Nitrogen effects and fate in ecosystems

Bridget Emmett (CEH-Bangor)

What happens to deposited N in soils and plants?

Gaseous losses from the soil

Deposition

Removed in animal or tree biomass or lost to fire

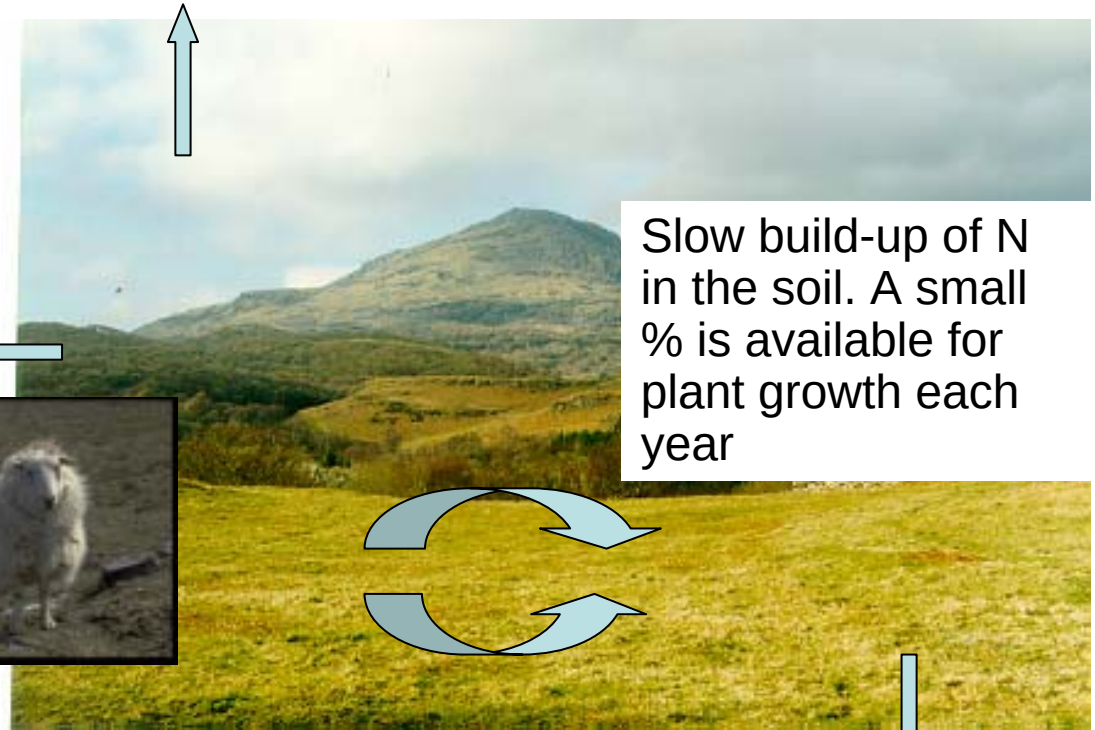
Taken up by plants and in the long term stored in the soil. Small % available for plant growth each year

Leached to streams and rivers

What characterises a site with low N deposition?

Greenhouse gas production (e.g. N_2O) is low

Plant production often limited by N availability. Advantage to plants with low N requirements



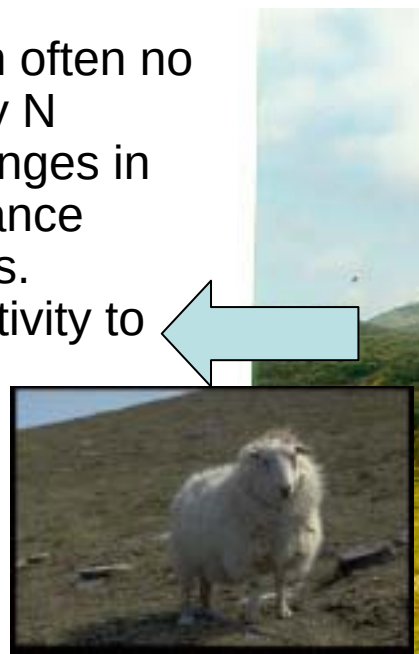
Slow build-up of N in the soil. A small % is available for plant growth each year

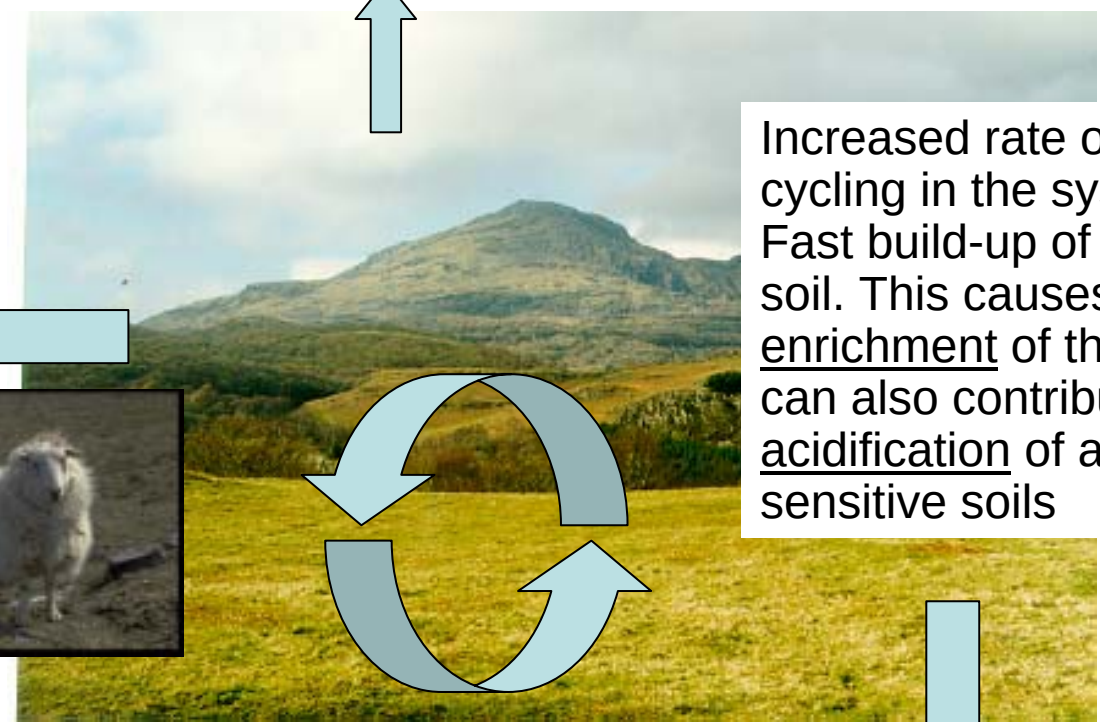
Low N concentrations in stream and rivers. Primary production often limited by N

What characterises a site with high N deposition?

Greenhouse gas production increases but very variable depending on soil type

Plant production often no longer limited by N availability. Changes in competitive balance between species. Increased sensitivity to stresses





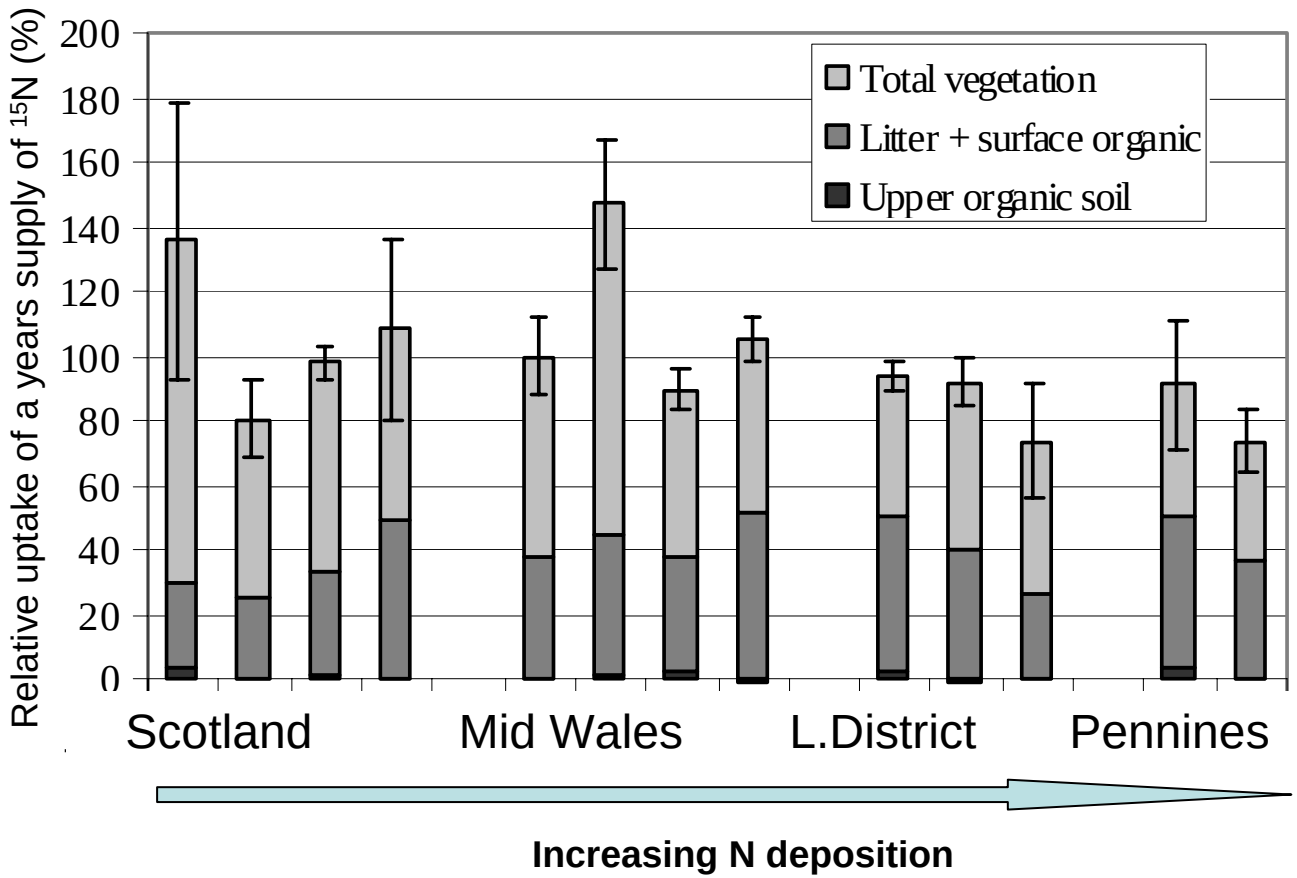
Increased rate of nitrogen cycling in the system. Fast build-up of N in the soil. This causes <u>enrichment</u> of the soil and can also contribute to <u>acidification</u> of acid sensitive soils

Increased N concentrations in stream and rivers. Primary production no longer limited by N alone

What happens to N when it is deposited?

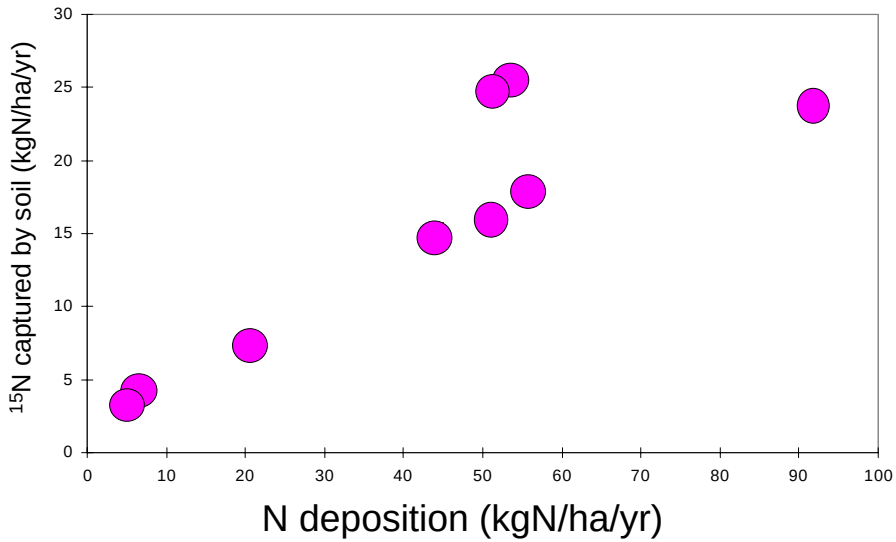
Various studies using the tracer ^{15}N have shown that vegetation and soil are both important in taking up deposited N in the short term (Tietema et al 2000, Curtis 2003, Phoenix 2003). However, in the longterm as plants shed their leaves it is the soil which is the long term sink for deposited nitrogen.

The role of soil and vegetation in capturing incoming ^{15}N applied over a year in 4 regions of the UK. Different bars indicate different soil types (Curtis 2003)

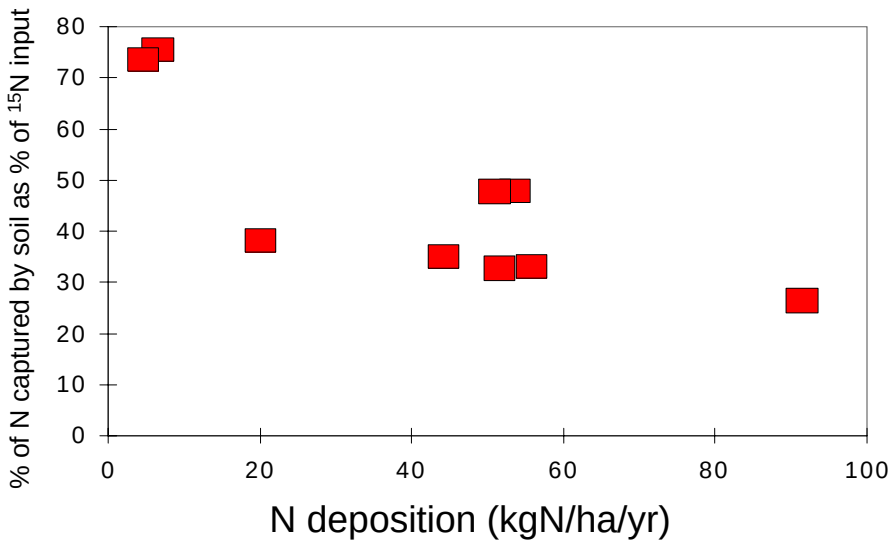


Storage of N in the soil

As N deposition increases so does the amount of N stored in the soil which enriches the soil.



But if expressed as a % of deposition, the soil is becoming less efficient (i.e. it is capturing a smaller % of incoming N) which means more N must be going elsewhere (plants, waters?)

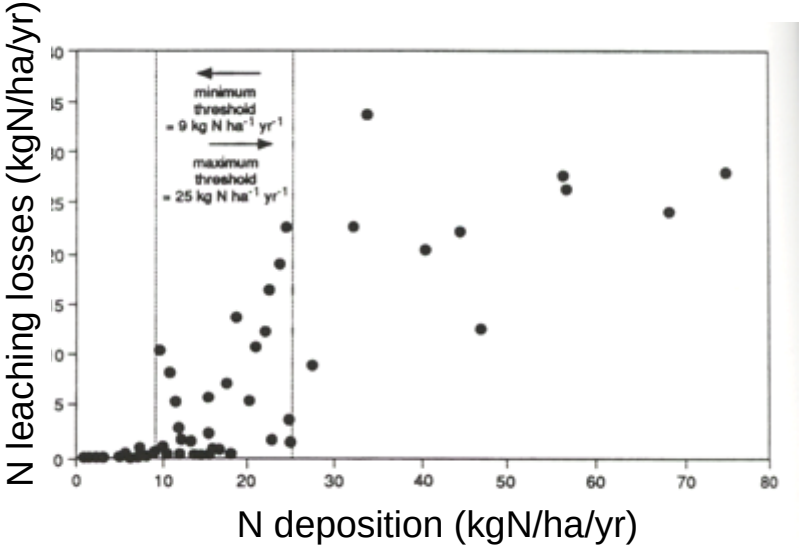


Redrawn from Tietema et al. (2000)

Some N may increase plant production but as the soil becomes less efficient at capturing N, some will be leached or lost to the atmosphere

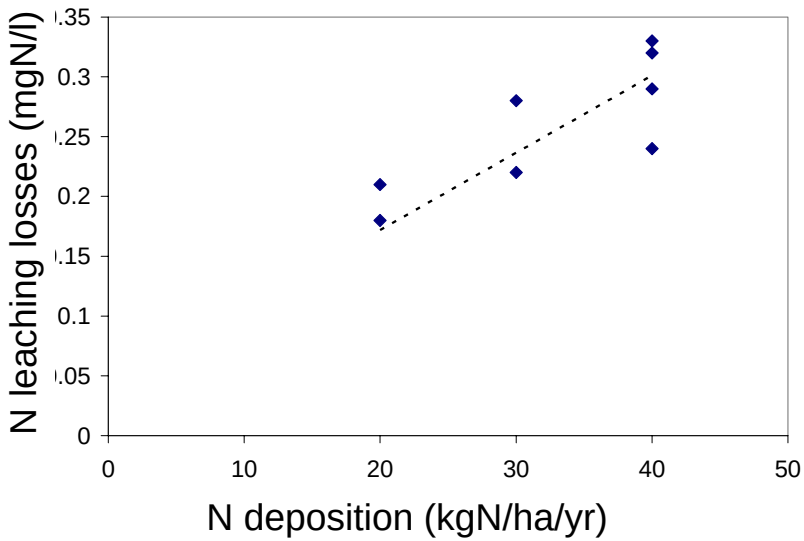
Forests

Increased nitrate leaching in European forest stands above 10 kgN/ha/yr (Dise and Wright 1995)



Grasslands

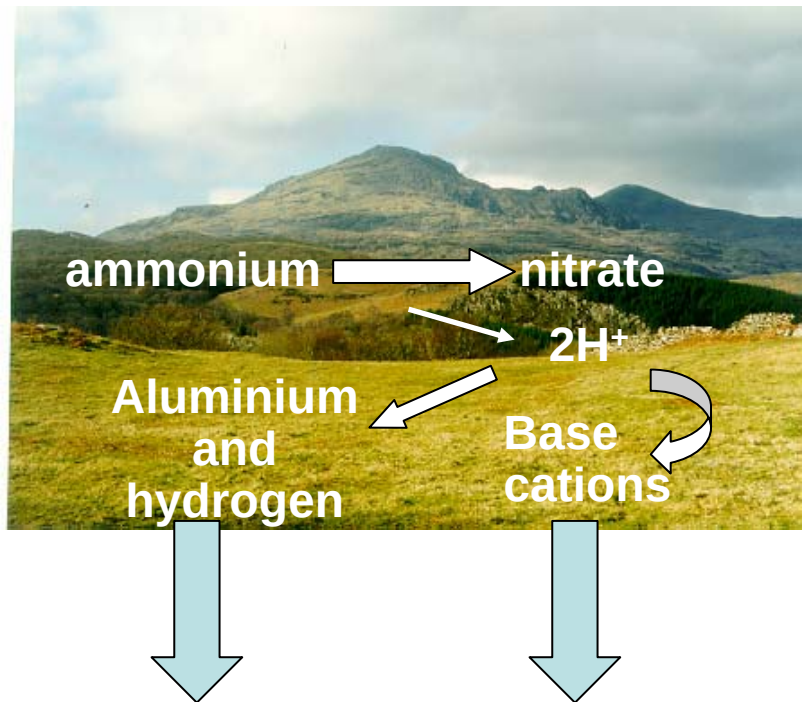
Increased N leaching with N deposition in an acid grassland. Variability is due to different N forms applied and grazing pressure. (Gordon et al. 2000).



Enrichment of soils with N and leaching of N can result in acidification which can affect both plants and stream biota

In acid sensitive soils such as many upland soils, increased N deposition can strip the soil of base cations (such as calcium) and increase acidity and aluminium concentrations. These can affect plants and stream biota.

Due to uptake and transformation processes in the soil, ammonium inputs may acidify to a greater extent that oxidised nitrogen

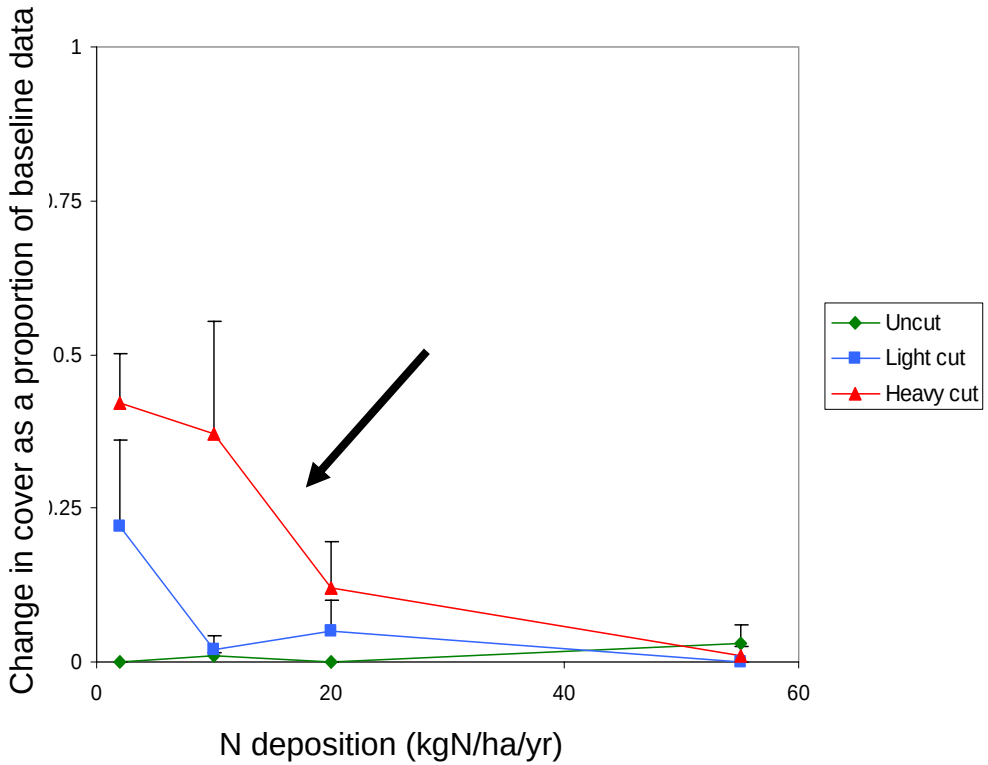


How have things changed in the UK?

1. Monitoring
    - Waters: Probably the best long term records available. Variable signal probably due to variable potential for soil to capture the N (e.g. peats compared to mineral soils)
    - Vegetation : Some evidence of change from CS2000, Plant Atlas and other monitoring programmes
    - Soils: This is difficult to assess as we don't have many long term records of soils
2. Gradient studies
    - Only a few available e.g. U4 grassland (C. Stevens et al. Unpubl.), Sand dunes (L.Jones et al. Unpubl.)
3. Recovery experiments from current conditions
    - Only two available; acidic and calcareous grassland (L. Jones et al. 2002) and acidic grassland (Wiliams et al. Submitted)

Recovery experiments

Results from the few gradient and recovery experiments we have suggest that vegetation is most sensitive to deposition changes from 10 – 20 kgN/ha/yr. This could mean most of the change has already happened in many parts of the UK.



Decline in *Racomitrium lanuginosum* at N deposition rates above 20kgN/ha/yr (Jones et al. 2000)

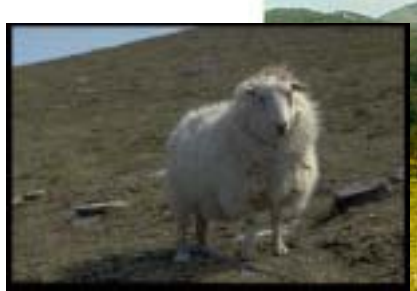
Predicting the threshold for change or ‘damage’

Below are the values currently used when calculating UK critical loads for acidity. These are rates taken as being ‘acceptable’ above which N deposition may contribute to acidification. Mike Ashmore will talk about critical loads for nitrogen.

Gaseous losses
1 - 4kgN

Removed in animal or tree biomass, or lost to fire:

animal	< 1 kgN
forestry	3 – 6kgN
fire	4.5 – 15kgN



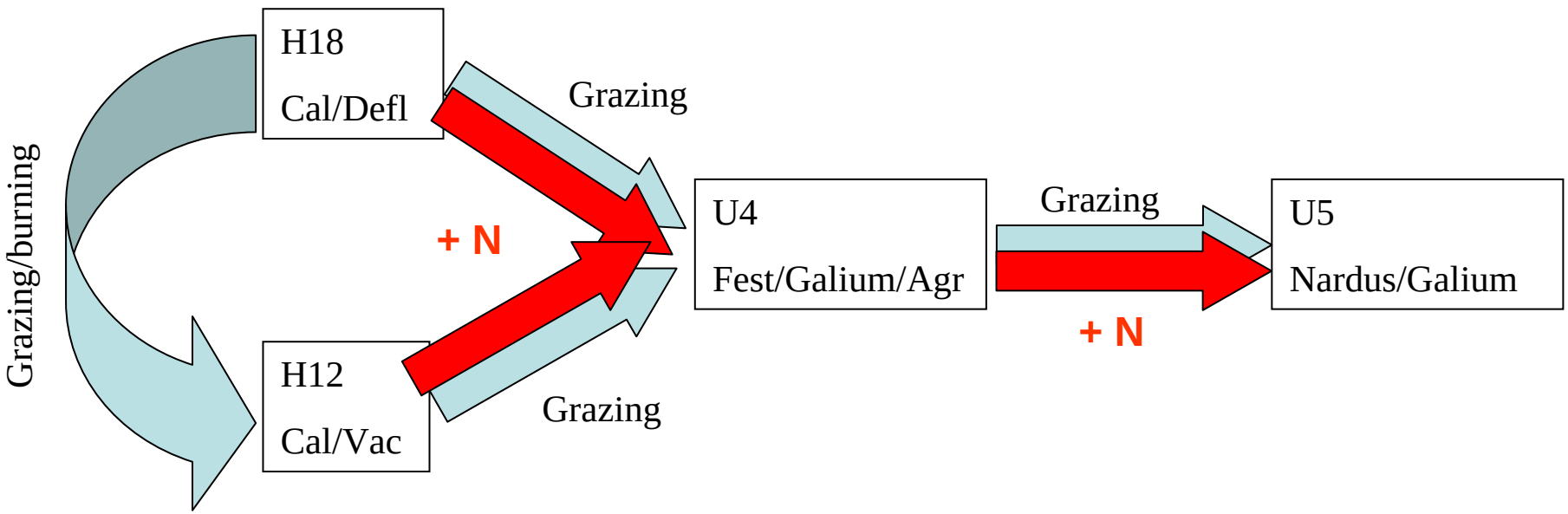
Long term Immobilisation in the soil
1 – 3kgN

Leached to streams and rivers
3 – 4 kgN

The threshold can depend on other variables such as grazing, management and P limitation?

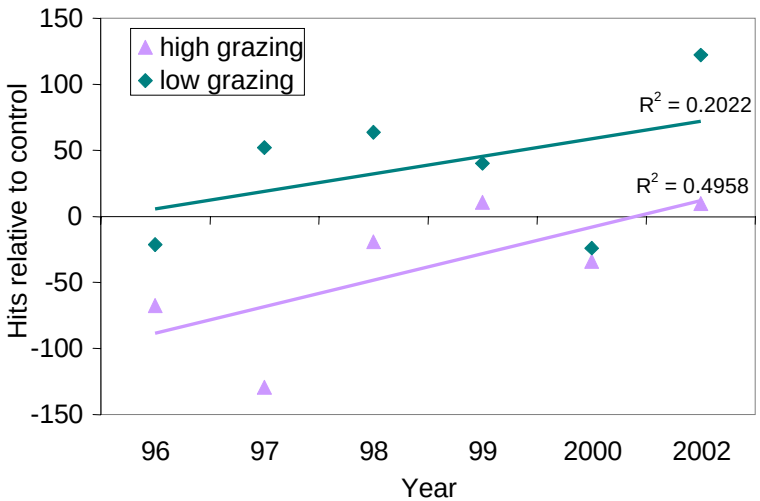
Grazing is a major influence on vegetation communities in many parts of the UK.

Nitrogen may have some similar effects to heavy grazing pressure (e.g. encouraging grasses in heathlands)



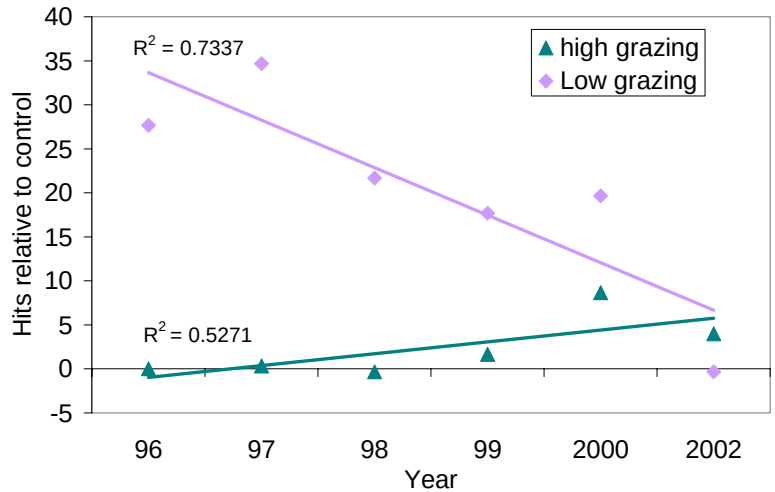
Evidence of positive effect of N on grasses and modifying effect of grazing

Positive response of *Nardus stricta* to N. Stronger relationship in heavily grazed paddock



Change in *Nardus stricta* with N addition (20kgN ammonium sulphate/ha/yr) over 6 years with low and high grazing

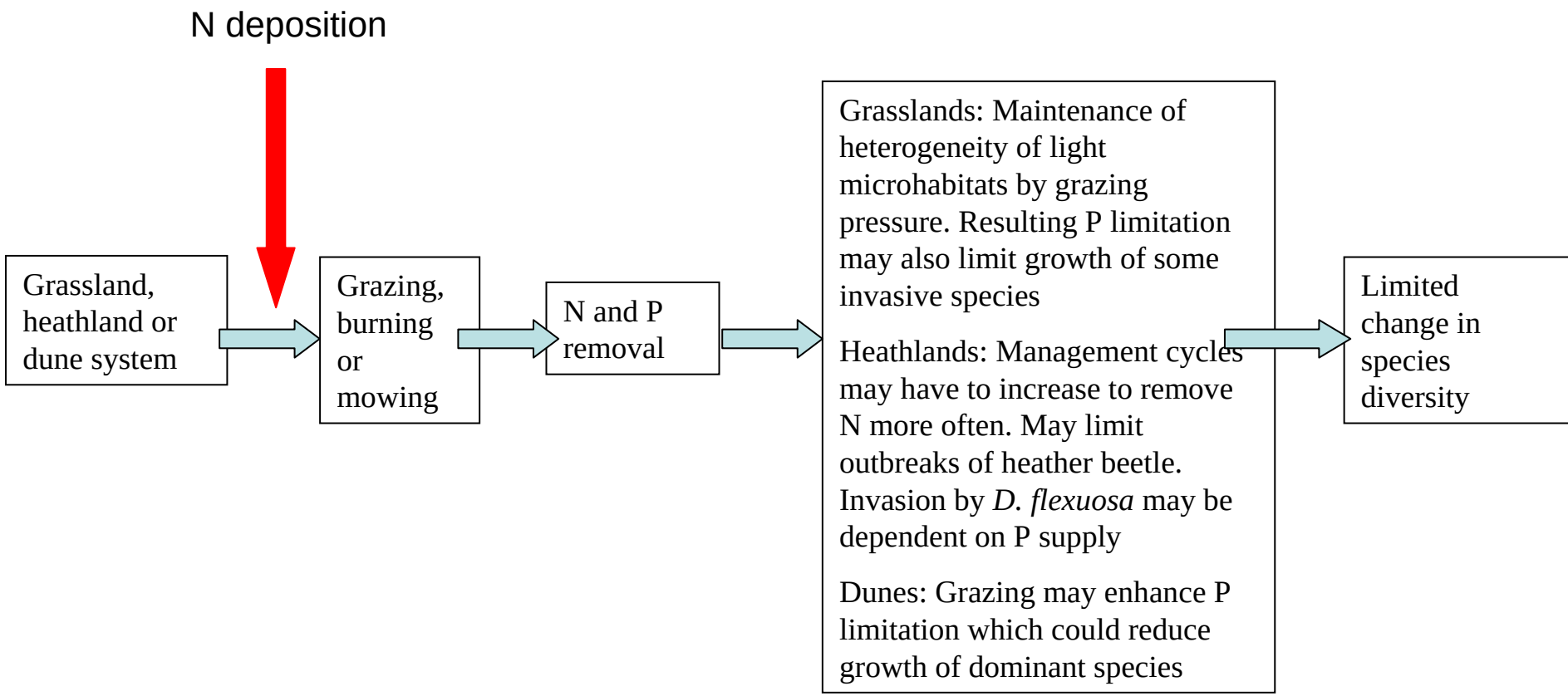
Negative response of *Racomitrium lanuginosum* to N where grazing is light. When only remnants remain in heavily grazed paddock evidence of a positive response



Change in *Racomitrium lanuginosum* with N addition (20kgN sodium nitrate/ha/yr) over 6 years with low and high grazing

Emmett et al (Unpublished data)

The possible role of phosphorus limitation in mediating the effects of N and the removal of N using grazing, fire or mowing



Predicting the timescale of damage or recovery

We need to use dynamic models ….but there is a lack of models which link the soil processes and vegetation response.

- This is important because plants respond to the past enrichment of the soil not just the current deposition
- We need to combine effects of S and N and their combined effects on acidity
- There is a need for climate change to be considered and the possible interactions with N and S (e.g. increased sensitivity of plants to drought with high N deposition)
- Grazing also needs to be included
- Water quality models already include soil processes. We are way behind the water quality community and we have a more complex system.

However work is starting – see talk in Session 3

Summary

- The soil is the ‘memory’ of past N deposition to a system
- Many UK systems are no longer N limited due to past N deposition
- It is likely many changes have already happened and we just don’t know about them
- Effects of N on plants are complex and species specific.
- We can’t deal with vegetation by itself. There is a need for integrating measurements at the catchment scale.