Terrestrial Net Primary Productivity - introduction

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Background

In current UK-based research projects within the NERC BESS and Macronutrient Cycles (MNC) programmes there are strong needs to know NPP, especially

(a) to explain, model and predict ecosystem nutrient cycling, and

(b) to investigate how ecosystem productivity and biodiversity affect one another.

NPP is also a key concept in the NERC Greenhouse Gas Emissions and Feedbacks (GHG) programme.

An appreciation of NPP is relevant to ecology, earth system science and environmental policy development.

This meeting will provide a forum for discussion and interchange of ideas from different perspectives.

Given the immediate demands of the BESS and MNC programmes, there will be a UK focus, but other places and larger scales are not excluded.

Productivity and Production

Net primary productivity (NPP) is defined as the net flux of carbon from the atmosphere into green plants per unit time. NPP refers to a rate process, i.e., the amount of vegetable matter produced (net primary production) per day, week, or year.

Definitions – 1 *(Schlesinger book, Chapin et al 2006)*

GPP = Gross Primary Production

R_{plant} = Plant Respiration

R_{herbiv} = Herbivore Respiration

R_{het} = Heterotrophic Respiration

NEE = Net Ecosystem Exchange
(CO_2-C input to atmosphere)

Units are gC m^{-2} a^{-1}

Definitions – 2 (Chapin et al 2006)

$$NPP = GPP - R_{plant}$$

$$NEP = GPP - R_{plant} - R_{herbiv} - R_{het}$$

$$= GPP - R_{tot}$$

$NEP = - NEE$ *if all inorg C is lost as CO_2*

$NEP < - NEE$ *if some inorg C is lost as DIC*

Definitions – 3 (Chapin et al 2006)

Net **E**cosystem **C**arbon **B**alance

$$NECB = GPP - R_t - F_{CO} - F_{CH4} - F_{VOC} - F_{DIC} - F_{DOC} - F_{PC}$$

$$NECB = - NEE - F_{CO} - F_{CH4} - F_{VOC} - F_{DIC} - F_{DOC} - F_{PC}$$

$$NECB = - NEP - F_{CO} - F_{CH4} - F_{VOC} - F_{DOC} - F_{PC}$$

Definitions – 4 (Curtis et al 2002)

Biometric NPP =

increment in live plant mass
\+ increment in dead plant mass
\+ increment lost to herbivory
\+ volatile losses
\+ DOC losses

Typical values

GPP	1000 gC m^{-2} a^{-1}	
NPP	500 gC m^{-2} a^{-1}	
R_t	500 gC m^{-2} a^{-1}	
ANPP	250 gC m^{-2} a^{-1}	***above-ground***
ANPP	500 gDW m^{-2} a^{-1}	***above-ground***

NPP in different biomes

boreal forest	354
deserts	109
shrubs	109
temperate deciduous	614
temperate evergreen	614
temperate grass	373
tropical deciduous	630
tropical evergreen	1011
tropical grassland	513
tundra	163
crops	500

$gC\ m^{-2}\ a^{-1}$

Kicklighter et al 1999

Global TNPP

60 Pg C a^{-1} 60 GT C a^{-1}

Global emissions in 2013 ~ 9 GT C

Total C in soil + peat + lake sediments ~ 3000 Pg

Total C in terrestrial plants ~ 560 Pg

Factors governing NPP

temperature

moisture

photosynthetically active radiation

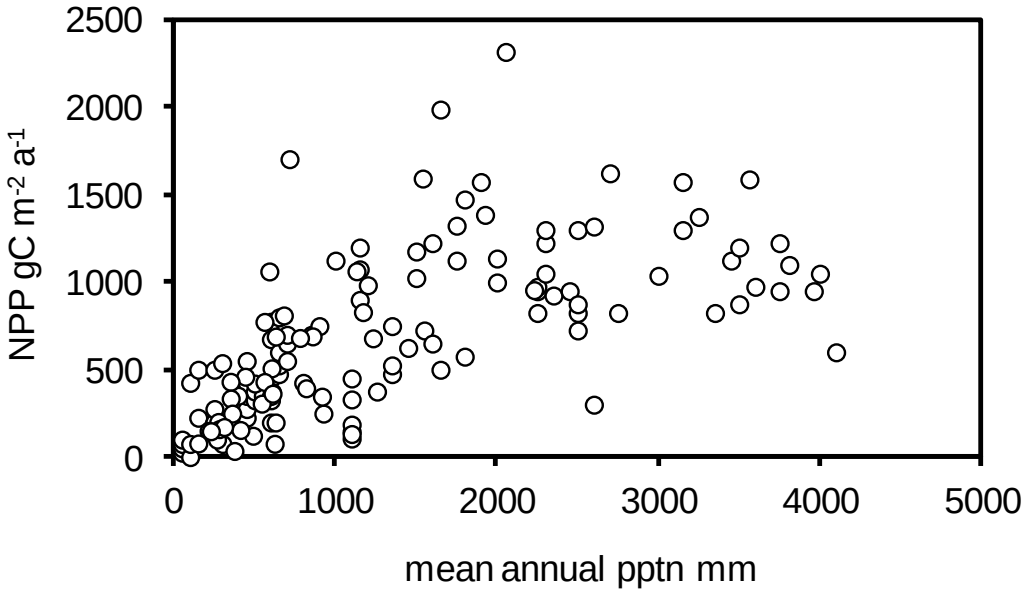
leaf area index

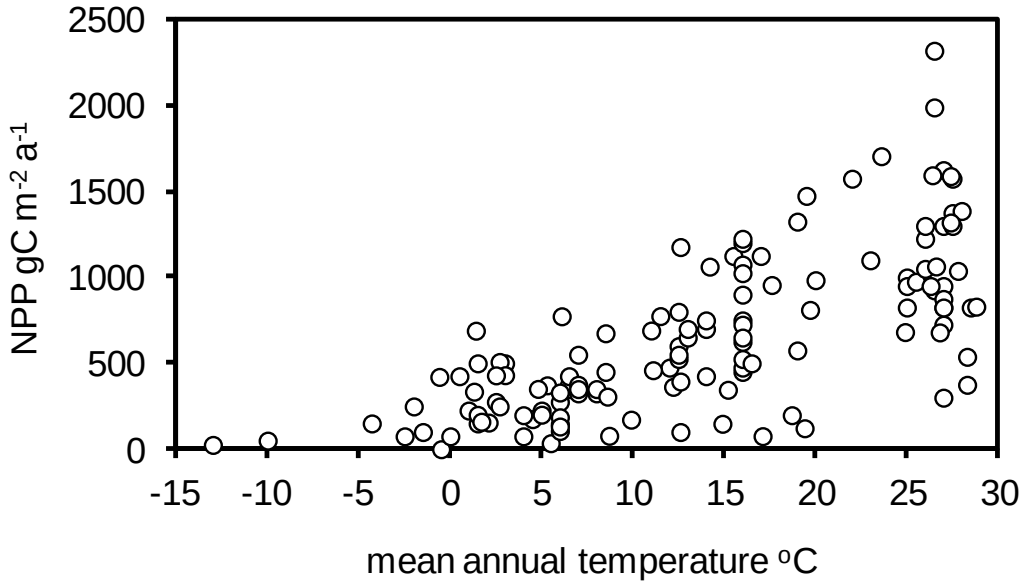
CO_2

nutrients

pollutants

Dependence of NPP on MAP and MAT





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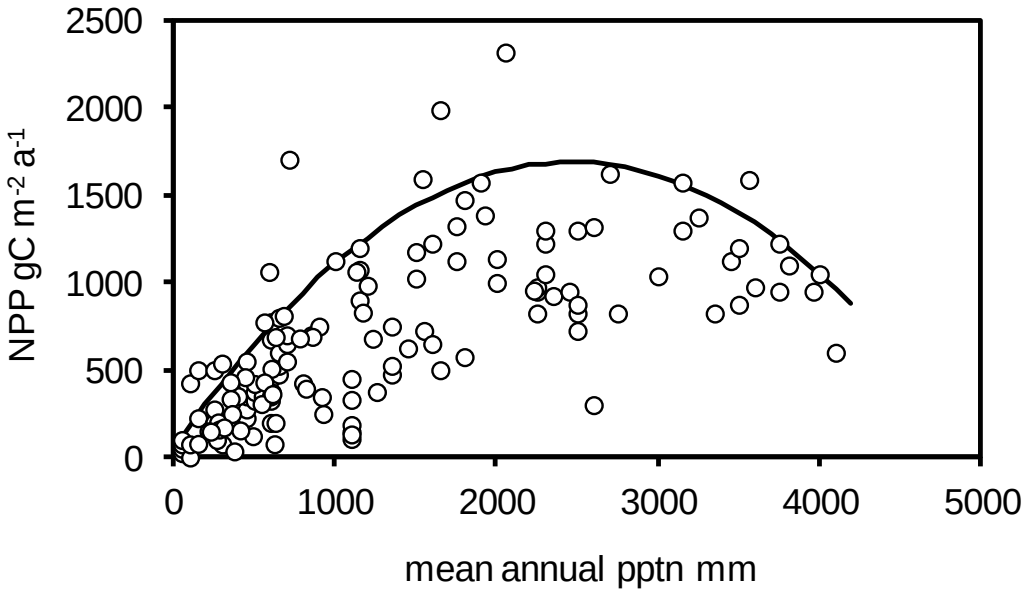
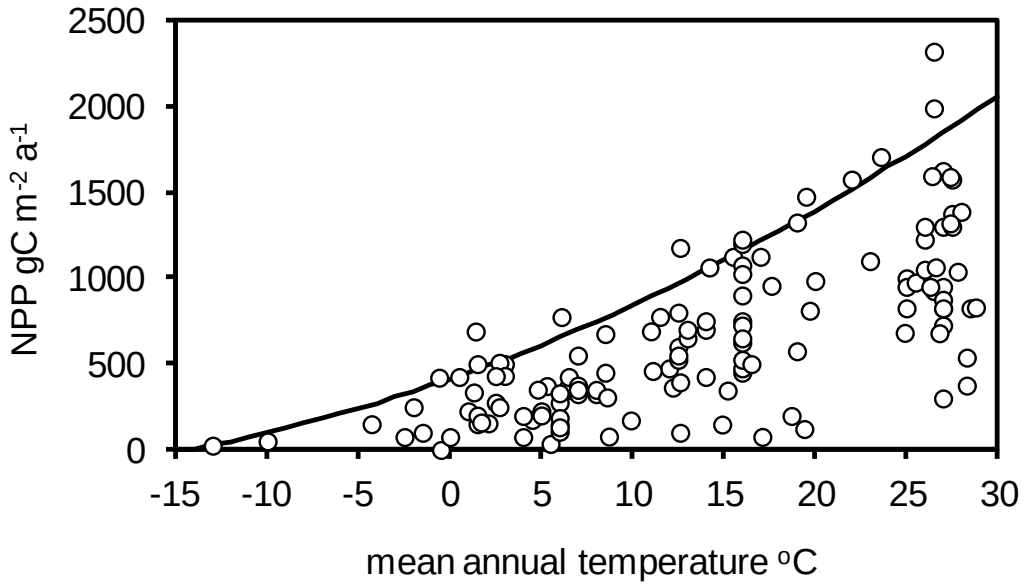
Dependence of NPP on MAP and MAT





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Elser et al. Ecol. Lett. 2007

Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems

The cycles of the key nutrient elements nitrogen (N) and phosphorus (P) have been massively altered by anthropogenic activities. Thus, it is essential to understand how photosynthetic production across diverse ecosystems is, or is not, limited by N and P.

Via a large-scale meta-analysis of experimental enrichments, ***we show that P limitation is equally strong across these major habitats and that N and P limitation are equivalent within both terrestrial and freshwater systems.*** Furthermore, simultaneous N and P enrichment produces strongly positive synergistic responses in all three environments.

Thus, contrary to some prevailing paradigms, freshwater, marine and terrestrial ecosystems are surprisingly similar in terms of N and P limitation.

LeBauer & Treseder, Ecology 2008

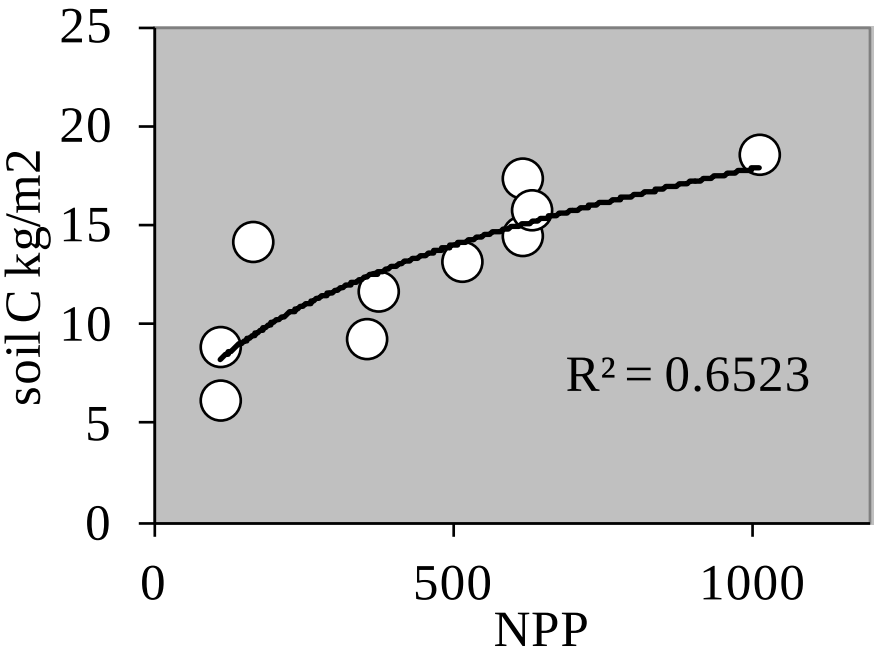
NITROGEN LIMITATION OF NET PRIMARY PRODUCTIVITY IN TERRESTRIAL ECOSYSTEMS IS GLOBALLY DISTRIBUTED

Our meta-analysis of 126 nitrogen addition experiments evaluated nitrogen (N) limitation of net primary production (NPP) in terrestrial ecosystems.

We tested the hypothesis that N limitation is widespread among biomes and influenced by geography and climate.

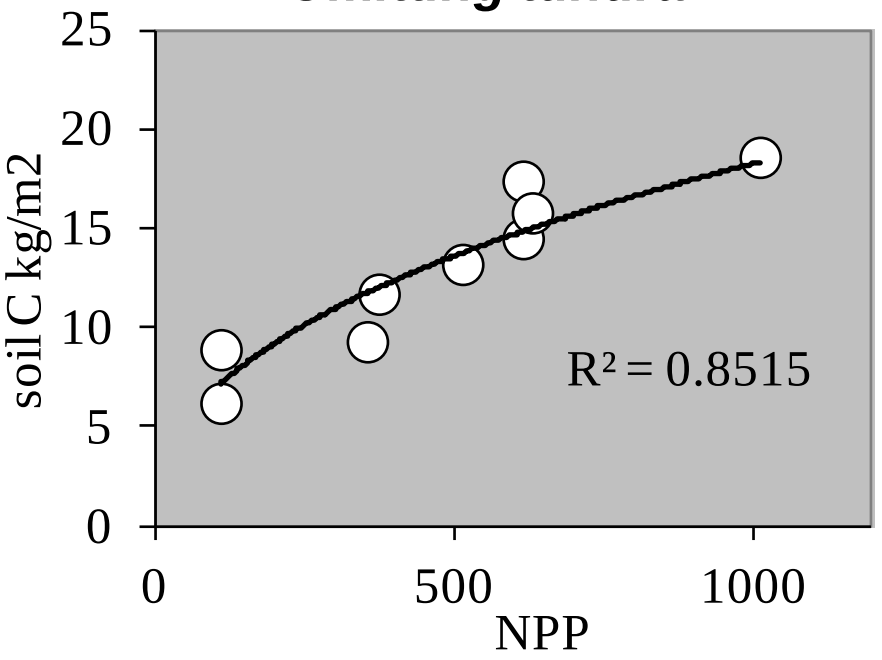
We used the response ratio (R)...of aboveground plant growth in fertilized to control plots and **found that most ecosystems are nitrogen limited** with an average 29% growth response to nitrogen (i.e., R ¼ 1.29).

Soil C and NPP



Soil pools to 1 metre

Omitting tundra



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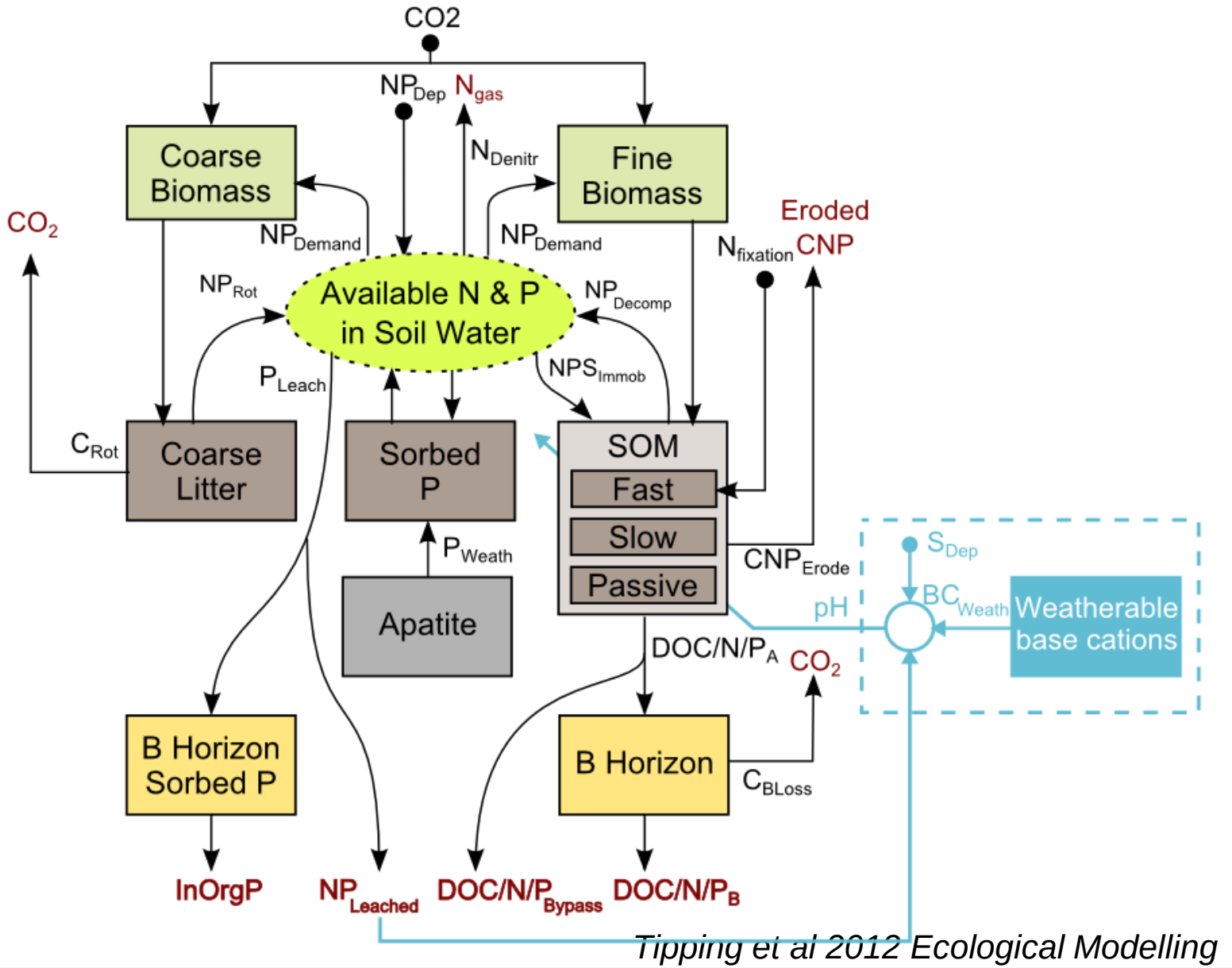
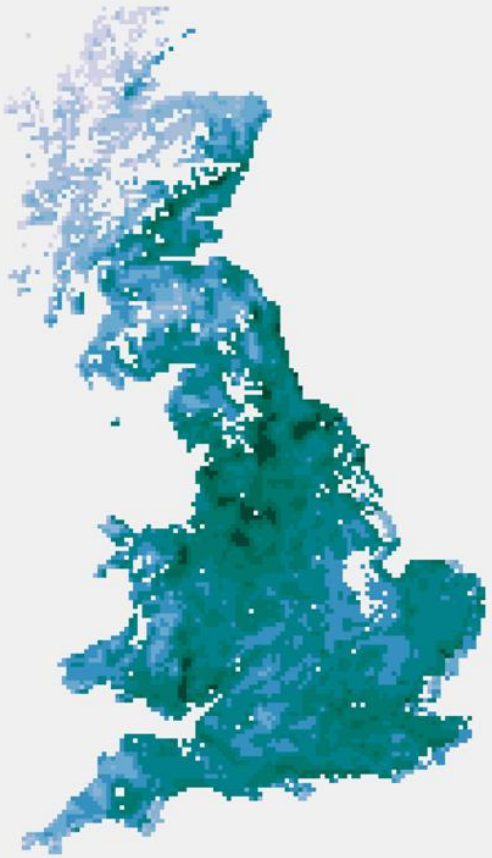
Semi-Natural Terrestrial Model: N14C

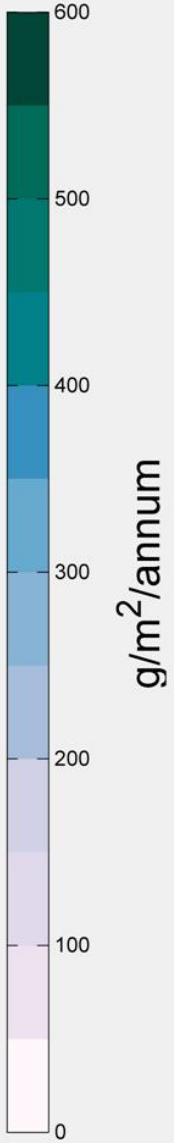


Tipping et al 2012 Ecological Modelling

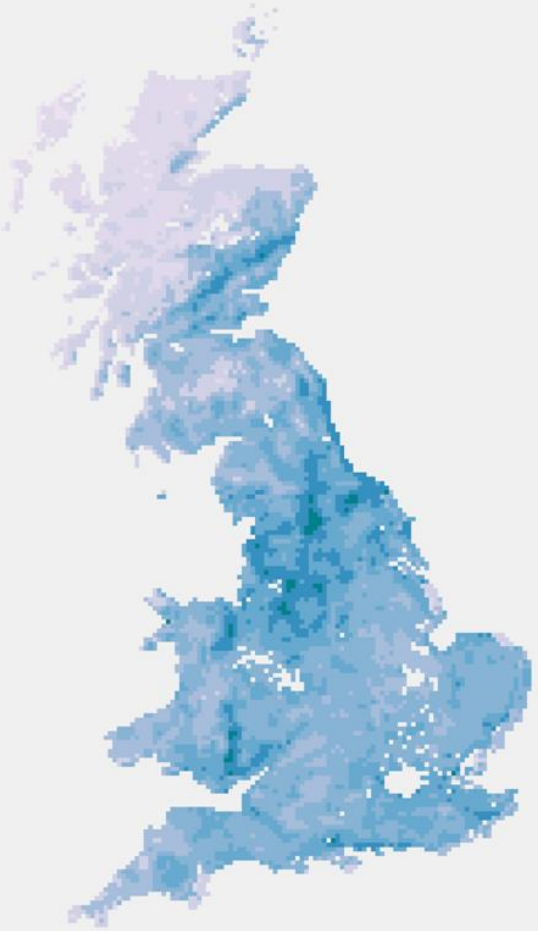
N14C simulation of NPP, 2007

Broadleaf woodland

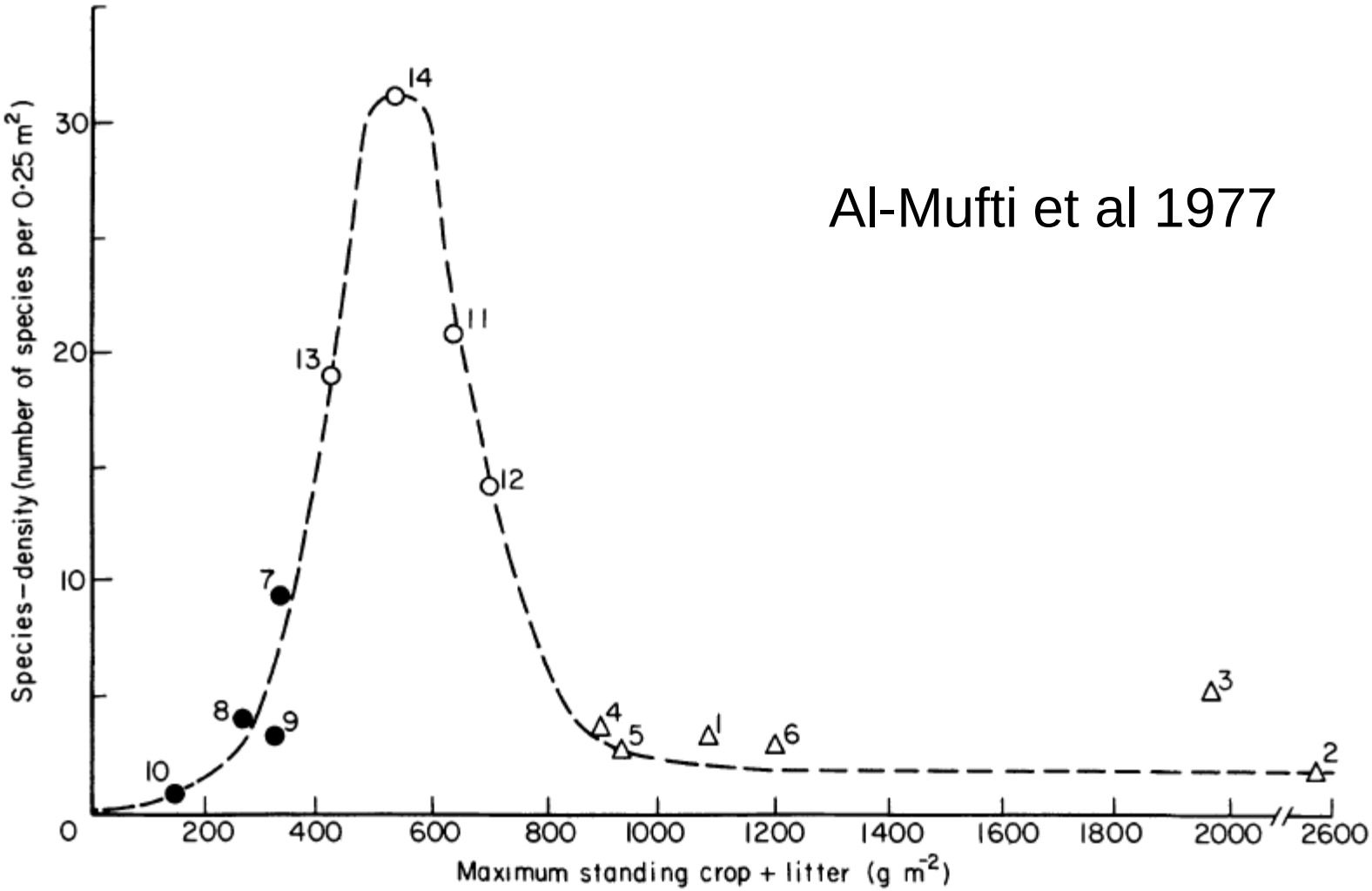




Rough grassland



Plant diversity & production



Al-Mufti et al 1977

FIG. 13. The relationship between maximum standing crop plus litter and species-density of herbs at fourteen sites. ○, Grasslands; ●, woodlands; △, tall herbs. The curve is fitted by eye.

Some questions

Do different measurements or estimates of NPP agree?

What spatial and temporal scales can we work at?

Are above-ground and below-ground NPP related?

What determines NPP?

How well can models perform?

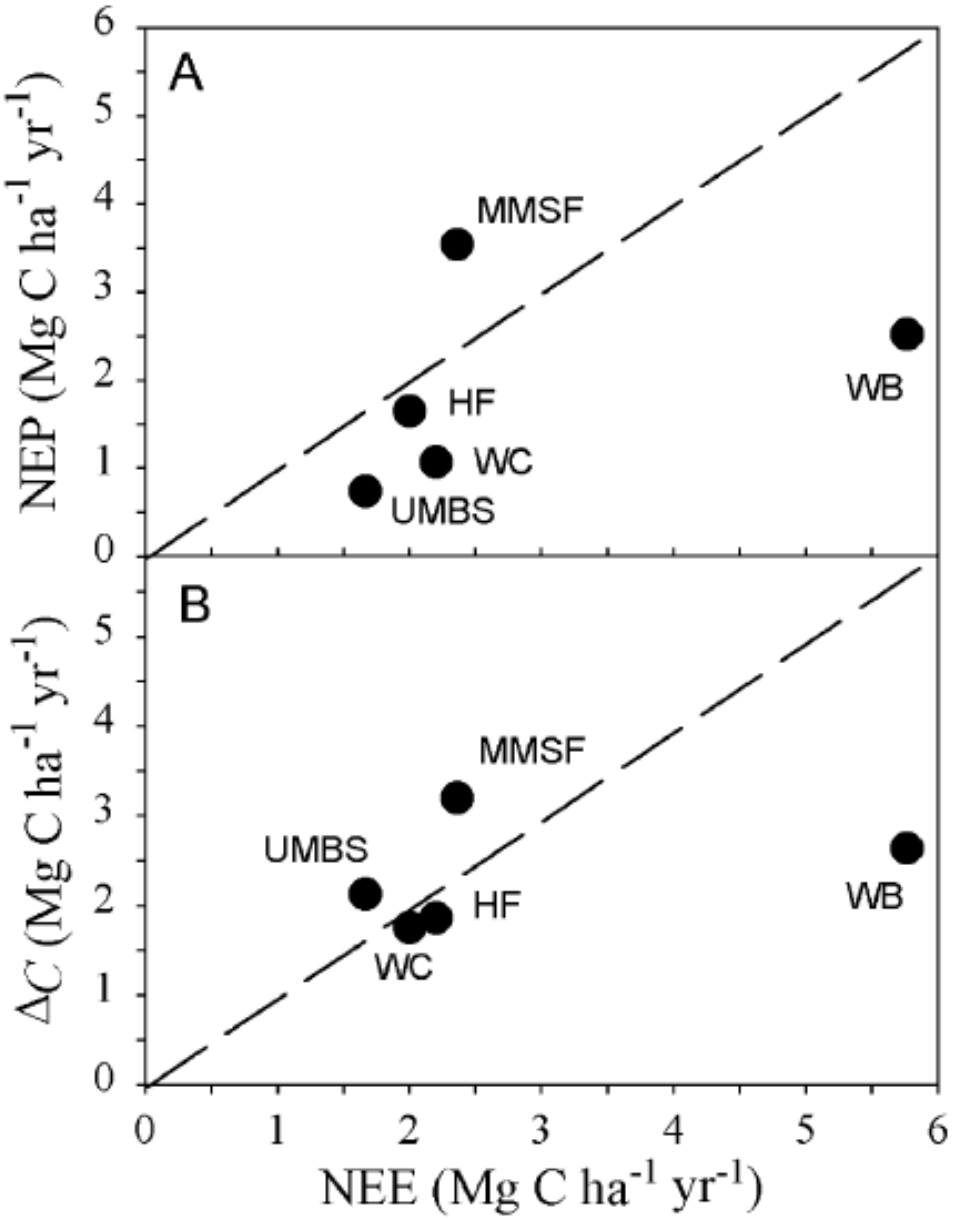
What factors need to be included?

What driving data are needed?

What is needed to relate productivity to diversity?

Others?

Curtis et al 2002 – deciduous forests



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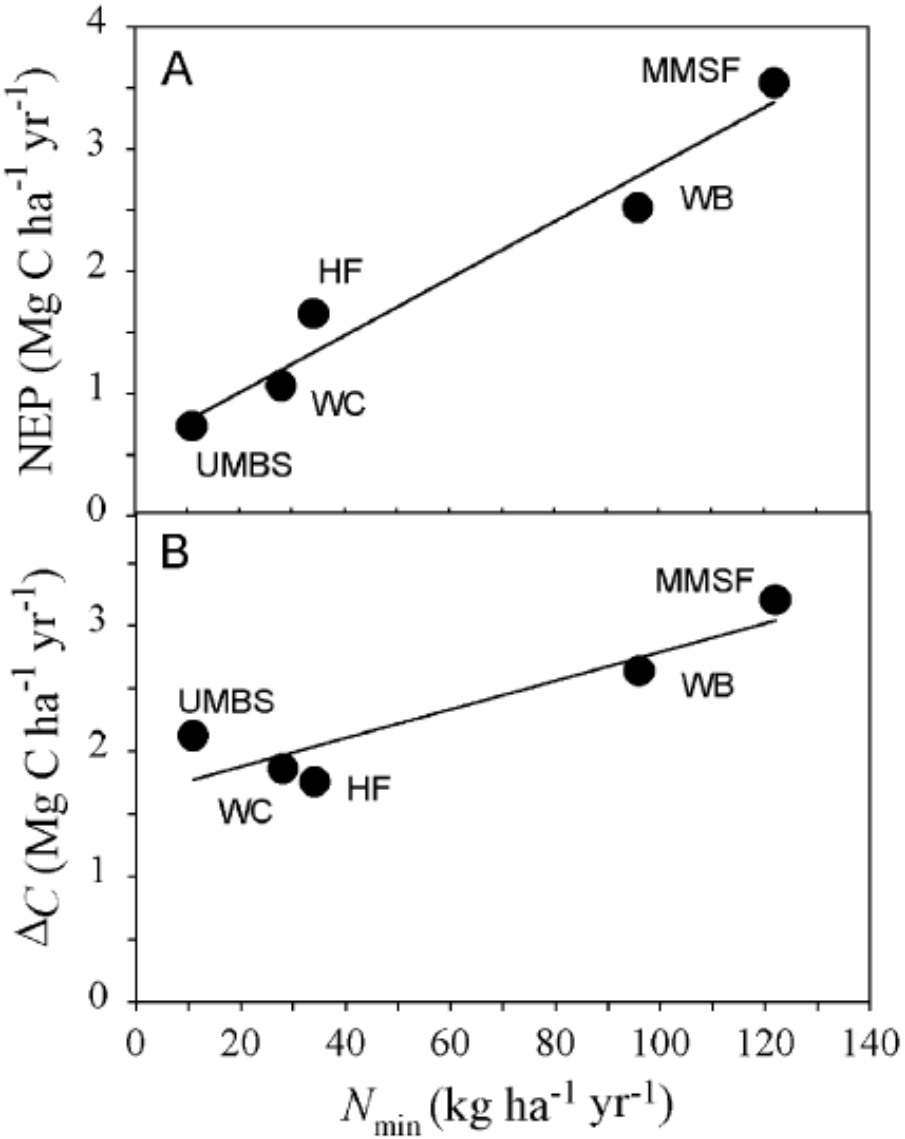

Curtis et al 2002 – deciduous forests