Forest Research

Assessing forestry and timber options for carbon impacts

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What I will cover …

- Some basic science
- Assessing forest (woodland) creation options
- Assessing management options for existing forests
- Available (and emerging) tools
- Some issues not to forget.

Some basic science

Carbon stock dynamics at different scales

Why are we doing this?

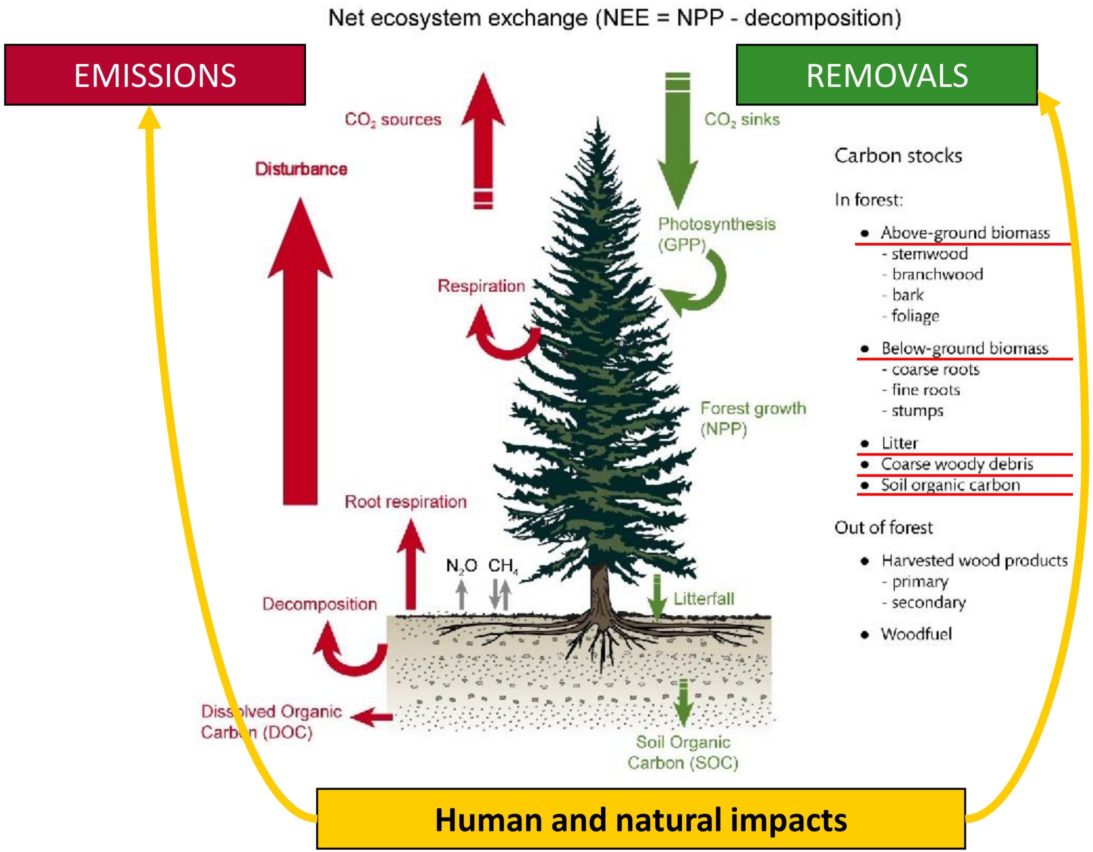
- What is the problem?
  - Climate change
- What is causing the problem?
  - GHG emissions
- What do we want to do about the problem?
  - Reduce GHG emissions
  - Adapt…
- How do we show that our actions are leading to the desired outcomes?
- GHG/carbon accounting!

CO_2 emissions from fossil fuels

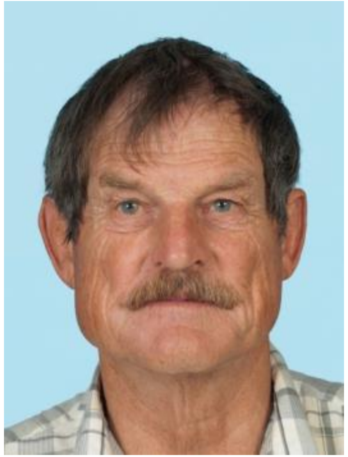
(Obviously simplified)

- 1 barrel contains about 0.15 tonne of fuel oil
- Carbon content of fuel oil is about 0.85 “tC” per tonne oil
- So, burning 1 barrel of fuel oil releases about $0.15 \times 0.85 \sim 0.13$ tC.
- 1 tC equates to 44/12 tCO_2
- Consuming 1 barrel of fuel oil emits $0.13 \times 44/12 \sim 0.47$ tCO_2.

CO_2 balances in forests

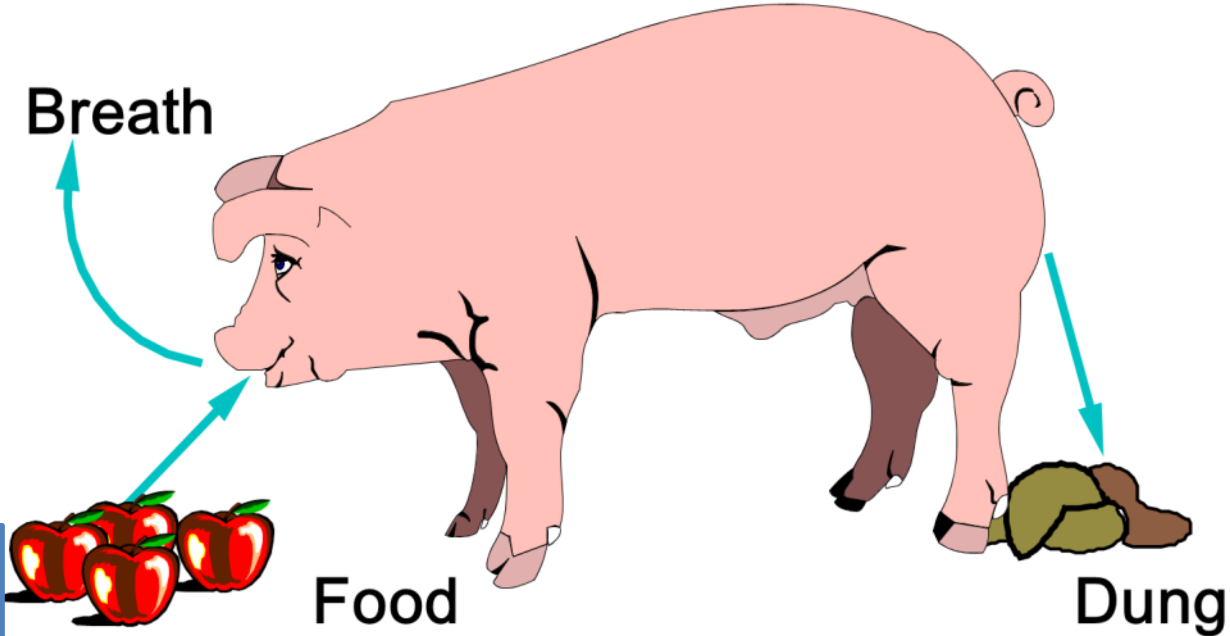


Keep it simple …



Piers Maclaren
formerly New Zealand
Forest Research Institute

Piers Maclaren's pig



Carbon balance =
Carbon stock change

"Don't try to measure all the fluxes, just weigh the pig!"…

Keep it simple …

Take measurements after a growing season

Estimate crownwood from standard relationships (e.g. 30% of result for stemwood)

Measure/model the stemwood volume

Mass = volume x density (e.g. 0.4)

Carbon = 0.5 x mass

CO_2 = (44/12) x carbon

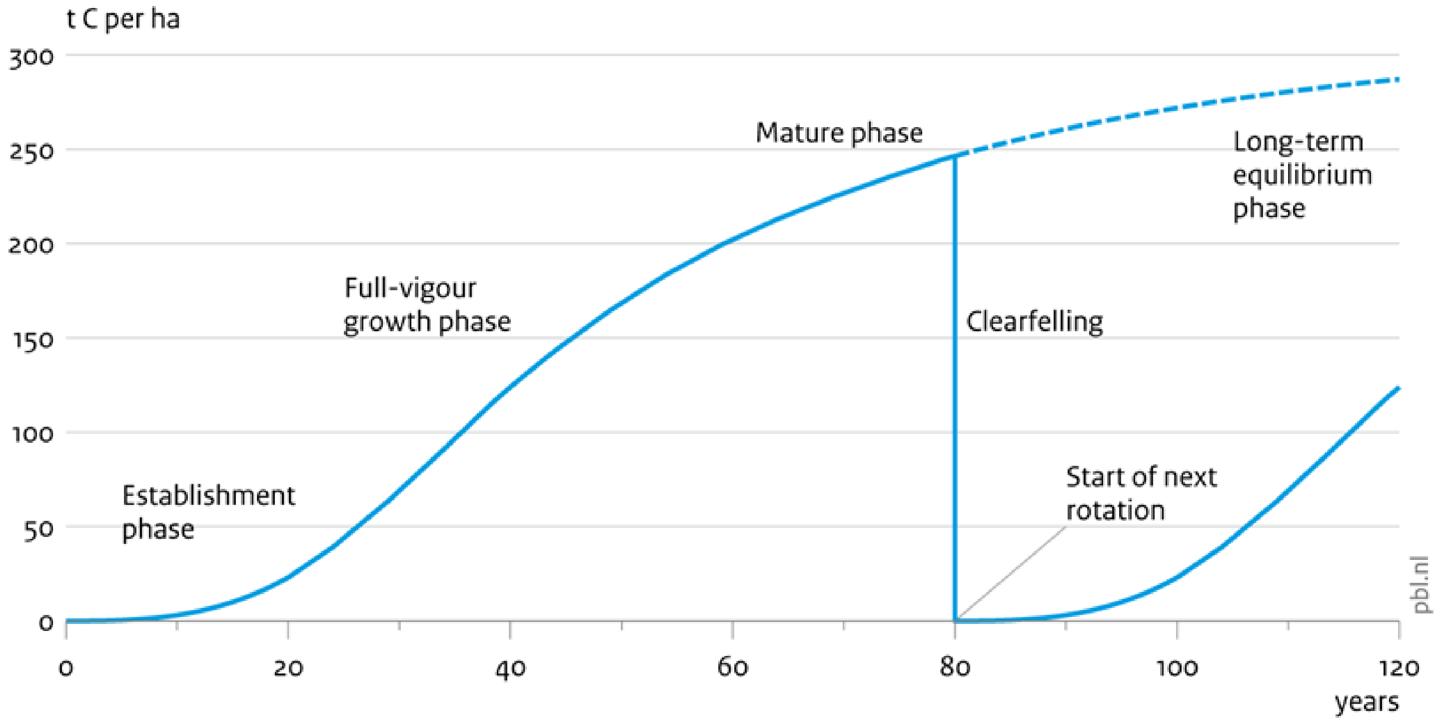
Estimate litter and soil using default values (e.g from IPCC) or model

Measure/model again 5 years later

The change tells you the CO_2 balance over 5 years

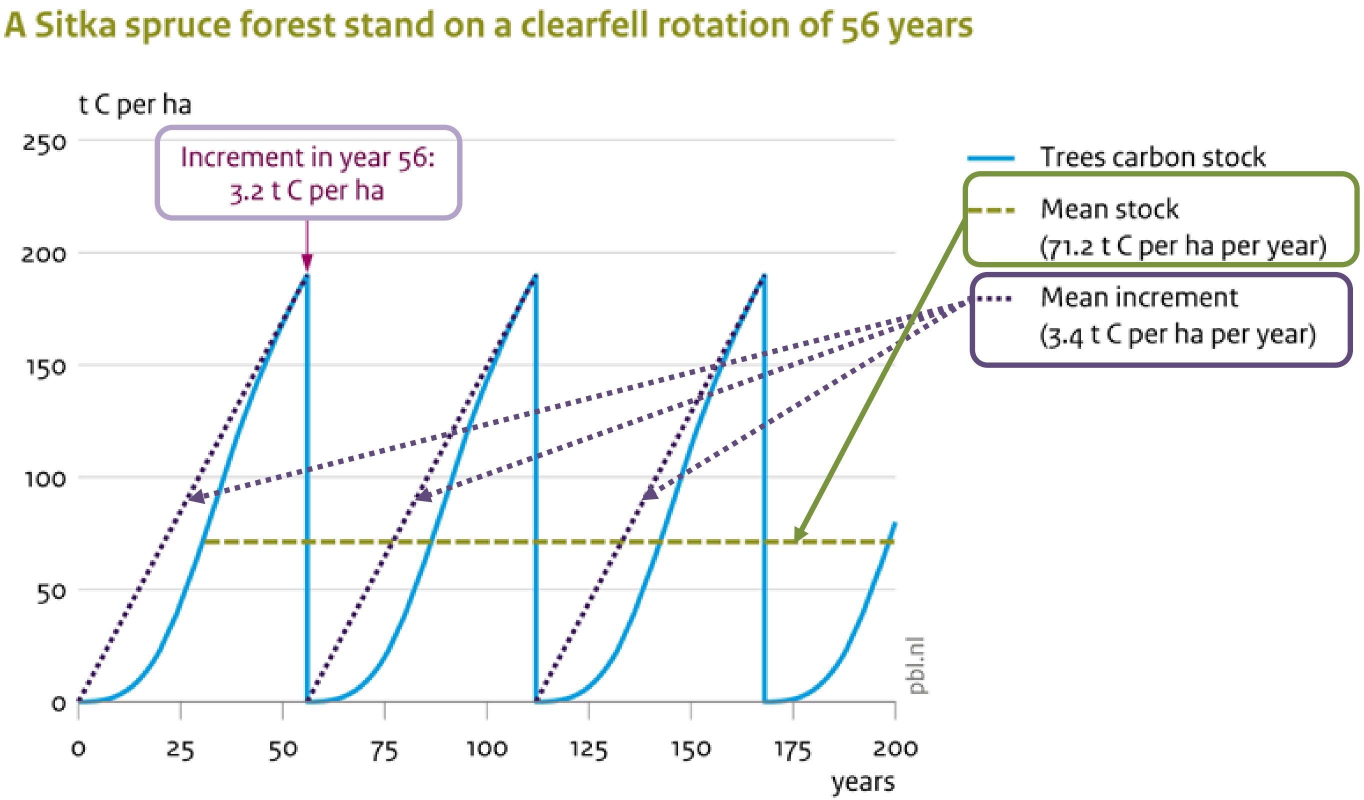
Carbon stock dynamics: stand scale

Tree carbon stocks in a Sitka spruce forest stand (No thinning to keep the example simple)



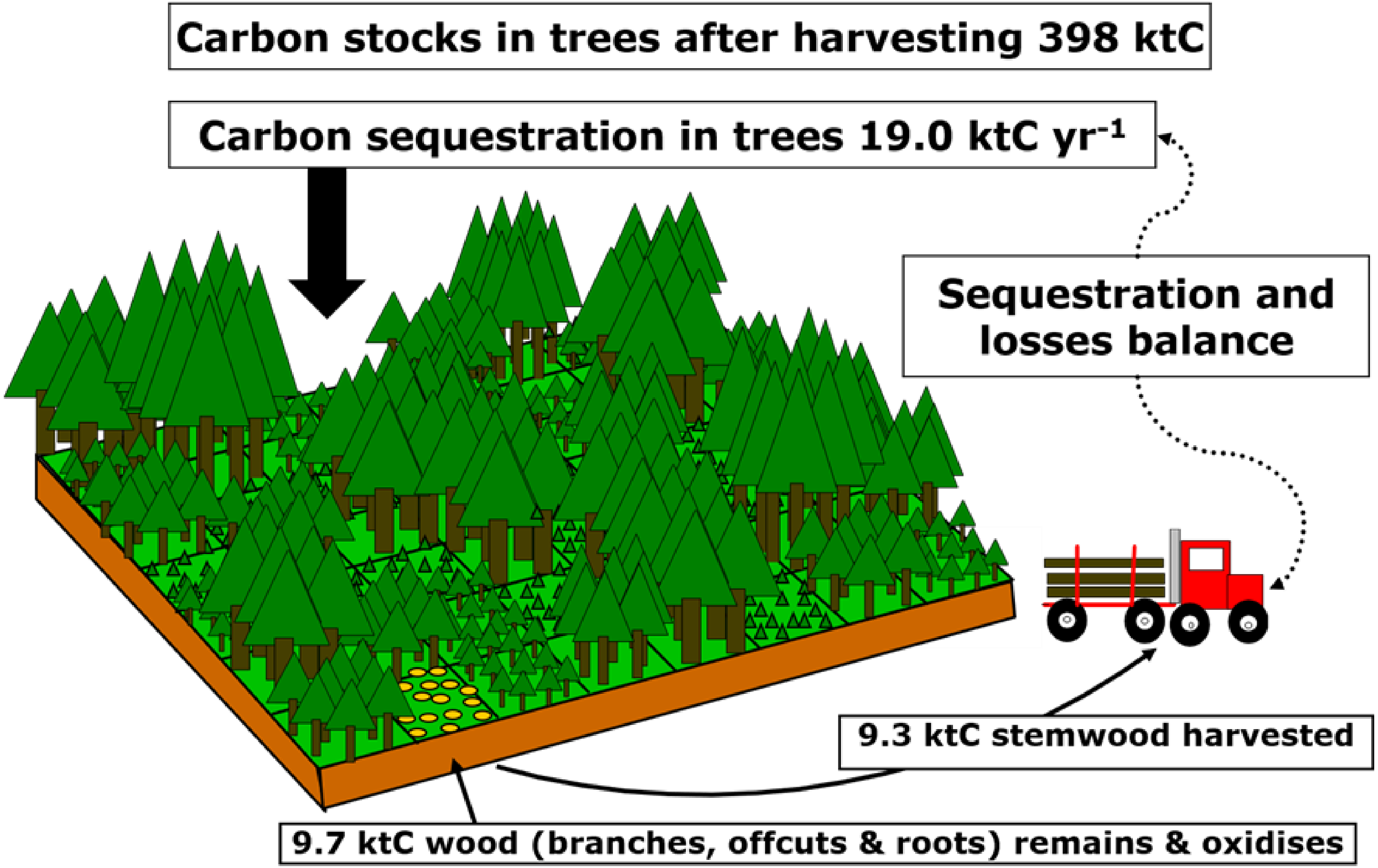
Source: Forestry Commission UK

How do you measure carbon sequestration?



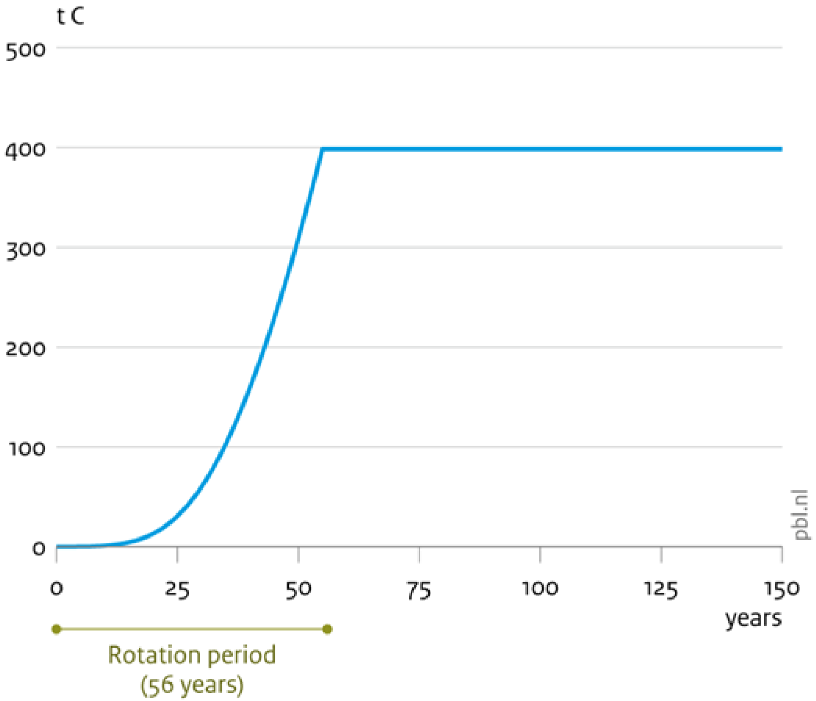
Source: Forestry Commission UK

Carbon stock dynamics: landscape scale



Carbon sequestration: landscape scale

Carbon stock of a Sitka spruce forest stand on a clearfell rotation of 56 years



Source: Forestry Commission UK

- Creating new forests results in a "one-off" (finite) increase in carbon stocks in vegetation
- (Size depends on – see next)
- It *does not* result in continuous long-term carbon sequestration
- (Variable in soil)
- It *could* allow you to continuously produce 'carbon-neutral' timber and biomass
- *BUT…*

Forest and wood product carbon dynamics

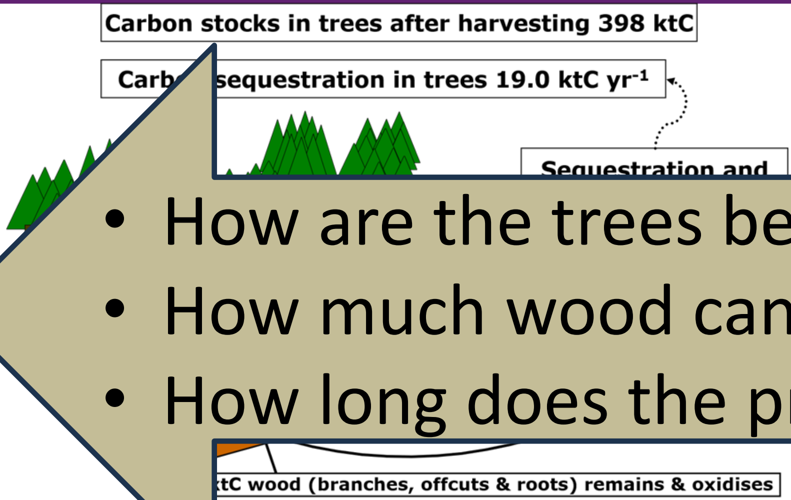
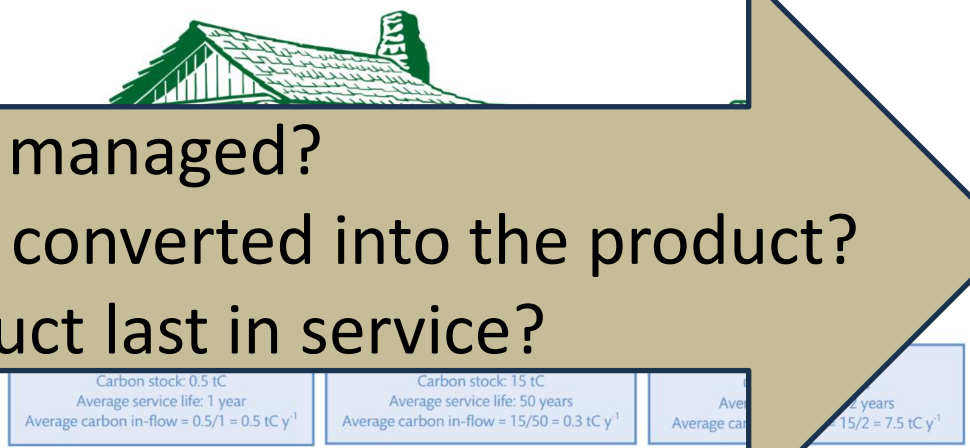


Figure A3.1 A log cabin, a sled and a stock of woodfuel illustrate the relationships among carbon stocks, flows and the service lives of wood products.



- How are the trees being managed?
- How much wood can be converted into the product?
- How long does the product last in service?

- What tree species?
- What type of site and soil?
- How fast are the trees growing?

- How big is the demand for the product?
- How much wood does the product contain?

Wood product “substitution effects”

Nigel Mortimer
formerly Director
North Energy Associates

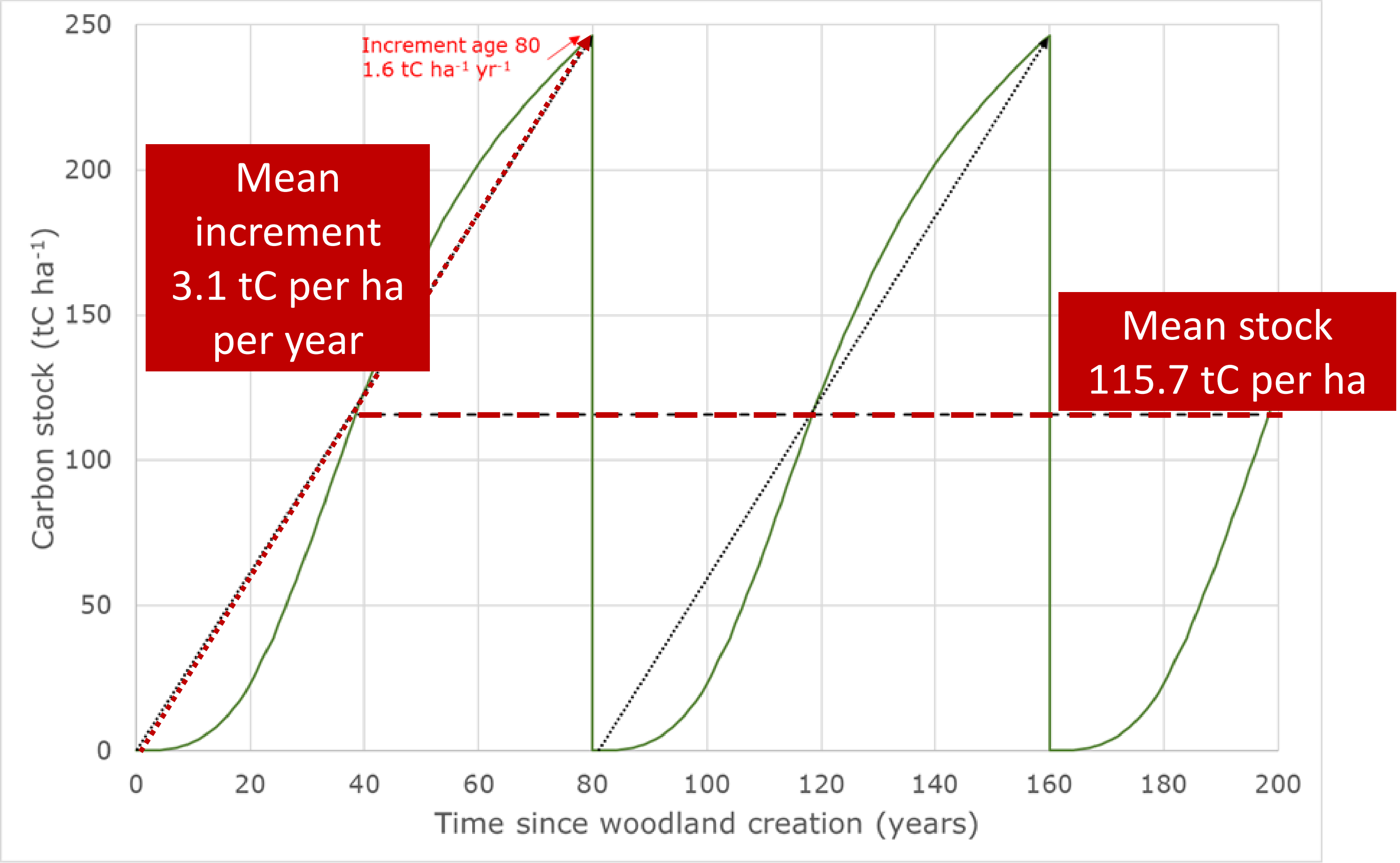
		Wooden Spoon 	Stainless Steel Spoon 	Plastic Spoon 
Energy required (MJ)		0.2	5.9	6.3
CO_2 emissions (g CO_2)		17	460	200
Potential emissions saved	g CO_2	-	443	183
	%	-	96	92

Wood product "emissions displacement"

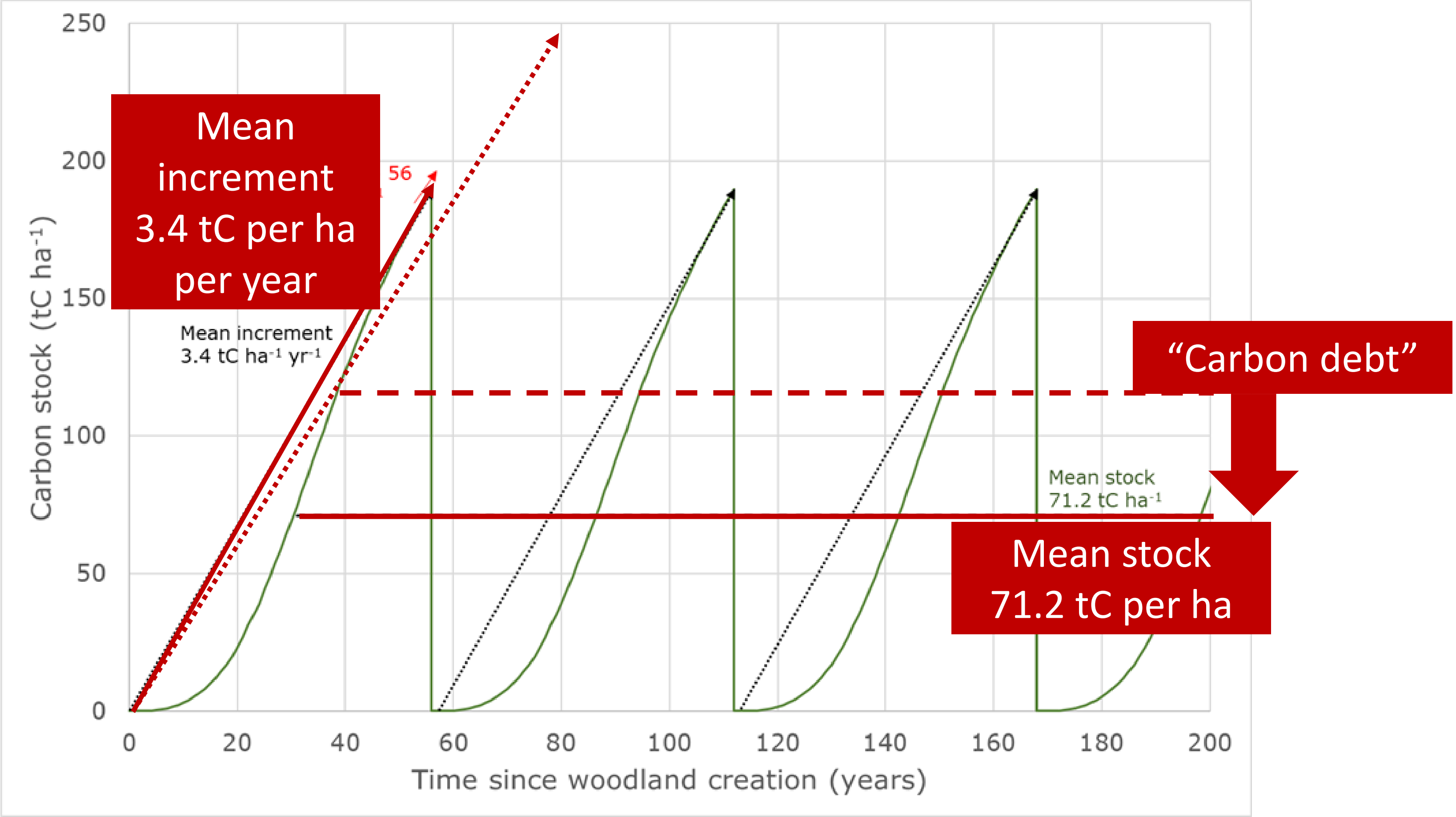
Wood product category	Average emissions displacement factor (tC per tC in wood product)
Structural construction (e.g. building, internal or external wall, wood frame, beam)	1.3
Non-structural construction (eg window, door, ceiling and floor cover, cladding, civil engineering)	1.6
Textiles	2.8
Other product categories (chemicals, furniture, packaging)	1 – 1.5
Grand average	**1.2**

Source: Leskinen et al. (2018)

Intensifying management in a forest (1)



Intensifying management in a forest (2)



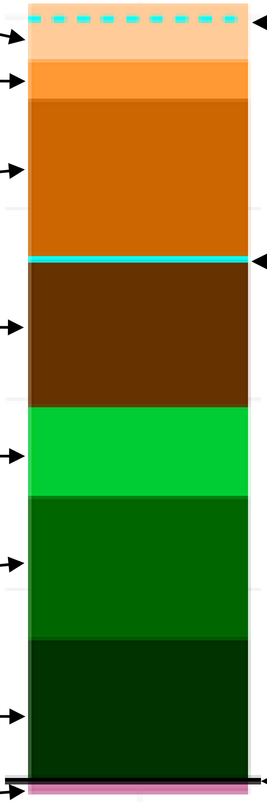
Assessment of forest creation options

(‘Quantifying the Sustainable Forestry Carbon Cycle’)

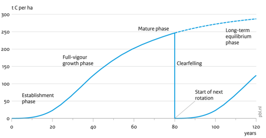
Forest creation options

Name	Yield class	Summary management
Broadleaves, light management	4	Regular but low intensity thinning (continuous cover), also areas left unthinned/unmanaged
Natural recolonisation, rapid	4	
Natural recolonisation, gradual	4	
Production broadleaves	4	Regular thinning (continuous cover)
Production pine	8	Thinning, final felling with restocking
Moderate growing conifer unthinned	12	No thinning, final felling with restocking
Fast growing conifer unthinned	18	
Moderate growing conifer thinned	12	Thinning, final felling with restocking
Fast growing conifer thinned	18	
Fast growing Sitka spruce thinned	24	
Conifer mixture	14	Regular thinning, patch felling (continuous cover)
Complex conifer/broadleaf mixture	14 and 6	

Key to results



Results are for a 1 hectare patch (so remember…
but also time-averaged!)



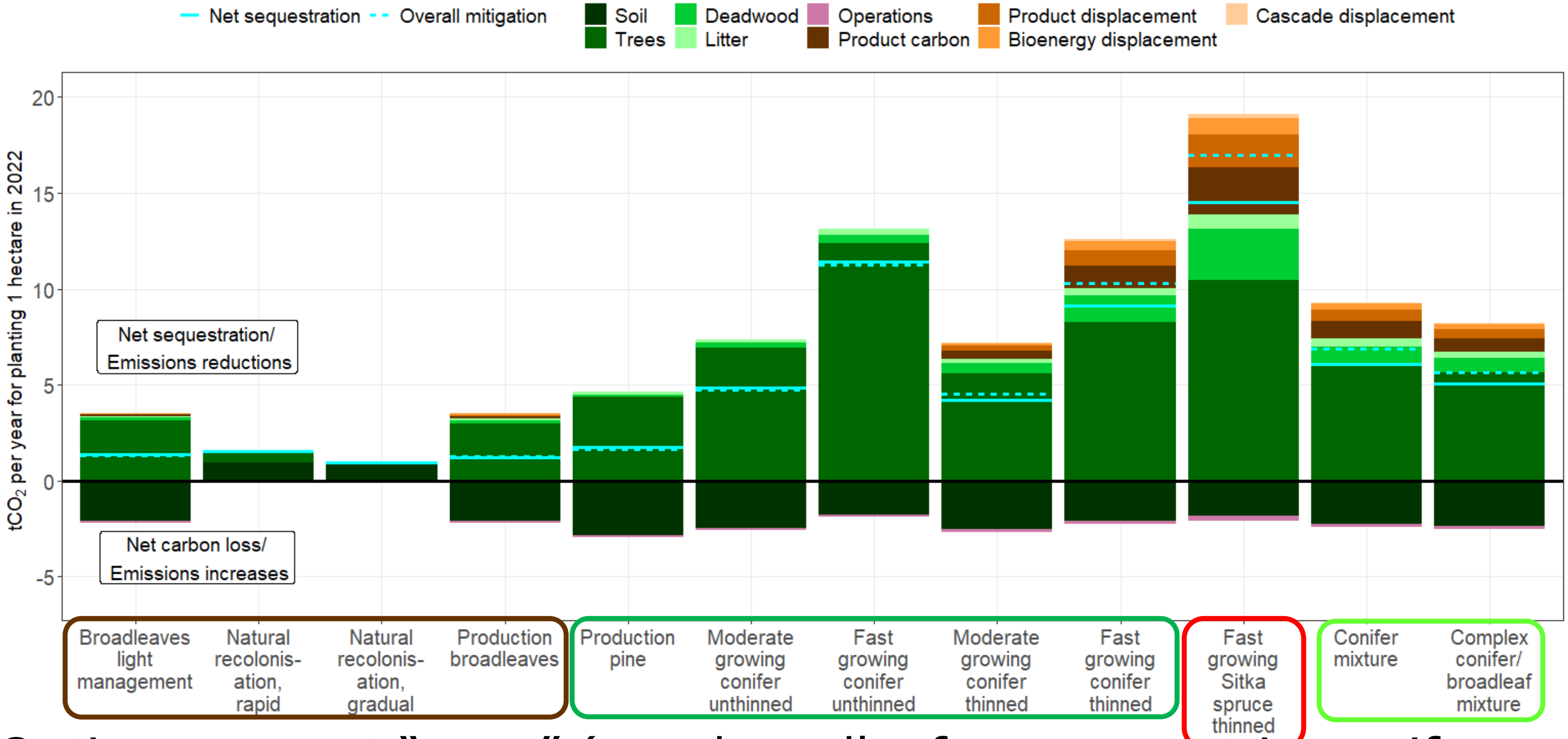
Source: Forestry Commission UK

Units are:

tCO_2/ha/yr for carbon stock changes

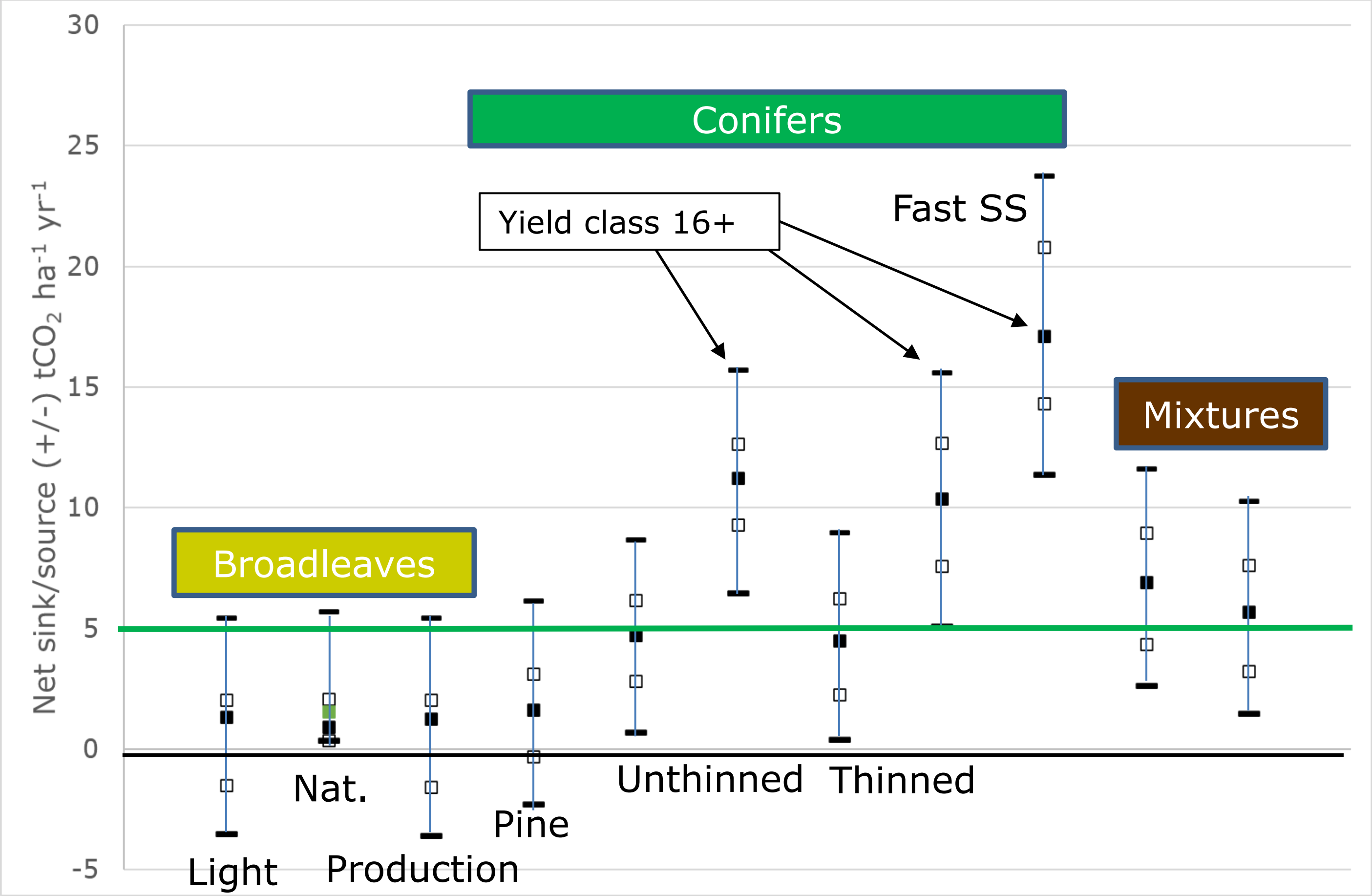
tCO_2-eq./ha/yr for GHG emissions/avoided

Forest options (1 ha): 2022-2050

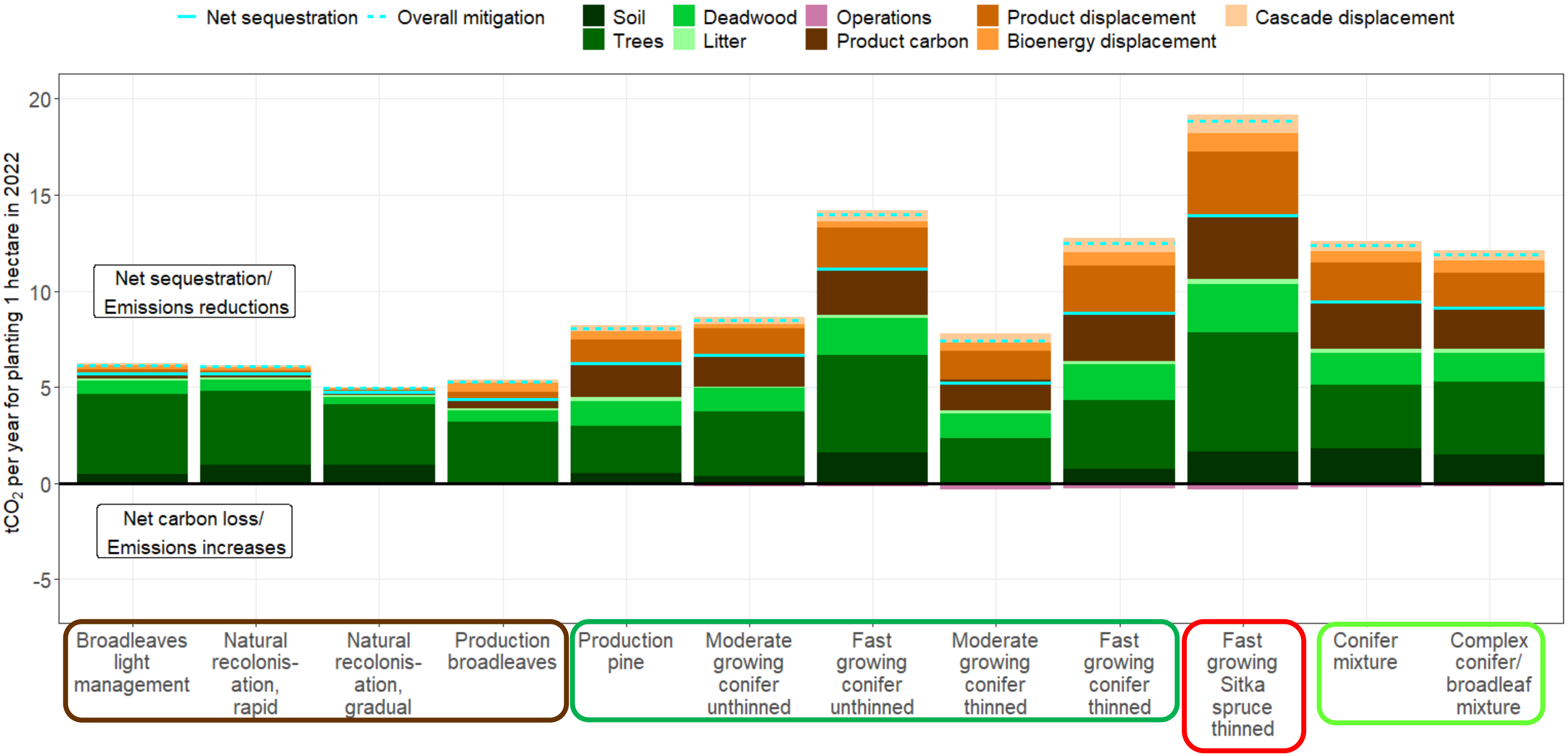


- Options are not "pure" (e.g. broadleaf component in coniferous woodlands); they are not interchangeable…

Sensitivity analysis (2022-2050)

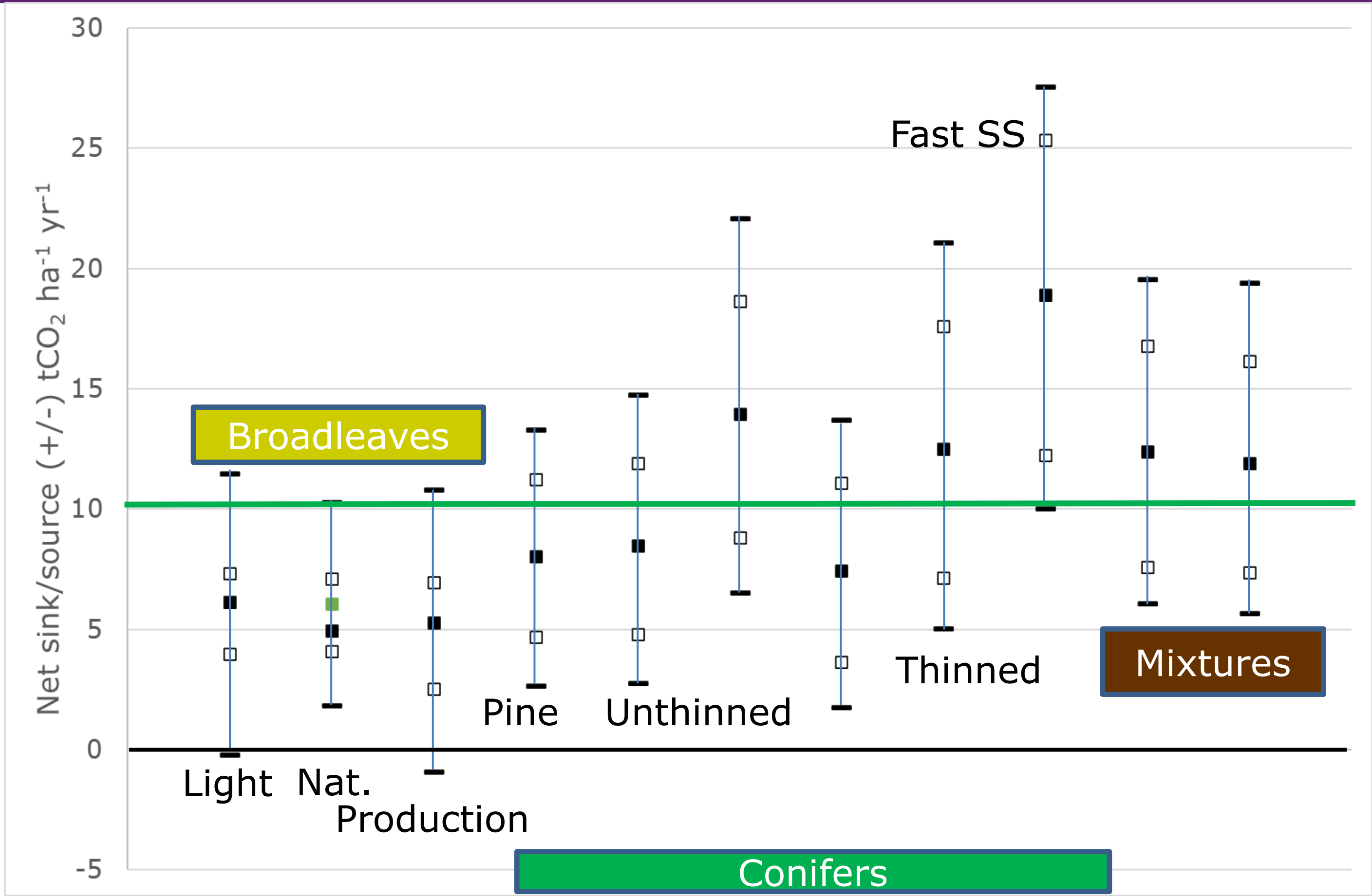


Forest options (1 ha): 2022-2100



- Results depend on the time interval

Sensitivity analysis (2022-2100)



Findings (2022-2050)

- Nearly all the forest options provide net GHG mitigation benefits in the period from 2022 to 2050; none result in significant net GHG emissions
- 2022 to 2050: net carbon sequestration in broadleaves in the range 0.9 to 1.6 tCO_2/ha/yr; conifers in the range 1.8 to 14.5 tCO_2/ha/yr
- But high sensitivity reveals significant overlaps
- Carbon sequestration strongly correlated with YC (2022-2050)
- Soil carbon losses can offset carbon sequestration in other carbon pools
- Minimising disturbance to soil and existing vegetation identified as a critical factor for achieving early carbon sequestration. Particularly for organo-mineral soils and woodlands where the trees have relatively slow growth rates.

Findings (longer term)

- Net carbon sequestration in the different forest options closer to one another.
  - Faster growing forests are being felled by thinning or clearfelling, diminishing the rate of carbon sequestration in these forests when this occurs.
  - At the same time, the slower growing and relatively lightly managed broad-leaved forest options continue to grow and sequester carbon in later decades during this period, so can eventually ‘catch up’ with coniferous forests.
- 2022-2100: net carbon sequestration in broadleaves in the range 4.4 to 5.7 tCO_2/ha/year; conifers in the range 5.2 to 14.0 tCO_2/ha/year (*BUT* recall the sensitivities)
- Avoided emissions through wood product/bioenergy substitution effects are potentially significant for managed coniferous forest options.

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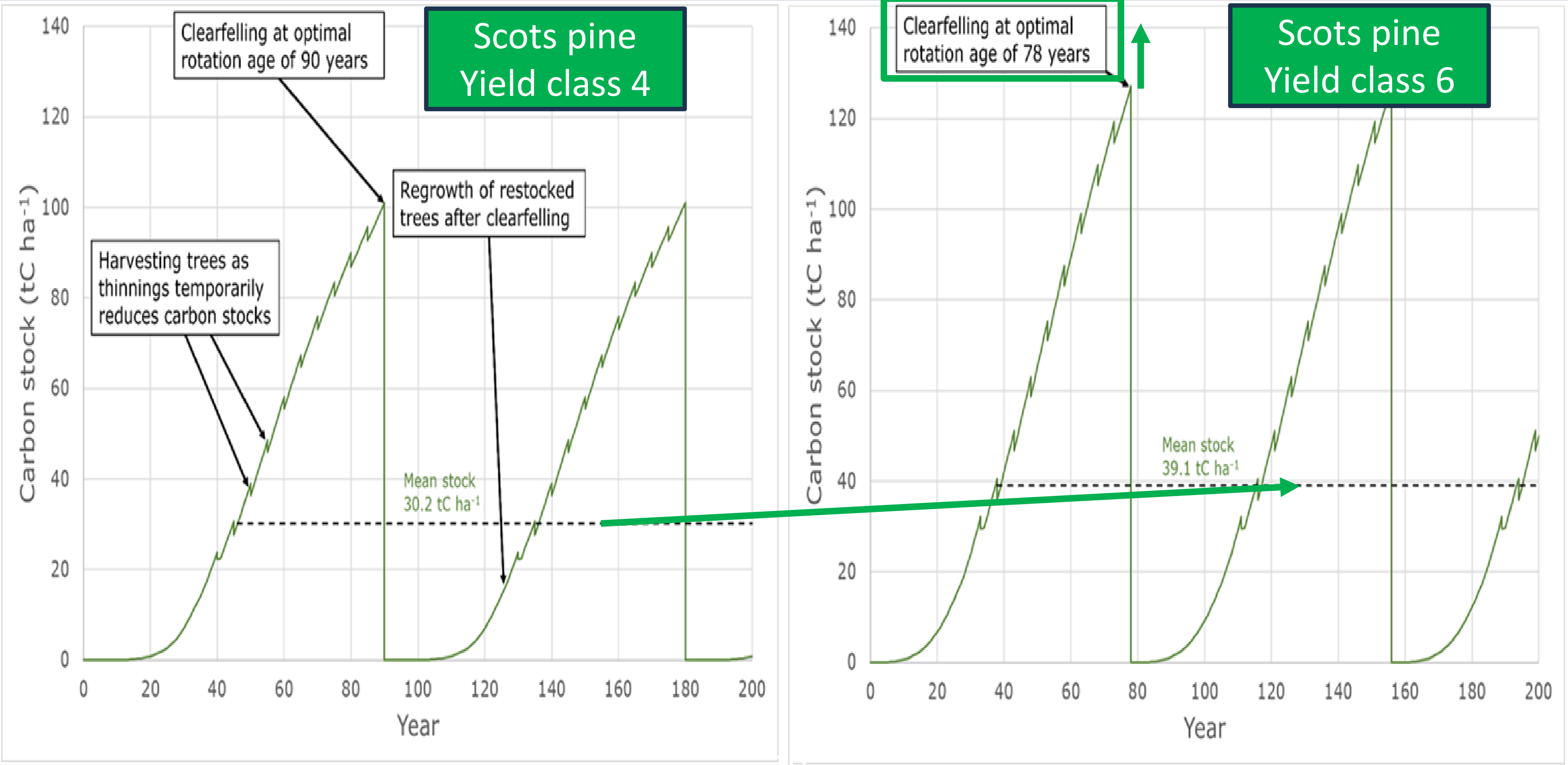
Assessment of forest management options

(Report for PBL Netherlands Environmental Assessment Agency, in preparation

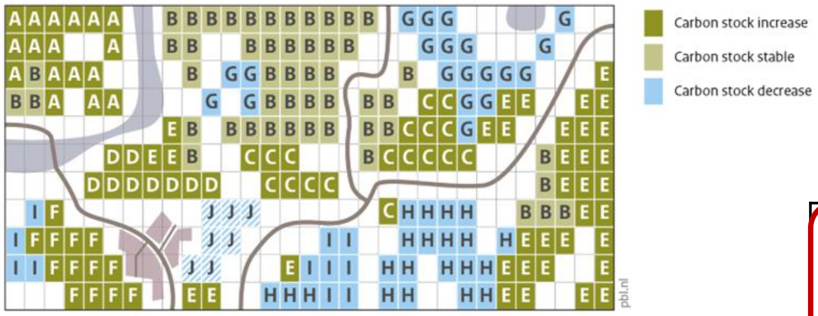
1. Divide the forest up into uniform 'forest units'
    - (Similar species, sites, soils, growth rates, management)
2. For each forest unit:
3. Characterise how the unit is being managed now
4. Calculate the mean carbon stock per hectare
5. Multiply by the area of forest in the unit to get the total carbon stocks in the unit
6. Add up the carbon stocks for all the forest units to get the total carbon stocks in the forest (long-term average)
7. Repeat (2-6) but for how units will be managed going forward from now
8. Carbon impact = carbon stock difference (before/after)

Carbon stocks: influence of 'stand improvement'



Managing carbon stocks and wood production

Hypothetical area of land including areas of forest managed in different ways



Area size	Class		Historical or planned action
17	A	New afforestation	Creation of a mixture of forest areas, either for wood production or for accumulation of maximum carbon stocks.
Existing forests			
50	B	Continuing production	Existing forest areas managed according to pre-existing plans, where levels of wood production are consistent with historical levels.
18	C	Carbon management	Enhancement of wood production in single-species forest areas by restocking with genetically improved trees in place of unimproved trees.
9	D	Carbon management	Enhancement of wood production in forest areas by restocking with tree species better suited to sites and climatic conditions, compared with existing tree species.
36	E	Carbon management	Increased resilience of single-species forest areas at risk of disease outbreaks by restocking with species mixtures.
13	F	Carbon management	Enhanced carbon stocks in forest areas with low productivity by minimising harvesting and other disturbances.
20	G	Increased production	Management of forest areas for increased wood production by increasing frequency of thinning interventions.
21	H	Increased production	Management of forest areas for increased wood production by optimising rotation periods, generally involving shortening of longer rotations.
11	I	Increased production	Extraction of forest harvesting residues where previously these would have been left to rot in the forest; decay rates estimated as moderate.
7	J	Deforested areas	Forest areas converted to non-forest land because of unavoidable development.

Source: Forestry Commission UK

Class of forest (manage-ment)	Area (arbitrary units[1])	Mean carbon stock per ha			Probability	Total[2]
		Initial	Resultant	Difference		
A	7	2.5	81.4	78.9	0.8	442
B	50	45.5	45.5	0.0	1.0	0
C	18	50.0	75.0	25.0	0.8	359
D	9	56.0	64.3	8.3	0.8	60
E	36	0.0	37.0	37.0	0.1	133
F	50	50.4	59.0	8.6	0.9	387
G	2	50.4	215.9	165.5	0.7	232
H	20	90.0	57,0	-33.0	1.0	-660
I	21	71.8	57.0	-14.8	1.0	-311
J	11	51.9	36.3	-15.6	1.0	-171
K	7	45.5	2.5	-43.0	1.0	-301
Total	**231**	-	-	-	-	**171**

Concept

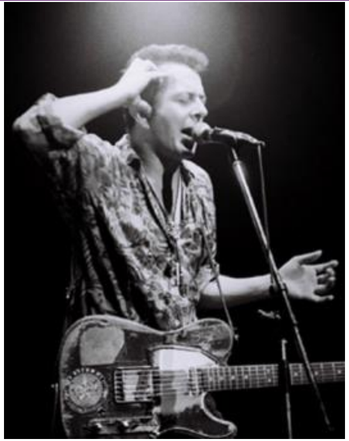
In conclusion …

- The science is relatively simple
- There are some other effects (albedo, biophysical)
  - Personally, I don't think these change the essential story
- There are lots of options when creating new forests – don't get caught up on one option
  - (Right tree, right place, right time – sorry ☹)
  - Best to focus on the other motives for creating the forests?
  - Sequestration initially, low-emissions timber/biomass long-term
- Planning and implementing management for GHG emissions mitigation can involve challenges (e.g. trade-offs), but is possible
- A (simple?) practical framework might help with this
  - Software tools?

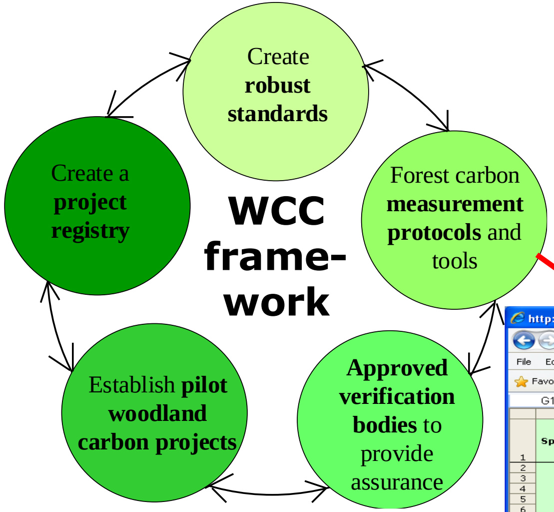
Some tools

(existing, improving and emerging)

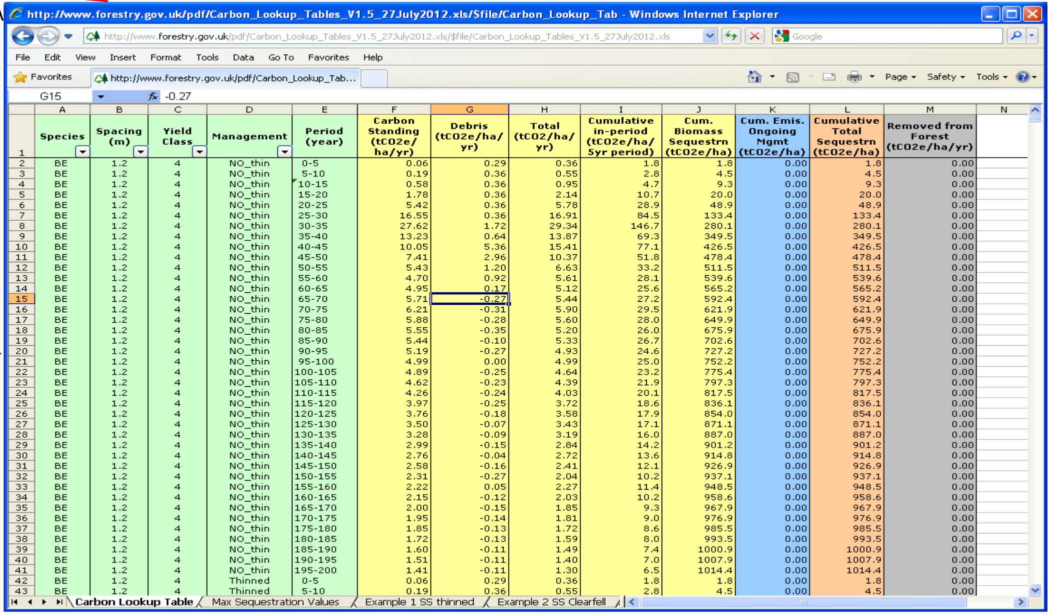
Tools: Forest creation



Joe Strummer
formerly The Clash
Photo: Masao Nakagami
[CC BY-SA 2.0]



Woodland Carbon CO_2de



1	Species	Spacing (m)	Yield Class	Management	Period (year)	Carbon Standing (tCO2e/ha/yr)	Debris (tCO2e/ha/yr)	Total (tCO2/ha/yr)	Cumulative in-period (tCO2e/ha/5yr period)	Cum. Biomass Sequestrn (tCO2e/ha)	Cum. Emis. Ongoing Mgmt (tCO2e/ha)	Cumulative Total Sequestrn (tCO2e/ha)	Removed from Forest (tCO2e/ha/yr)
2	BE	1.2	4	NO_thin	0-5	0.06	0.29	0.36	1.8	1.8	0.00	1.8	0.00
3	BE	1.2	4	NO_thin	5-10	0.19	0.36	0.55	2.8	4.5	0.00	4.5	0.00
4	BE	1.2	4	NO_thin	10-15	0.58	0.36	0.95	4.7	9.3	0.00	9.3	0.00
5	BE	1.2	4	NO_thin	15-20	1.78	0.36	2.14	10.7	20.0	0.00	20.0	0.00
6	BE	1.2	4	NO_thin	20-25	5.42	0.36	5.78	28.9	48.9	0.00	48.9	0.00
7	BE	1.2	4	NO_thin	25-30	16.55	0.36	16.91	84.5	133.4	0.00	133.4	0.00
8	BE	1.2	4	NO_thin	30-35	27.62	1.72	29.34	146.7	280.1	0.00	280.1	0.00
9	BE	1.2	4	NO_thin	35-40	13.23	0.64	13.87	69.3	349.5	0.00	349.5	0.00
10	BE	1.2	4	NO_thin	40-45	10.05	5.36	15.41	77.1	426.5	0.00	426.5	0.00
11	BE	1.2	4	NO_thin	45-50	7.41	2.96	10.37	51.8	478.4	0.00	478.4	0.00
12	BE	1.2	4	NO_thin	50-55	5.43	1.20	6.63	33.2	511.5	0.00	511.5	0.00
13	BE	1.2	4	NO_thin	55-60	4.70	0.92	5.61	28.1	539.6	0.00	539.6	0.00
14	BE	1.2	4	NO_thin	60-65	4.95	0.17	5.12	25.6	565.2	0.00	565.2	0.00
15	BE	1.2	4	NO_thin	65-70	5.71	-0.27	5.44	27.2	592.4	0.00	592.4	0.00
16	BE	1.2	4	NO_thin	70-75	6.21	-0.31	5.90	29.5	621.9	0.00	621.9	0.00
17	BE	1.2	4	NO_thin	75-80	5.88	-0.28	5.60	28.0	649.9	0.00	649.9	0.00
18	BE	1.2	4	NO_thin	80-85	5.55	-0.35	5.20	26.0	675.9	0.00	675.9	0.00
19	BE	1.2	4	NO_thin	85-90	5.44	-0.10	5.33	26.7	702.6	0.00	702.6	0.00
20	BE	1.2	4	NO_thin	90-95	5.19	-0.27	4.93	24.6	727.2	0.00	727.2	0.00
21	BE	1.2	4	NO_thin	95-100	4.99	0.00	4.99	25.0	752.2	0.00	752.2	0.00
22	BE	1.2	4	NO_thin	100-105	4.89	-0.25	4.64	23.2	775.4	0.00	775.4	0.00
23	BE	1.2	4	NO_thin	105-110	4.62	-0.23	4.39	21.9	797.3	0.00	797.3	0.00
24	BE	1.2	4	NO_thin	110-115	4.26	-0.24	4.03	20.1	817.5	0.00	817.5	0.00
25	BE	1.2	4	NO_thin	115-120	3.97	-0.25	3.72	18.6	836.1	0.00	836.1	0.00
26	BE	1.2	4	NO_thin	120-125	3.76	-0.18	3.58	17.9	854.0	0.00	854.0	0.00
27	BE	1.2	4	NO_thin	125-130	3.50	-0.07	3.43	17.1	871.1	0.00	871.1	0.00
28	BE	1.2	4	NO_thin	130-135	3.28	-0.09	3.19	16.0	887.0	0.00	887.0	0.00
29	BE	1.2	4	NO_thin	135-140	2.99	-0.15	2.84	14.2	901.2	0.00	901.2	0.00
30	BE	1.2	4	NO_thin	140-145	2.76	-0.04	2.72	13.6	914.8	0.00	914.8	0.00
31	BE	1.2	4	NO_thin	145-150	2.58	-0.16	2.41	12.1	926.9	0.00	926.9	0.00
32	BE	1.2	4	NO_thin	150-155	2.31	-0.27	2.04	10.2	937.1	0.00	937.1	0.00
33	BE	1.2	4	NO_thin	155-160	2.22	0.05	2.27	11.4	948.5	0.00	948.5	0.00
34	BE	1.2	4	NO_thin	160-165	2.15	-0.12	2.03	10.2	958.6	0.00	958.6	0.00
35	BE	1.2	4	NO_thin	165-170	2.00	-0.15	1.85	9.3	967.9	0.00	967.9	0.00
36	BE	1.2	4	NO_thin	170-175	1.95	-0.14	1.81	9.0	976.9	0.00	976.9	0.00
37	BE	1.2	4	NO_thin	175-180	1.85	-0.13	1.72	8.6	985.5	0.00	985.5	0.00
38	BE	1.2	4	NO_thin	180-185	1.72	-0.13	1.59	8.0	993.5	0.00	993.5	0.00
39	BE	1.2	4	NO_thin	185-190	1.60	-0.11	1.49	7.4	1000.9	0.00	1000.9	0.00
40	BE	1.2	4	NO_thin	190-195	1.51	-0.11	1.40	7.0	1007.9	0.00	1007.9	0.00
41	BE	1.2	4	NO_thin	195-200	1.41	-0.11	1.30	6.5	1014.4	0.00	1014.4	0.00
42	BE	1.2	4	Thinned	0-5	0.06	0.29	0.36	1.8	1.8	0.00	1.8	0.00
43	BE	1.2	4	Thinned	5-10	0.19	0.36	0.55	2.8	4.5	0.00	4.5	0.00

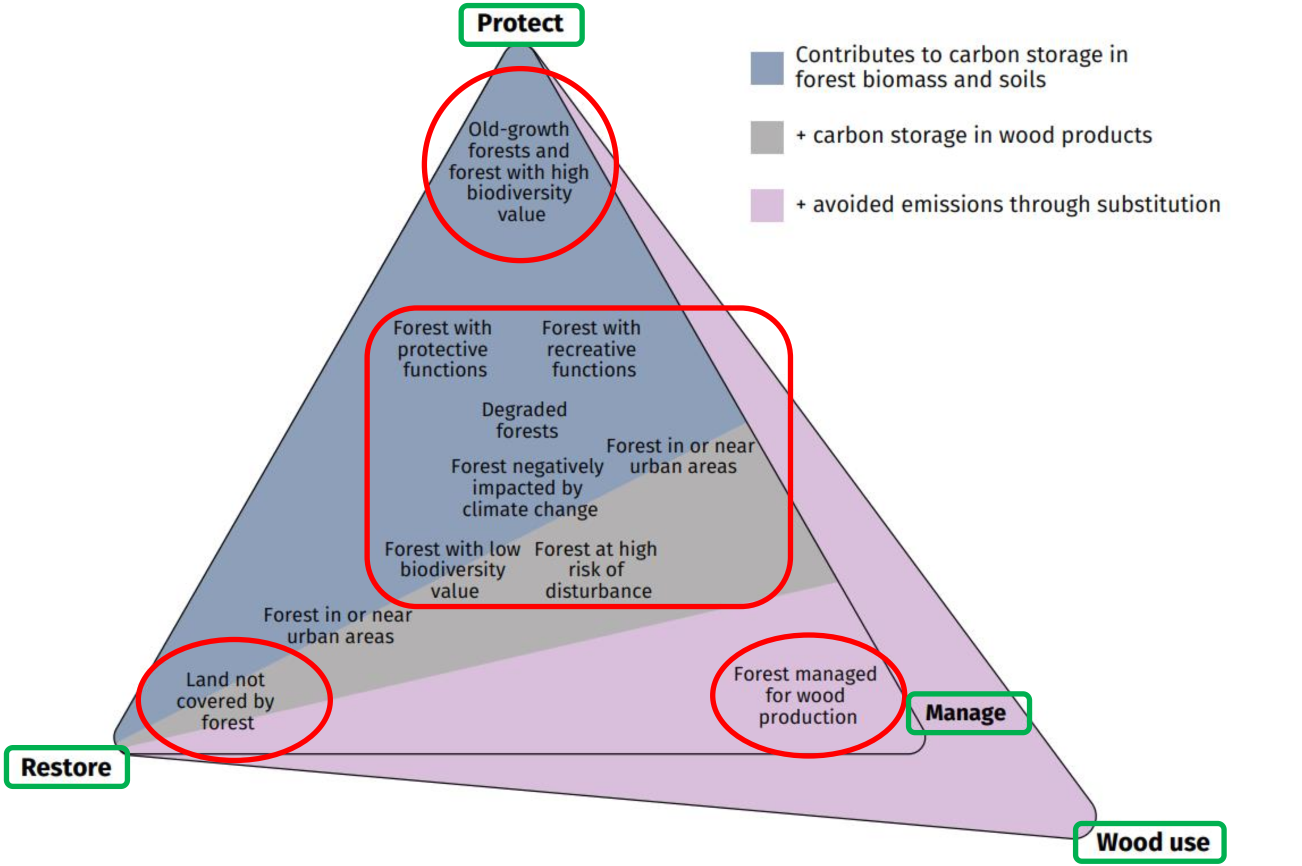
"Conceived around a campfire at Glastonbury Festival in 1996"

"Why not get people to pay to plant trees to offset their CO_2 emissions?"…

Tools: Ground preparation and soil

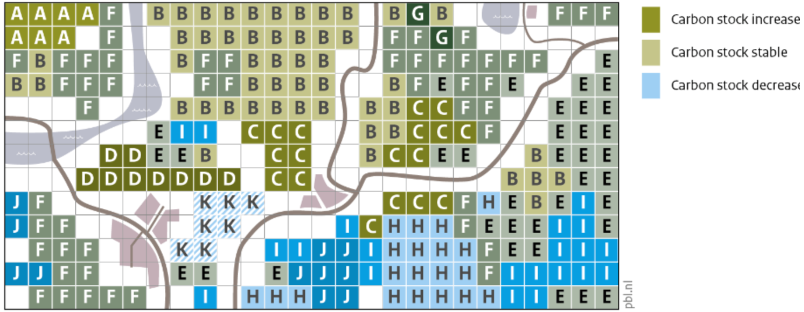
Soil type	Soil carbon total to depth indicated (tC ha^{-1})					Cultivation method, and total soil carbon losses (tC ha^{-1}) over one rotation									
	1 m	10 cm	20 cm	30 cm	50/60 cm	No cultivation	Subsoiling/Ripping	Inverted mounding	Patch scarification	Disc scarification (linear)	Mulching	Hinge mounding	Trench mounding	Shallow strip ploughing	Deep complete ploughing
					Carbon loss:	0%	5%	5%	5%	20%	5%	5%	10%	20%	50%
					Depth of cultivation (cm):	-	45-60 (60 assumed)	30	15-20 (20 assumed)	20	10	30	50	<30 (30 assumed)	>30 (50 assumed)
Brown earth (poor, medium fertility)	152	39	63	81.5	108.5/117	**0**	*5.9*	*4.1*	**3.1**	**12.6**	**2.0**	*4.1*	*10.8*	16.3	*54.3*
Brown earth (high fertility	152	39	63	81.5	108.5/117	**0**	*5.9*	*4.1*	3.1	12.6	*2.0*	*4.1*	*10.8*	*16.3*	*54.3*
Podzol	154	37	66	85.5	113/121	**0**	*6.1*	**4.3**	**3.3**	**13.2**	**1.9**	4.3	*11.3*	17.1	*56.5*
Ironpan soil (Pan no obstacle to roots)	154	37	66	85.5	113/121	**0**	**6.1**	**4.3**	3.3	13.2	1.9	*4.3*	*11.3*	17.1	*56.5*
Ironpan soil (Pan limits root growth)	154	37	66	85.5	113/121	*0*	**6.1**	**4.3**	*3.3*	*13.2*	*1.9*	*4.3*	*11.3*	*17.1*	56.5
Ironpan soil (Pan out of reach)	154	37	66	85.5	113/121	Treat like gley/peaty gley/deep peat depending on presence and depth of organic layer									
Ranker	108	43	75	108	-/-	**0**	n/a	*5.4*	**0***	*15.0*	*2.2*	*5.4*	n/a	*21.6*	n/a

“Climate Smart Forestry…?”



Tools: Existing forests?

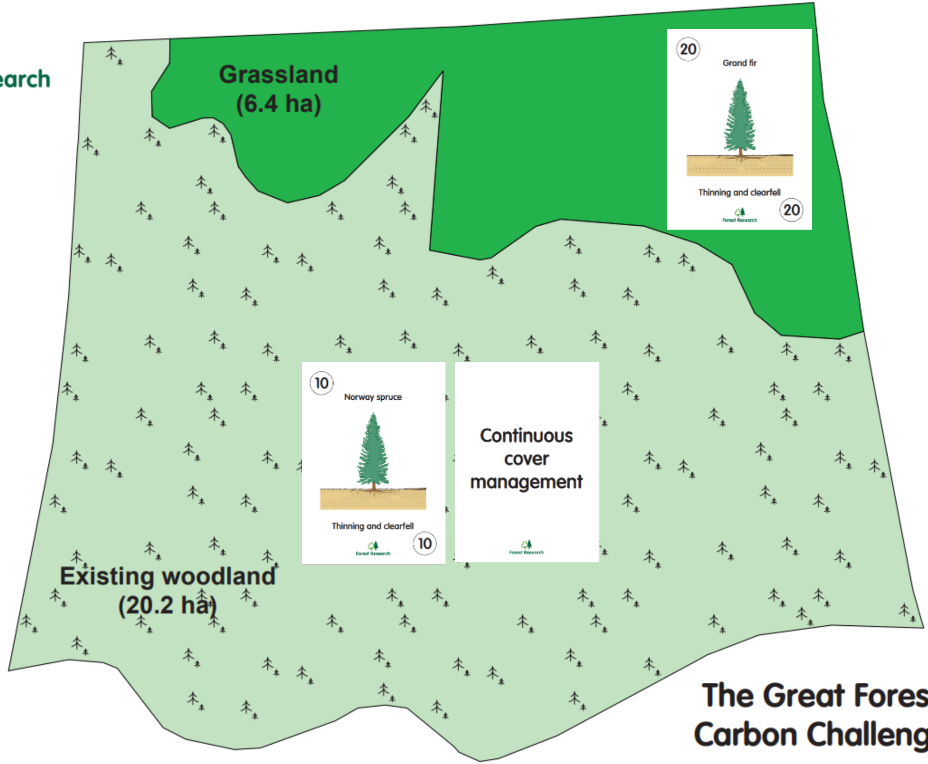
Hypothetical area of land including areas of forest managed in different ways



Area	Class		Historical or planned action
7	A	New afforestation	Creation of a mixture of forest areas, either for wood production or for accumulation of maximum carbon stocks.
Existing forests			
50	B	Continuing production	Existing forest areas managed according to pre-existing plans, where levels of wood production are consistent with historical levels.
18	C	Carbon management	Enhancement of wood production in single-species forest areas by restocking with genetically improved trees in place of unimproved trees.
9	D	Carbon management	Enhancement of wood production in forest areas by restocking with tree species better suited to sites and climatic conditions, compared with existing tree species.
36	E	Carbon management	Increased resilience of single-species forest areas at risk of disease outbreaks by restocking with species mixtures.
50	F	Carbon management	Enhanced carbon stocks in forest areas by extending rotation periods, while avoiding significant reductions in wood production.
2	G	Carbon management	Enhanced carbon stocks in forest areas with low productivity by minimising harvesting and other disturbances.
20	H	Increased production	Management of forest areas for increased wood production by increasing frequency of thinning interventions.
21	I	Increased production	Management of forest areas for increased wood production by optimising rotation periods, generally involving shortening of longer rotations.
11	J	Increased production	Extraction of residues left behind after forest harvesting where previously these would have been left to decay in the forest; decay rates estimated as moderate.
7	K	Deforested areas	Forest areas converted to non-forest land because of unavoidable development.

Source: Forest Research UK

Forest Research



The Great Forest Carbon Challenge

Watch out!

- Carbon sequestration is reversible/”lock-in”
- How to ensure wood products give GHG savings
  - Joined-up sectoral policies (environmental integrity)
- Pay now to get (long-term) benefits eventually
- Environmental/social benefits difficult to monetise
  - Carbon prices can be very volatile
- Who’s carbon is it anyway?
  - Forests
  - Wood products
- Need “no regrets” action (risk management)
- “Mind your language” (terminology, definitions …)
- Beware simplistic arguments/positions
  - Too big for sectoral interests.

ACT NOW

Assessing forestry and timber options for carbon impacts

Thank you