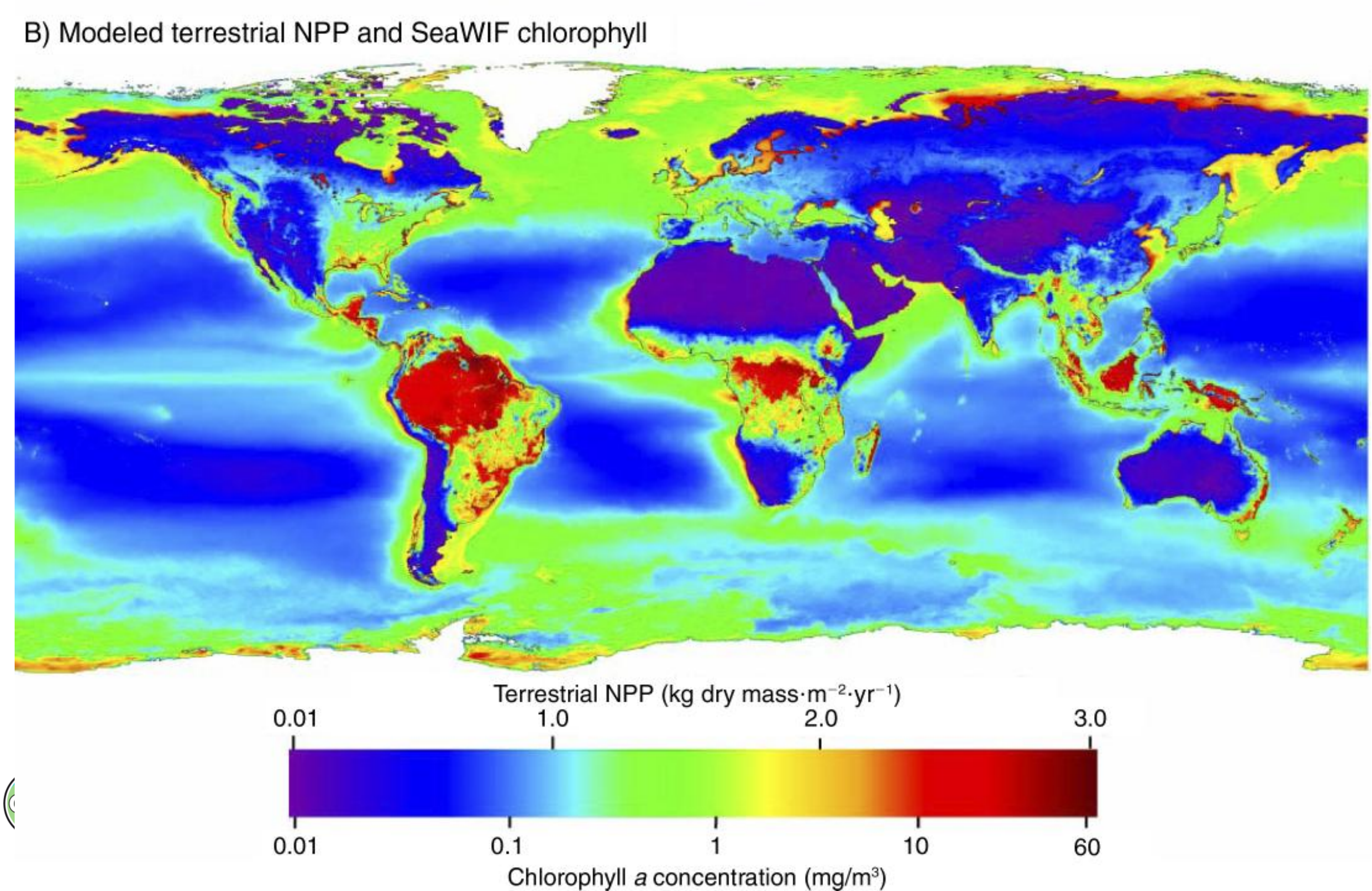
TNPP measurement: plant-based sampling

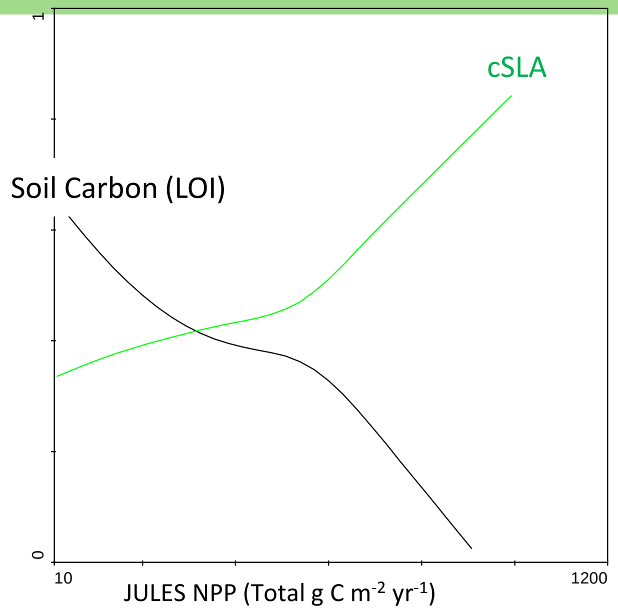
Simon Smart, Miles Marshall, Helen Glanville, David Cooper

GLOBAL MODELS GET TNPP WRONG

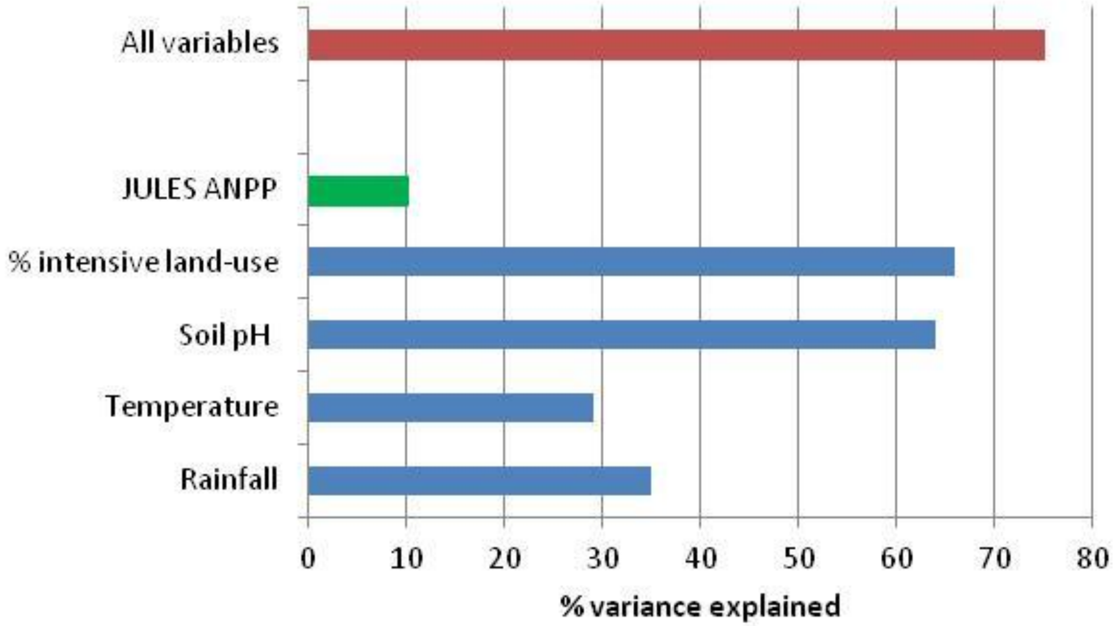
- Explored by Huston & Wolverton (2009) *Ecol. Mon.*

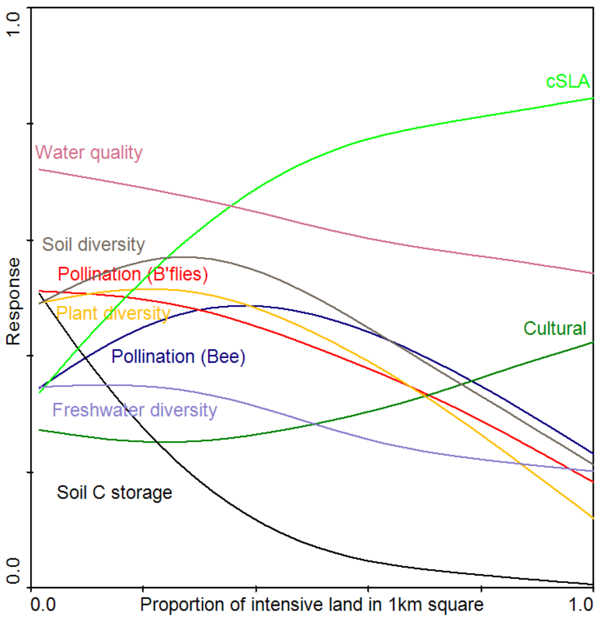


Why model enhancements?



Because: Currently JULES lacks the processes (e.g. P and N cycling) needed to capture the ecosystem function/ biodiversity versus productivity gradient across Britain and to model future ecosystem states.

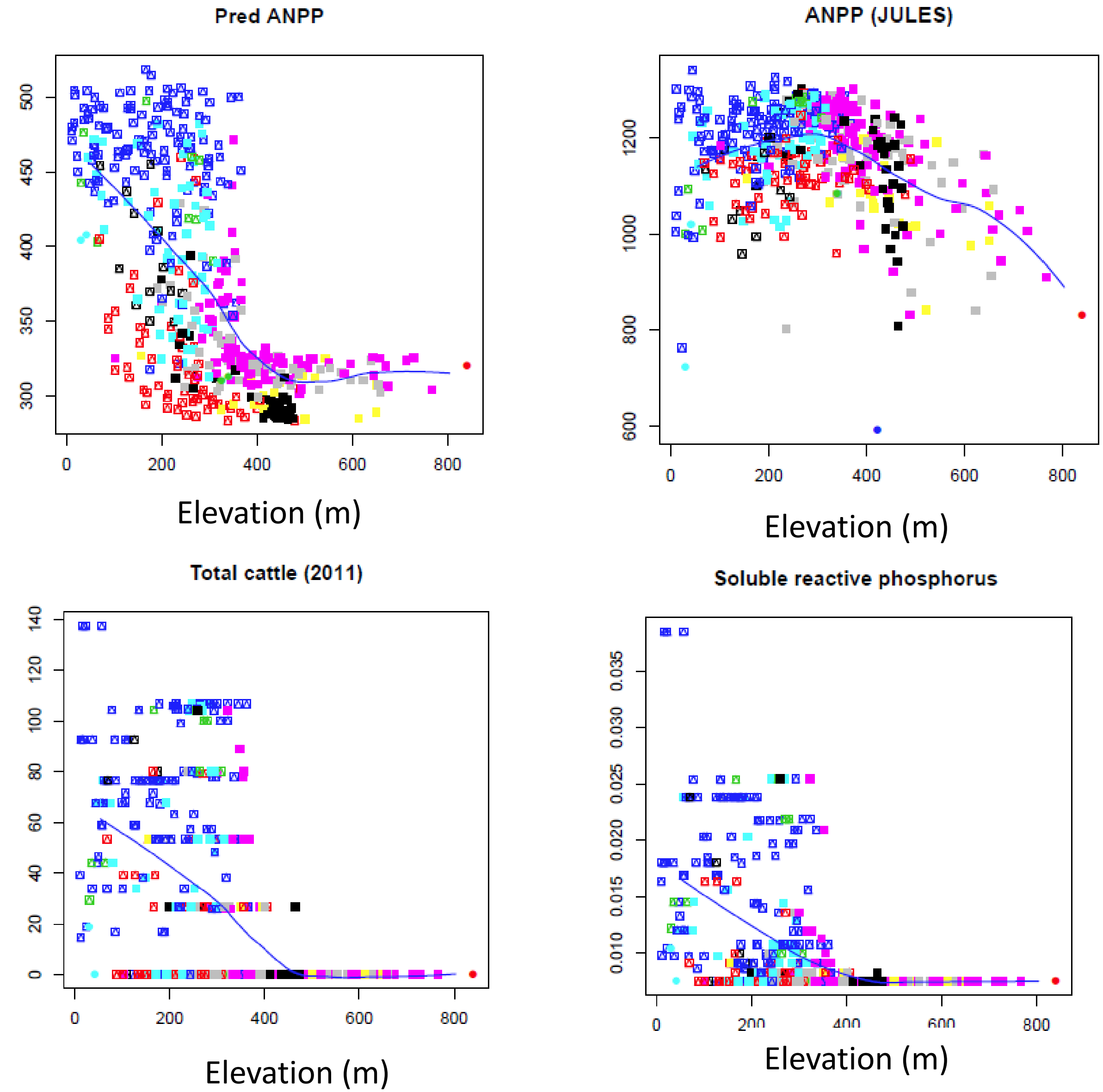




Maskell et al (2013) J.Appl.Ecol

JULES versus plant trait model; Conwy valley 1km sqr means

- Improved grassland
- Arable and Horticulture
- Rough grassland
- Suburban
- Acid grassland
- Heather grassland
- Broadleaved woodland
- Coniferous woodland
- Heather
- Montane habitats
- Freshwater
- Bog
- Inland rock



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Direct measurements over 2 years for NERC Macronutrients projects

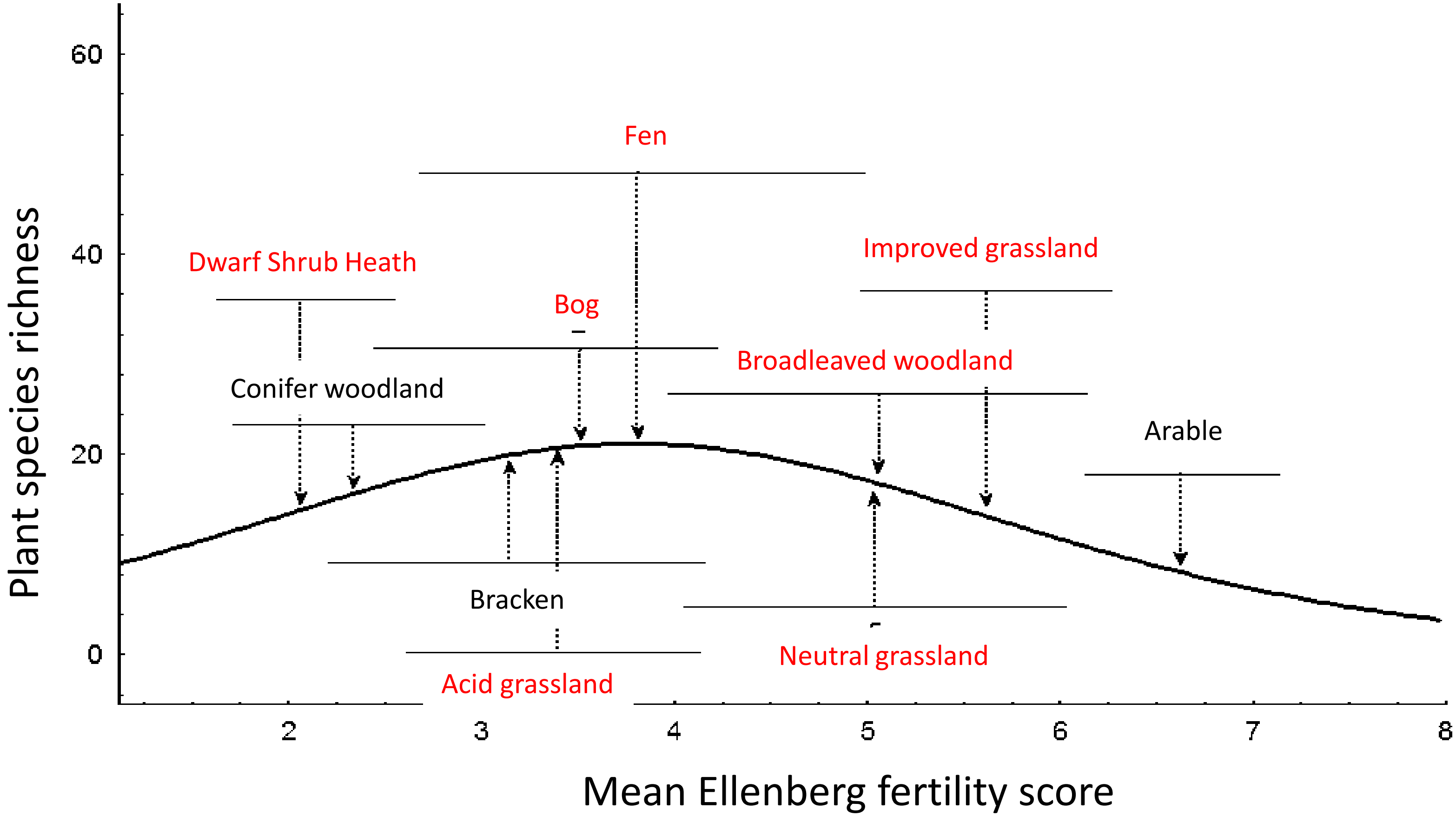






The UK productivity/biodiversity gradient

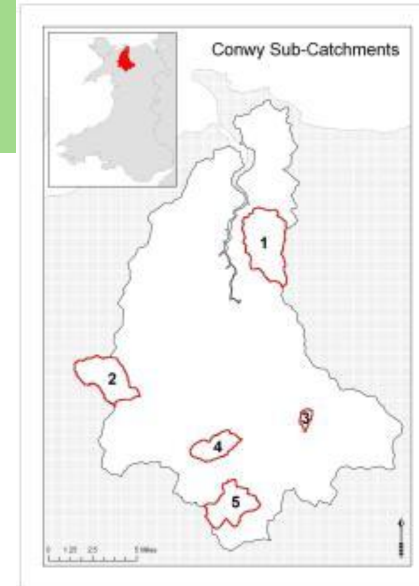
- "Britain is heterogenous" Ed Tipping 2013 (Macronutrients annual meeting)
- "Britain is a grassy country" Mark Hill (1997) J.Veg.Sci.

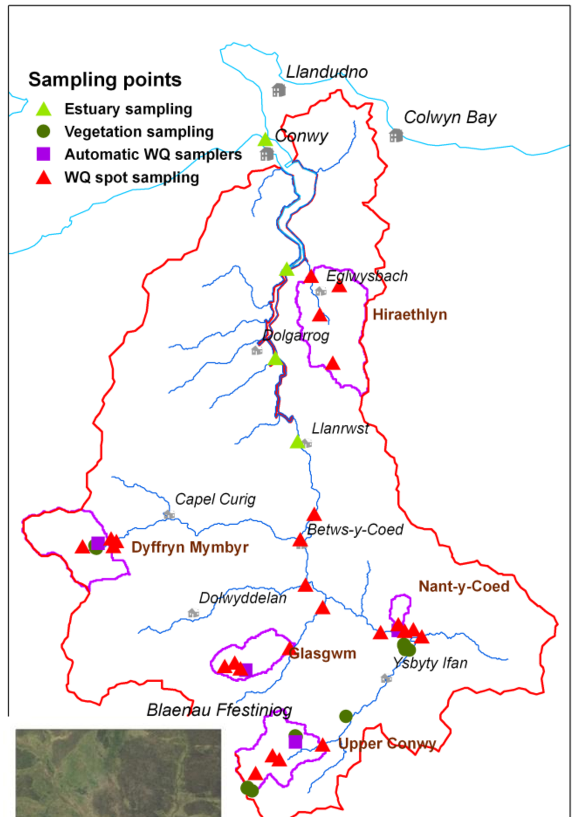


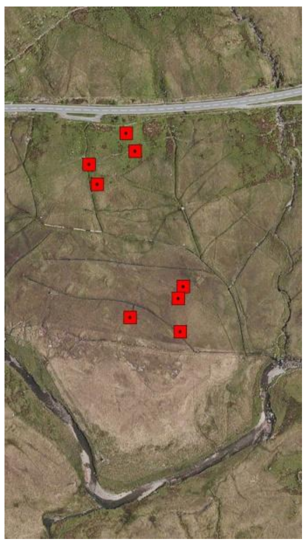
Smart et al (2003) J.Env.Man.

Sampling in sub-catchments

- 52 plots in 12 habitat types in 2013-’14
- Plant species identified in all
- 30 *Sphagnum* wires





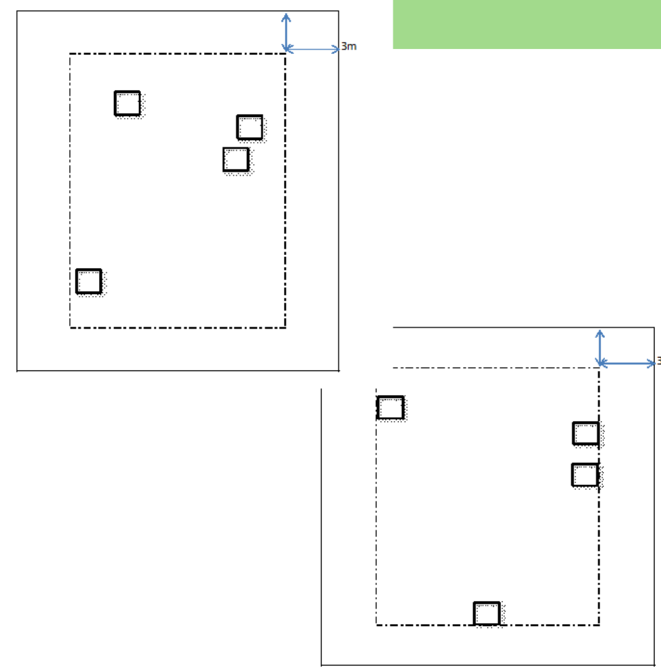


Each habitat type presents its own unique problems

	Graminoids	Forbs	Mosses	Dwarf shrubs	Trees & shrubs	
Annual cultivation, NPK, pesticides	D	F				Arable
>=1 cut pa, NPK, high grazing, reseeding	D	O				Improved grassland
Moderate to low grazing, lime and P	D	A	A			Neutral, Acid and Calcareous grasslands
15 to 20 yr biomass cut, low grazing	D	O	D	D		Heath & Bog
No biomass cut, low grazing	O		D	D		Montane
30 to >40 yr felling, low or no grazing	A	A	A		D	Woodlands

Dominant, Abundant, Frequent, Occasional

Methods: Enclosed grasslands



- Stock excluded; peak biomass cuts (Smart et al (2002) *Agric.Eco.Env.*) plus autumn cuts
- Issues of compensatory growth but no superior method seems to exist unless you can manipulate stock (eg. Laliberté et al (2013) *Ecology*).


profi electronics

Electronic walking stick probes pasture for returns

Methods: Unenclosed grasslands

- Stock excluded; winter, summer and autumn cuts
- Acid and calcareous grasslands

Methods: Heaths & Bogs

- Estimate ANPP by functional type of plant

Sphagnum

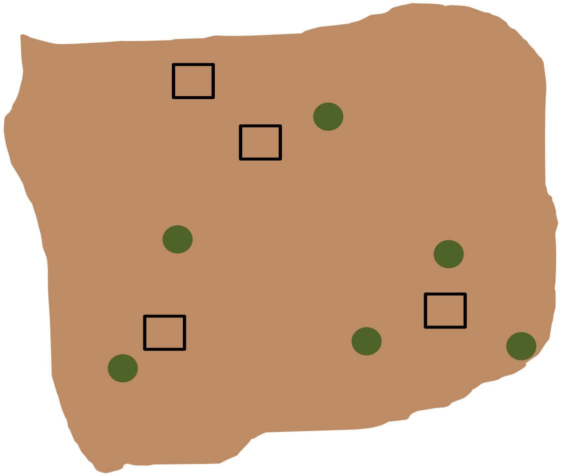
Graminoids

(Poaceae, Juncaceae,

Cyperaceae)

Dwarf Shrubs

- Total biomass harvest in patches with different time since last burnt

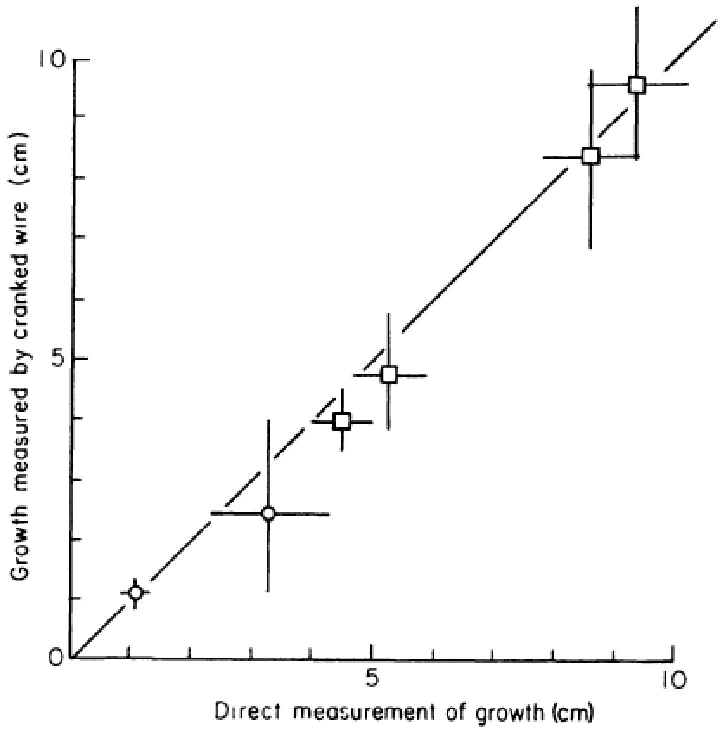


Dwarf Shrubs: *Calluna vulgaris*

- Growth rate changes with *Calluna* age
- Total harvest of above-ground *Calluna* in three replicate plots in three areas of different burn history at Llyn Serw
- Build a growth curve

Sphagnum spp.

- **Cranked wires.** After Clymo (1967) applied following Kivimäki (2011)



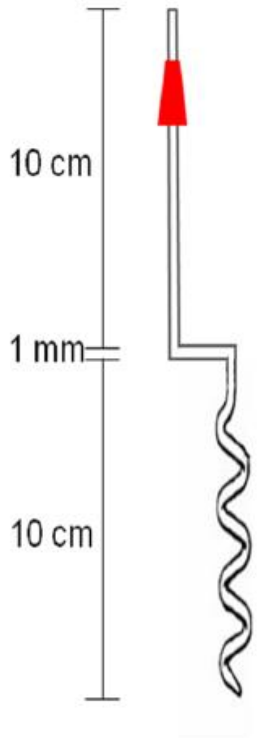
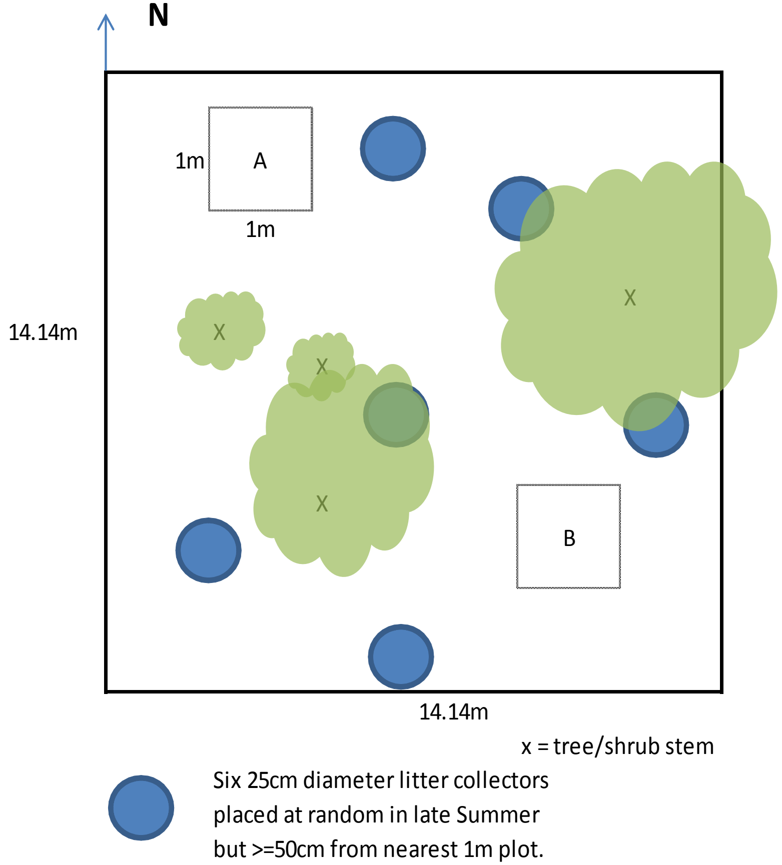


FIG. 2. Comparison of growth in length by direct measurement on plants of known initial length, with estimates by cranked wire. For details of methods see text. Values are mean of ten (containers near laboratory, □) or twenty-five (field, ○) measurements. Bars are ± twice the S.E. of the mean. The line of slope + 1·0 is that on which the points would fall if the methods were in exact agreement.

Methods: Woodland

ANPP = Leaf litter + ground flora + woody increment

- Litter collectors in autumn
- Ground flora in summer, and spring if vernal flora
- Mean annual woody increment



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Methods: Woodland

- Mean annual woody increment
  - Allometry isn't good enough to translate DBH into yearly volume in any one place for a particular species (eg. Coomes & Allen, 2007. *J.Ecol*).
  - Combine DBH, tree height and **tree ring measurement** to give annual woody increment (Husch , B. 1963. *Forest Mensuration & Statistics*).

$$I = \pi.F.D.H.W$$

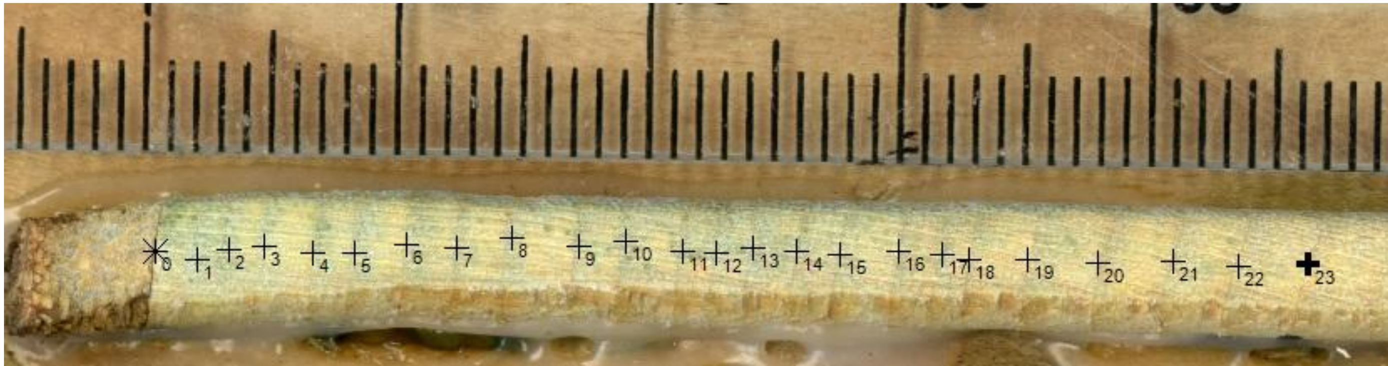
I used Cdendro and CooRecorder software. We calculate mean annual volume increment over the 5 trees in the plot.

F= 0.462 (form factor expresses ratio of volume of tree stem to a cylinder)

D = current DBH

H = height

W = width of most recent ring



Methods: Woodland

- Ground flora
  - Exclosures if grazed
  - None if not

Methods: Woodland

- Pleurocarpous moss mesh
- July 2013 November 2013

- 20 x Litter buckets in 200m^2

Montane

- *Racomitrium* mesh to be installed in January
- 6 x 0.25m^2 exclosures in *Empetrum* heath and *Salix herbacea* dwarf scrub at 1044m

Other habitats in 2014

Easier methods

- Bracken
- Arable (Barley, Maize, *Brassica* spp.)

Will use approaches already described, for the following:

- Conifer woodland
- Hay meadow (Colt Park NNR)
- Purple Moor-grass & Rush-pasture
- Lowland calcareous grassland (Wiltshire, Avon Valley)

Further issues and caveats:

- Resources limit what we can do
- Low replication but many habitats covered

- ANPP will be a function of weather in 2013 (eg 4-47% of biomass variation at Rothamsted PG was explained by rainfall in preceding year (Silvertown et al (1994) *Ecology*)

- In terms of coverage of PFT, range of habitats and growing season length it will be a uniquely comprehensive dataset
- ..especially when coupled with soil, plant traits and below-ground data

- All locations are GPS'd to 3m accuracy with photos and sketch maps, so can be revisited in future

Acknowledgements:

- Lucy Sheppard, Peter Levvy, Alex Turner, Chris Evans, Ed Rowe, Bridget Emmett, Rob Marrs and the Central Teaching Laboratory at Univ. Liverpool

The contentious relationship between biodiversity and NPP

- Early results by Tilman and others including BIODEPTH were based on experimental systems showing positive effect of biodiversity on productivity
- Criticised by *inter alia* Thompson et al (2005) *Funct.Ecol*. and Huston (1997) *Oecologia*
  - Immature communities, unrealistic species manipulations, NOT bulbs popping on an Xmas tree (Grime 1998), only part of the NPP gradient studied
- Cardinale et al (2011) *Am.J.Bot.* summarised 20 years of BEF results.
- Trait-based ecology of land plants gained strength building on the Sheffield Grime powerhouse and now offers better explanation of the biodiversity effect. Trait identity more important than species richness *per se*. So the Leaf Economics Spectrum (Wright et al 2004, *Nature*) tells us which traits are likely to respond to increased NPP and increase NPP themselves (the response and effect trait framework ; Suding et al (2008), *GCB*)
- Most productivity and ecosystem function rests on the dominants and these can often be defined by their traits (Garnier et al 2004 *Ecology;* Smith & Knapp 2003; *Ecol.Letts*. Grime 1998, *J.Ecol*.).

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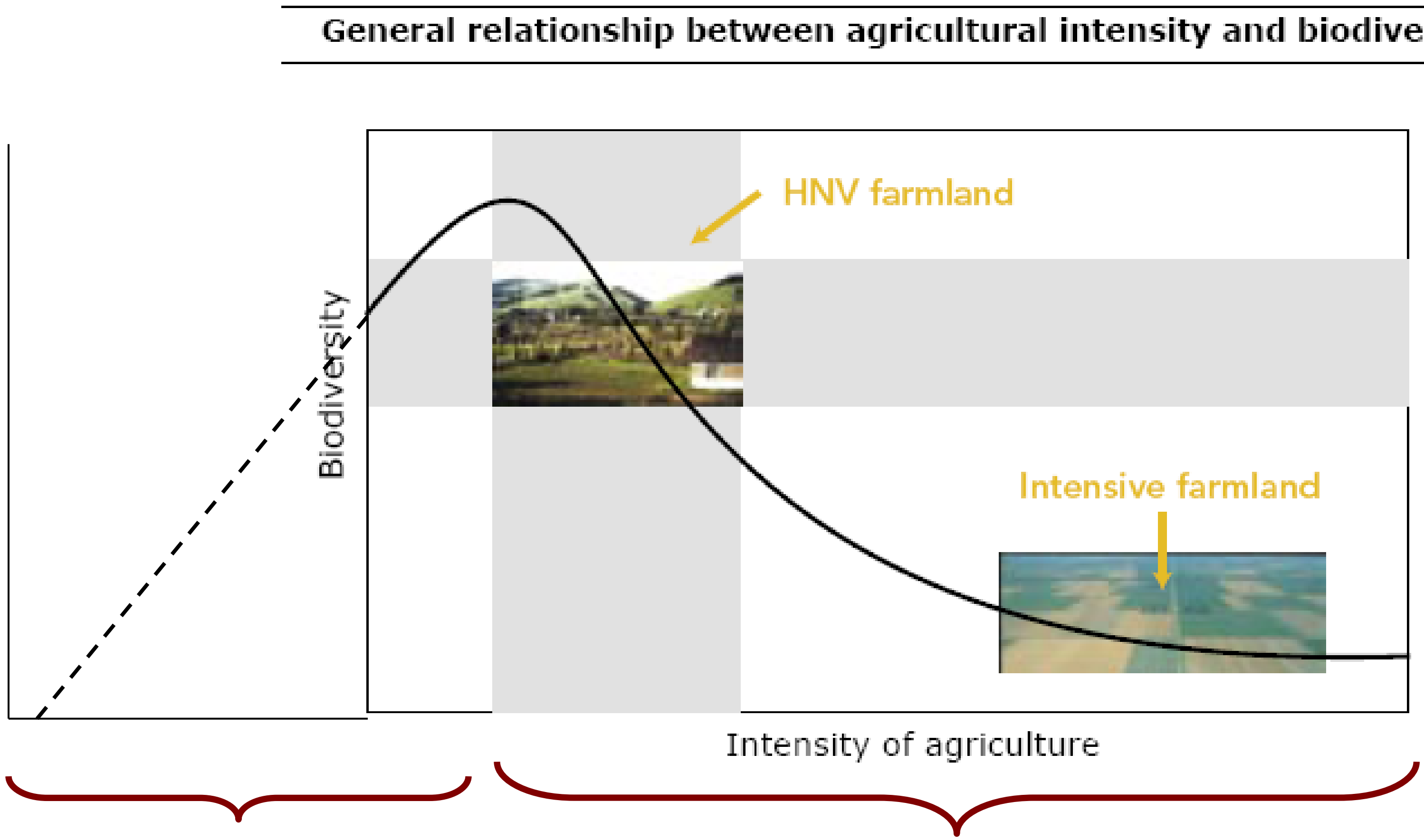

Domain of experiments; NPP increases with species diversity

Domain of agricultural ecosystems; management deliberately promotes dominance at the expense of species diversity (Smart et al 2006 *J.Appl.Ecol*)

The possible mechanisms whereby biodiversity increases NPP

- Selection or Sampling effect; originally a criticism by Michael Huston but deftly turned into something he knew about all along by Tilman in a clever rearguard action in PNAS.

"As you randomly draw more species from a pool you increase chance of selecting a productive species...simples!"

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The possible mechanisms whereby biodiversity increases NPP

- Complimentarity leading to transgressive overyielding; species interact in a positive way such that diverse polycultures are more productive than the most productive species grown in monocultures.

- Classic example is a legume and high-yielding grass
- But in 67% of studies Cardinale et al (2011) found that the highest yield was the monoculture even though the polyculture outperformed the average of the monocultures..

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The possible mechanisms whereby biodiversity increases NPP

- Niche partitioning: maximum use of resources requires exploitation of all niche space which requires more species

Smith & Rushton (1994) studied the unimproved hay-meadow at Ravenstonedale and suggested productivity was related to occupancy of many microsites by a diverse mix of species

Cardinale et al (2011) suggested there was strong evidence for niche partitioning

Current evidence and questions (Cardinale et al 2011) Am.J.Bot.

New questions we need to address	Evidence
Q9. How do diversity effects documented in experiments scale-up to "real" ecosystems?	Insufficient evidence to address
Q10. Sure… diversity effects are significant. But how strong and important are they compared to other forms of environmental change?	Insufficient evidence to address
Q11. What types of biological diversity have the greatest impact on ecosystem processes—would conservation and management of ecological functions be better achieved by focusing on genetic, species, functional, or higher levels of diversity?	Insufficient evidence to address
Q12. How does biodiversity simultaneously impact the suite of ecosystem processes that are required to optimize the "multi-functionality" of diverse ecosystems?	Insufficient evidence to address

- Tilman et al 2012 says he has helped answer Q9 and Q10 above...

- Vellend et al 2013 suggest otherwise

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PNAS

Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory

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Contributed by David Tilman, May 15, 2012 (sent for review March 30, 2012)

Although the impacts of the loss of biodiversity on ecosystem drivers, the resolution of this debate will require approaches that

PNAS

Global meta-analysis reveals no net change in local-scale plant biodiversity over time

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