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The European potential to produce bio-energy: *Miscanthus* potential for current and future climates.

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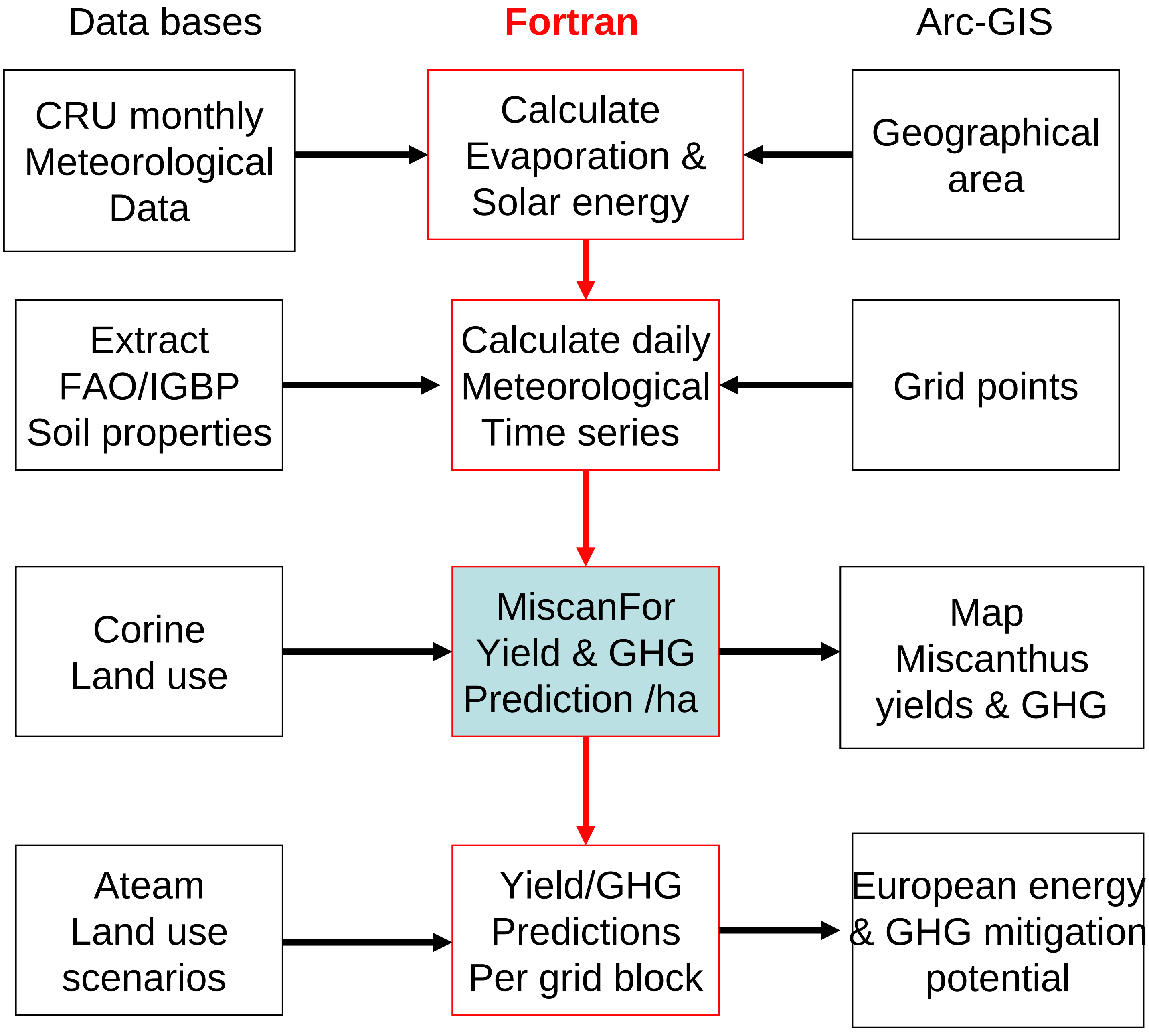
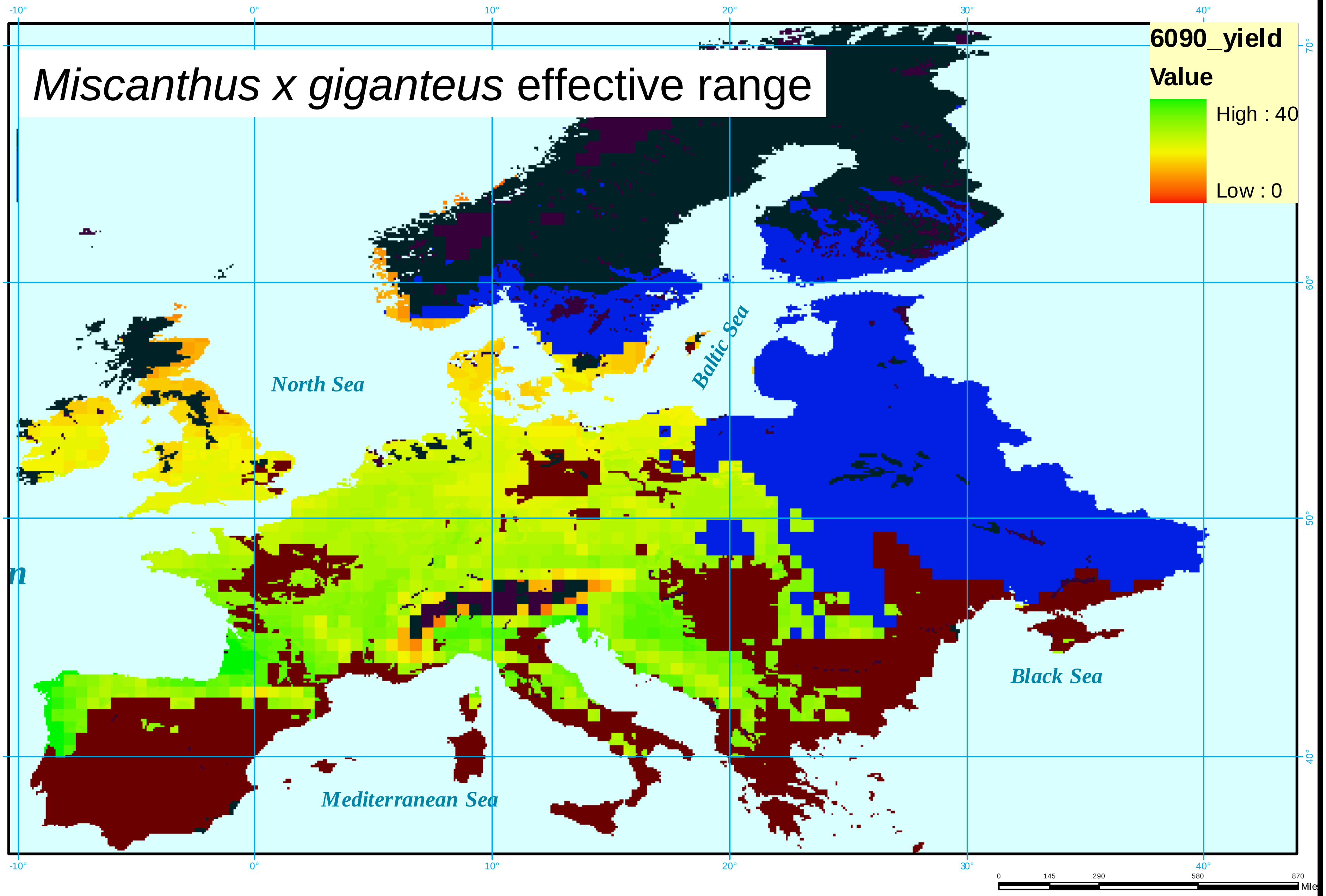
LCA sustainability criteria

- Net energy produced per ha land GJ ha^{-1}
- Net energy / Energy input (EUE)
- Carbon Intensity (CI) g CO_2 C Equiv MJ^{-1}



MiscanFor model framework



WGS-84

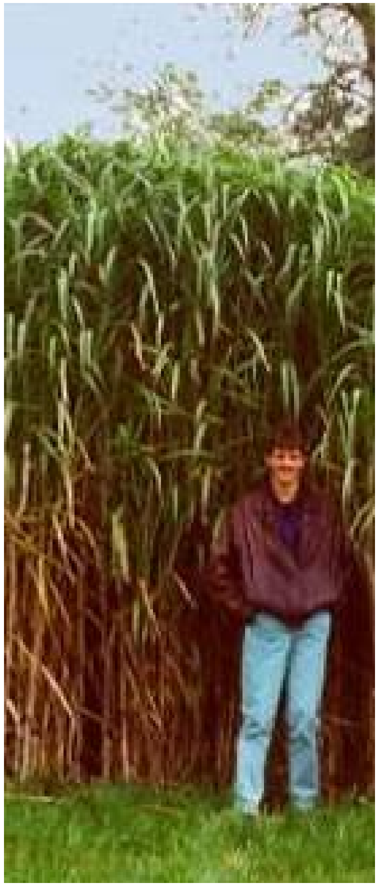
1960-1990 Mean peak yield

Miscanthus

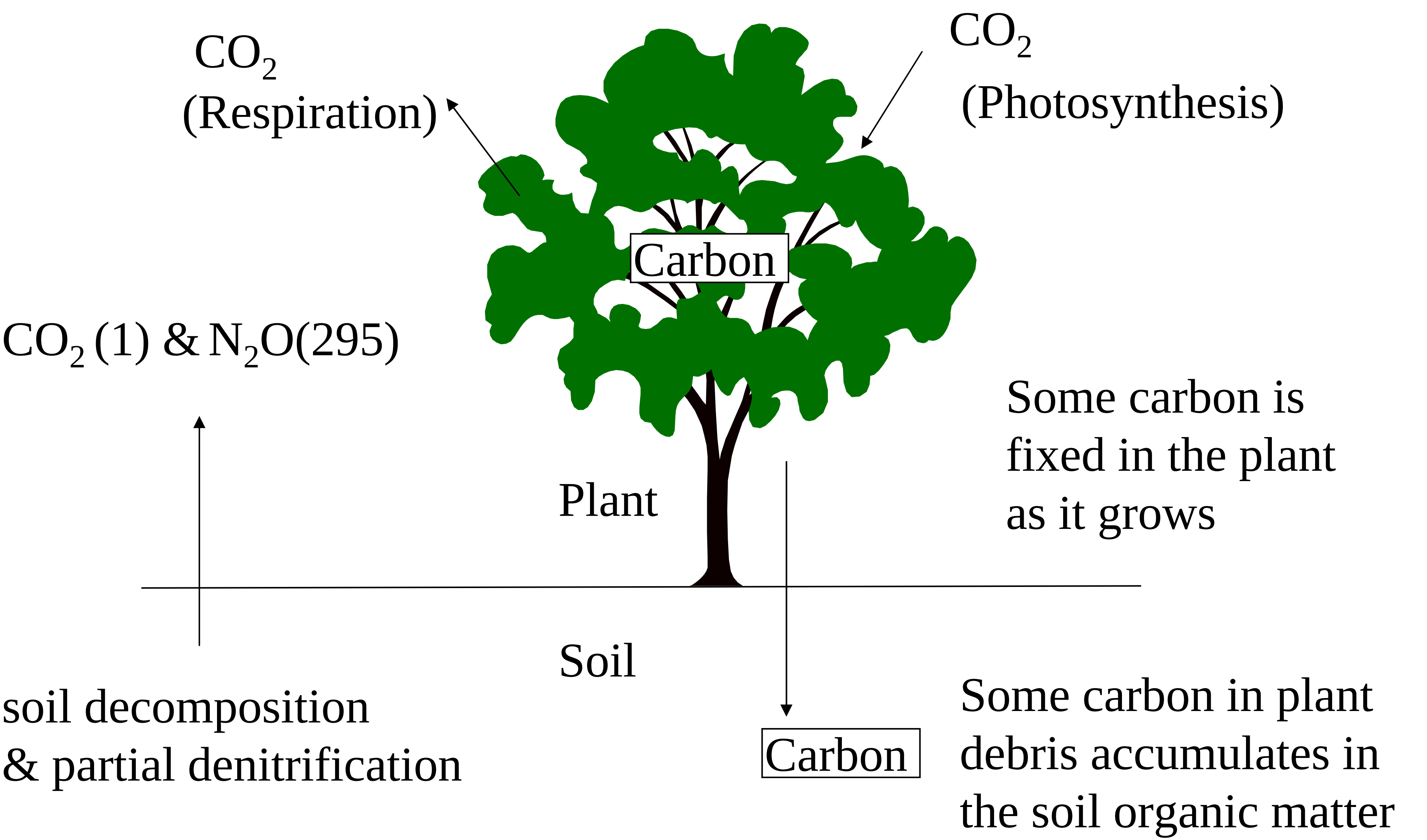
Energy yields net GJ/ha

• Ethanol from sugar beet	15
• Ethanol from wheat	7
• Bio-diesel from oil seed rape	17
• SRC Willow	42
• *Miscanthus*	191

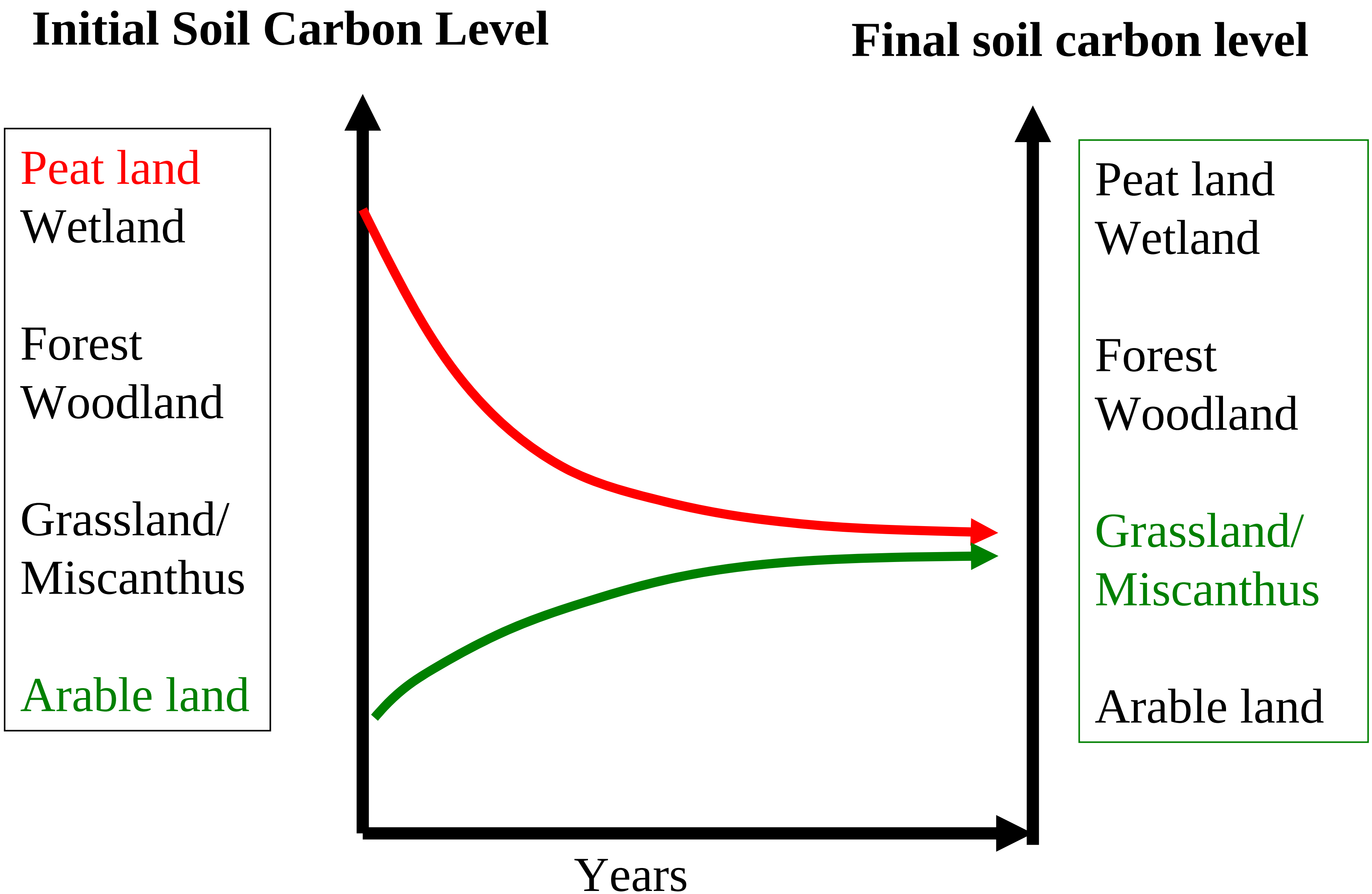
Sims et al (2006)



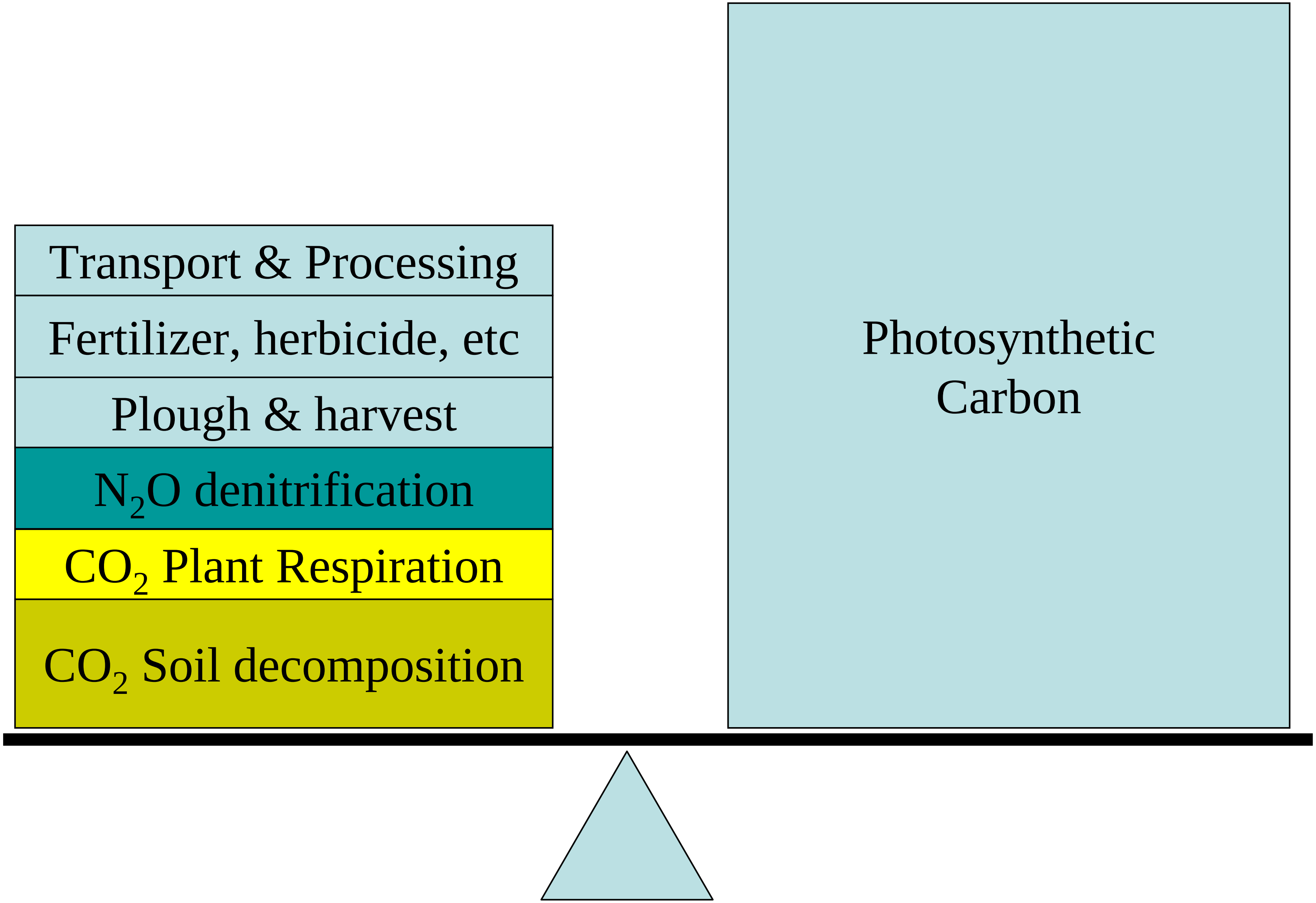
Soil emission of greenhouse gasses

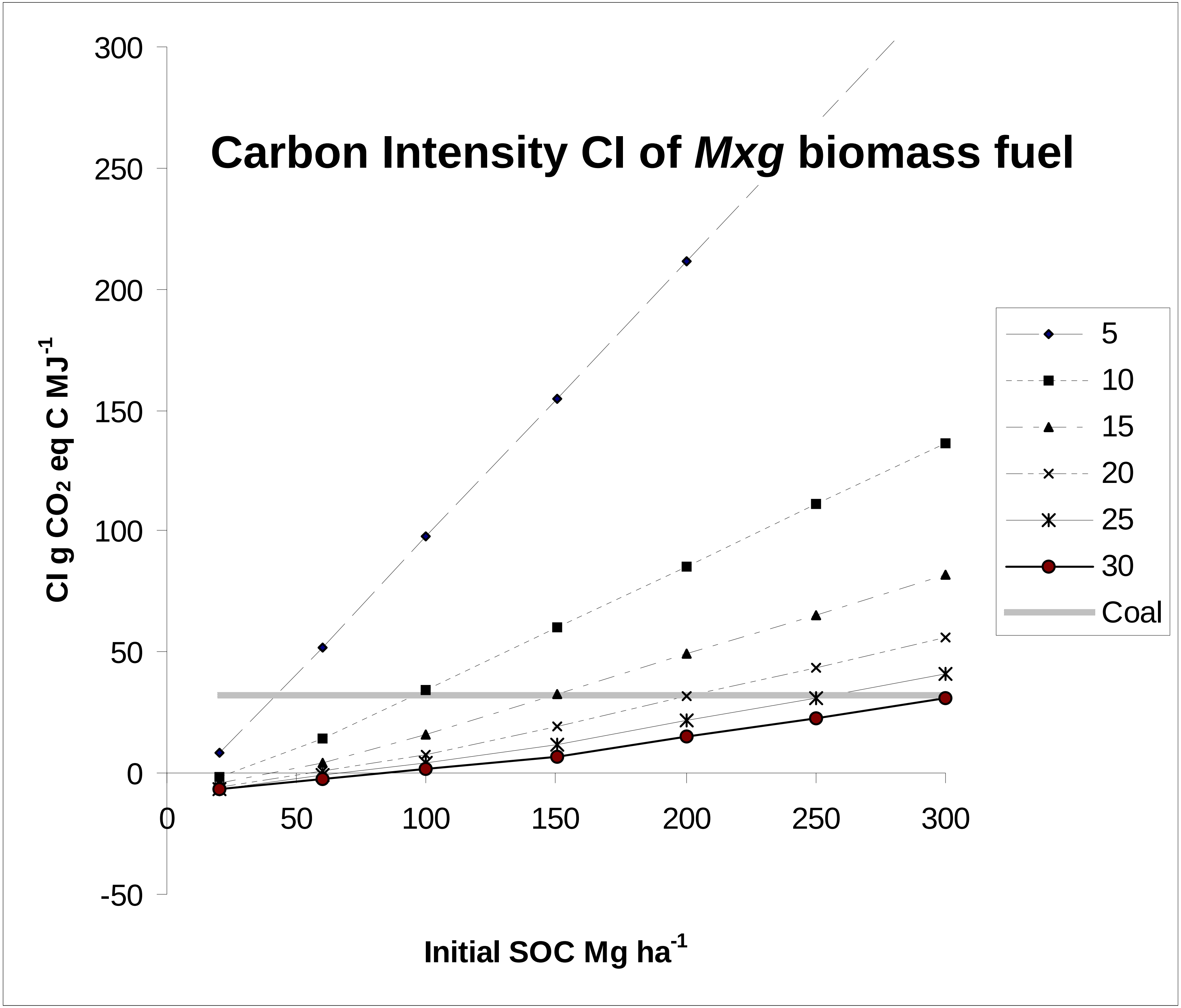


Each ecosystem has a carbon equilibrium



Greenhouse gas and energy balance

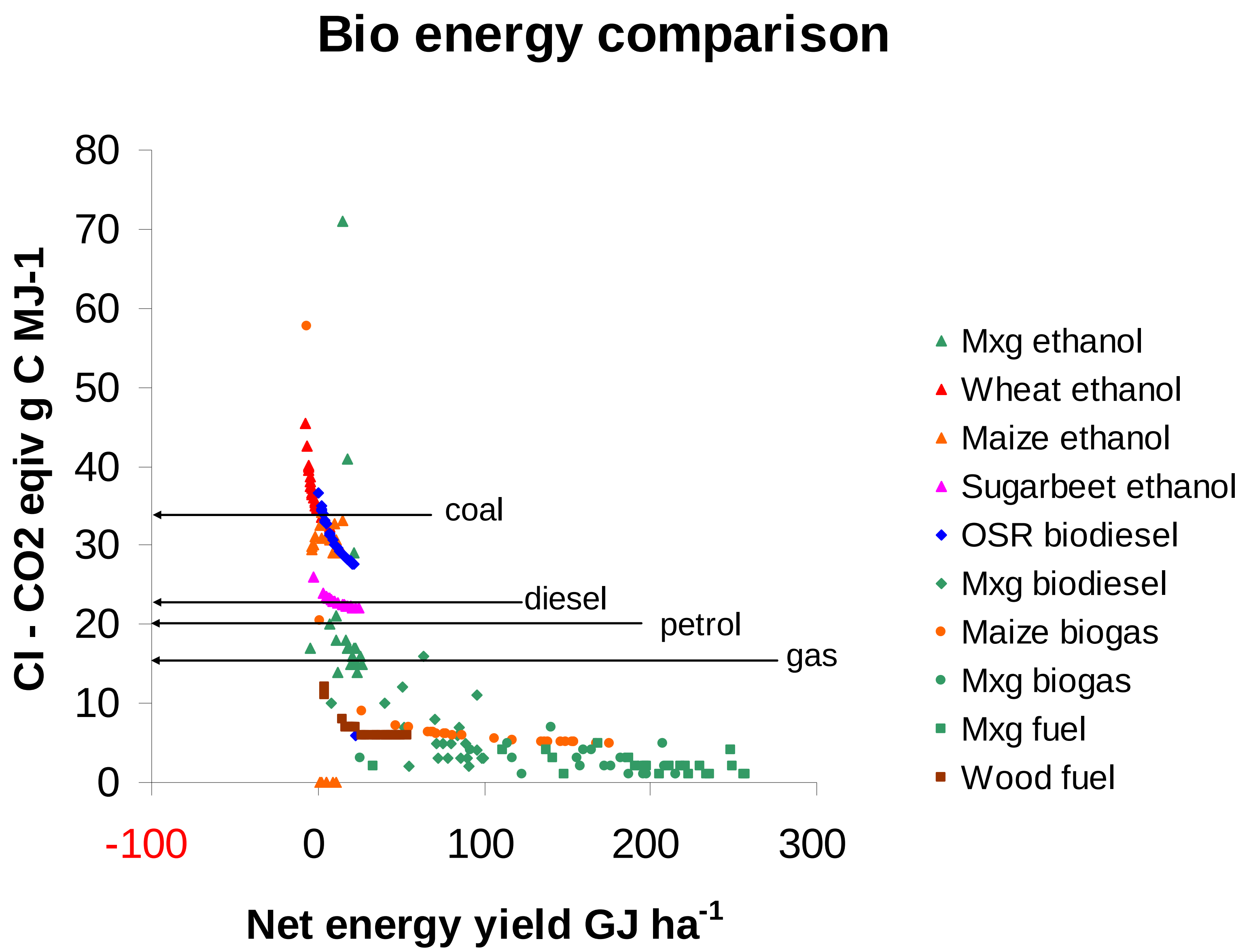




Carbon Intensity CI of *Mxg* biomass fuel
CI g CO_2 eq C MJ^{-1}
Initial SOC Mg ha^{-1}
300
250
200
150
100
50
0
-50
0
50
100
150
200
250
300
5
10
15
20
25
30
Coal

Sustainability of bio-energy systems in Europe

	EUE $MJ\ MJ^{-1}$	CI $g\ C\ MJ^{-1}$	Energy Intensity $GJ\ ha^{-1}$
Wheat ethanol	1.0	89	7
Maize ethanol	1.2	77	15
Sugarbeet ethanol	1.1	67	15
Miscanthus cellulosic ethanol	1.2	40	14
Oil seed rape biodiesel	1.7	67	17
Miscanthus biorefinery biodiesel	3.6	9	61
Green maize biogas (local use)	6.8	13	116
Miscanthus biogas (Local use)	8.9	4	137
SRC willow co-fired biomass fuel	5.5	14	42
Miscanthus co-fired biomass fuel	6.1	3	191



Bio energy comparison
80
70
60
50
40
30
20
10
0
CI - CO2 eqiv g C MJ-1
coal
diesel
petrol
gas
-100
0
100
200
300
Net energy yield GJ ha-1
Mxg ethanol
Wheat ethanol
Maize ethanol
Sugarbeet ethanol
OSR biodiesel
Mxg biodiesel
Maize biogas
Mxg biogas
Mxg fuel
Wood fuel

Typical car

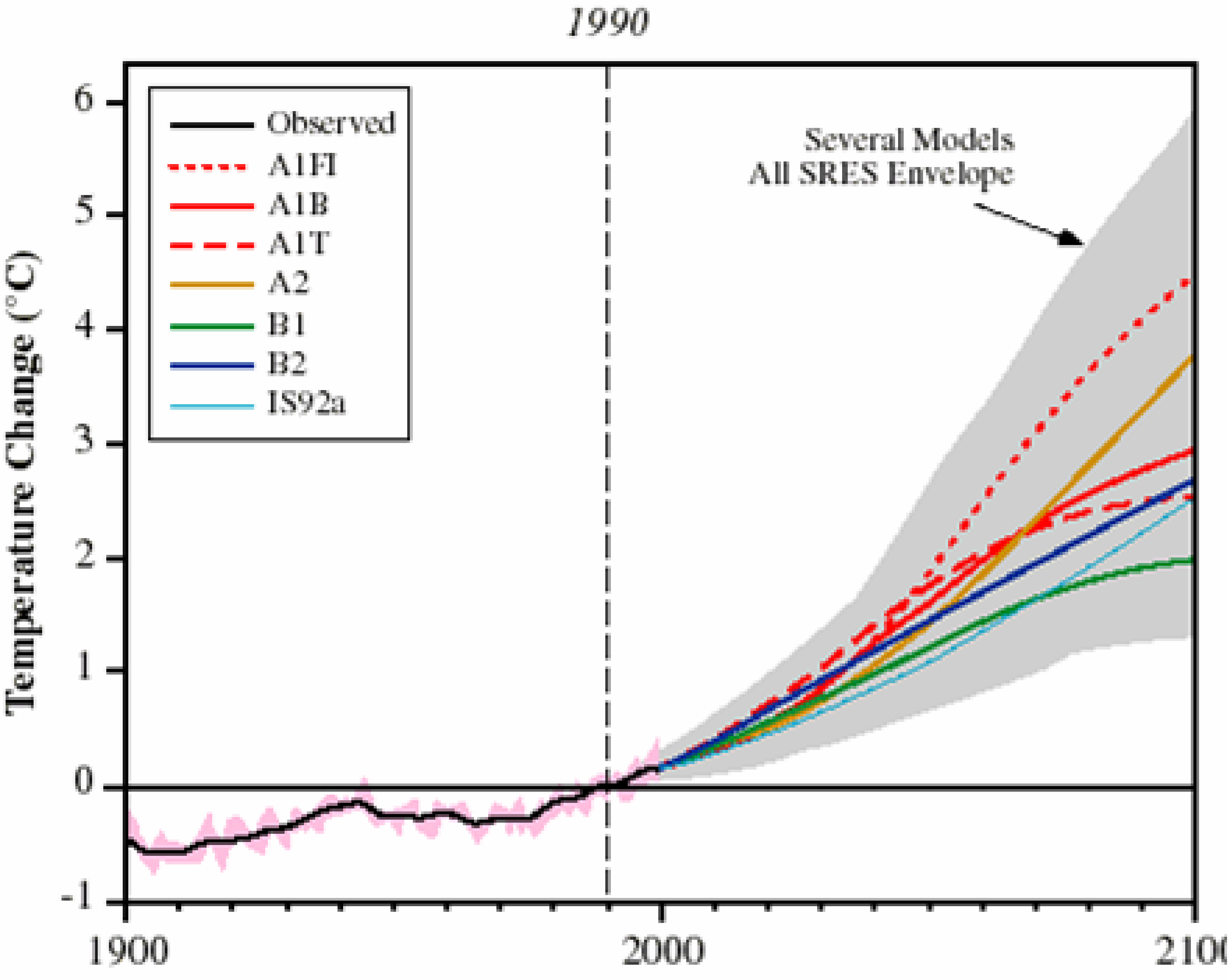
- 90% transmission efficiency
- Front wheel drive
- Needs 34 MJ to travel 1km at 60 kph

Assume all types of fuel require the same amount of construction carbon

E.g. Ignore battery carbon cost

Carbon emission & fuel system - g CO_2 km^{-1}

Otto cycle	Gasoline	129
	Maize ethanol	423
	Sugar-beet ethanol	369
	Wood cellulosic ethanol	281
	Miscanthus cellulosic ethanol	221
Diesel cycle	Diesel	106
	OSR biodiesel	334
	Wood bio-refined diesel	64
	Miscanthus bio-refined diesel	45
Electrical	UK national grid	134
	Coal	240
	Gas combined cycle	129
	Nuclear	40
	Land wind	41
	Offshore wind	88
	CHP wood	63
	CHP *Miscanthus*	36

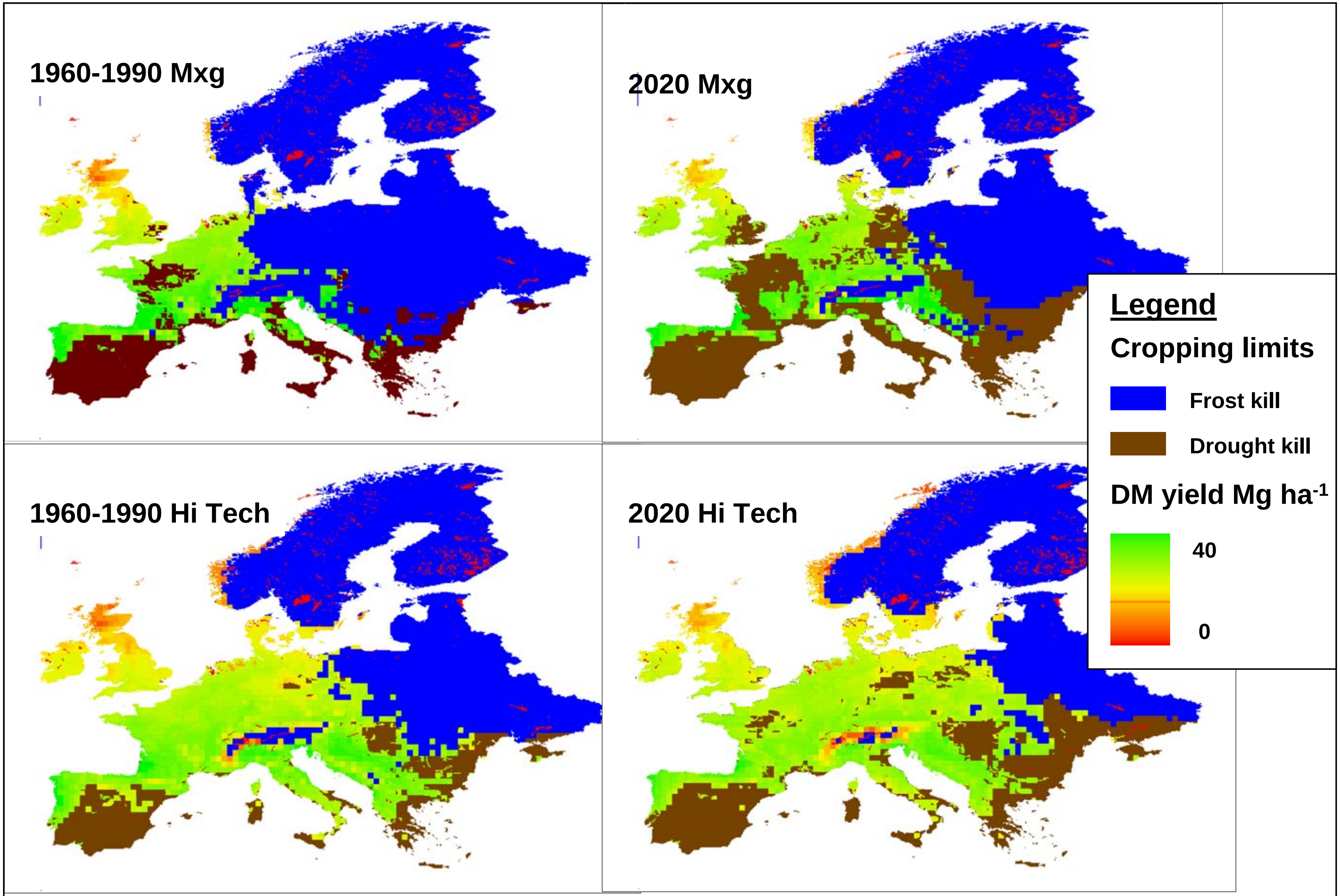


1990
Observed
A1FI
A1B
A1T
A2
B1
B2
IS92a
Several Models
All SRES Envelope
Temperature Change (°C)
6
5
4
3
2
1
0
-1
1900
2000
210

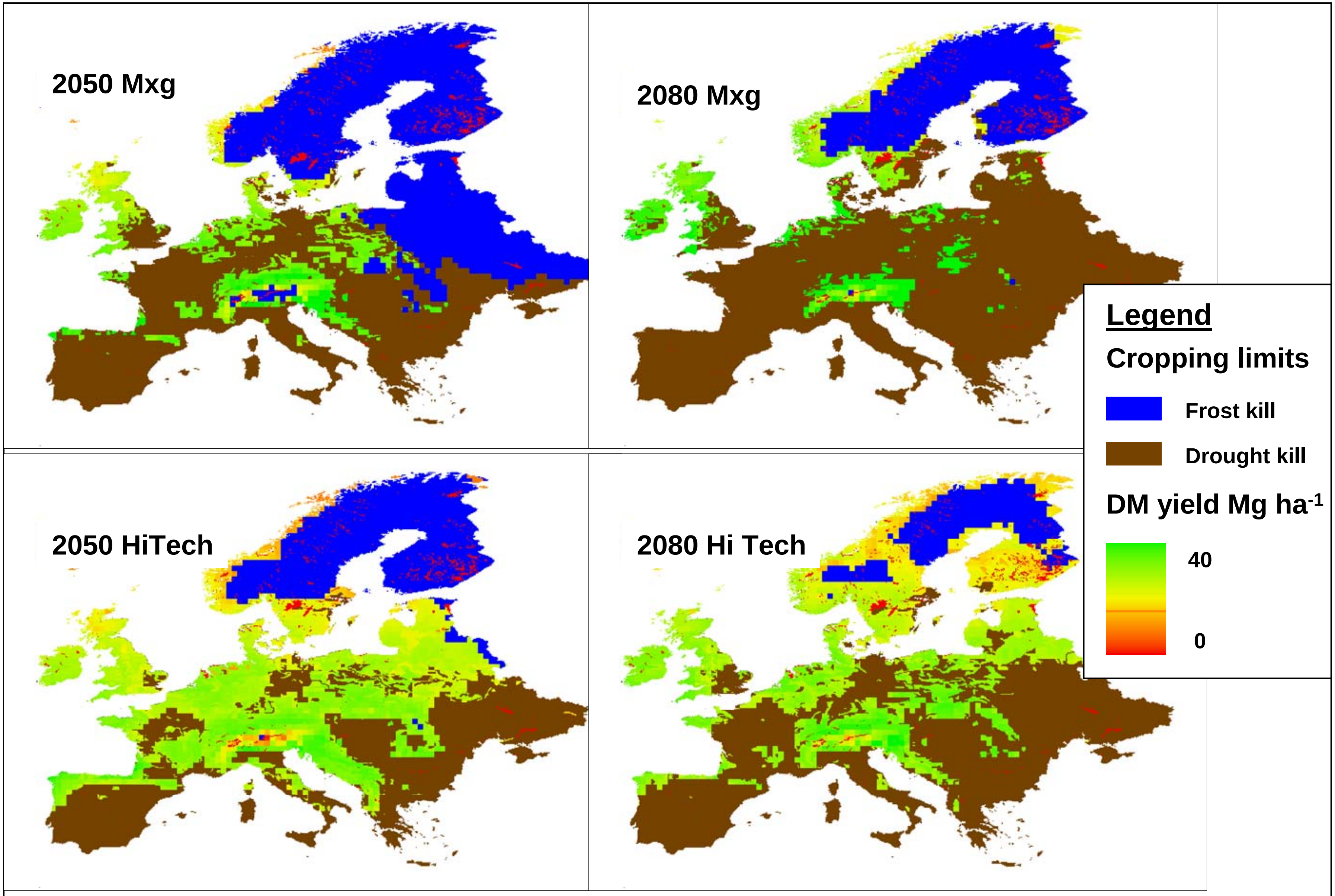
IPCC (2001)

Future of two genotypes

- *Miscanthus x giganteus*
- Theoretical ‘hi-tech hybrid’ with yield of *Mxg* and improved frost and drough tolerance observed in *M. sinensis*.

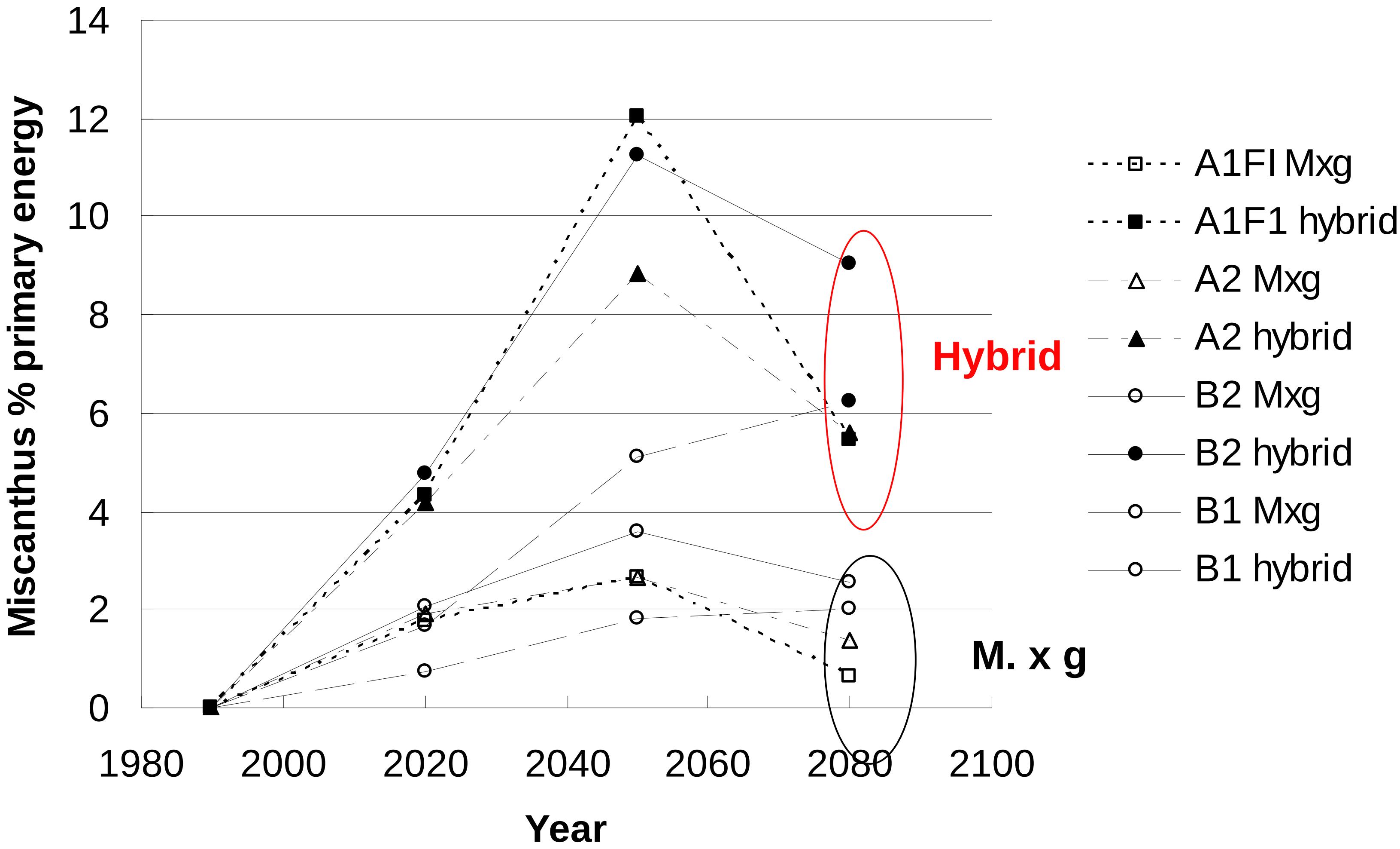

1960-1990 Mxg
2020 Mxg
1960-1990 Hi Tech
2020 Hi Tech
Legend
Cropping limits
Frost kill
Drought kill
DM yield Mg ha-1
40
0

A2 scenario


2050 Mxg
2080 Mxg
2050 HiTech
2080 Hi Tech
Legend
Cropping limits
Frost kill
Drought kill
DM yield Mg ha-1
40
0

A2 scenario

Potential bio-energy % European primary energy



Conclusions

- "MiscanFor" is an improved model
- *M. x giganteus* yields will drop with climate change
- Drought resistant hybrid could provide 12% EU primary energy (7,900 PJ)
- GHG intensity is 3 g C MJ^{-1} (18% Gas)
- 10% UK arable land produce 40,000 boed
- *Miscanthus* is a viable crop BUT..
- Requires the 'h-tech' hybrid.

Acknowledgements

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