Climate change and the sustainable intensification of planted forests

Peter Freer-Smith and James Morison

Population growth/demand for wood and a wish to conserve natural & semi natural forests. Is there an additional argument that intensive plantation production helps to prevent deforestation ?

What proportion of the potential production are we harvesting?

Climate and [CO_2] are changing – may be a threat to natural forests but in plantations we select genotypes.

FCCC Paris agreement 2015

A global legally binding agreement establishes a credible regime for reducing global c emissions based on nationally determined commitments. The goal is 0 emissions by the end of the century (to hold global temp rise well below 2 ºC). Independent assessment of progress in 2018 and then reviewed every 5 yrs.

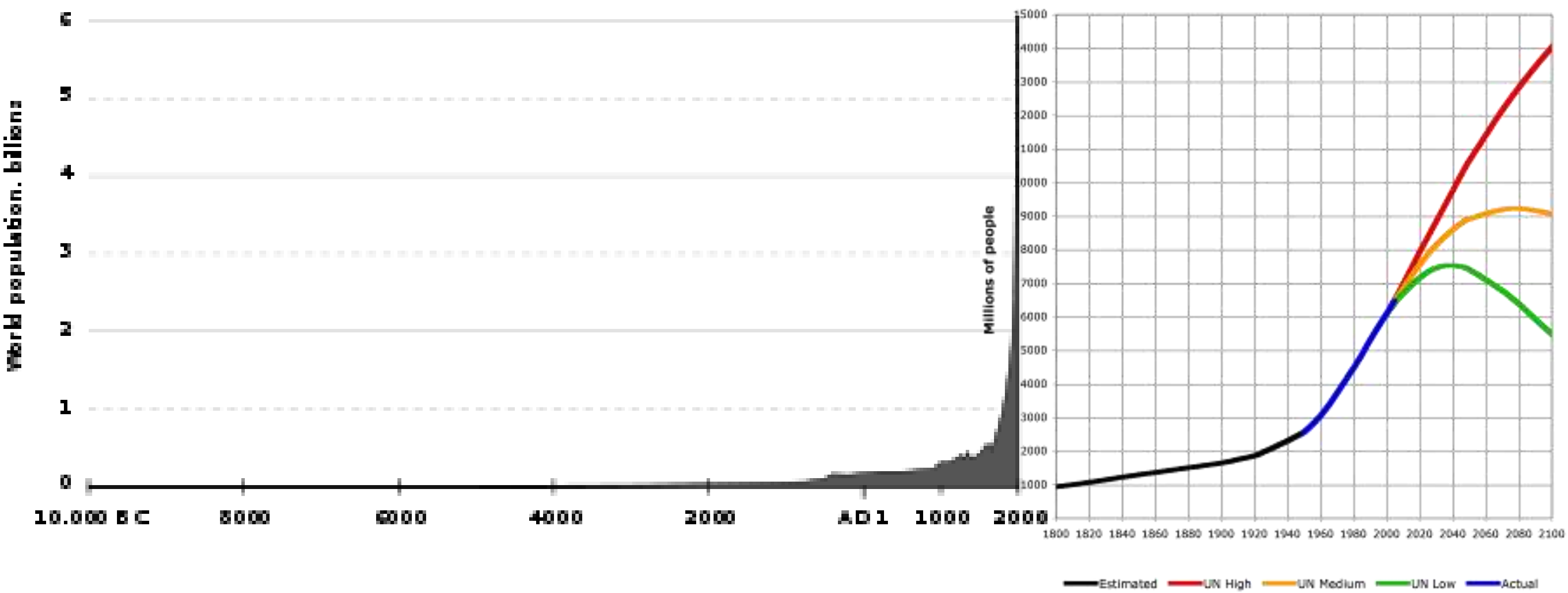
County plans to cut emissions by 2030 thereafter new post 2030 commitments every 5 yrs.

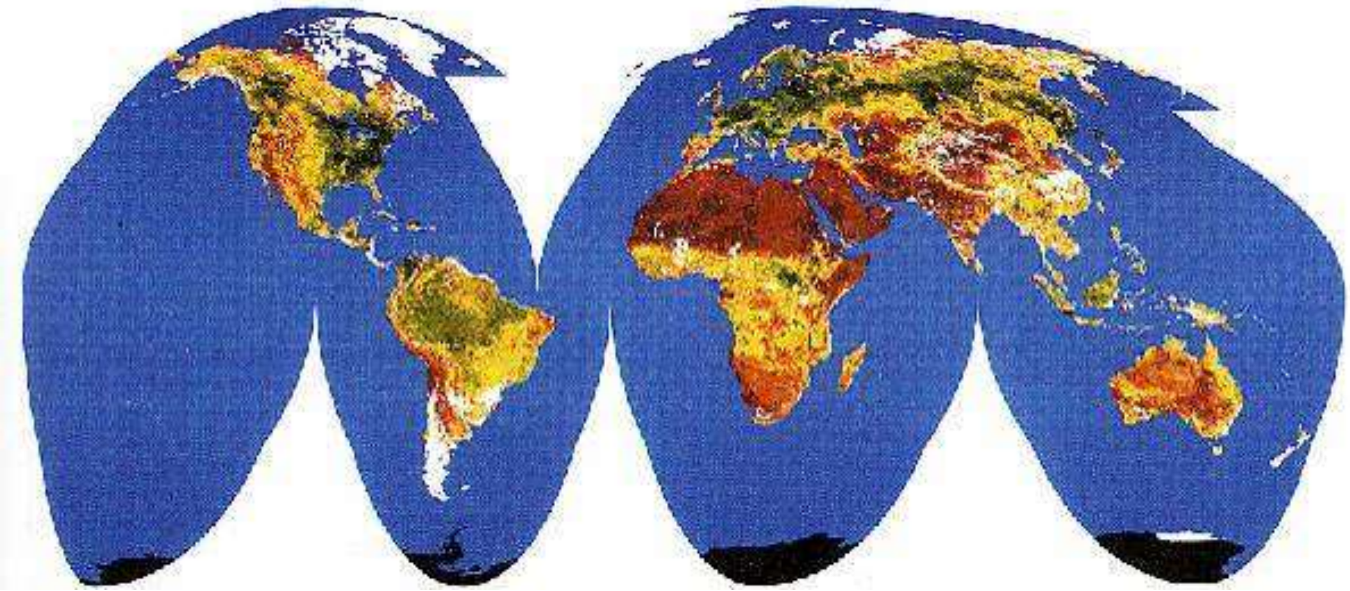
UK contribution: National plan plus adaptation, agriculture, forestry and funding to prevent deforestation (REDD++) and climate finance (international climate fund for least developed countries).

Population and land use

- World population will grow; 8 bn by 2025, 9 bn by 2050
- Land for agriculture will stay c. constant, so intensification needs to continue – more food, feed and fuel produced per ha
- Growth in per capita food consumption
- Equitable elimination of hunger

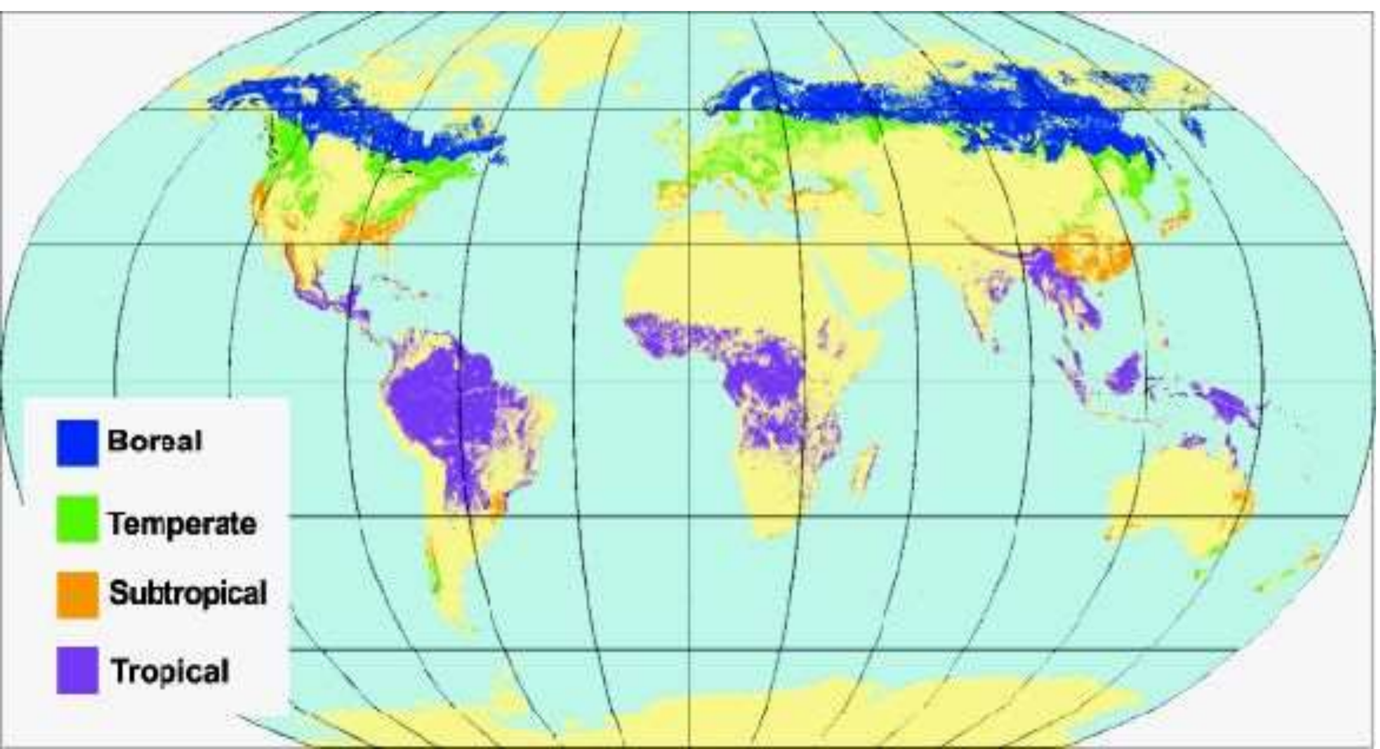
US Census Bureau 10 K BC to 2000 AD & UN Projections 2000 - 2100





Forests make up about 1/3 of the world's land area (c. 45.38 10^6 km^2 or 3.99 Billion ha)

Of this 93.05% in natural, 6.95% planted (0.277 B ha) Payn et al 2015.



Tropical 41%
Subtropical 9%
Temperate 11%
Boreal 39%

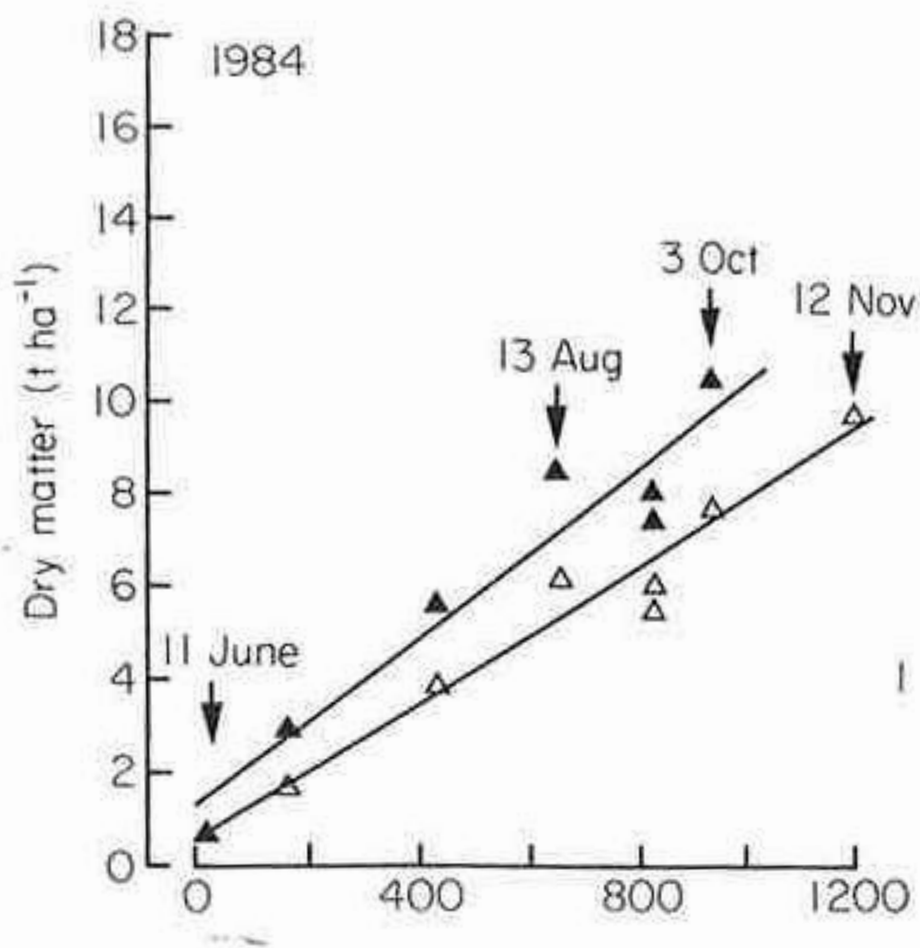
1 Euroasia
2 The Pacific Region
3 Africa
4 South America
5 Boreal forests of US & Canada

Rates and causes of net global forest loss - FAO Global Forest Resource Assessment - www.fao.org

- 1980 - 1990 9.9 M ha yr^{-1}
- 1990 - 2000 8.9 M ha yr^{-1}
- 2000 - 2005 7.3 M ha yr^{-1}
- 2005 - 2010 5.2 M ha yr^{-1}
- 2010 – 2015 3.3 M ha yr^{-1}

- In Africa - small scale subsistence farmers
- In South America - large farming enterprises for beef & soya for expert
- In South East Asia both the above plus oil palm, coffee and construction timber
- Losses (conversion to agric.) continue in S America & Africa, but gains in Asia – China, India & Vietnam programmes.
- Loss continue in C & S America, Africa, E & S Asia

Monteith 1981, Cannell et al 1987……



Accumulated intercepted solar radiation MJ m-2

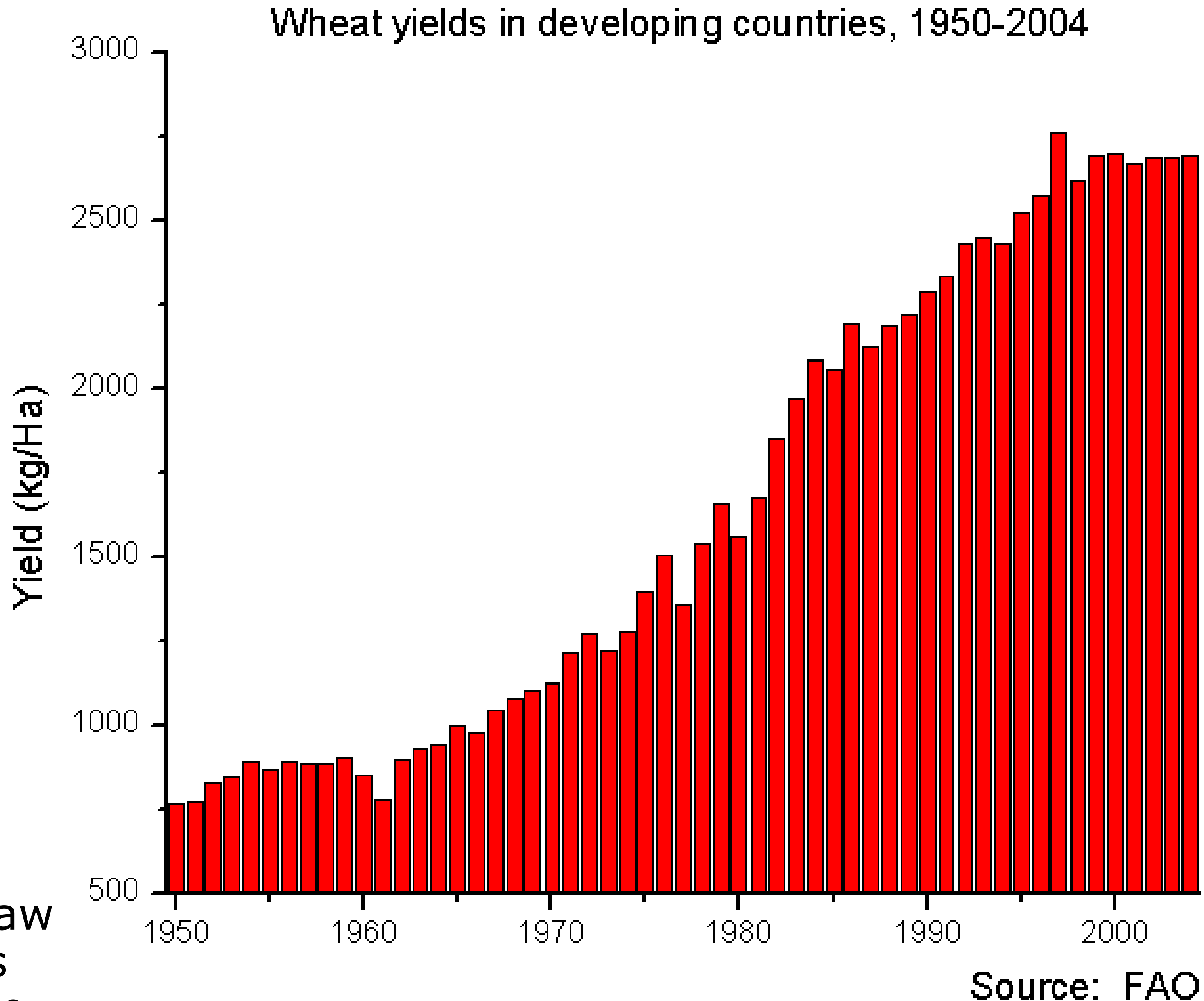
Cannell et al 1987

Annual dry matter production, seasonal mean ‘growth efficiencies’ ($\varepsilon \pm$ S.E., the slopes of the lines) and ‘energy efficiencies’, of willow stands grown in 1984 and 1985 at the Bush Estate near Edinburgh.

Year	Plant parts included	Annual production ($t\ ha^{-1}y^{-1}$)	Growth efficiency ($g\ MJ^{-1}$)	Energy efficiency (%)
1984	Total above-ground	11	0.99 ± 0.13	1.9
	Stems only	9	0.74 ± 0.07	1.4
1985	Total (including roots)	17	1.58 ± 0.04	3.0
	Total above-ground	14	1.38 ± 0.03	2.6
	Stems only	10	1.06 ± 0.04	2.0

Temperate planted forests on average 8.8 t ha $^{-1}$y^{-1}
planted forests in South America 48 t ha $^{-1}$y^{-1}
Jurgensen et al 2014, Payn et al 2015

Assumes dry matter energy content of 19 kJ g-1



Agricultural revolution saw wheat yields increase by c. 100% on average.

"Peter needs to make more effort & could do better."

- 93% of the world's forest cover is natural 7% is planted (164 m ha) and plantations produce c. 50% of the world's industrial roundwood (FAO GFRA 2005)

- Plantations are increasing (c. 5 m ha per year) and are 2/3 of the **potential** industrial wood production (FAO State of the World's Forests, 2009). GFRA 2015 plantations at 277.9 m ha – 6.95 % producing 46.3 % of industrial roundwood.

- Light interception models, growth & conversion efficiencies show how much more could be achieved theoretically.

- Agricultural revolution saw wheat yields increase by c. 100% on average. Sitka yields have increased by a maximum of 25% so far and further increases in **quality and value** are available.

- Energy biomass and carbon benefits (LCA) put new emphasis on the need to achieve good productivity.

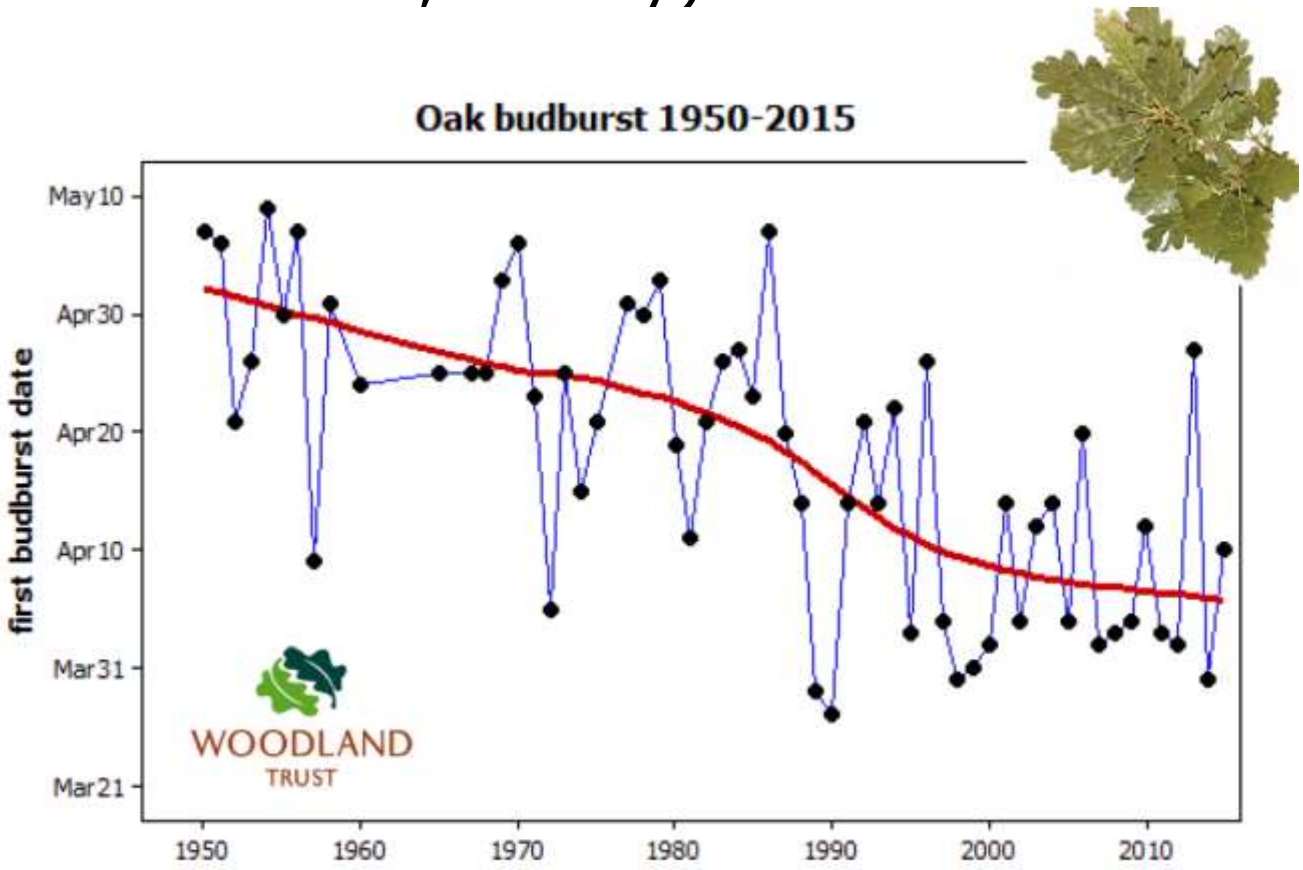
Opportunities - climatic

- 'Improved' climate for tree growth in some areas
  - warmer and sunnier but drier (temperate zone)
  - should lead to higher productivity in some areas, extended growing season (esp. higher latitude and altitude)
  - increasing CO_2 concentration
    - extent of effect ? evidence for mature stands?
- Phenology changes already well documented
- Evidence for increase in productivity
- (but also evidence of declines…)
- Reduction in frost/cold periods/snow

- Choice of species – higher productivity in cooler areas ?

Clear GSL impacts so far

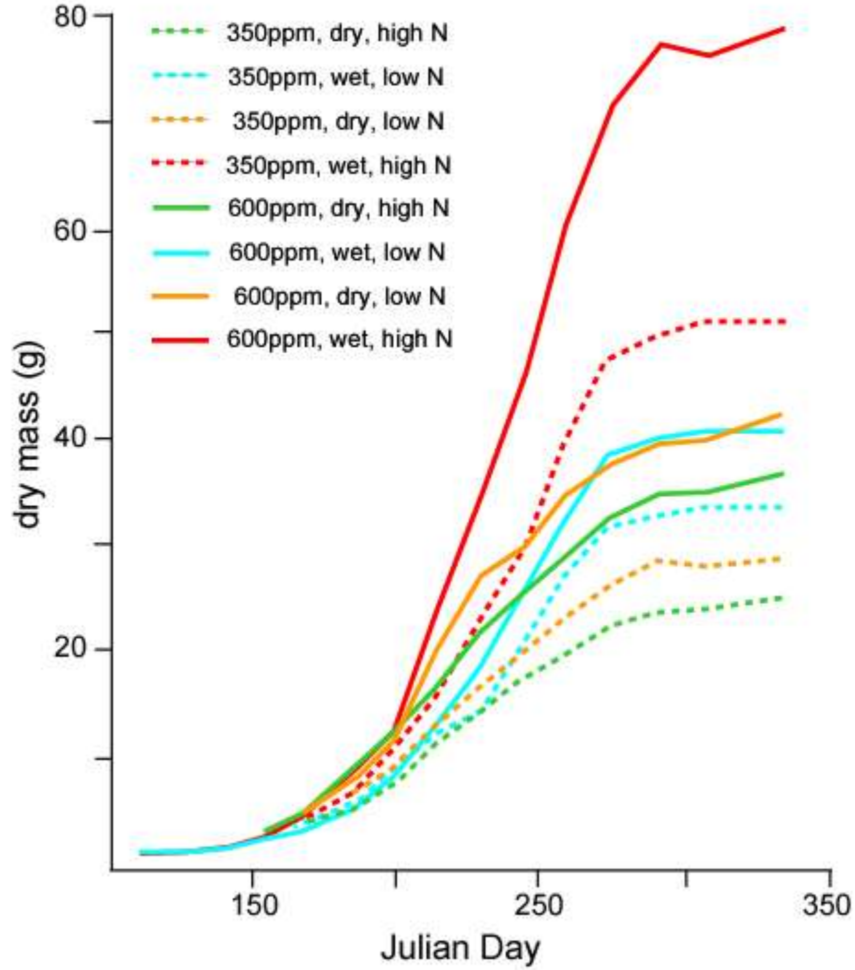
Changes in oak bud burst date
(Jean Combes, Surrey)



Nearly 1 month earlier; also Met O has shown 1 month longer 'growing season' as defined by T>5^{o}C

Forest Research experiments - Glen Devon 1990s

Biomass growth curves estimated from periodic height and diameter measurements



New UK FACE experiment in planted oak (1880) at Mill Haft Wood

Growth rate increases

- Based on the oldest existing experimental forest plots in Central Europe, we show that, currently, the dominant tree species Norway spruce and European beech exhibit significantly faster tree growth (32 to 77%), stand volume growth (10 to 30%) and standing stock accumulation (6 to 7%) than in 1960.
- Statistical analyses of the experimental plots, and application of an ecophysiological model, suggest that mainly the rise in temperature and extended growing seasons contribute to increased growth acceleration, particularly on fertile sites.

Forest stand growth dynamics in Central Europe have accelerated since 1870
Pretzsch, Biber, Schu¨tze, Uhl & Ro¨tzer, Nature Comms 2014

Schelhaas 2015, Hanewinkel 2013

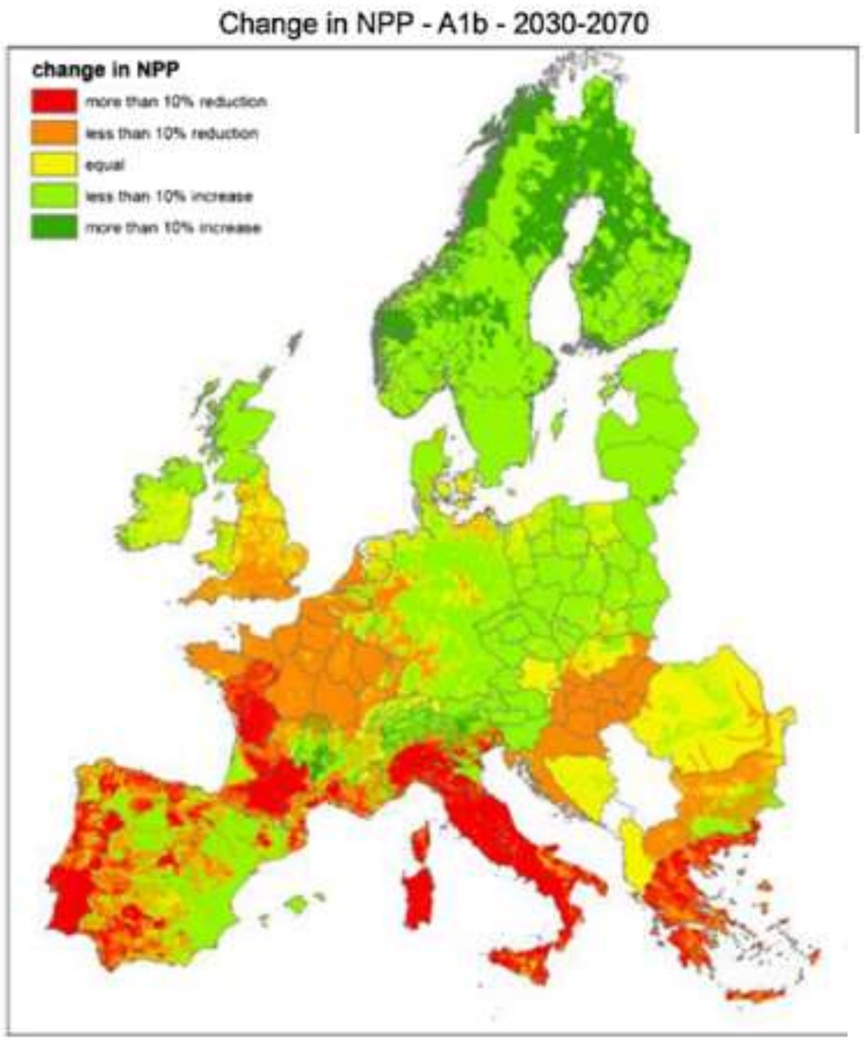


Fig. 2 Change in NPP as a result of climate change, made by combining the tree species map (Brus et al.) and growth effects (including CO_2 fertilisation effect) according to Reyer et al. (2014)

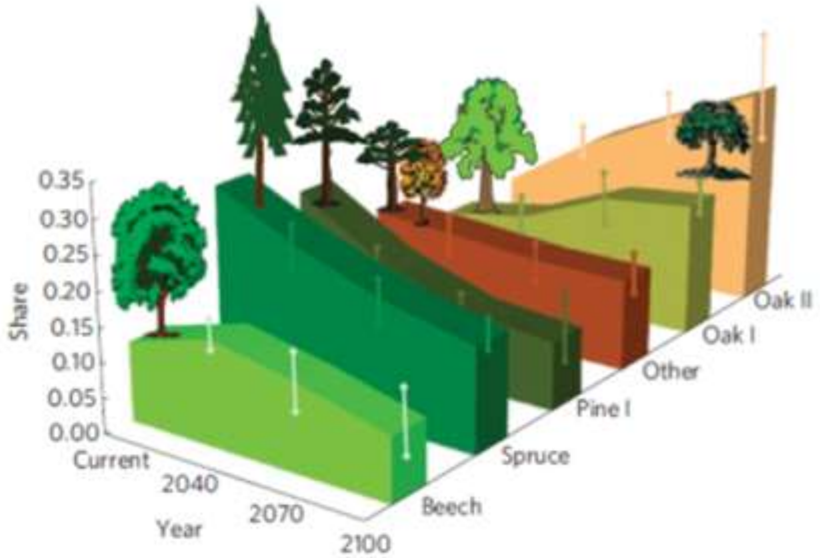


Figure 3 | Development of the share of the area of major tree species in Europe under scenario A1B until 2100. The relative size of the icons approximately corresponds to the relative height of mature trees of the species groups. The tree species group labelled 'Other' includes Pine II, Birch and Other spp. from Figs 1 and 2. The bars reflect the standard deviation resulting from four different model realizations of scenario A1B (see Supplementary Tables S5 and S6).

EUROPEAN FOREST INSTITUTE
ATLANTIC EUROPEAN REGIONAL OFFICE – EFIATLANTIC

REINFFORCE

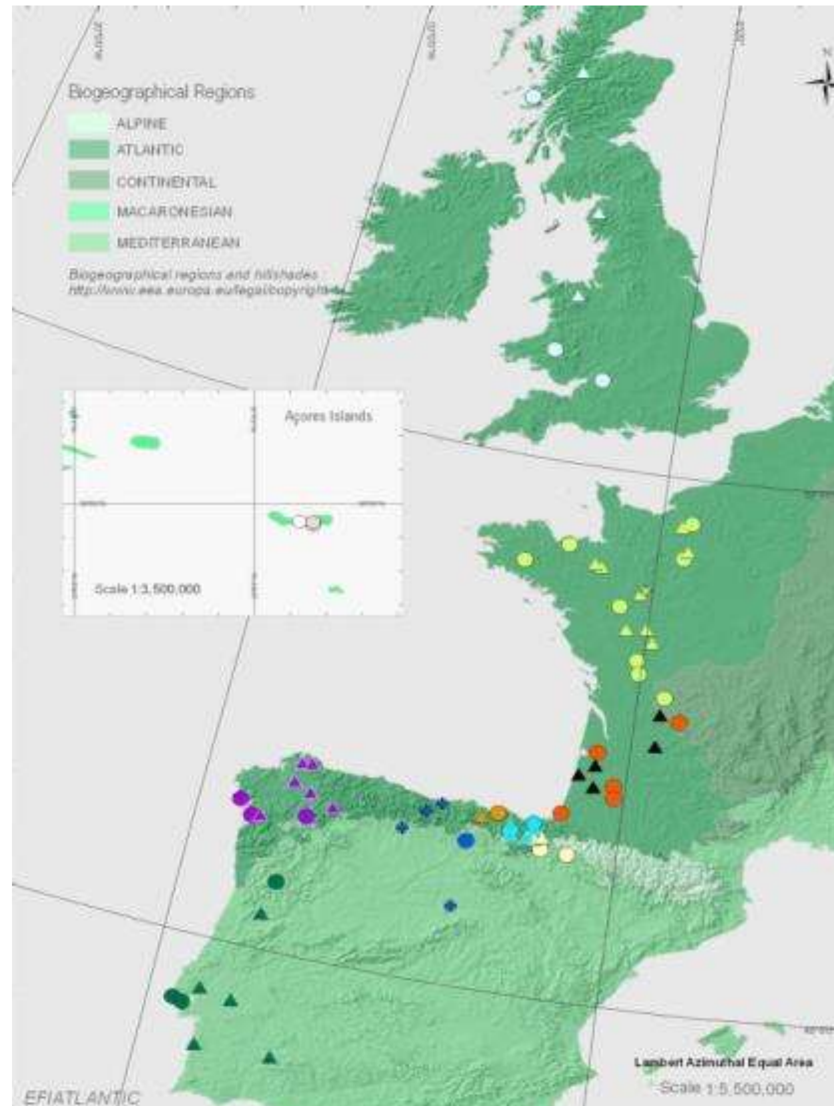
Experimental approaches – biogeographic level

Longterm R&D Infrastructure for species selection and demonstration

- Network of 38 arboreta: 35 species, 150 provenances = 135000 seedlings planted
- Network of 41demonstration sites: alternative management options
- Databases, protocols and reference tools: FORESTRIAL database on long term monitoring trials

- See www.efiatlantic.efi.int/

  → research→current research projects



European Union
European Regional Development Fund

ATLANTIC AREA
Transnational Programme

REINFFORCE site: the Forest Garden at Kilmun, Argyll, Plots of over 160 tree species.

- A network of 32 species trials along the Atlantic region of Europe
- 3 provenances each of 30 species
- 3 sites in the Atlantic forests of England, Scotland and Wales

Potential broadleaved spp for production forestry in Britain.

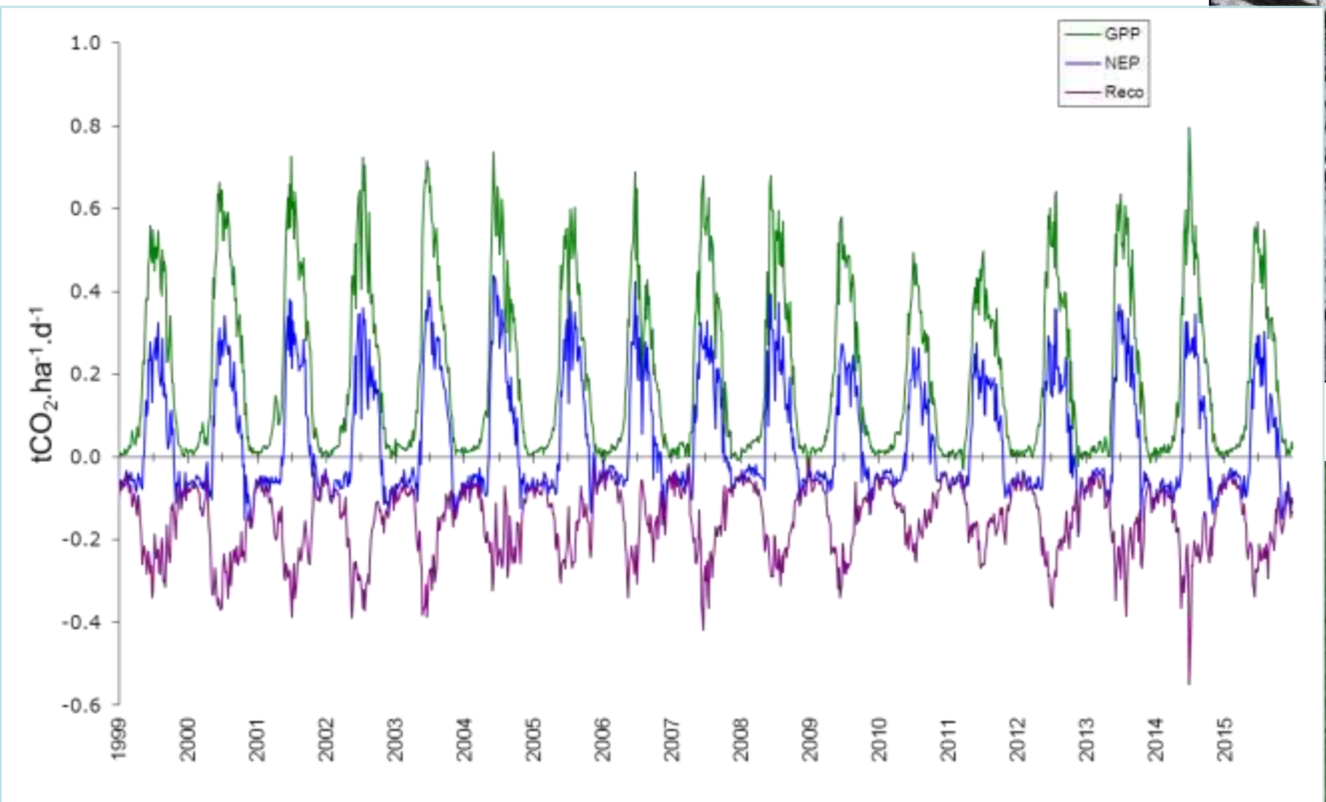
with knowledge of performance

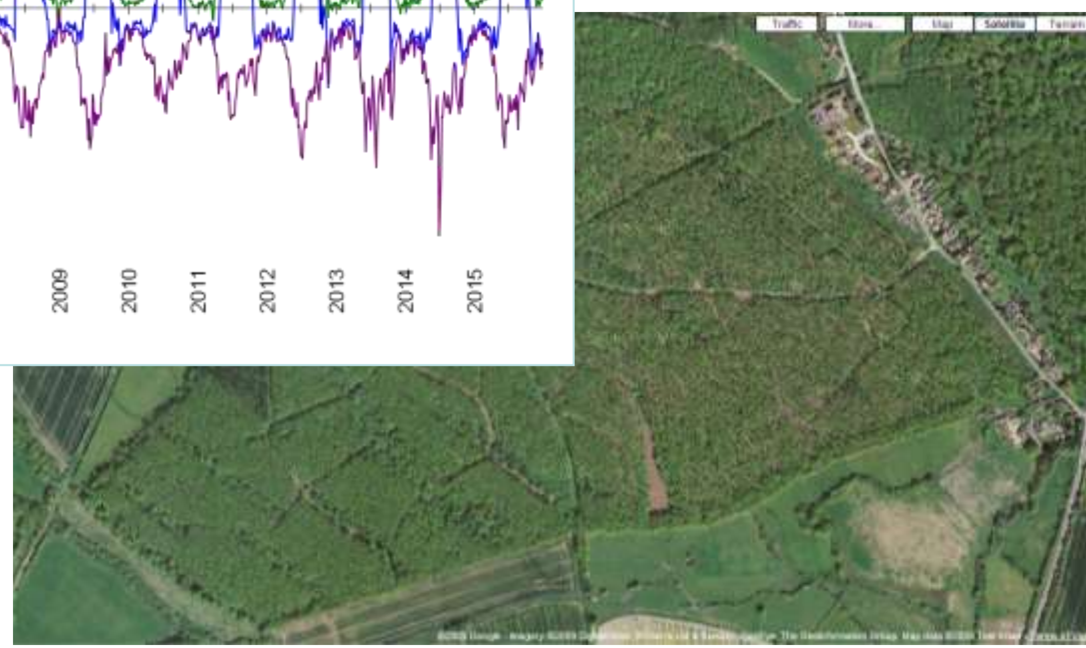
Acer macrophyllum
Acer saccharinum
Alnus rubra
Alnus viridens
Eucalyptus gunnii
Eucalyptus nitens
Juglans regia
Nothofagus obliqua
Nothofagus alpina (syn. N. procera)
Nothofagus pumilio
Platanus spp.
Populus spp.

no UK trials data

Betula papyrifera
Carya ovata
Eucalyptus spp
Fagus orientalis
Fraxinus americana
Fraxinus angustifolia
Fraxinus pennsylvanica
Juglans nigra
Liriodendron tulipfera
Quercus alba
Quercus frainetto
Quercus pubescens
Quercus pyrenaica

Forests as CO_2 sinks





48 ha, 15 seed sources 155,000 trees

- **14 sites**

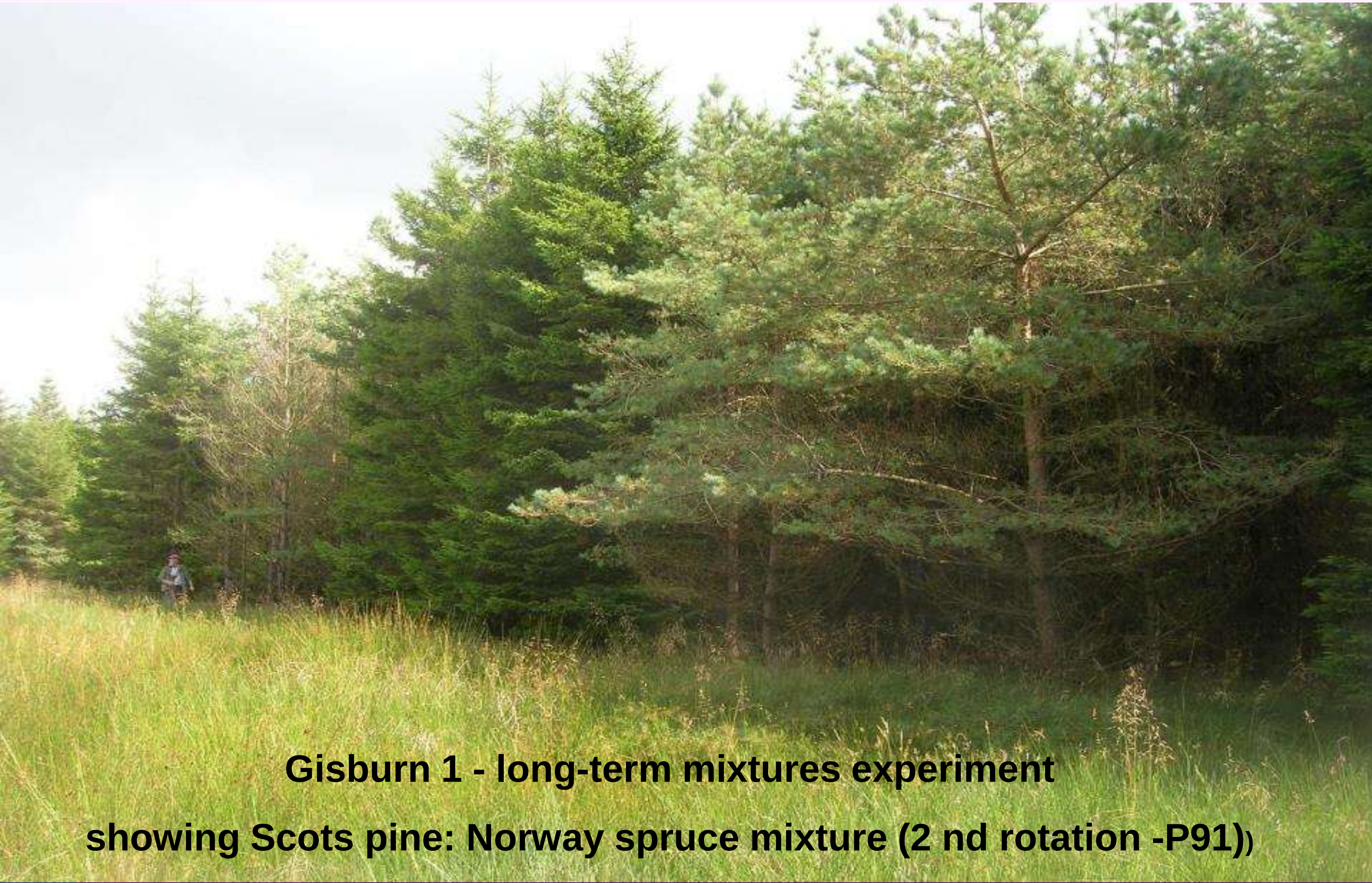
WOODLAND TRUST

Norfolk County Council

Suffolk Wildlife Trust

Forestry Commission England

Mixed species, even-aged

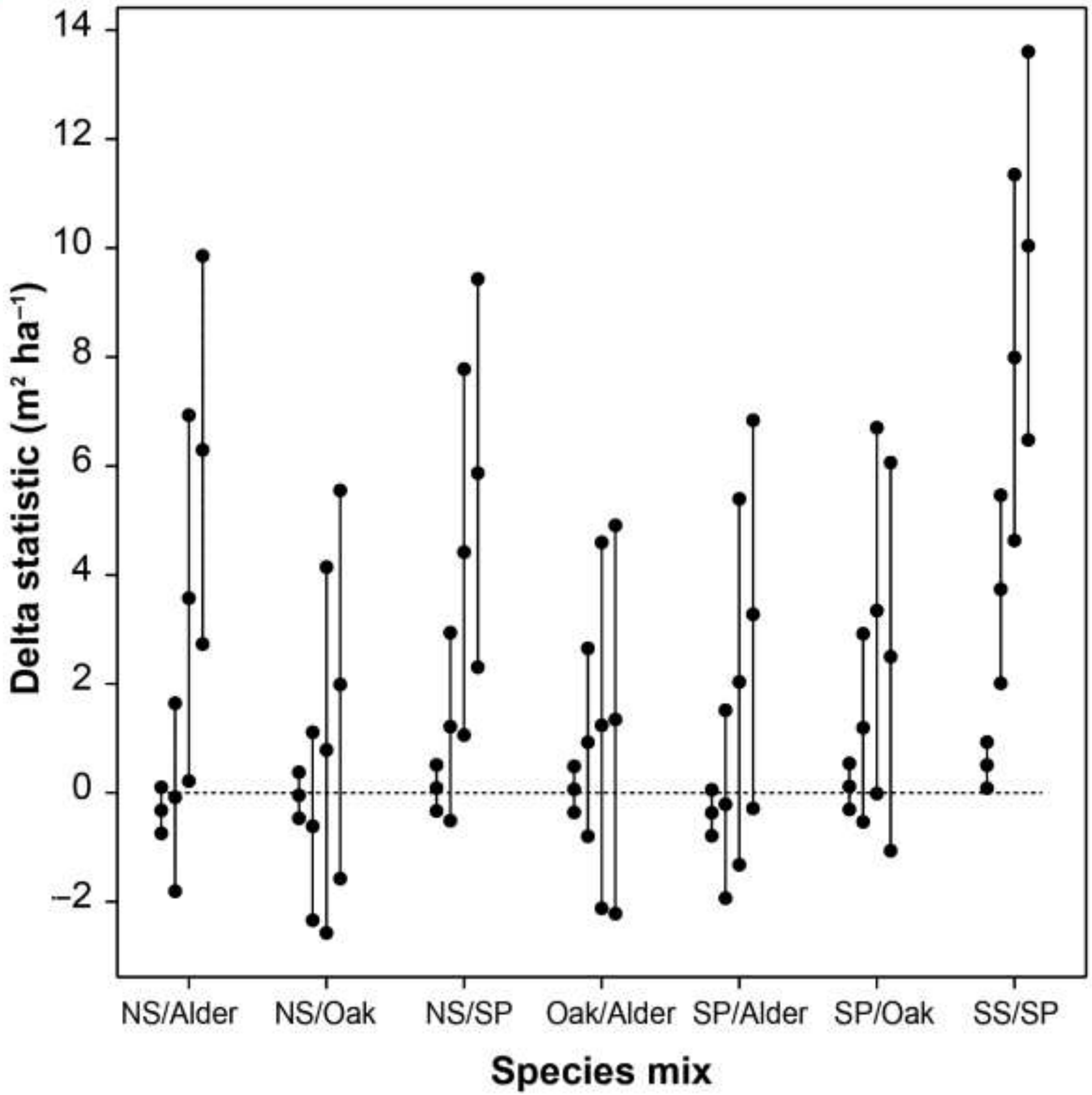


Gisburn 1 - long-term mixtures experiment

showing Scots pine: Norway spruce mixture (2 nd rotation -P91))

Mason and Connolly Forestry 2014;87:209-217

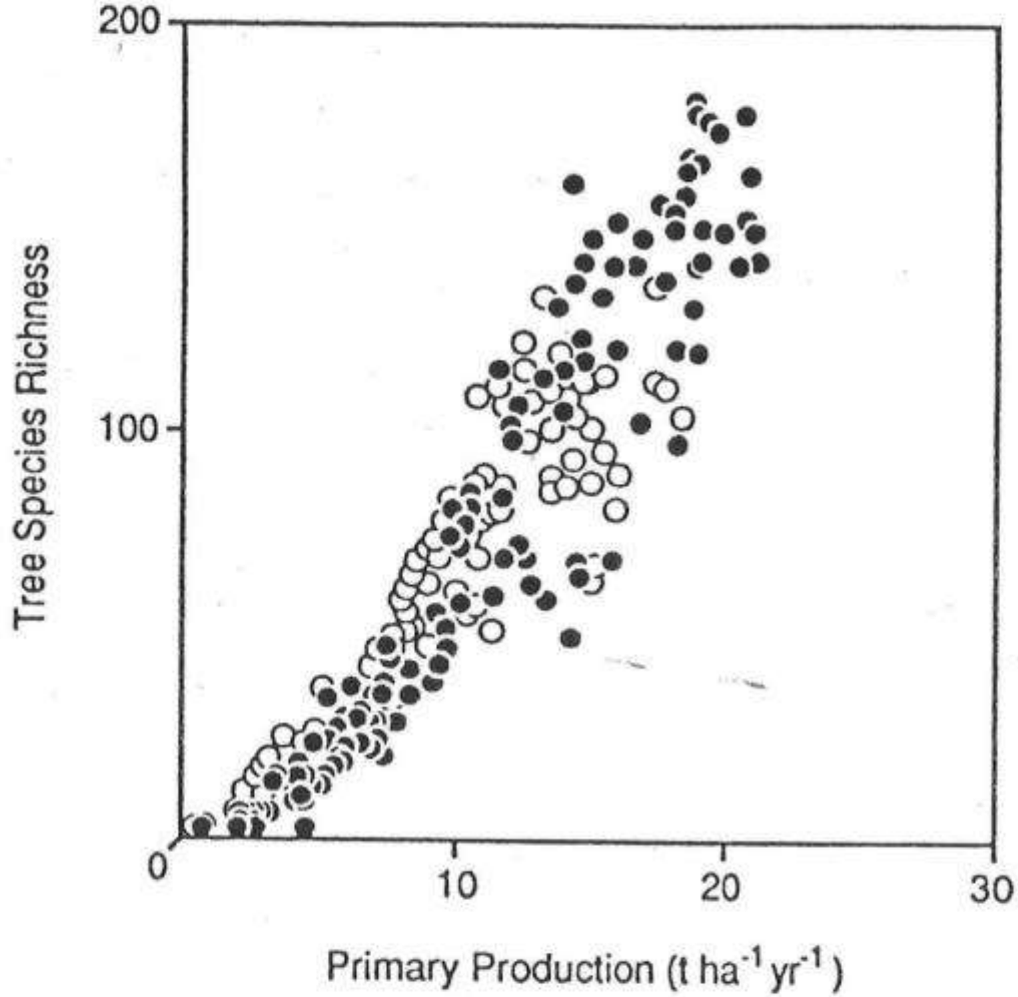
Difference in basal area (m2 ha–1) between mixed plots and expected values based on pure species performance in the 2 nd rotation of the Gisburn experiment. Data at 6, 10, 15 & 20 yrs for each mixture.



From Waring & Running 1985

Adams and Woodward 1989 in Nature. Tree species richness in European and North American forests against NPP.

Harsher boreal and arid regions support fewer species than tropical rain forests and have lower NPP



Advantages of planted (vs 'natural') for c c.

- Allows rapid adoption of new species,
- Can deploy new genotypes (P & D resistance, drought resistance, higher growth rates, improved timber quality, better 'adaptation'),
- Management on shorter timescales – important because of need for continuous change and to lessens risk.
- Planted achieves higher yield and allows natural to be protected.