British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Impact of climate change on future groundwater nitrate

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Reducing Effects of Agriculture

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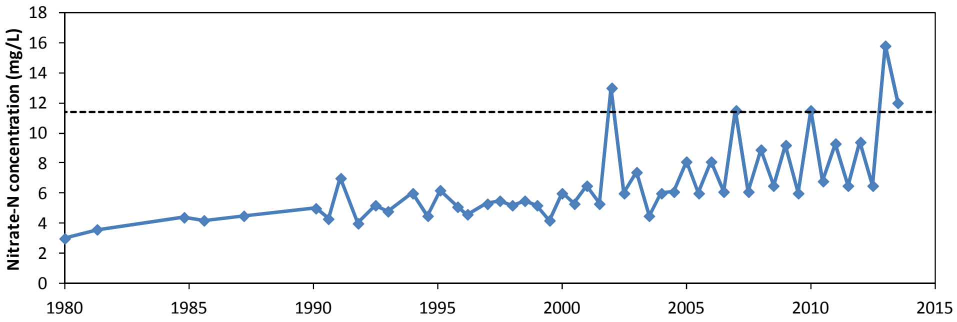
Key questions



Present:

- Groundwater nitrate concentrations are already a serious problem with many abstractions exceeding the drinking water limit (50 mg/L as N)
- Under current climate conditions and agricultural practices, concentrations are predicted to continue to rise

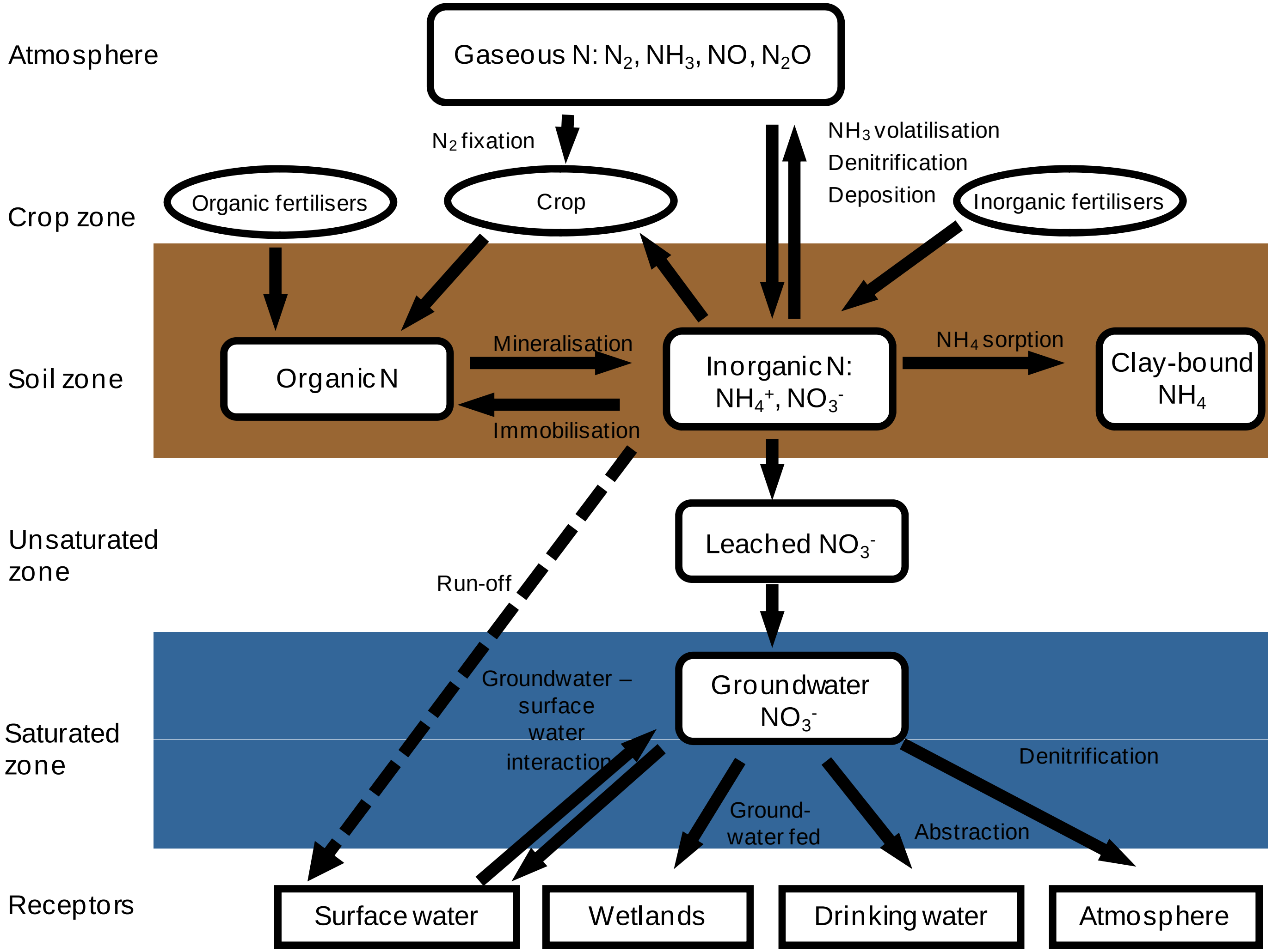
What are the likely impacts of climate change to:

- Agricultural practices and nitrate leaching from the soil zone?
- Groundwater recharge mechanisms and levels?
- Nitrate concentrations in groundwater and impact on groundwater receptors?

Projected changes by 2080 (UKCP09)

Variable	Overall	Area most affected	Area least affected
Mean daily maximum summer temperatures	Increase everywhere	Up to 5.4ºC (2.2 to 9.5ºC) in parts of south	2.8ºC (1 to 5ºC) in parts of north
Mean daily minimum winter temperature	Increase everywhere	increases by about 2.1ºC (0.6 to 3.7ºC) to 3.5ºC (1.5 to 5.9ºC) across the country	
Annual precipitation	Very little change	Changes range from –16% to +14% with no simple pattern	
Winter precipitation	Regional variation	Up to +33% (+9 to 70%) along the west coast	Small decreases (–11 to +7%) over parts of Scotland
Summer precipitation	Decrease for most places	Up to –40% (–65 to –6%) in parts of far south	Little change (–8 to +10%) over parts of north

Nitrogen cycle

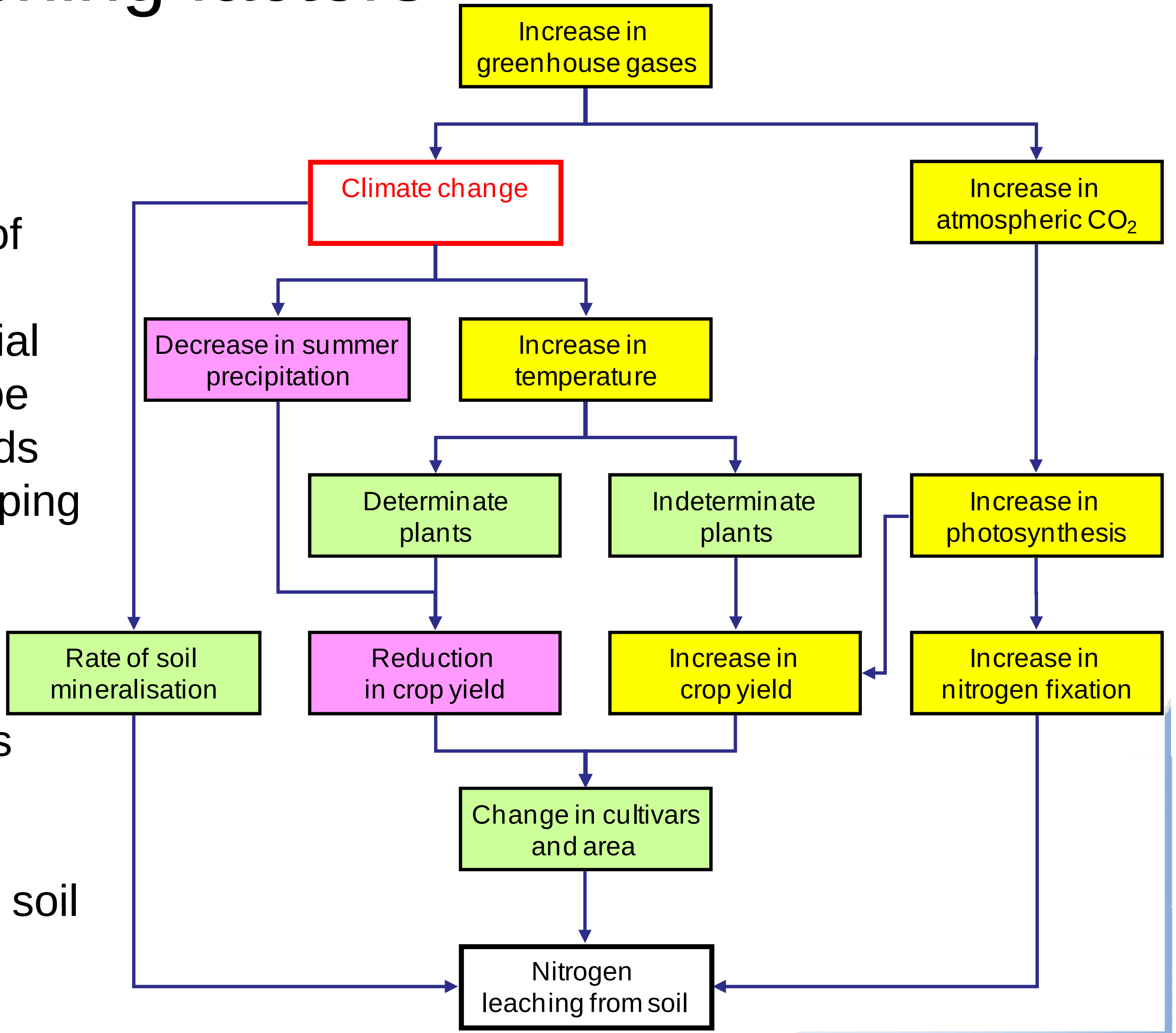


Temperate crops

Crop group	Growth type	Temperature increase	CO_2 increase
Cereals, oilseed and legumes		Shorter growing period & reduced yield	Increased growth & N fixation
Root and tubers	Determinate e.g. Potatoes	Shorter growing period , increased water requirement	Increased yield
	Indeterminate e.g. sugar beet	Longer growing period	Increased yield
Horticultural field and glasshouse	Determinate e.g. onion, cauliflower, broccoli	Shorter growing period , increased water requirement	
	Indeterminate e.g. carrots	Positive-	
	Lettuce	None	Increased yield
Perennial	Vines, orchards, soft fruit	Increased yield variability	Increased yields
		Increased growth	
Forage crops and grass	Determinate e.g. whole wheat	Increased digestibility but decreased yield	Increased yield but decreased digestibility
	Indeterminate e.g. sugar beet, silage maize	Increased yield	Increased yield
	Intensively managed grass	Increased yield	increased yield
	N-poor and species-rich grass	Varies depending on species	
	Legumes		Increased fixation
Livestock	Grazing		Increase in milk production for clover swards

Soil leaching factors

- Agricultural productivity well-studied in terms of changes in crop yields and potential cultivars, crop type and the northwards extension of cropping area



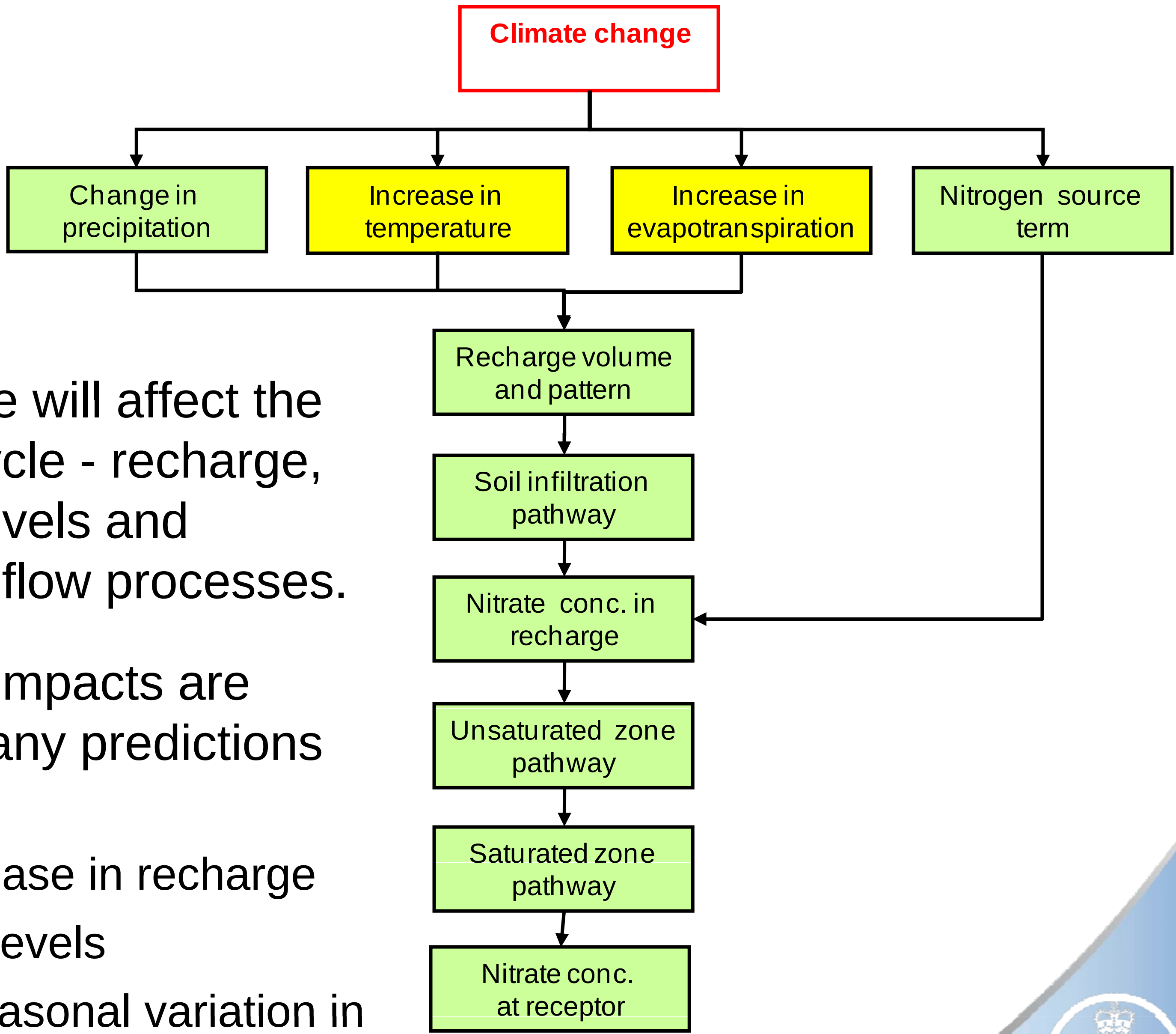
- Climate change is likely to lead to increased nitrate leaching from the soil

Soil leaching processes

Losses from crops function of interactions of:

- Over winter rainfall – run off
- Soil type – soil mineralisation
- Water holding capacity
- Freezing and thawing – losses during frost
- Cropping
- Rate/timing of fertiliser applications

Pathways

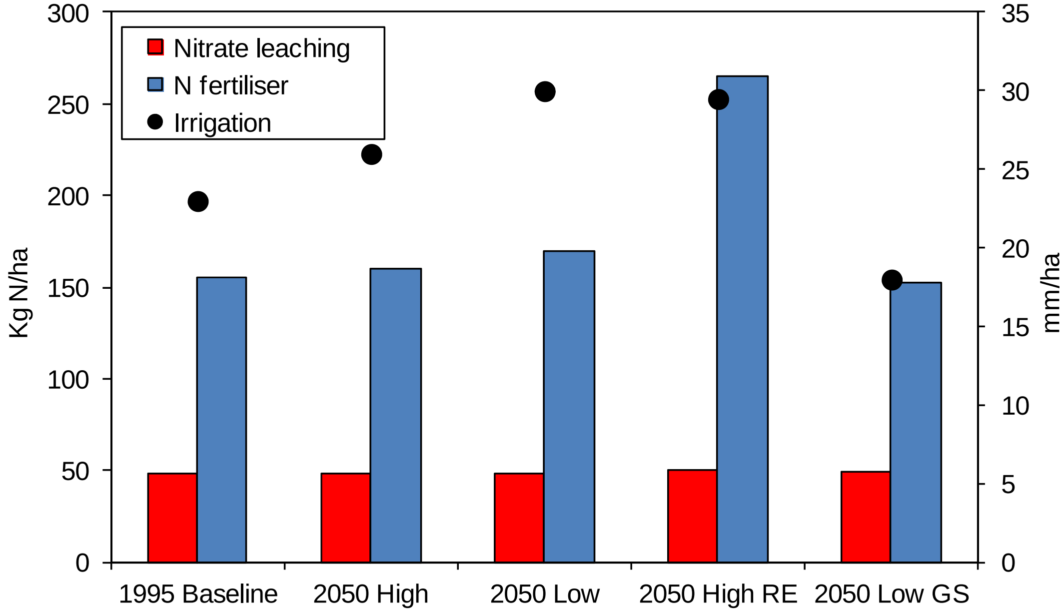


- Climate change will affect the hydrological cycle - recharge, groundwater levels and resources and flow processes.
- The predicted impacts are variable but many predictions suggest:
  - Overall decrease in recharge
  - Fall in water levels
  - Enhanced seasonal variation in water levels

Groundwater receptors

- Abstracted groundwater for public supply:
  - N predicted to continue to rise where thick unsaturated zone store
  - Seasonal behaviour considerable for fractured aquifers
- Surface water, wetlands and groundwater dependent ecosystems:
  - Very sensitive to N
  - Changes in seasonal recharge critical effect on baseflow
  - Hyporheic zone
- Atmosphere:
  - N_2O emissions from groundwater from denitrification

Predictions



Predicted effects for East Anglia

REGIS (Holman et al)

- 4 scenarios modelled:
  - High
  - Low
  - High RE
  - Low GS
- In East Anglia increased droughts could lead to some abandonment and reduced leaching
- In NW England improved conditions and expansion
- Increased seasonality and irrigation demand

Predictions

Seine Basin (Ducharne et al, 2007)

- 30-year simulation based on SRES-A2 using 7 scenarios including climate change, CO_2, GAP & reduction in point sources
- Moderate CO_2 impact on evapotranspiration
- Increase in temperature shortens crop cycle allowing slower growing cultivars and longer period for catchcrops
- Crop biomass and yield enhanced although limited by water stress
- Soil mineralisation increased due to temperature
- Net increase in leaching (up to 100%) but could be compensated by GAP

Anticipatory adaptations

- Proactive steps to reduce negative consequences
- Reducing greenhouse emissions
- Increasing recharge, including ASR
- Managing water e.g. through promoting efficient water use, recycling and differential pricing
- Intensification and diversification of crops and livestock, and changing land use
- Technological development, e.g. new cultivars, weather information

Conclusions

- Climate change impacts on nitrate leaching to groundwater are not well enough understood to make useful predictions without more site-specific data
- Studies which address the whole cycle show likely changes in nitrate leaching ranging from limited increases to a possible doubling of aquifer concentrations by 2100 under current agricultural practice
- Predictions are within the margins of uncertainty
- These changes may be masked by nitrate reductions from improved agricultural practices
- Future impact may also be driven by economic responses to climate change

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