British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

The impacts of historical agricultural landuse on the nitrate concentration trend in the major aquifers in England and Wales

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British Geological Survey (BGS)

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Background: Agricultural diffuse water pollution – nitrate

- Nitrate water pollution, the biggest remaining problem of water pollution in many countries, has been identified as a major threat to water quality and the implementation of the EU WFD (EHS, 2000; DoE & DARD UK, 2003; Torrecilla et al., 2005)

- Agricultural land is the major source of nitrate water pollution (Ferrier *et al.*, 2004; Thorburn *et al.*, 2003; Torrecilla *et al.*, 2005).

- Nitrate water pollution is not only an environmental issue but also a threat to economics and human health (Defra, 2002)
  - Eutrophication in rivers, lakes and estuaries;
  - The annual costs for nitrate water treatment in the UK: £16 million;
  - Nitrate (>10mg N/l) in drinking water may cause blue baby syndrome;
  - A potential cancer risk from high nitrate/nitrite in water and food has been reported;

Background: Nitrate in UK groundwater

- Average nitrate concentrations in the UK groundwater have been rising with a rate of 0.35 – 0.53 mg NO3 L^{-1} $year^{-1}$ (European Environment Agency, 1999; Roy *et al.*, 2007; Stuart *et al.*, 2007)

- In England, over one third of the sites exceeded the 50 mg NO3 L^{-1} EU drinking water standard (Stuart et al., 2007). It is estimated that ~60% of all groundwater bodies will fail to achieve good status by 2015 (Defra, 2006; Rivett *et al.*, 2007).

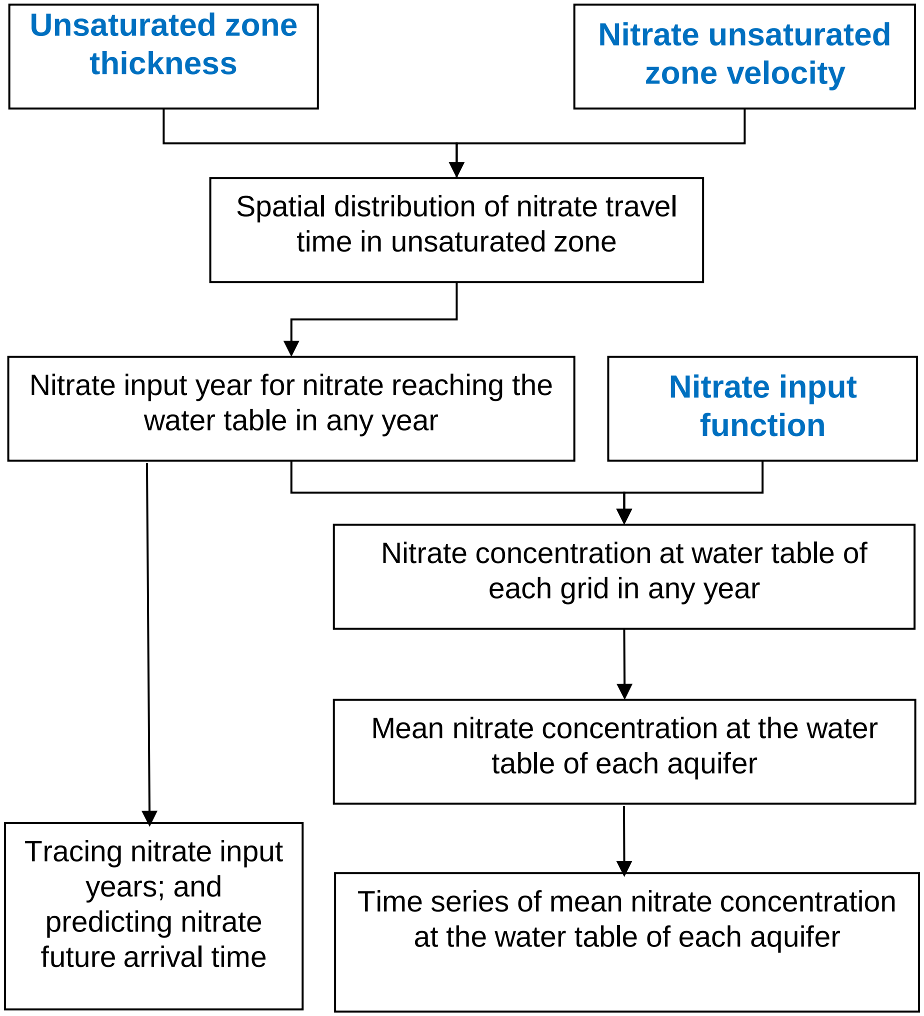
Background: The aim of the research

It could take decades for nitrate to transport in unsaturated zones (USZs) and saturated zones. ***Historical nitrate storage and lag-time*** in groundwater system, however, have ***rarely been considered*** in the ***current water resource management in many countries including the UK***.

It is necessary to address this issue to help regulators and water companies in making sound decisions in water resource management.

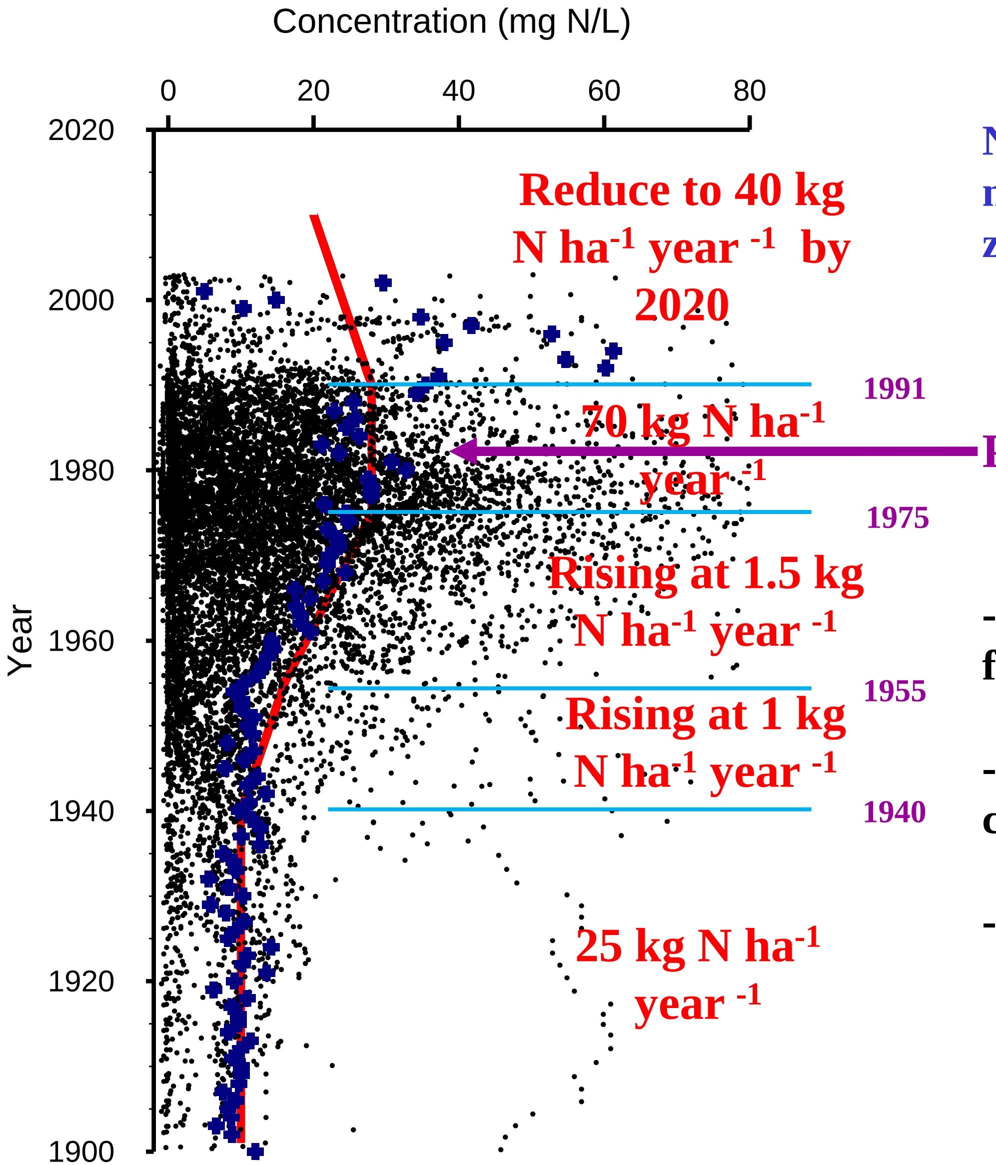
To develop a feasible method to simulate the impacts of historical nitrate loadings from agricultural landuse on the nitrate concentration trend in aquifers

Methodologies- nitrate time bomb (NTB) conceptual model



Flow chart of the spatial-temporal NTB model used in this study

Methodologies – single background nitrate input function



Nitrate input function – the time-varying nitrate loading at the bottom of the soil zone

Peak nitrate loading (around 1983)

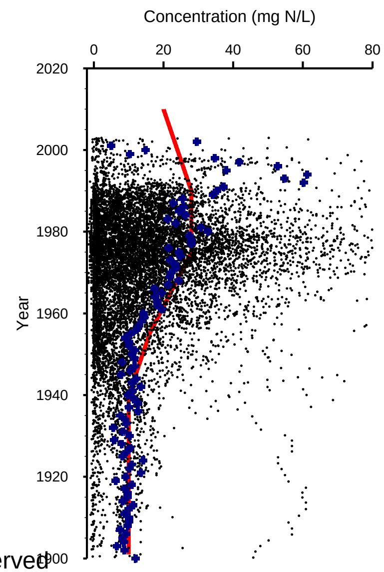
-**Red line:** the derived nitrate input function from literature data.

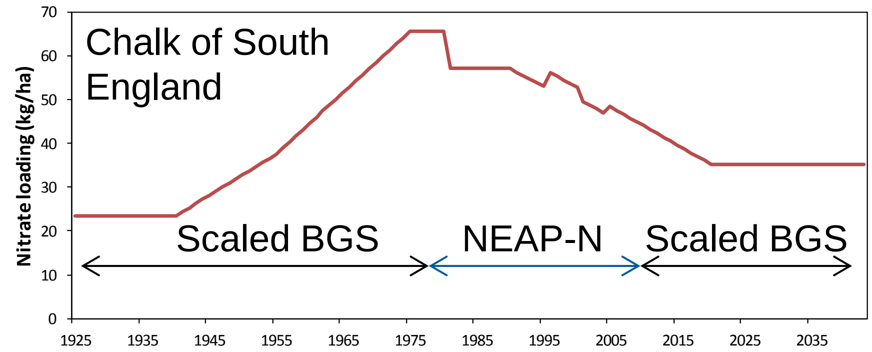
-**Black dots:** observed porewater nitrate concentrations from BGS database.

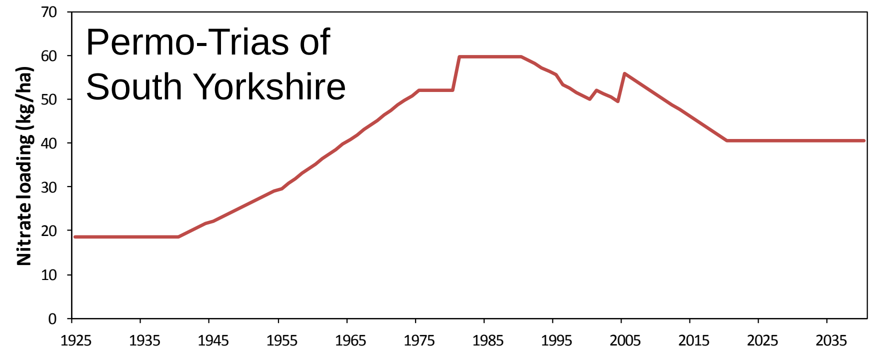
-**Blue crosses:** the average observed value.

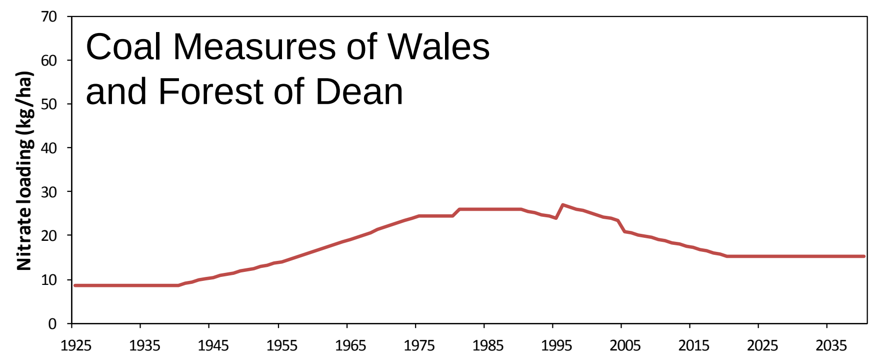
Methodologies – Introducing spatio-temporal nitrate input functions (1925 – 2050)

- **NEAP-N (**Anthony *et al.*, 1996; Environment Agency, 2007, Lord and Anthony, 2000**) predicts the total annual nitrate loss from agricultural land across England and Wales.**
- **NEAP-N 1980, 1995, 2000, 2004 and 2010 was used**
- **BGS NIF function (pre-1980 and forwards)**

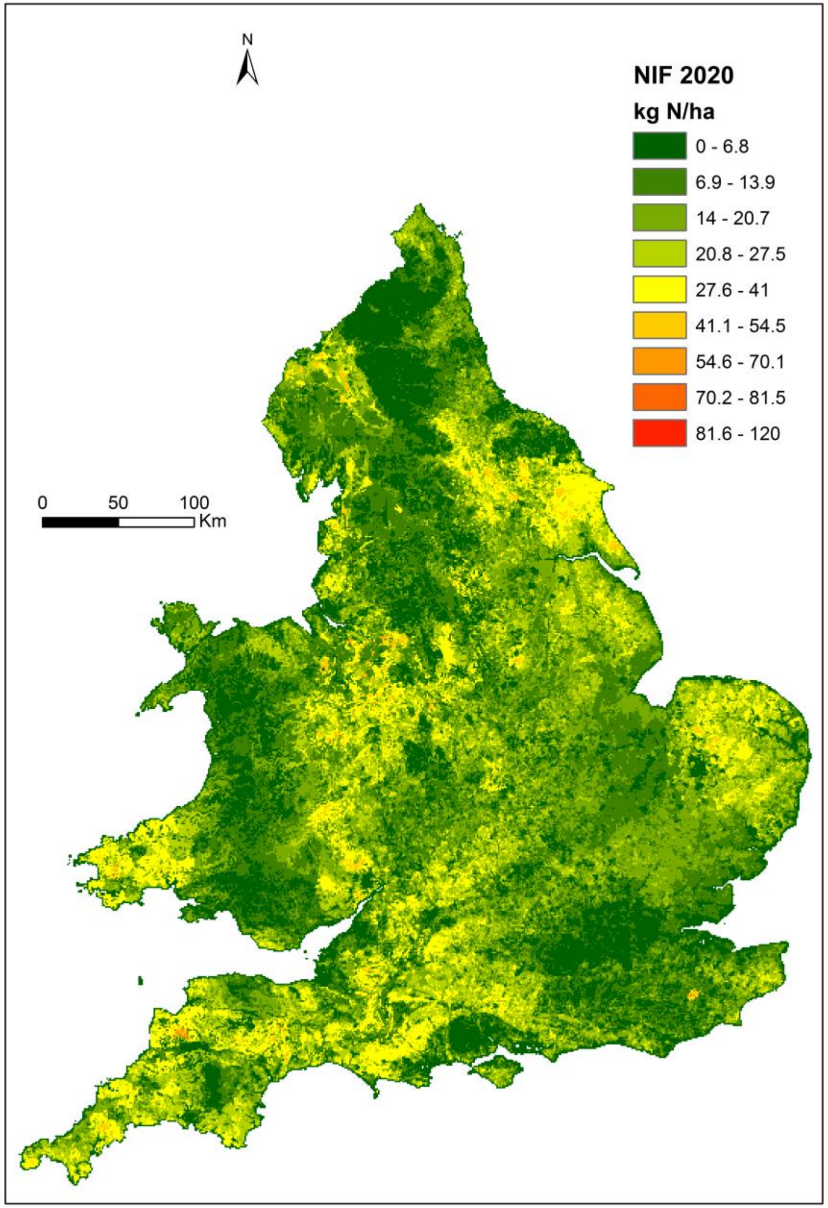






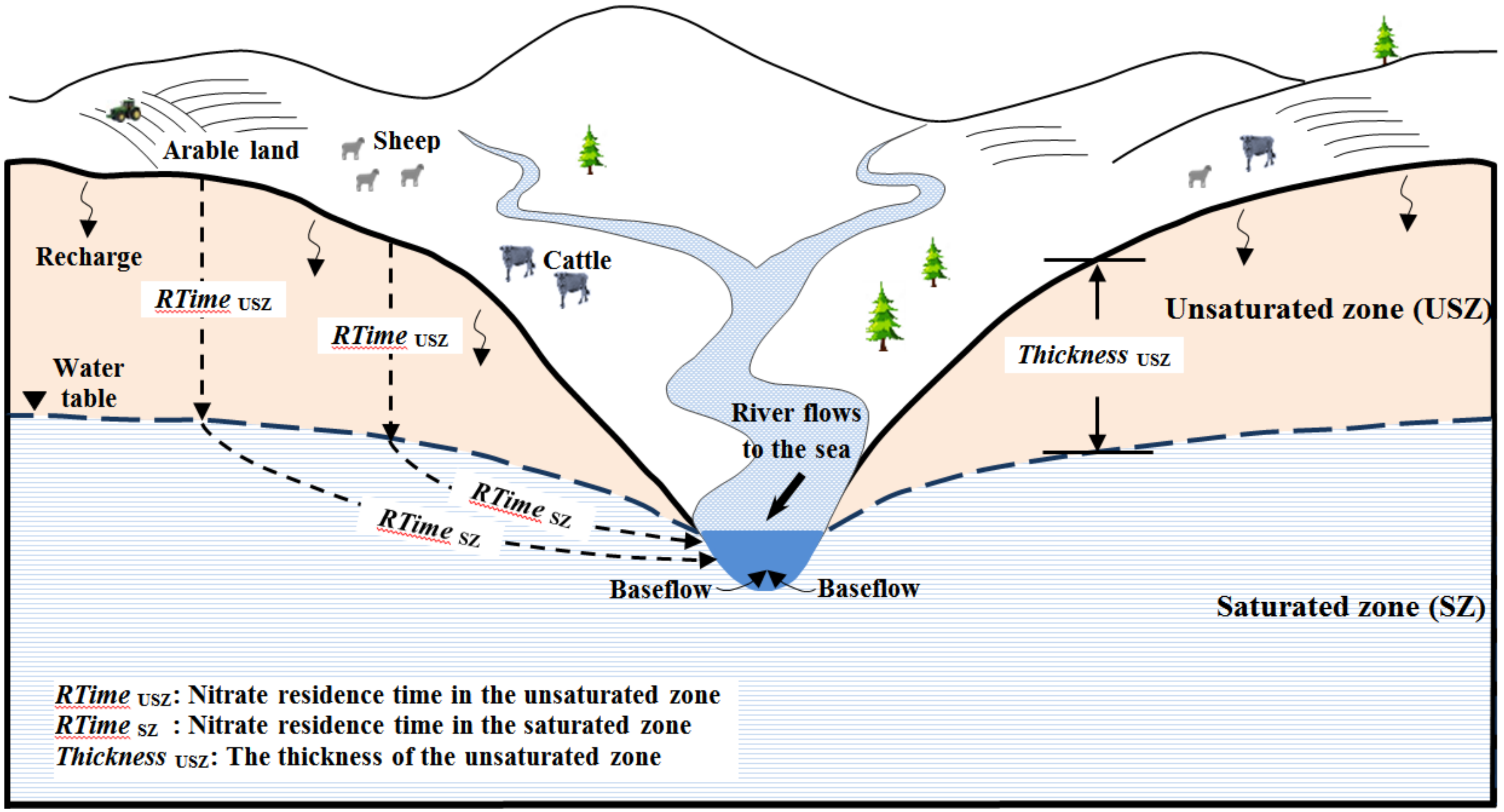


Interpolated NIF maps (1950-2020)



Methodologies – groundwater transport and dilution in aquifers

Hydrogeological conceptual model



- An island system;
- Reach dynamic balance;
- Nitrate travel speed in aquifer;
- Nitrate travel time;
- Active groundwater volume

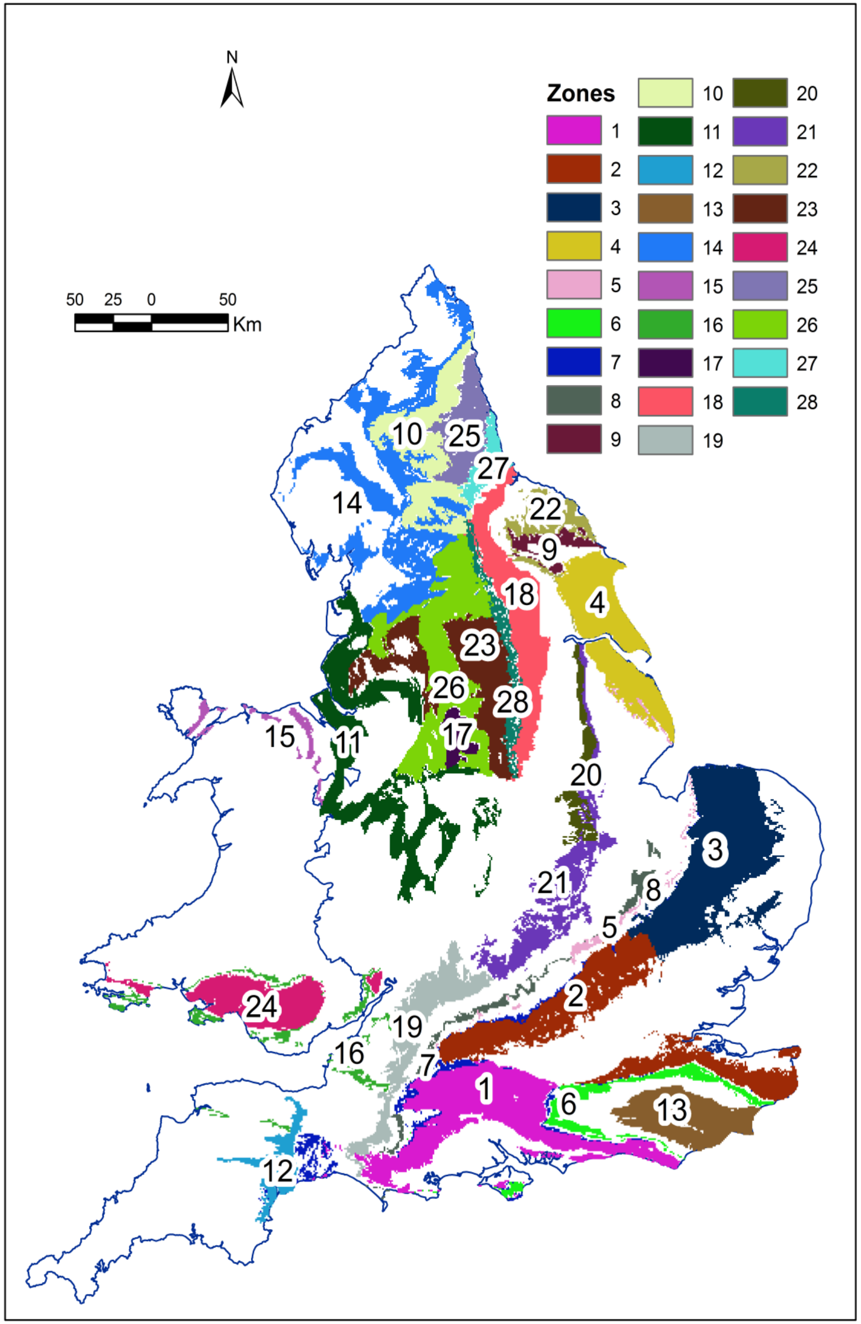
Other components in the NTB model

- Estimating nitrate transport velocity in the USZ using recharge, aquifer porosity and storage coefficient
- Calculating groundwater available for nitrate dilution
- Calculating the velocity of nitrate transport in aquifers
- Simulating nitrate concentration in groundwater

Fixed / Monte Carlo Calibration	Parameter (units)	Description
Fixed	A_i (m^2)	The area for cell i
	q_i (m year^{-1})	The recharge value for cell i
	The nitrate-input-functions (kg/ha)	-
	Rp_q (year)	The water table response time to recharge events
	GWL_i (m)	The groundwater level for cell i
	RL_i (m)	The river level for cell i
	ATT (-)	the nitrate attenuation factor in the USZ
	$Thickness_{USZ,i}$	The thickness of USZ at cell i
Monte Carlo Calibration	$\Phi_{aquifer}$ (-)	The porosity for an aquifer zone
	$Sy_{aquifer}$ (-)	The specific yield for an aquifer zone
	$Rf_{aquifer}$ (-)	The retardation factor for calculating the nitrate velocity in USZs
	$T_{aquifer}$ (m^2 day^{-1})	The transmissivity for an aquifer zone
	$D_{aquifer}$ (m)	Depth of active groundwater for an aquifer zone

Model construction

- 28 aquifer zones (1 km x 1 km)
- DEM
- Groundwater levels
- Long term average recharge
- Aquifer prosperities
- Observed datasets of nitrate velocity in USZs and groundwater nitrate concentrations



Model calibration

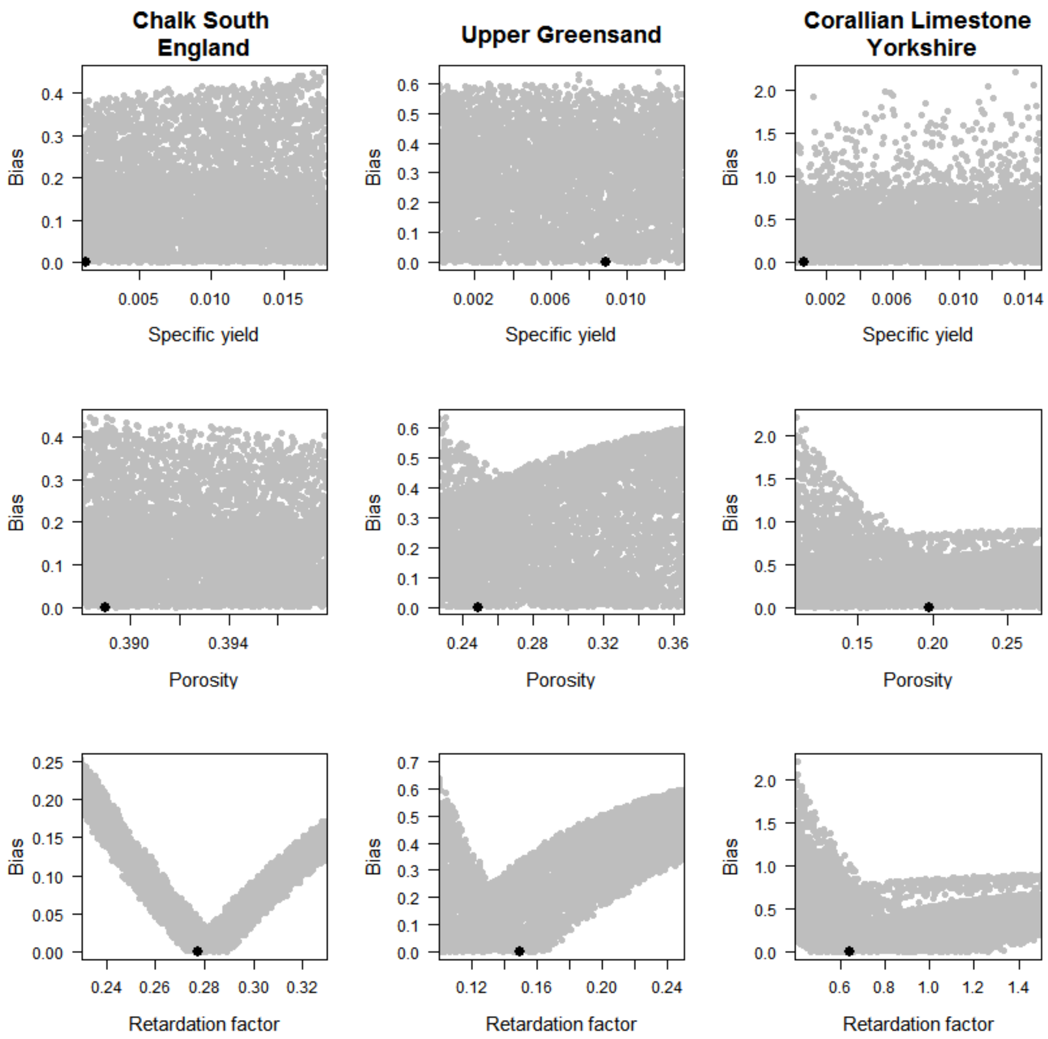
Two sets of MC simulations were conducted to calibrate the model against:

1) the nitrate velocity values in USZs derived from measurements of porewaters from drill cores (Wang *et al.*, 2012)

2) the observed average nitrate concentrations for each aquifer zone calculated from monitoring data

Sensitivity analysis

- Sensitivity scatter plots for parameter values in estimating the nitrate velocity in USZs of some aquifer zones.
- Grey dots are individual parameters from Monte Carlo simulations and the black dots denote the optimum parameter value



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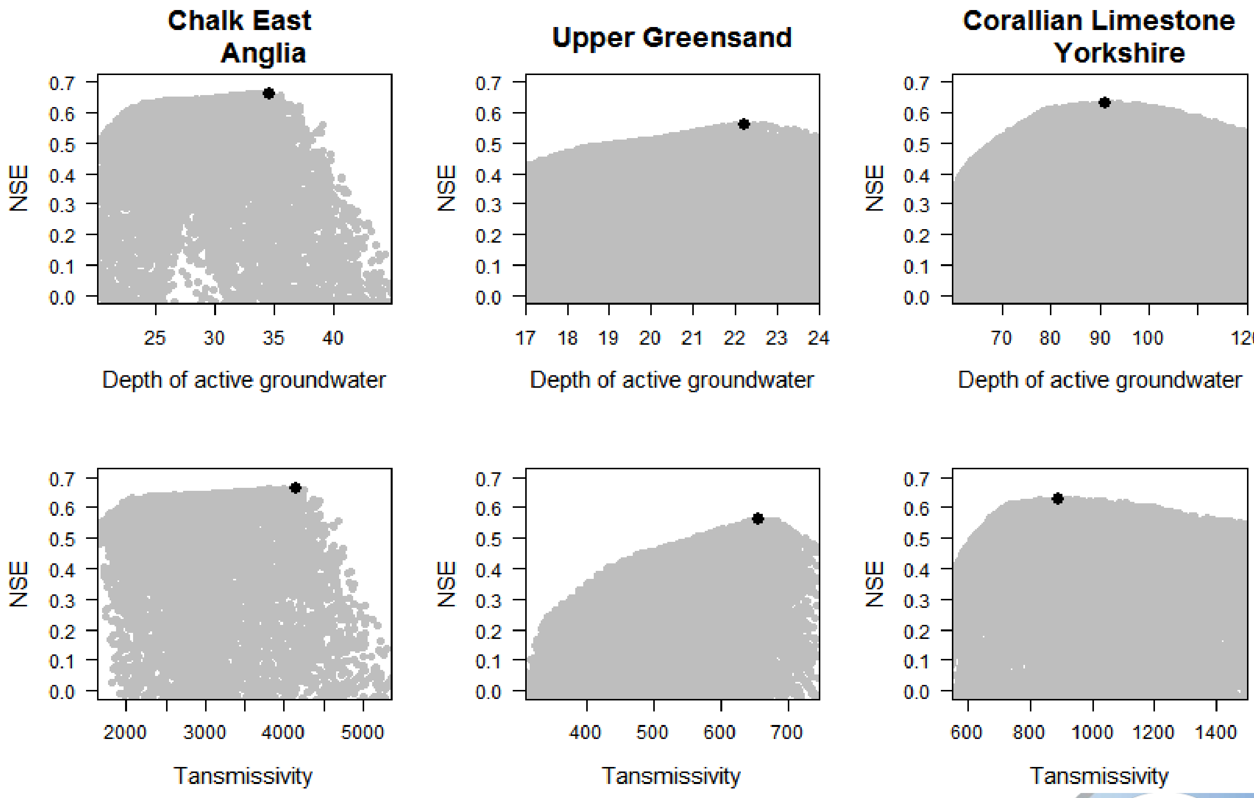
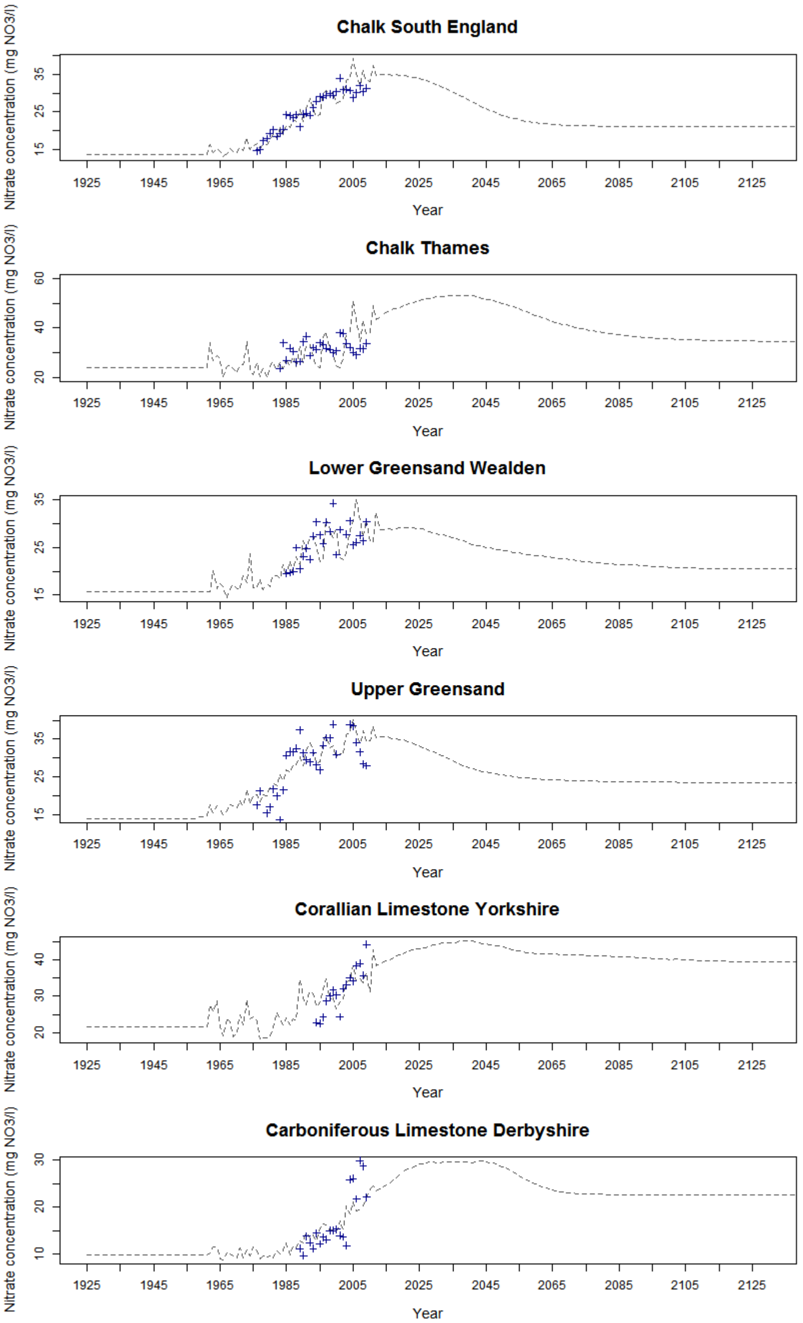


The changing trend of nitrate concentrations

The results show that 16 aquifer zones have an increasing trend in nitrate concentration, while average nitrate concentrations in the remaining 12 are declining



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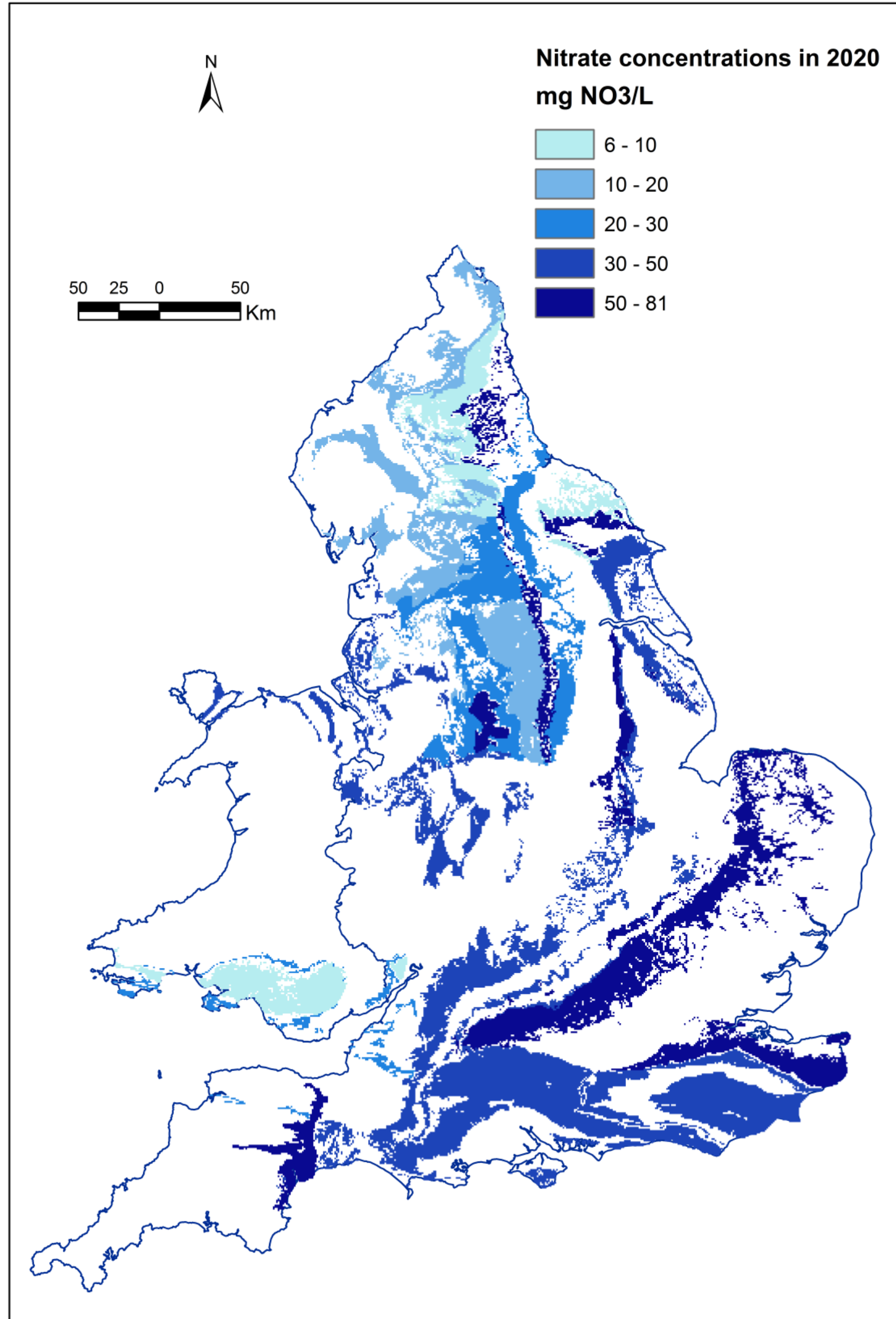
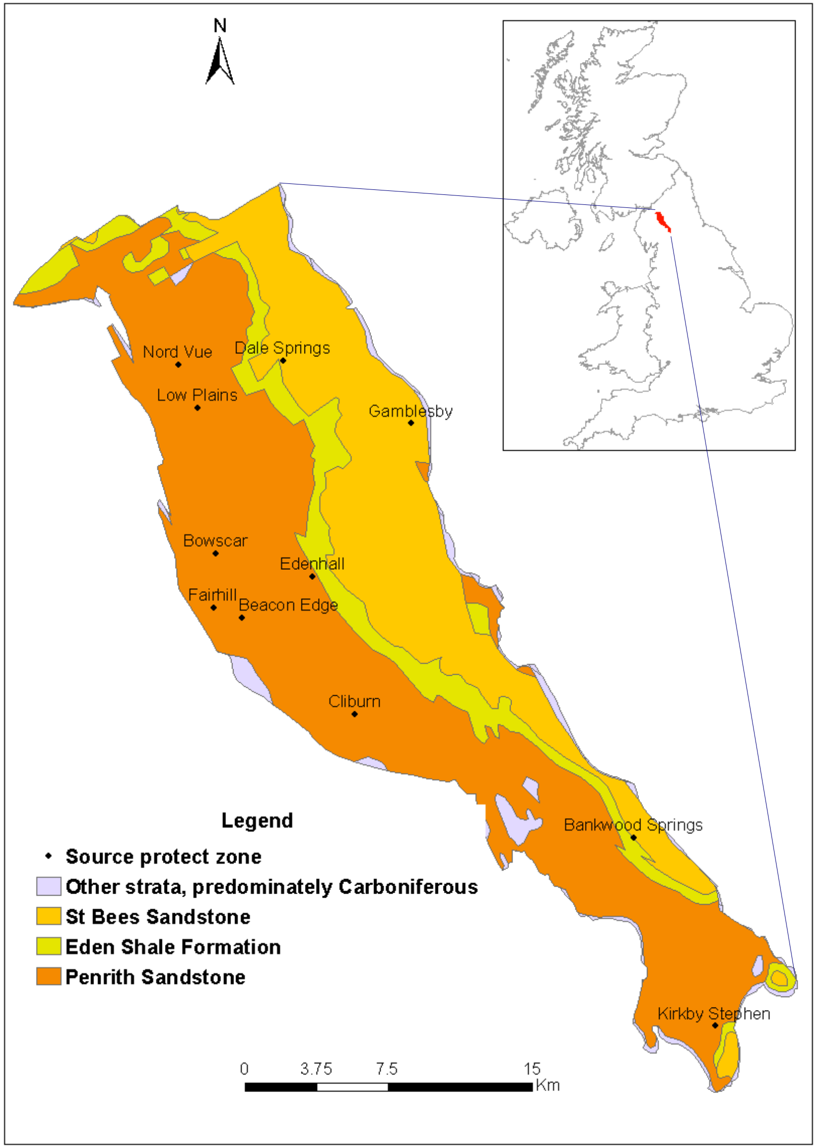


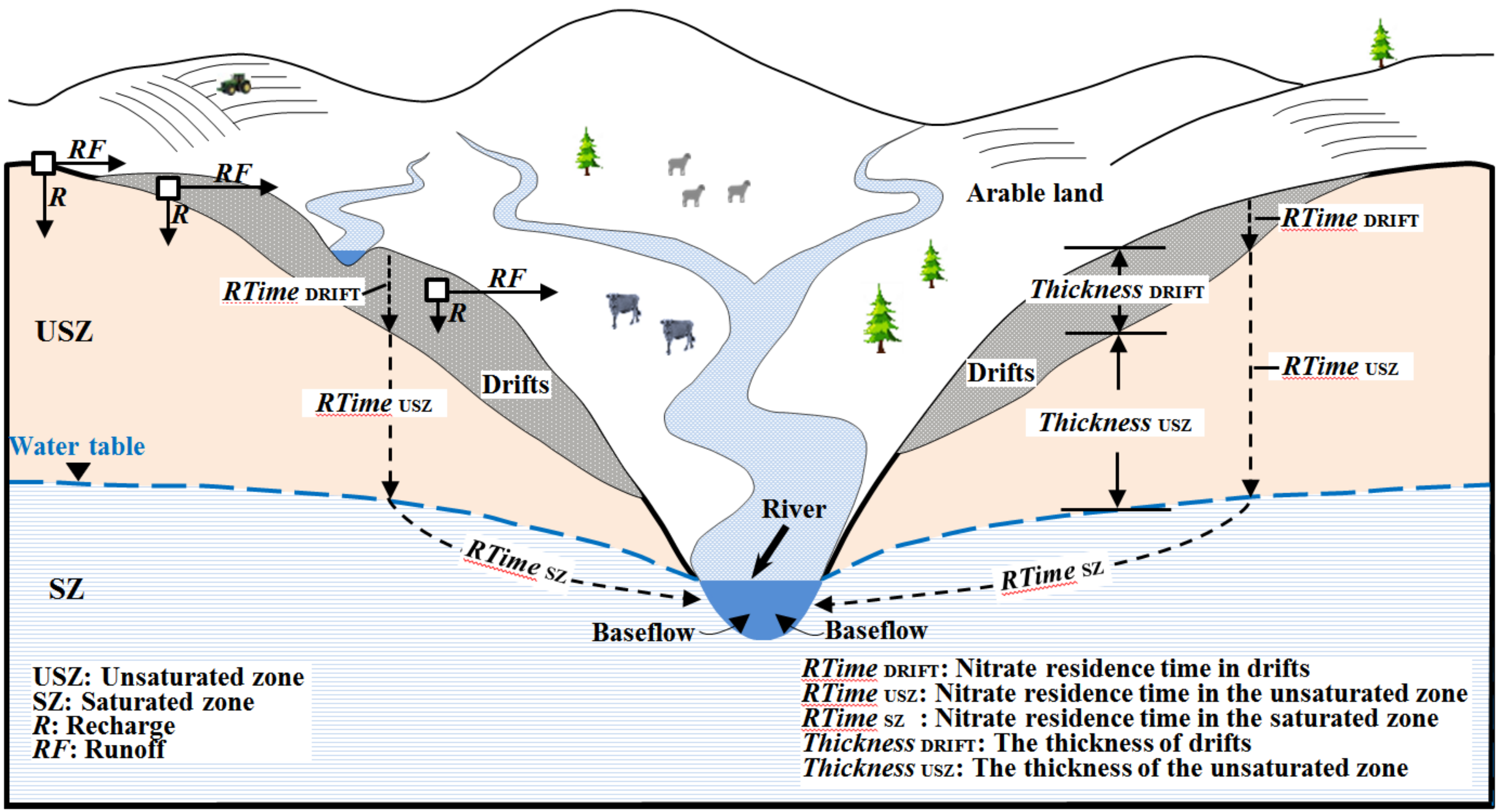
Catchment-scale application in the Eden Valley, England



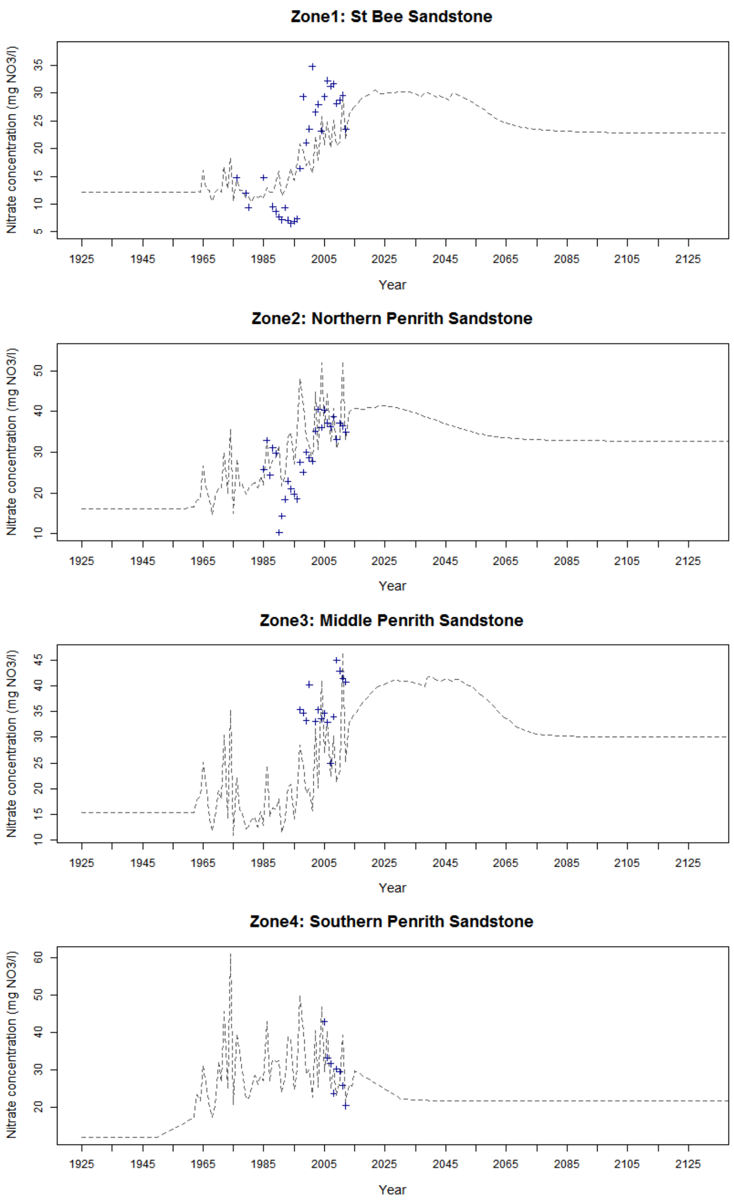
Glacial till covers 54 % of the sandstones in the area; and 59 % of them has the thickness of less than 2 m.

It is necessary consider the nitrate transport in low permeable glacial till.

Catchment-scale application in the Eden Valley, England



Catchment-scale application in the Eden Valley, England



Conclusions

- The NTB model requires relatively modest parameterisation and runs on an annual time-step
- It provides useful estimates of present and future average groundwater nitrate concentrations in aquifers
- It help decision makers to evaluate the long-term impact and timescale of land-management scenarios introduced to help deliver water-quality compliance
- It is readily transferable to other areas
- It can be integrated with others models in freshwater cycle

Thanks for your attention

Questions, comments and suggestions?

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