Comparing Agricultural and Urban Nutrient Loads to Coastal Systems

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Nutrient loads and aquaculture

- Aquaculture and nutrients: an ambivalent relation
  - Nutrients support primary production and food, but…
  - Excessive loads can cause eutrophication

- Nutrient management has focused on wastewater
  - Point sources: easy to locate, measure and control

- Agricultural sources are more difficult to manage
  - Variable in space, depend on weather
  - Difficult to measure and to identify sources
  - Difficult to design control measures

Objectives of this work

- Compare nutrient loads to coastal systems from wastewater and agriculture…
  - Recent evolution
  - Spatio-temporal patterns
  - Sources and potential impacts

- … for two coastal systems with important aquaculture sites
  - Lough Foyle, UK
  - Ria Formosa, Portugal

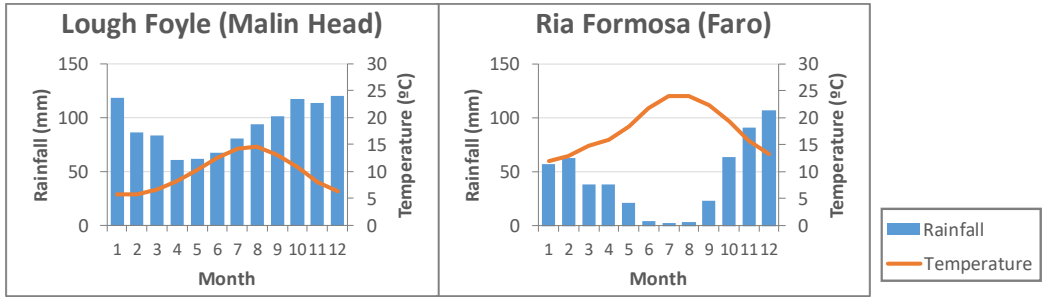
Study systems

Lough Foyle

- Oceanic climate
- Aquaculture: mussels and native oysters (bottom culture)
- Trophic status:
  - High nutrient loads, mostly N
  - Few eutrophication symptoms: shellfish filtration (?) and P limitation (?)

Ria Formosa

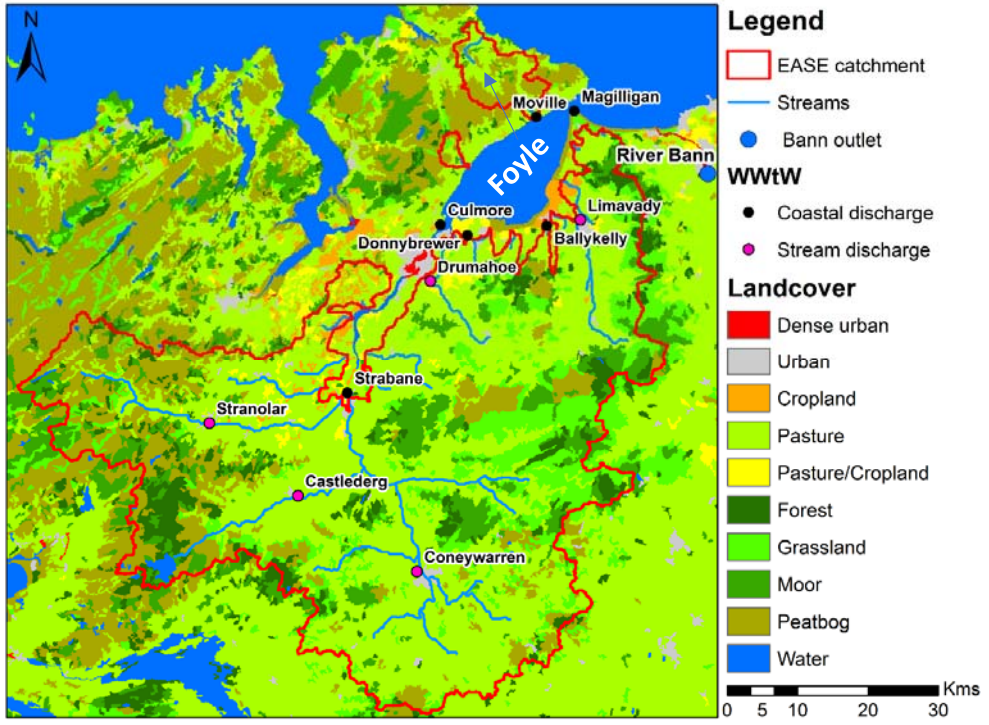
- Mediterranean climate
- Aquaculture: clams (traditional) and mussels (offshore, developing)
- Trophic status:
  - High nutrient loads
  - Few eutrophication symptoms due to strong water exchange…
  - … but occasional water quality issues and macroalgae blooms



Lough Foyle: Loughs Agency 2012: Lough Foyle Status Report
Ria Formosa: Ferreira et al. 2013: FORWARD project report

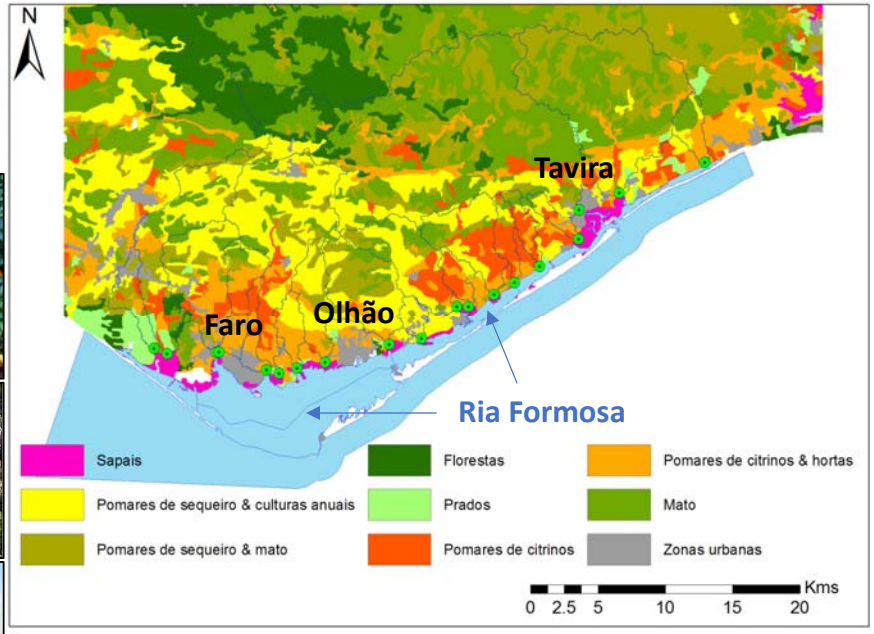
Lough Foyle watershed

- Area: 3709 Km^2
- Wastewater discharge: 210,000 inhabitants
- Landuse:
  - Pasture: 54%
  - Rangelands: 43%
  - Croplands, urban: 3%



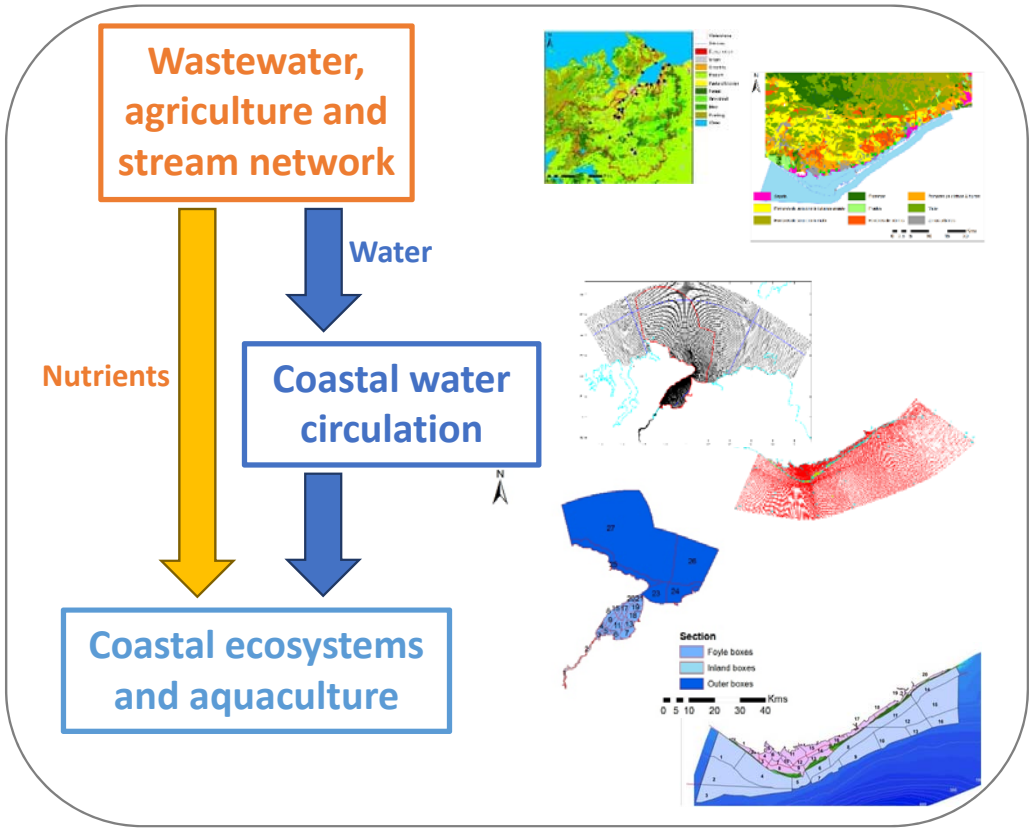
Ria Formosa Watershed

- Area: 745 Km^2
- Wastewater discharge: 300,000 inhabitants
- Landuse:
  - Croplands – intensive orchards: 18%
  - Croplands – rainfed orchards: 29%
  - Rangelands: 48%
  - Other crops, urban, pasture: 5%
- Contaminated coastal aquifer



Research framework

- Large-scale aquaculture assessment projects in both systems
  - Linking catchments to coasts
  - Linking management agencies and research institutes
  - Tool: complex modelling framework



Lough Foyle

EASE: Enhanced SMILE for Lough Foyle

Ria Formosa

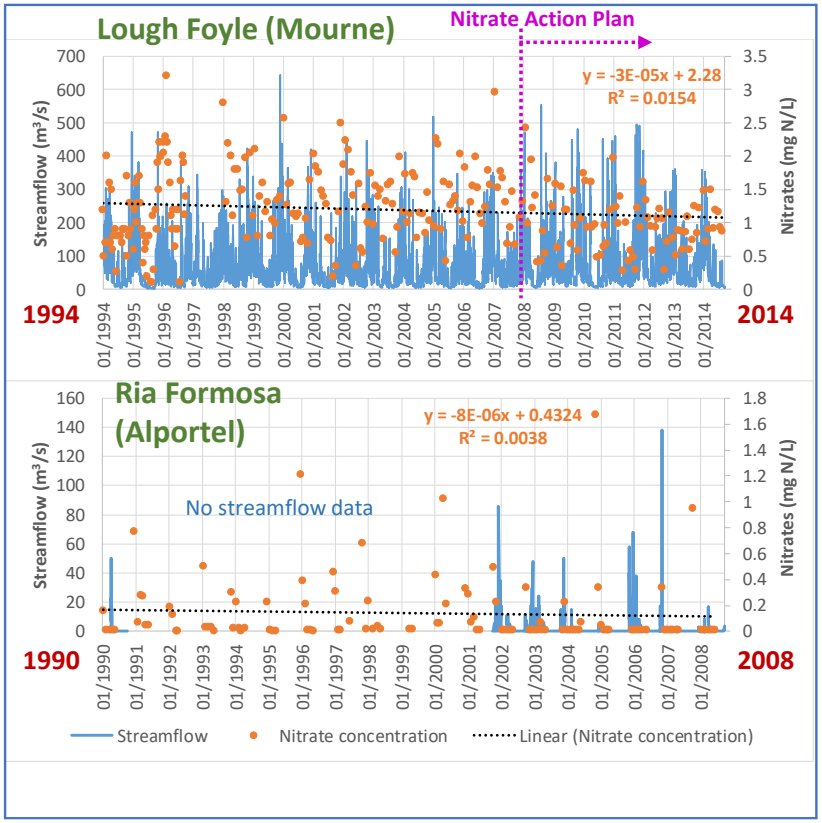
Framework for Ria Formosa water quality, aquaculture & resource development

Wastewater nutrient loads

- Point-sources:
  - Measured, easy to quantify
  - Relatively constant along the year
- Recent trends:
  - Improved wastewater treatment by adding nutrient removal
  - Ria Formosa: increase in population served by treatment plants
- Wastewater treatment close to maximum

Agriculture nutrient loads

- Diffuse sources:
  - Difficult to measure, quantify and assign to sources
- Trends difficult to assess:
  - Monthly measurements do not capture peak flows
  - High temporal variability
- What was the impact of fertilizer control measures?



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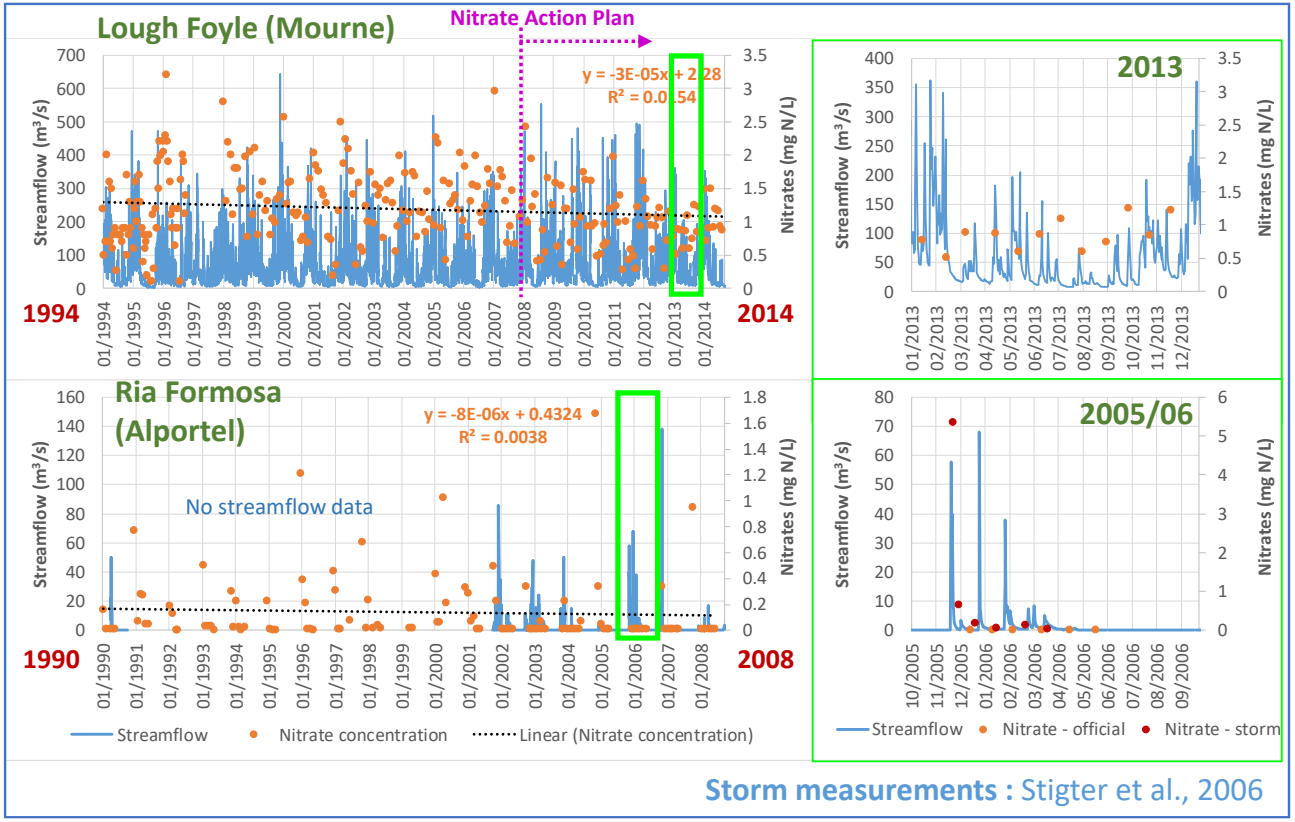
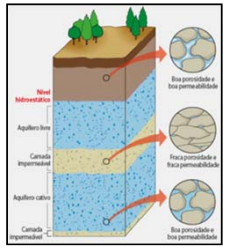
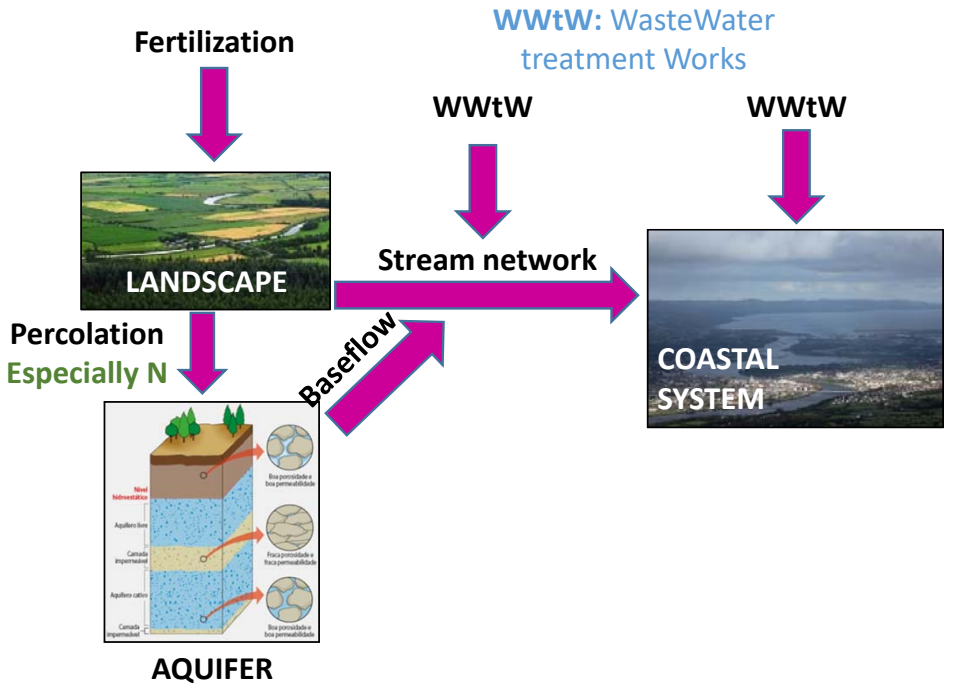


Storm measurements : Stigter et al., 2006

Nutrients and aquifers



- Lough Foyle: impermeable geology
  - Delays part of nutrient loads: spread during several months
- Ria Formosa: coastal aquifer
  - Permeable and already contaminated
  - Flows under the coastal system: only part resurfaces
  - Delays part of nutrient loads: spread during years/decades



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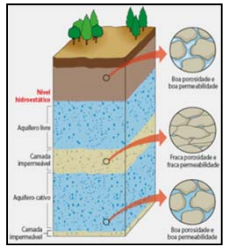

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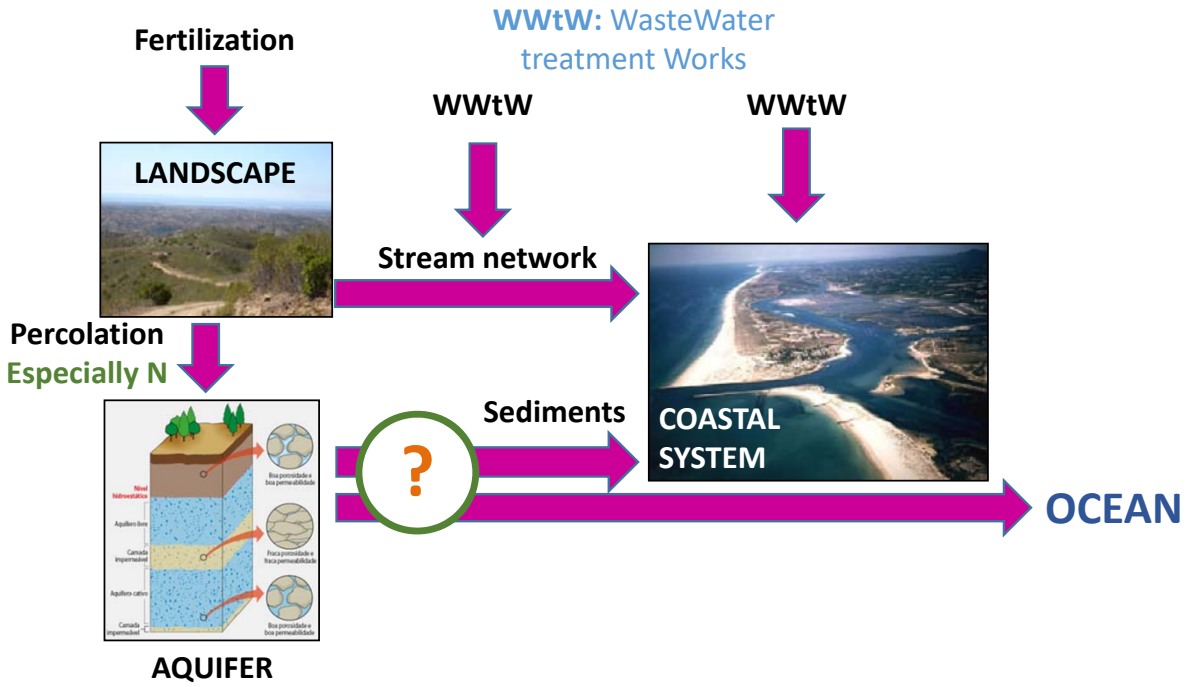
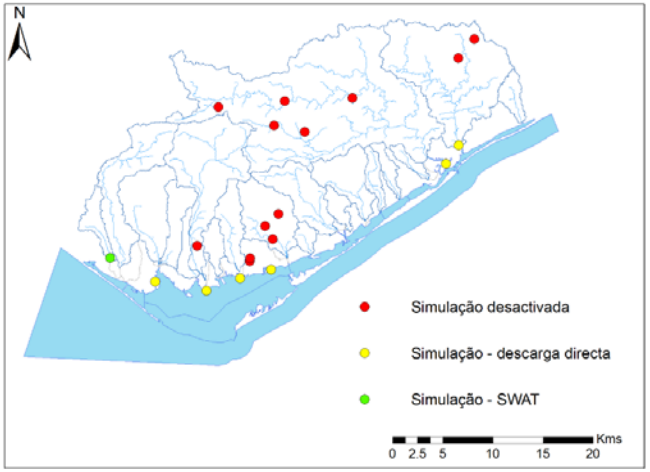


Nutrient load assessment strategy

- Calculate daily loads and assess sources:
  - Wastewater: direct measurements
  - Agricultural loads: hydrological model SWAT
  - Aquifer loads (Ria Formosa): measurements on the Ria Formosa sediment bed

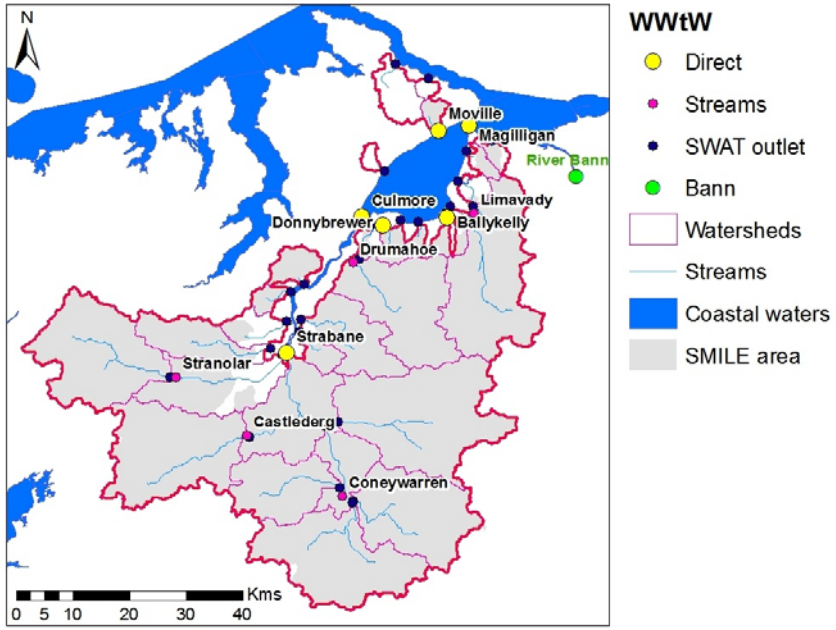
Sediment measurements: Leote et al., 2008



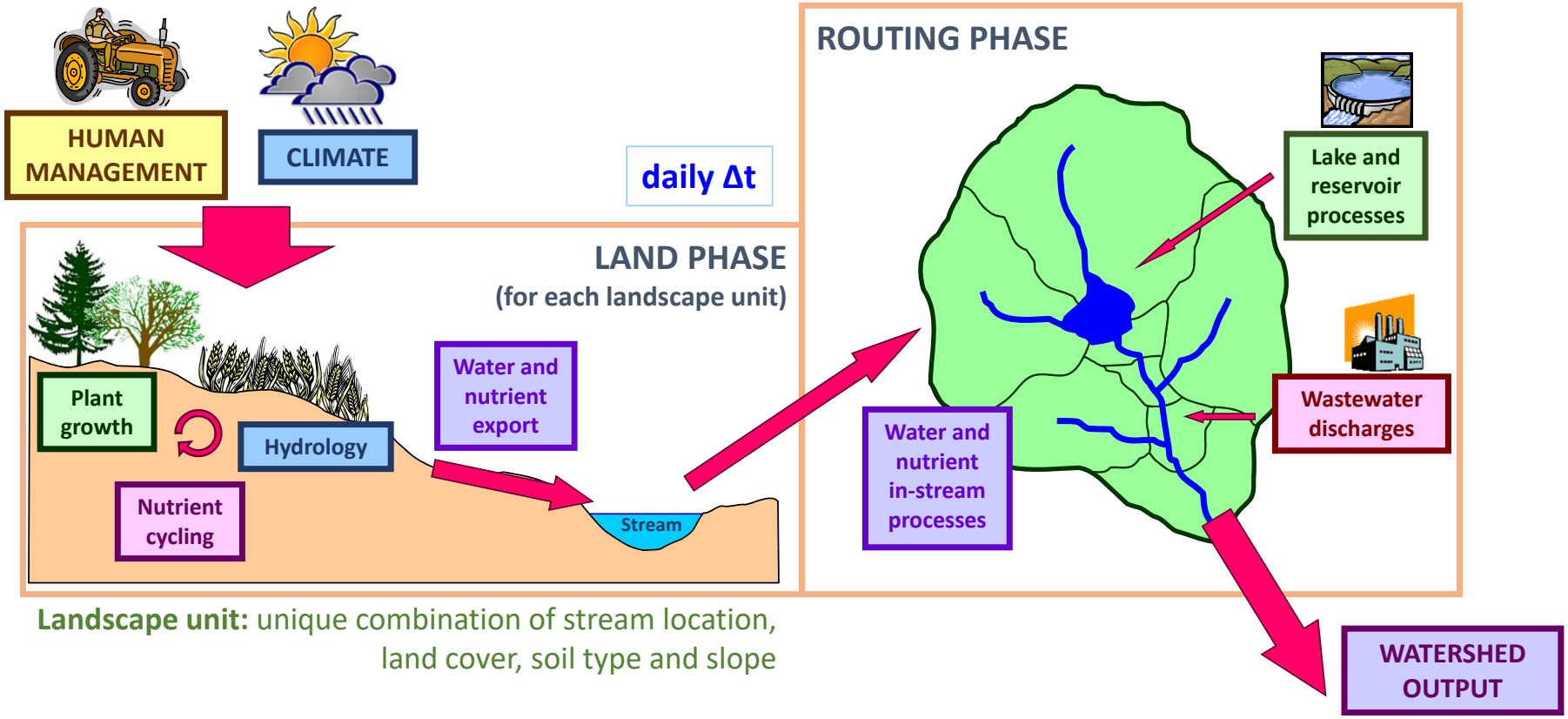
Ria Formosa
→ 7 WWtW
→ SWAT: 331 landscape units in 50 streams
→ Representative year: **10.2007** to **09.2008**

WWtW: WasteWater treatment Works

Lough Foyle
→ 11 WWtW
→ SWAT: 330 landscape units in 29 streams
→ Representative year: **2014**



SWAT: Soil and Water Assessment Tool

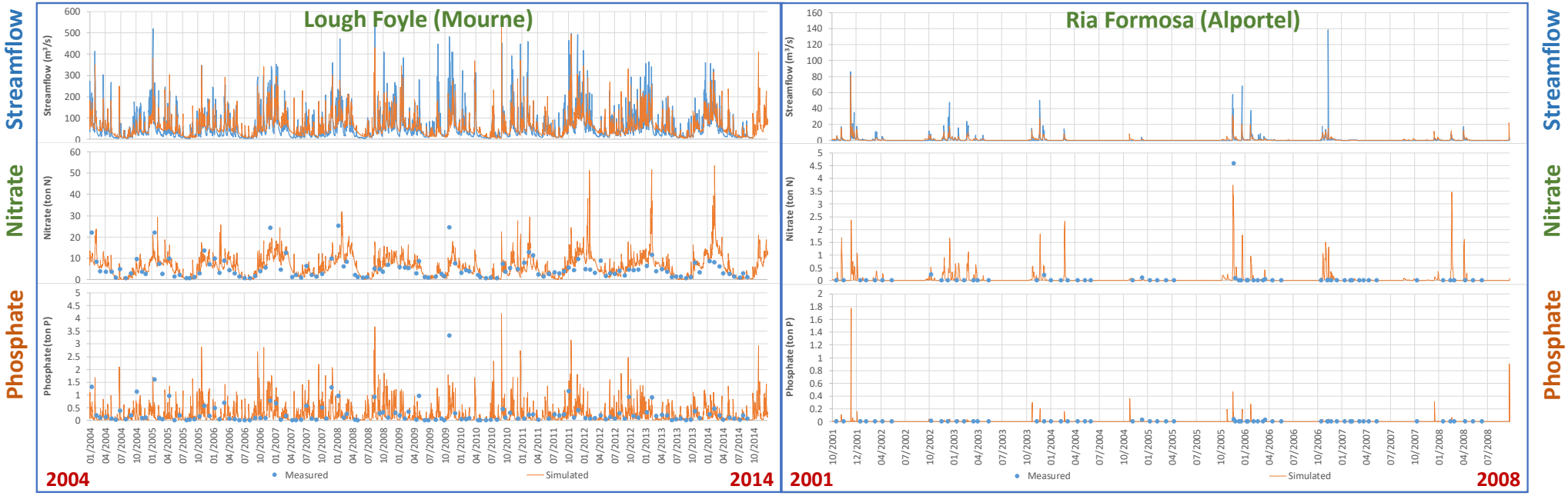


Landscape unit: unique combination of stream location, land cover, soil type and slope

Calibration & validation

SWAT Soil & Water Assessment Tool

- Measurements do not capture the major peaks, especially in Ria Formosa
  - Streamflow: good model performance
  - Nutrients: model not easy to evaluate; **best available estimate**



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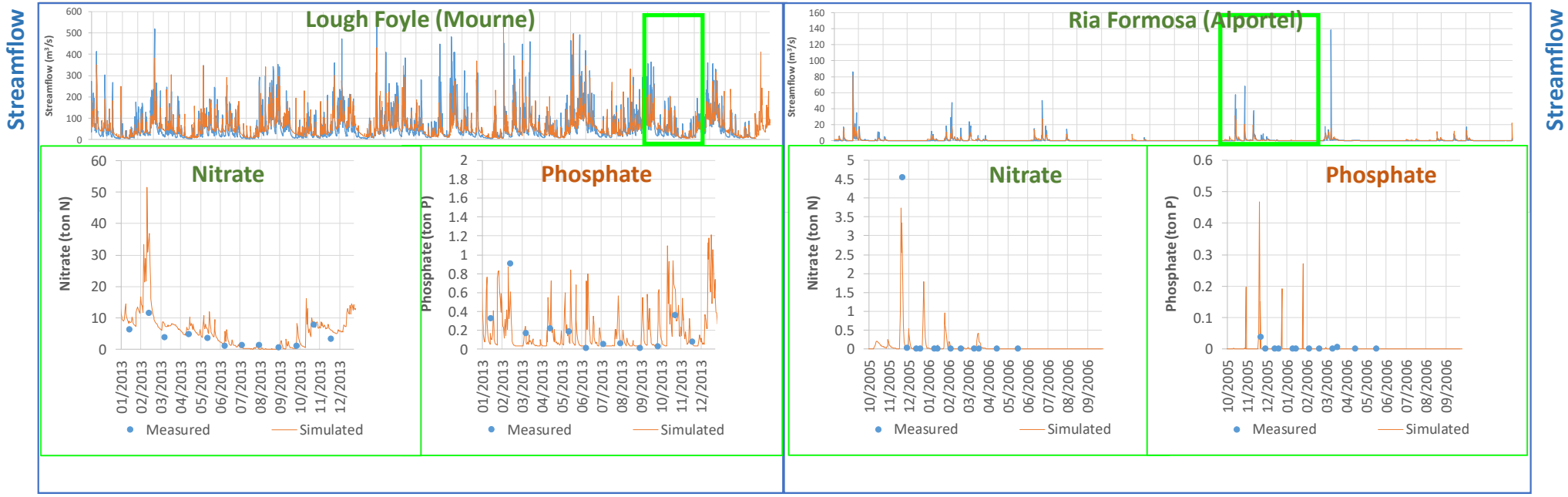
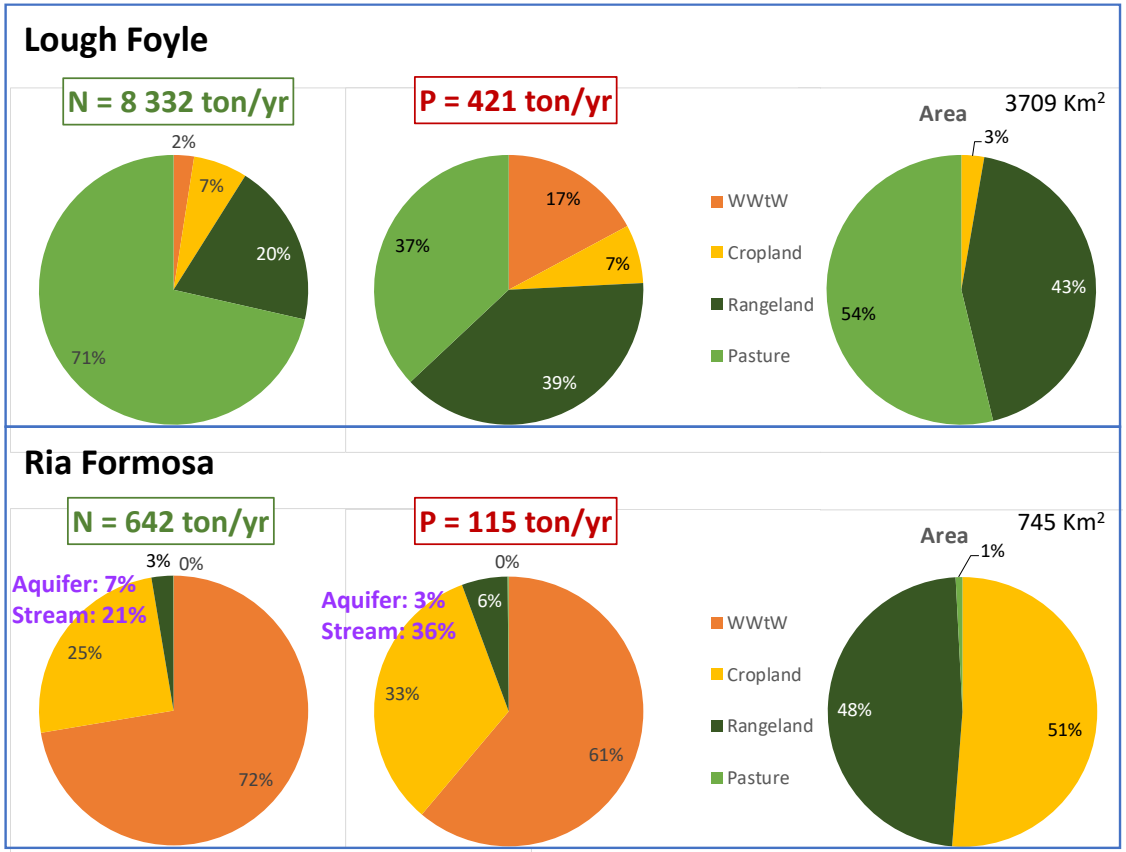


Nutrient budgets & sources

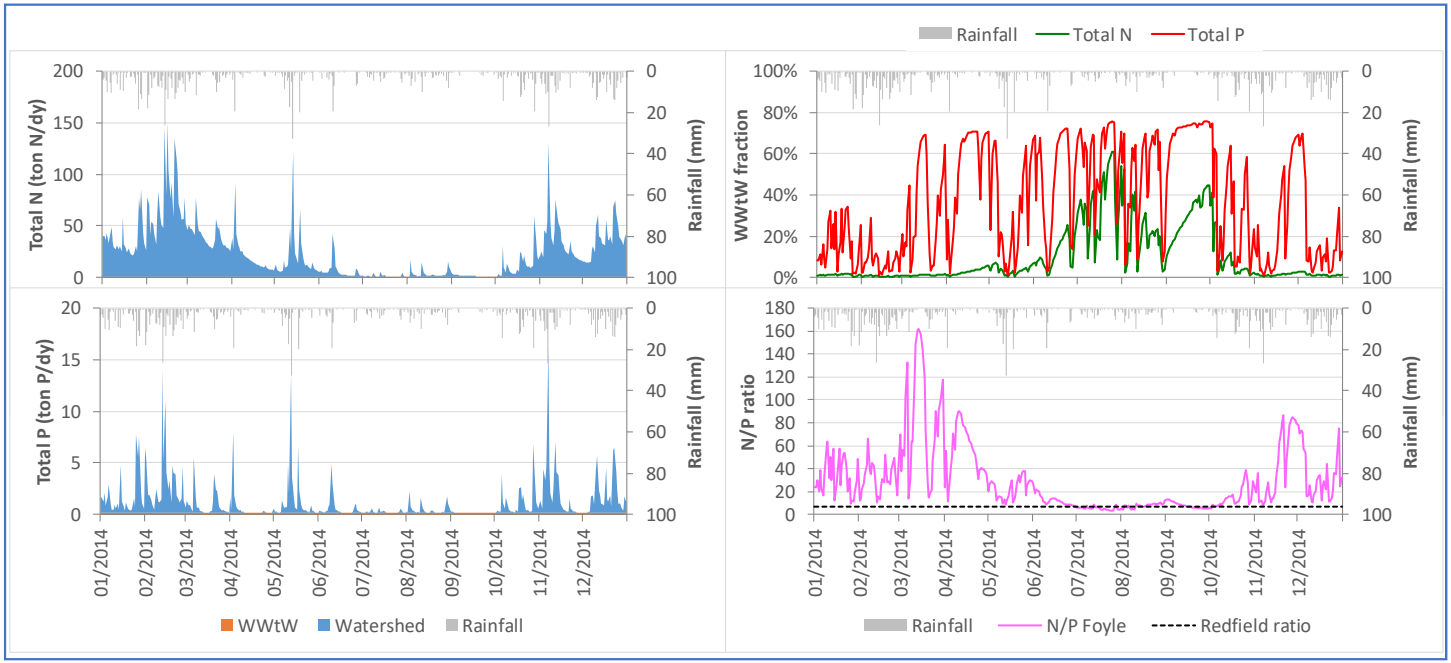
- Agriculture loads dominate in Lough Foyle:
  - large watershed, no aquifer losses
  - high N mobilization
- N/P ratio:
  - Redfield Ratio (mass): N/P = 7.2
  - Lough Foyle: N/P = 19.8
  - Ria Formosa: N/P = 5.6

	System	Nitrogen	Phosphorus
Agriculture per area (kg/ha.yr)	Lough Foyle	21.9	0.9
	Ria Formosa	2.8	0.7



Lough Foyle: time patterns

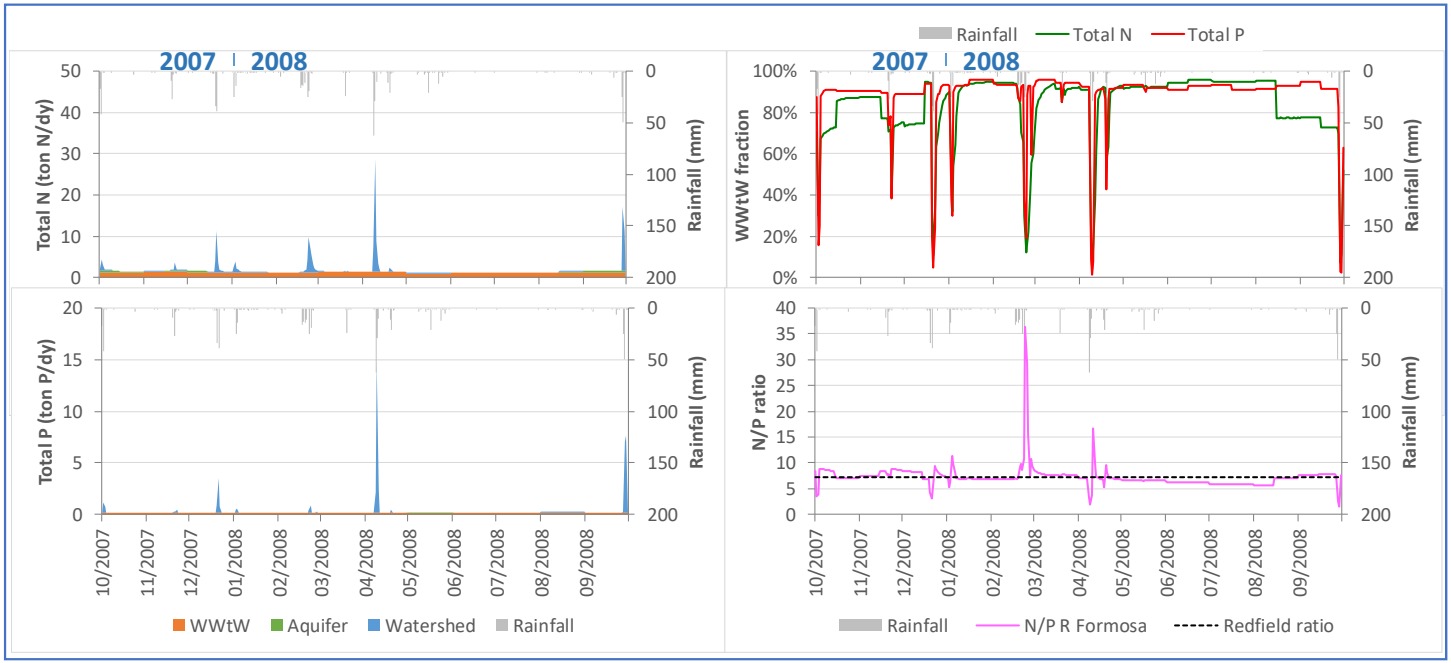
- Loads concentrated in Autumn and Winter:
  - N: regular baseflow (groundwater) + stormflow peaks
  - P: stormflow peaks
- Seasonality:
  - Autumn/Winter: dominated by watershed and N
  - Summer: dominated by wastewater, N&P equilibrium



- Agricultural loads cause: seasonality, irregularity and N dominance

Ria Formosa: time patterns

- Relatively regular loads, with irregular stormflow peaks
- Small seasonality:
  - Autumn to Spring: dominated by wastewater
  - … except for a few days dominated by watershed stormflow
  - Summer: dominated by wastewater



- Agricultural loads cause: high irregularity (with small seasonality)

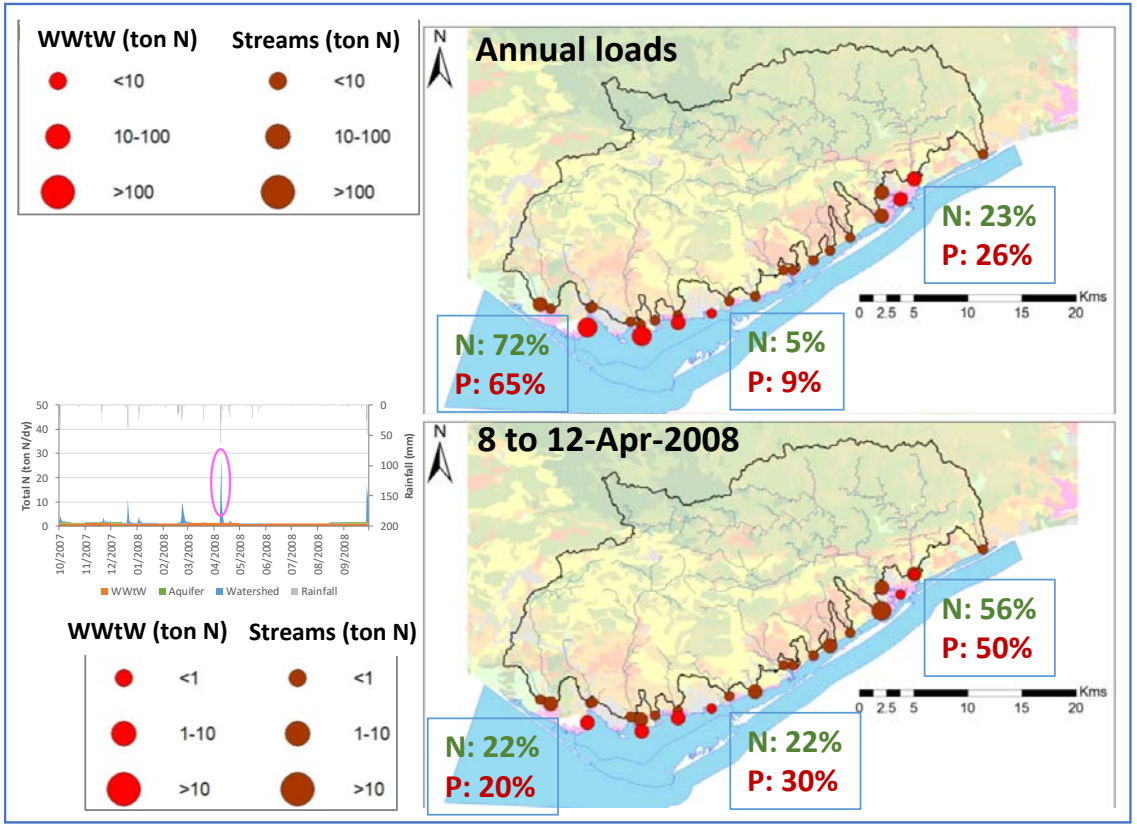
Ria Formosa: spatial patterns

- Contrast between annual and stormflow loads
  - annual: mostly western RF – WWtW
  - stormflow: mostly eastern RF – rivers
  - more sensitive coastal area due to restricted ocean exchange

- Agricultural loads may cause localized, short-term problems

Fraction of annual load in 8 to 12-Apr-2008

Nutrient	WWtW	Watershed	Total
Nitrogen	1.6%	30%	8%
Phosphorus	1.6%	44%	19%



Agricultural impacts

Lough Foyle nutrient loads

- Wet climate: strong seasonality + peaks after rainfall
- Wet climate + Pasture:
  - Abundant water mobilizes N
  - Vegetation cover: low P exports
- Simple geography: most loads from the estuary of River Foyle
- Simple geology: strong N load seasonality via baseflow

Ria Formosa nutrient loads

- Dry climate: loads concentrated in peaks after rainfall
- Dry climate + Orchards:
  - Less water available to mobilize N
  - Lower vegetation cover: P exports
- Complex geography: load locations vary with weather
- Complex geology: not all N loads reach the coastal system

Nutrient loads and aquaculture

- Aquaculture and nutrients: an ambivalent relation
  - Nutrients support primary production and hence food, but…
  - Excessive loads can limit aquaculture through eutrophication

- Lough Foyle: low impacts despite high N loads; P limitation?

- Ria Formosa: occasional impacts due to agriculture
  - High loads counteracted by strong exchange with ocean…
  - … but occasional acute water quality issues: stormflow loads?

- Wastewater control should be supplemented with agricultural nutrient management

Agricultural nutrient management

- Water Framework Directive quality goals might require load reduction to streams and coastal systems

- Challenges for agricultural nutrient management:
  - Monitoring: often too infrequent to understand issues
  - Fertilization control: limited by plant requirements
  - Agricultural abandonment: negative economic impacts
  - Long-term contamination: nutrient stocks remain in soils and groundwater decades after fertilization control

- Innovative solutions: limiting the connectivity between fields and streams through landscape management

Connecteur
Connecting European Connectivity Research

http://connecteur.info/

Conclusions

- Agricultural nutrient loads can impact coastal systems

- With wastewater treatment widespread, nutrient management should focus on agriculture
  - Often as important as wastewater loads
  - Irregular loads, complex impacts
  - More challenging to monitor and control

- If farmers (land and sea) understand their watersheds, they can participate on nutrient management decisions