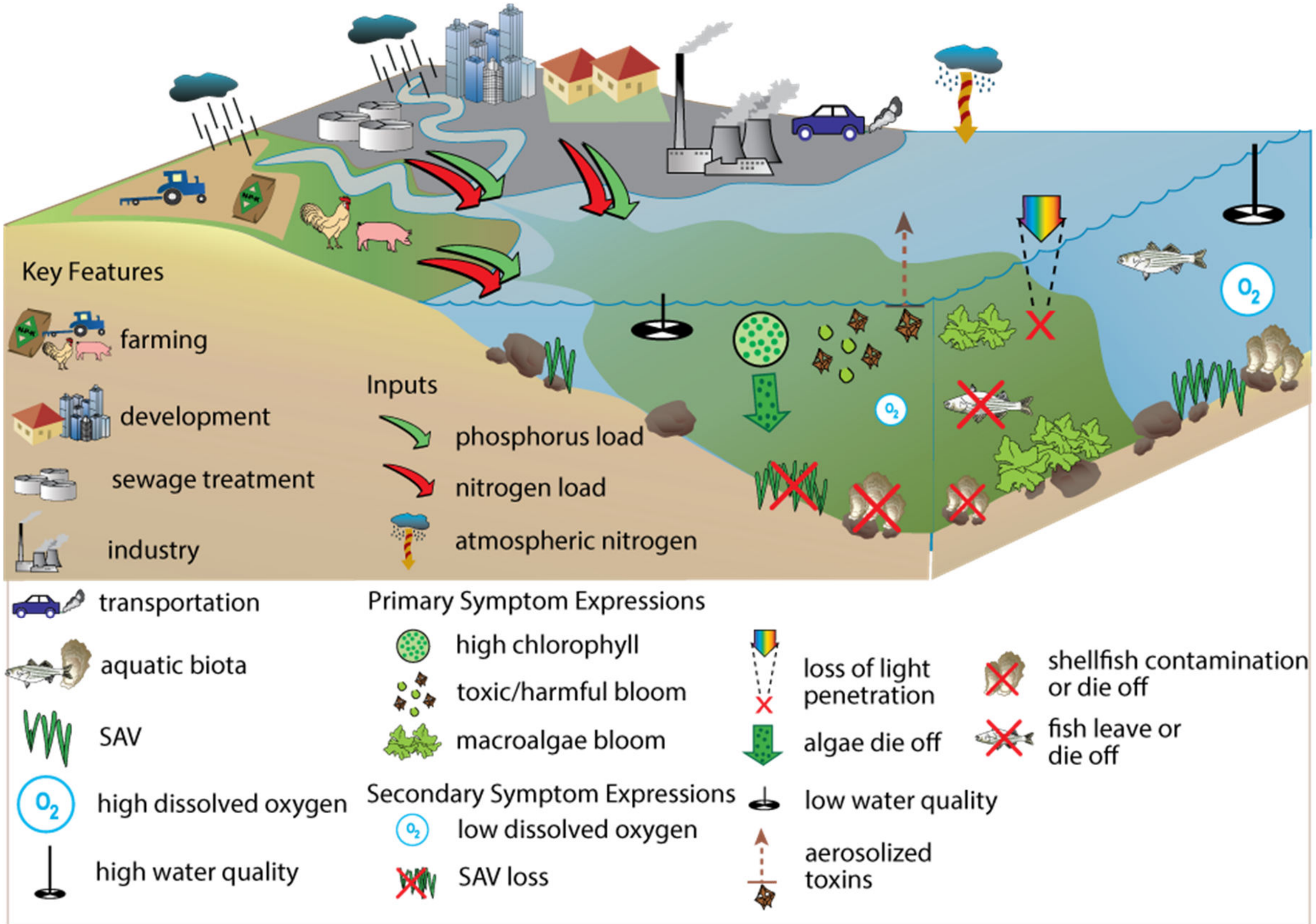
Net fluxes of molecular nitrogen



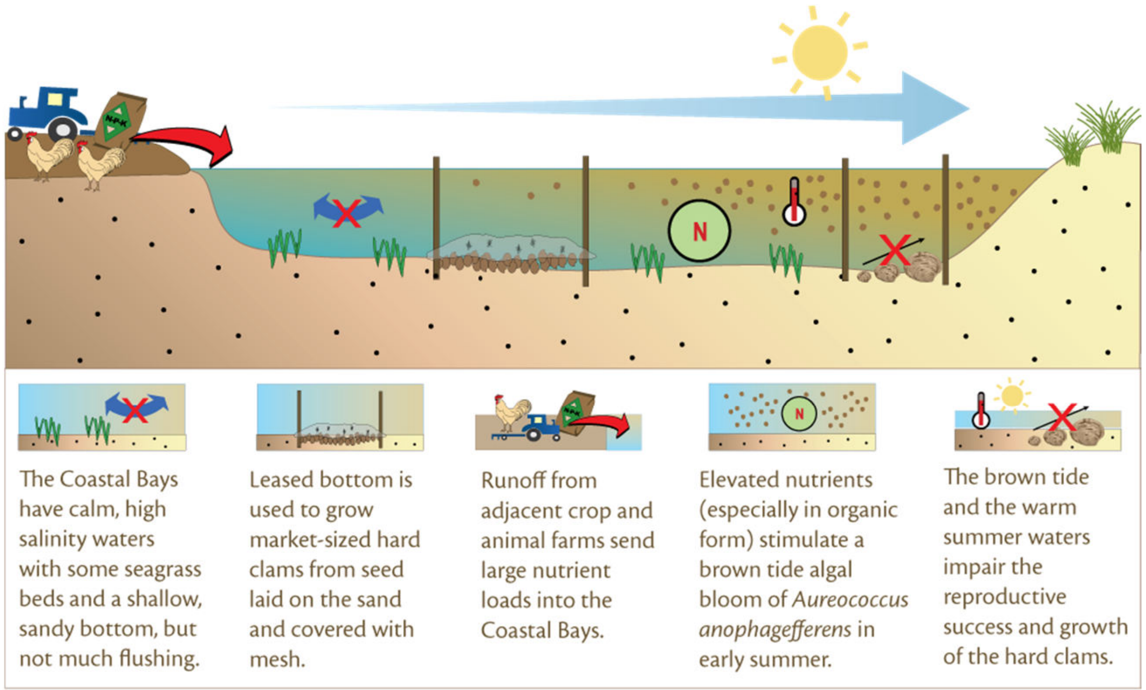
In July nitrogen fixation exceeded denitrification in 5 out of 6 analyzed systems, resulting in net N2 fluxes directed to the benthic system and not to the atmosphere.
Paradoxically nitrogen is imported to the system

Concluding remarks

- The Maceri represent an opportunity
- They should be the center of a large scale requalification project
- They can link the secondary drainage network, in a canal-pond sequence: as such they can slow or even reverse the continuous loss of species and have a role for plant and animal biodiversity in a oversimplified agricultural context
- They can also metabolize efficiently a relevant fraction of excess nitrate via denitrifcation, in particular if they are permanently connected to canals.
- This service is relevant, but at present is sometimes offset by N-fixation
- Other countries (i.e. Denmark) have requalified, enlarged or created new ponds and have moved towards a precision agriculture, including the evaluation of denitrification potential of different areas
- Such interventions were monitored and resulted successful and appreciated by farmers



Key Features
farming
development
sewage treatment
industry
transportation
aquatic biota
SAV
high dissolved oxygen
high water quality
Inputs
phosphorus load
nitrogen load
atmospheric nitrogen
Primary Symptom Expressions
high chlorophyll
toxic/harmful bloom
macroalgae bloom
Secondary Symptom Expressions
low dissolved oxygen
SAV loss
loss of light penetration
algae die off
low water quality
aerosolized toxins
shellfish contamination or die off
fish leave or die off



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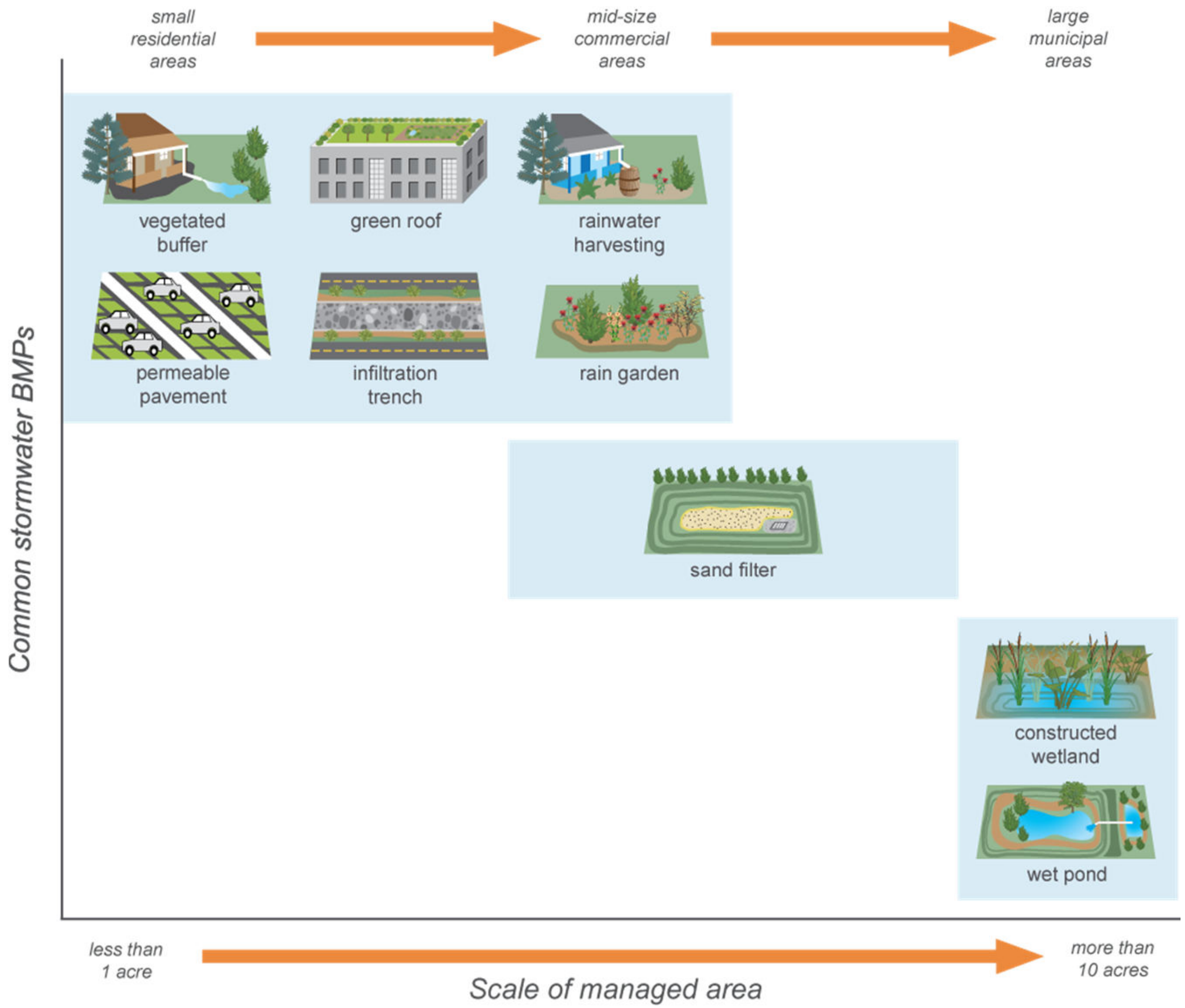
A conceptual diagram illustrates the characteristics of the Coasta Bays and how some human activites stimulate the growth of agal blooms. These blooms impair the repoductive sucess of several species, particularily the hard clam.

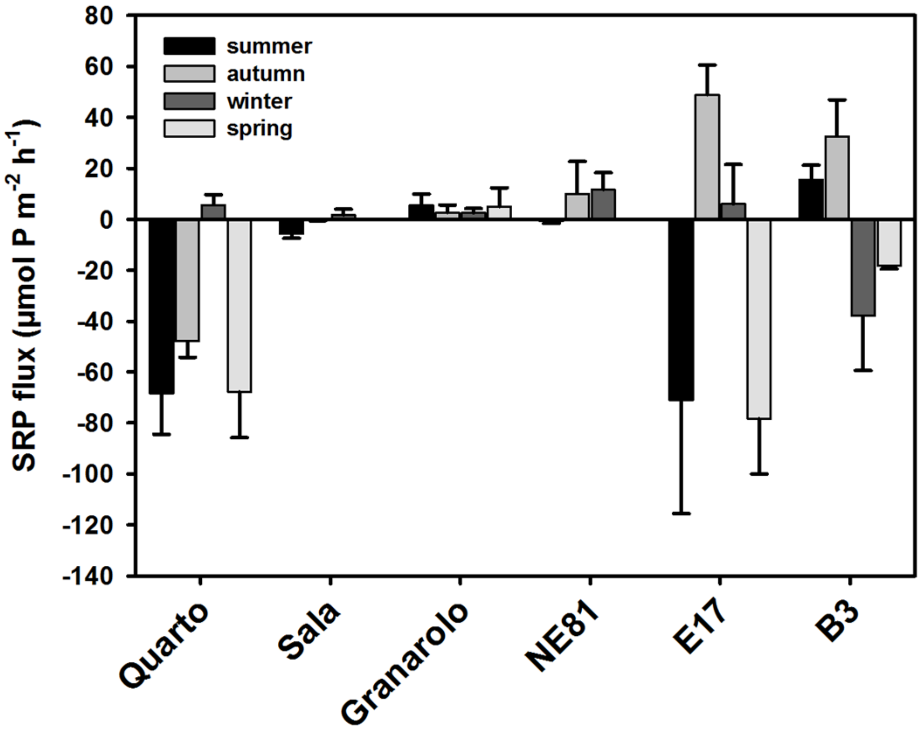
Diagram courtesy of the Integration & Application Network, University of Maryland Center for Environmental Science.

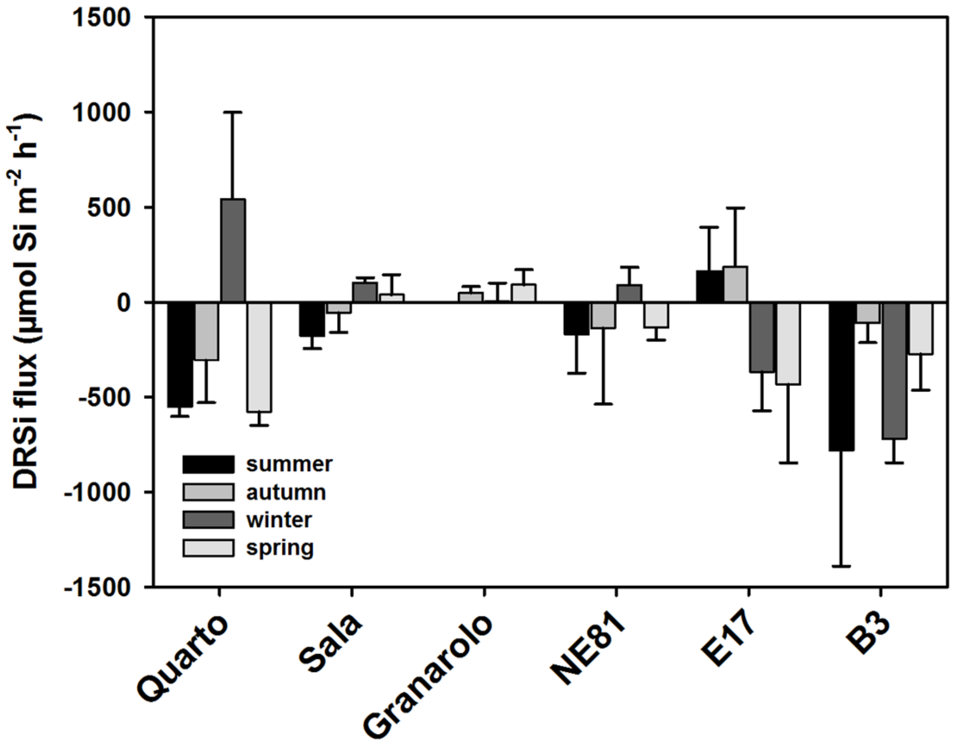


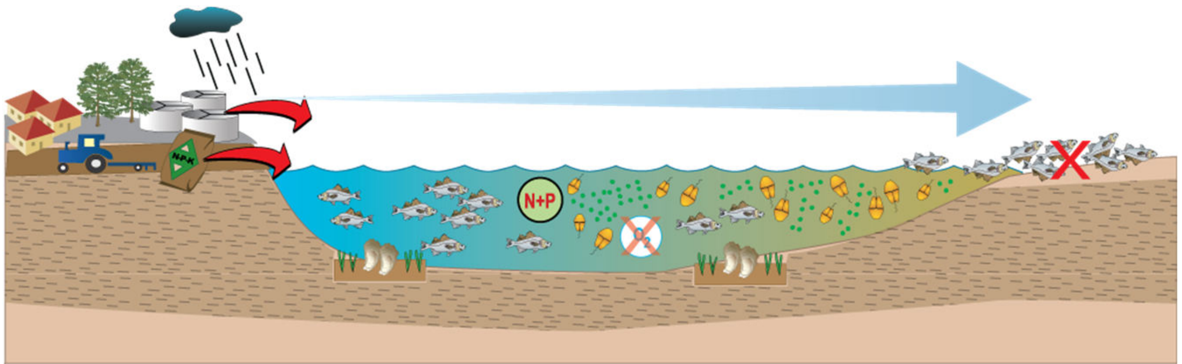
Conceptual diagram illustrating Best management practices (BMPs). Maryland's stormwater management program encourages existing and new developments to adopt strategies that minimize the impacts of stormwater runoff from the impervious surfaces. Best management practices (BMPs) are strategies that can be used to manage this runoff. Examples of some of the more common BMPs designed for small residential areas, mid-size commercial areas, and large municipal areas are shown in the table.

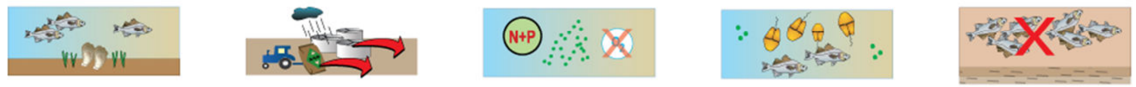
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013. Stormwater Management: Reducing Water Quantity and Improving Water Quality. IAN press, newsletter publication.

Fluxes of reactive P and Si display a large variability with different patterns among seasons and sites









The shallow, brackish Corsica River is home to white perch and menhaden. Restoration of aquatic vegetation and oyster beds are underway.

Agricultural input, as well as sewage overflow following heavy rains, sends large nutrient loads into the river.

Elevated nutrients stimulate a large phytoplankton bloom which, as it decomposes, leads to low oxygen levels.

Karlodinium veneficum, an abundant dinoflagellate found in the algal bloom, releases karlotoxins.

The levels of karlotoxins are sufficient to cause a large fish kill, primarily of white perch.

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A conceptual diagram illustrates the characteristics of the Corsica River and how certain human activities, such as agriculture and sewage disposal, elevate nutrient levels in the river and stimulate algae bloom growth.

Diagram courtesy of the Integration & Application Network, University of Maryland Center for Environmental Science.