UK FOREST CARBON MODELS

Robert Matthews

(UK) Forest Research
(Forestry Commission Research Agency)
Alice Holt Research Station
Surrey, England

r.matthews@forestry.gov.uk

UK FOREST CARBON MODELS

What models are there in the UK?

What are the models like?

What has the UK done with them?

What is planned?

Show examples – M3 and ERGO

WHAT MODELS ARE THERE ?
WHAT ARE THEY LIKE?

- Carbon accounting models
- Process-based models
  - Forest
  - Soil
- Forest industry sector models
- Forest management and Plantation Forestry (PF) models
- National/regional scenario models
- Energy/carbon budgeting models

CARBON ACCOUNTING MODELS

CARBINE (Forest Research)

Matthews, Thompson

CFLOW-98 (CEH, Edinburgh)*

Dewar, Cannell, Milne

*Centre for Ecology and Hydrology

Very similar to CO_2fix

FOREST INDUSTRY SECTOR MODELS

CARBINE (Forest Research)

Matthews

Very similar to GORCAM

PROCESS-BASED MODELS (FOREST)

MAESTRO (Edinburgh University)

Wang, Jarvis, Friend

GROMIT (Forest Research)

Ludlow, Randle

M5 (Forest Research)

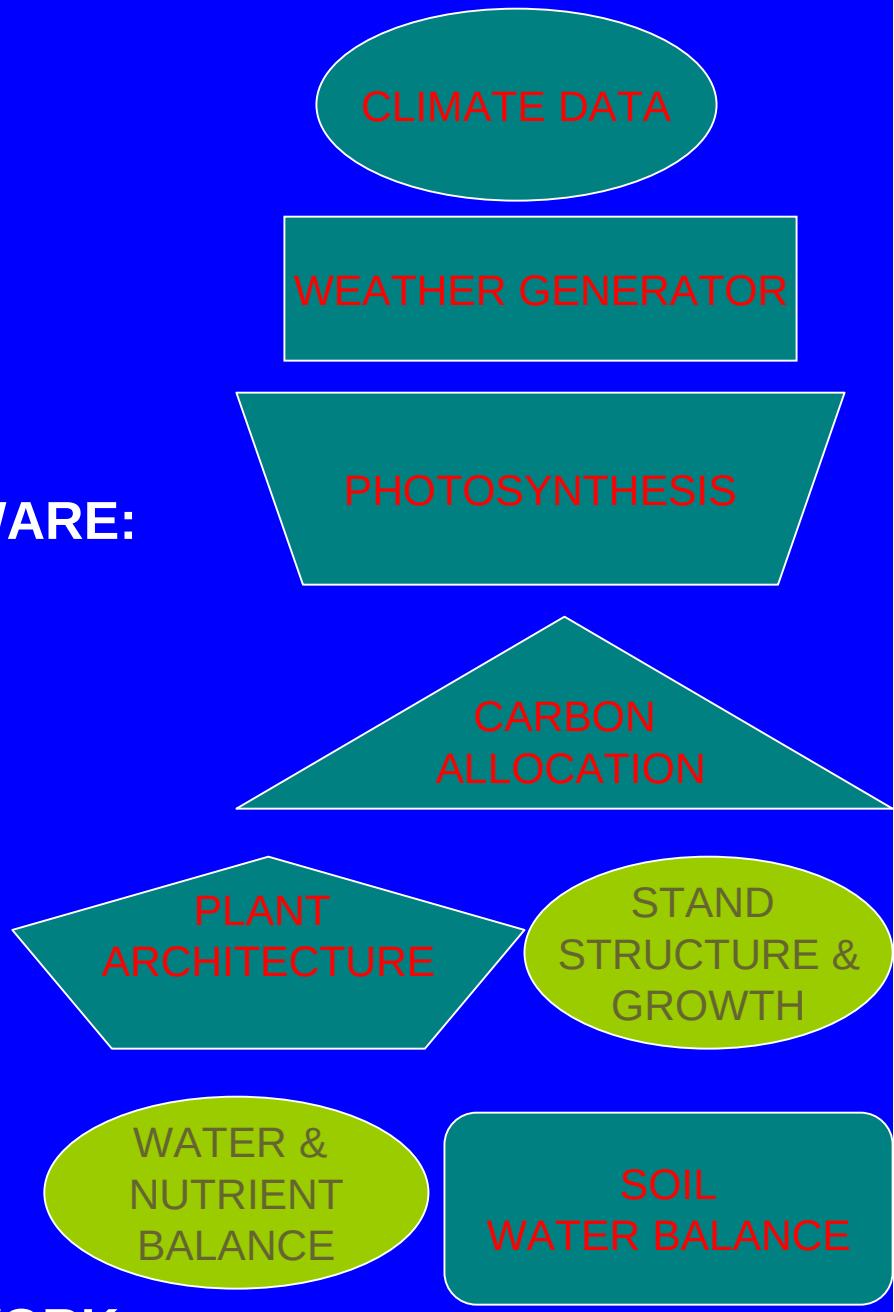
Evans, Matthews, Broadmeadow

Not yet applied to C sequestration

STRUCTURE OF PROCESS-BASED MODEL

- **REQUIRED FOR YIELD MODEL SOFTWARE:**
  - **DEVELOPMENT**
  - **CALIBRATION**
- **CAN BE APPLIED TO**
  - **NUTRIENT BUDGET**
  - **WATER BUDGET**
  - **LONG TERM YIELD**

- **FUTURE POTENTIAL:**
- **CAN SERVE AS MODELLING FRAMEWORK**



PROCESS-BASED MODELS (SOIL)

ROTH-C (IACR, Rothamsted)*

Jenkinson et al.

*Institute for Arable Crops Research

FOREST MANAGEMENT AND PF MODELS

FORESTER (Forest Enterprise)

Coppock, Ditchburn, Halsall

Like EFISCEN but with GIS

M3 (Forest Research)

Matthews et al.

ASORT (Forest Research)

Methley, Anderson

FIAP (Forestry Commission)

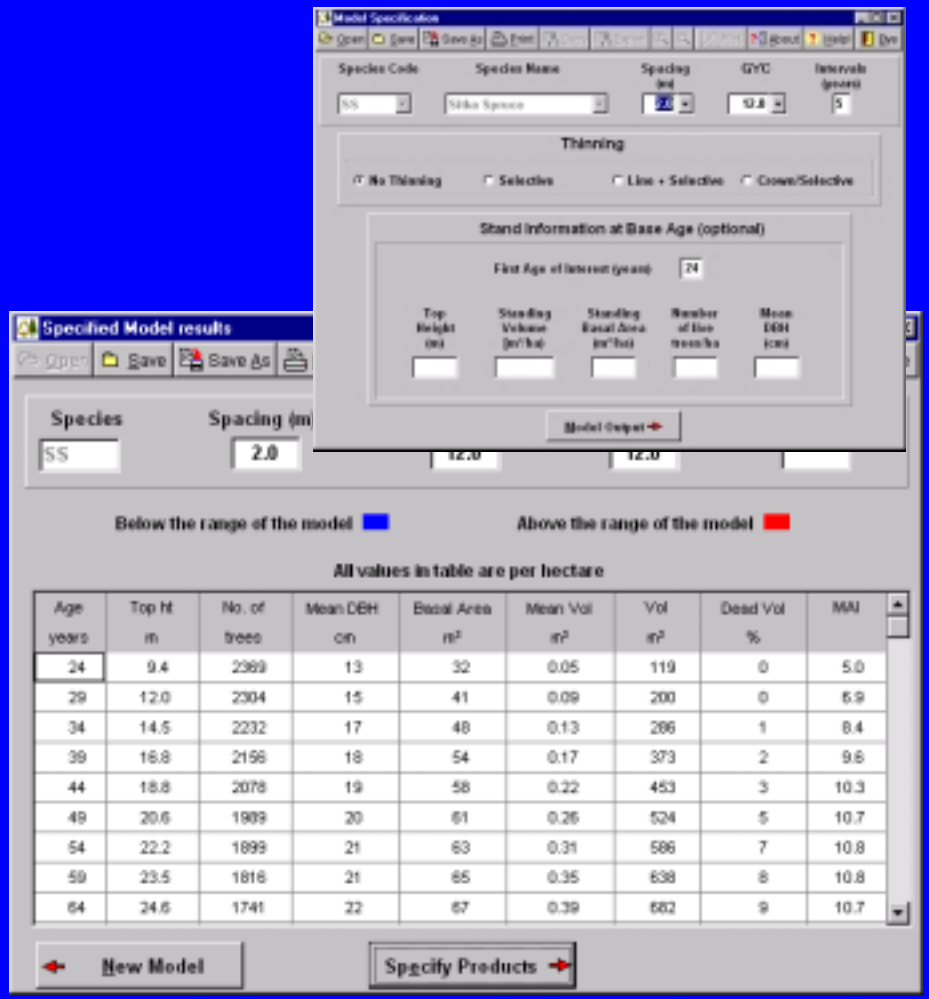
Various, Lorrain-Smith

Not yet integrated with each other or with C sequestration models

FOREST MANAGEMENT (M3)

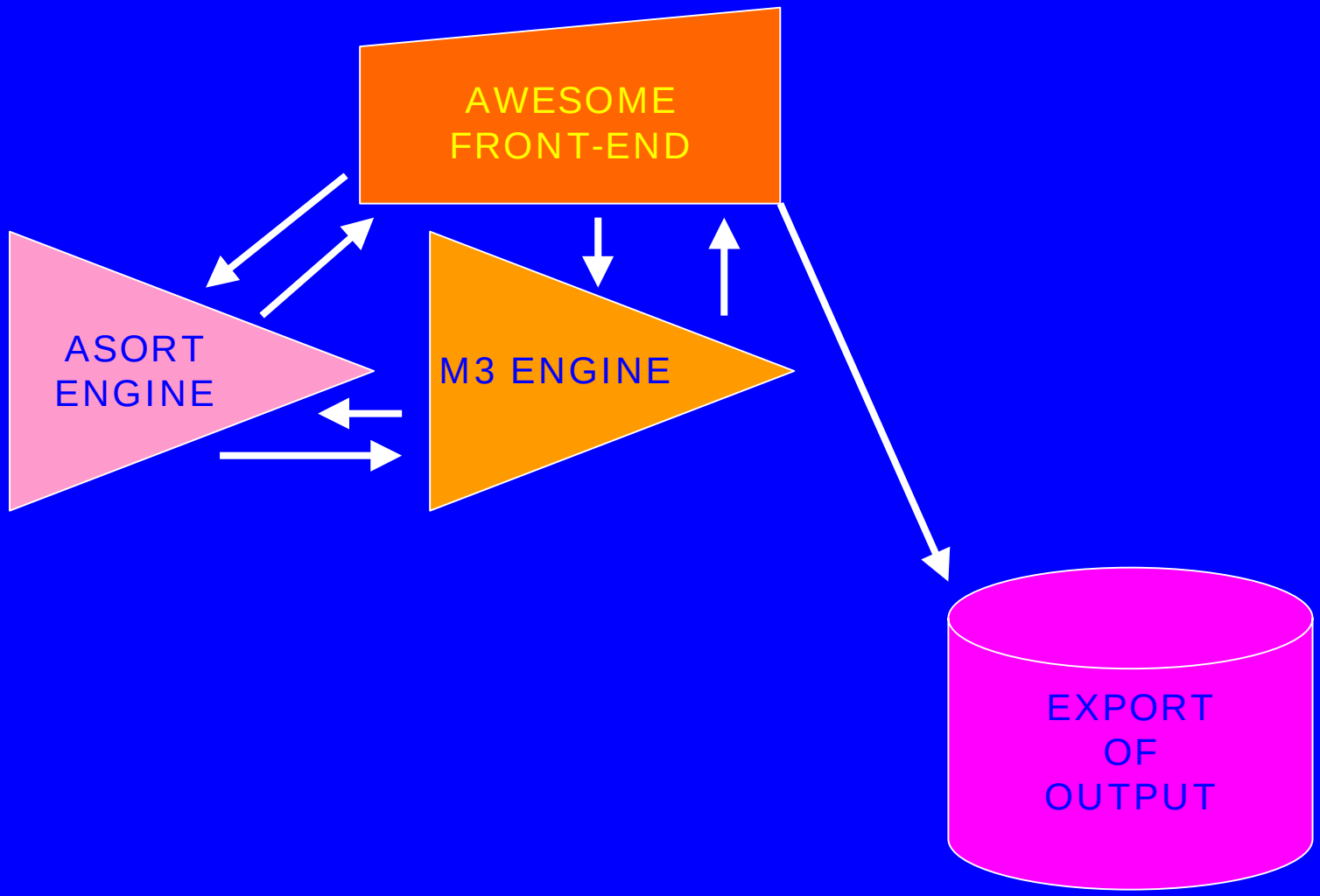
- FORECASTING YIELD
  - NEW SITES
  - EXISTING SITES
- SUITABLE FOR:
  - PRODUCTION FORECASTING
  - GUIDING MANAGEMENT

Resembles MELA



Age years	Top ht m	No. of trees	Mean DBH cm	Basal Area m²	Mean Vol m³	Vol m³	Dead Vol %	MAI
24	9.4	2369	13	32	0.05	119	0	5.0
29	12.0	2304	15	41	0.09	200	0	6.9
34	14.5	2232	17	48	0.13	286	1	8.4
39	16.8	2156	18	54	0.17	373	2	9.6
44	18.8	2078	19	58	0.22	453	3	10.3
49	20.6	1999	20	61	0.26	524	5	10.7
54	22.2	1899	21	63	0.31	586	7	10.8
59	23.5	1816	21	65	0.35	638	8	10.8
64	24.6	1741	22	67	0.39	682	9	10.7

STRUCTURE OF M3

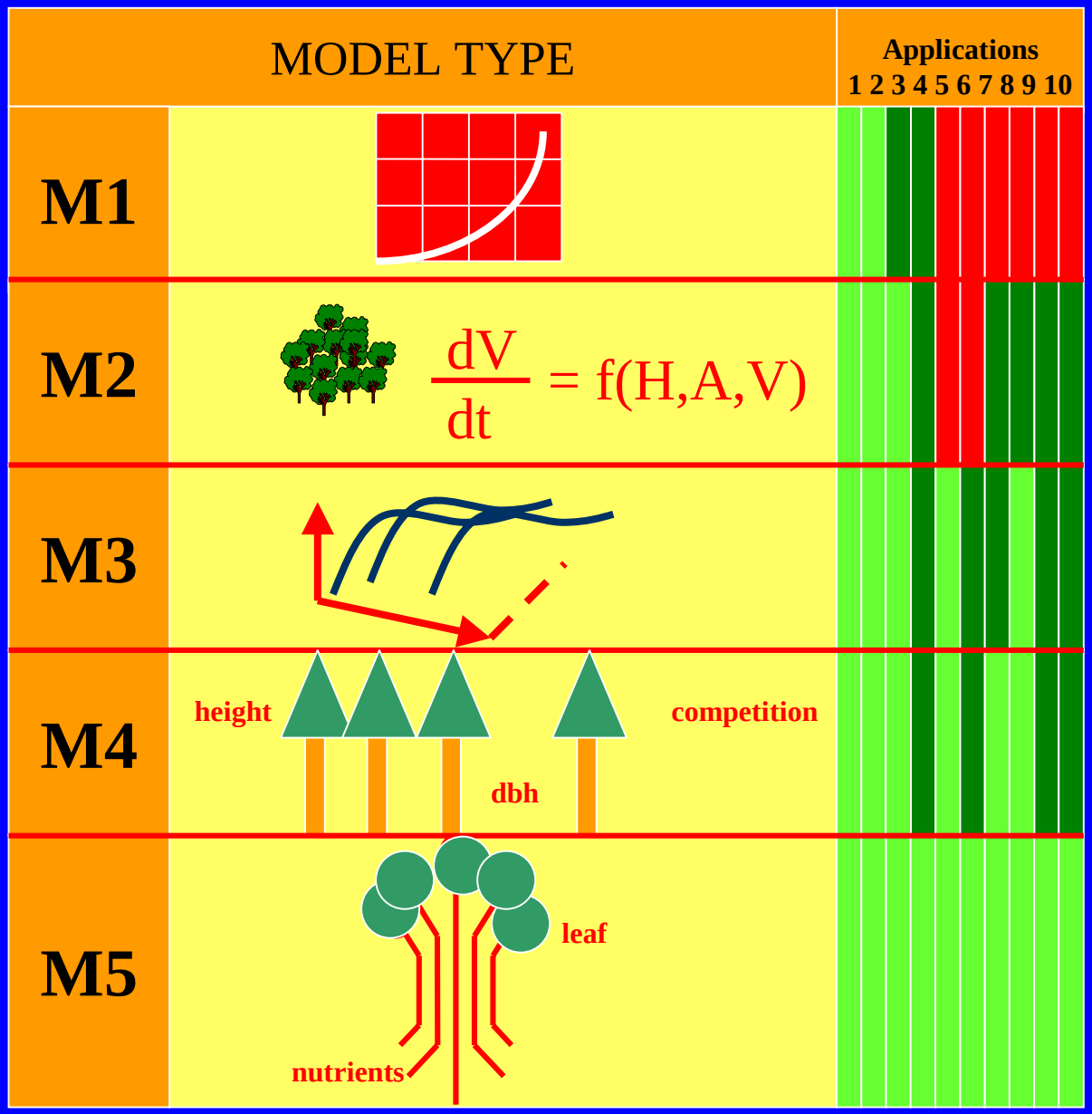


EMPIRICAL → PROCESS

M1 → M5

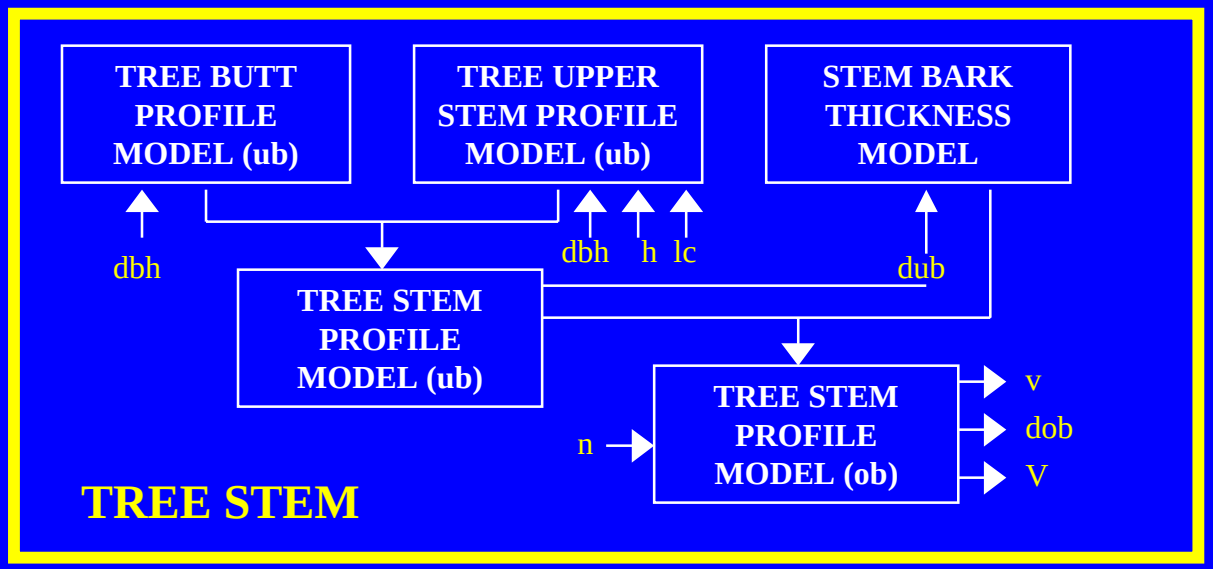
SYSTEM → INDIVIDUAL

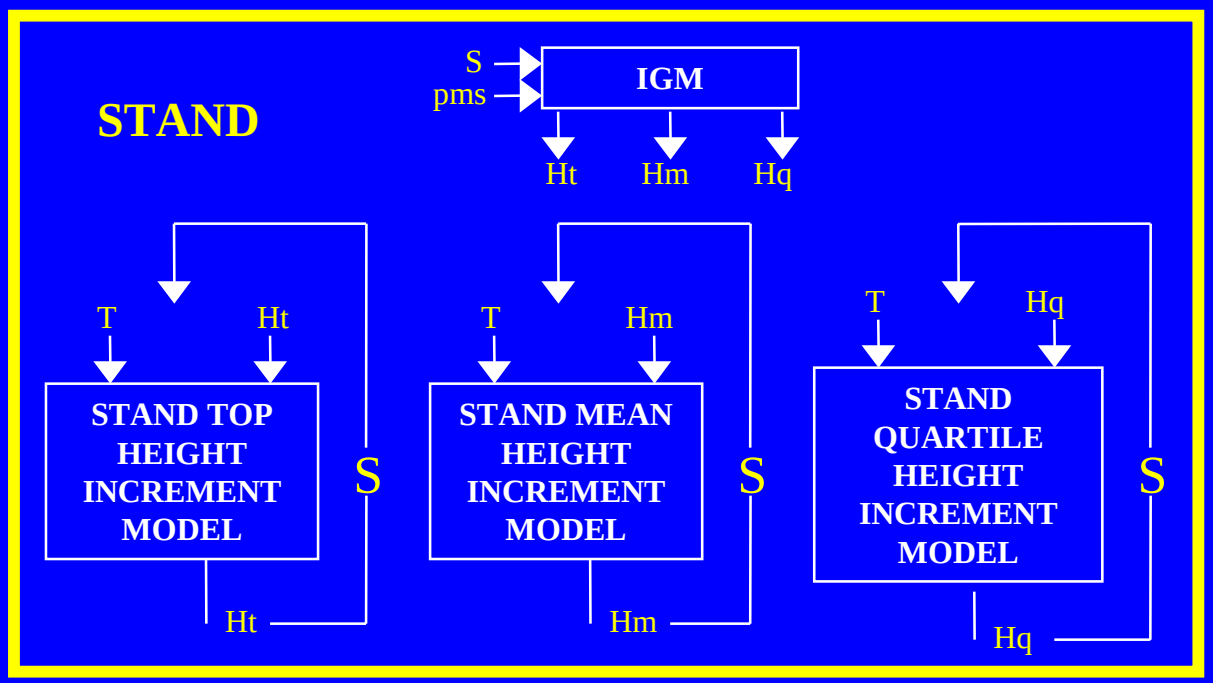
MATRIX PROJECTION → MATRIX INTEGRATION

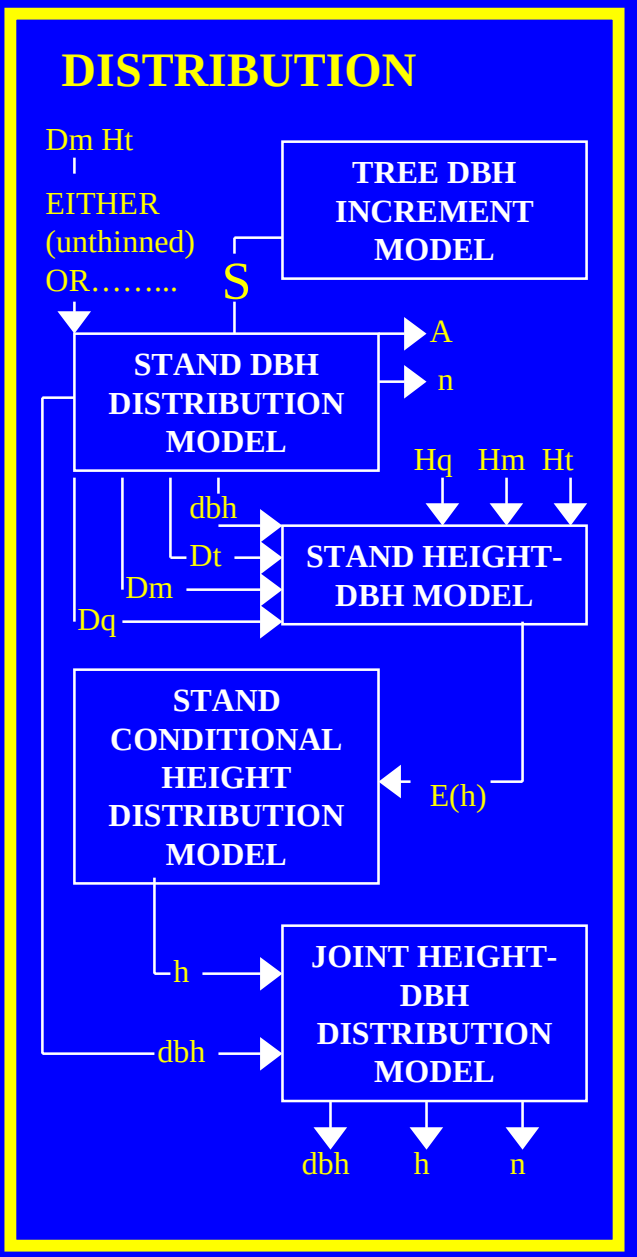


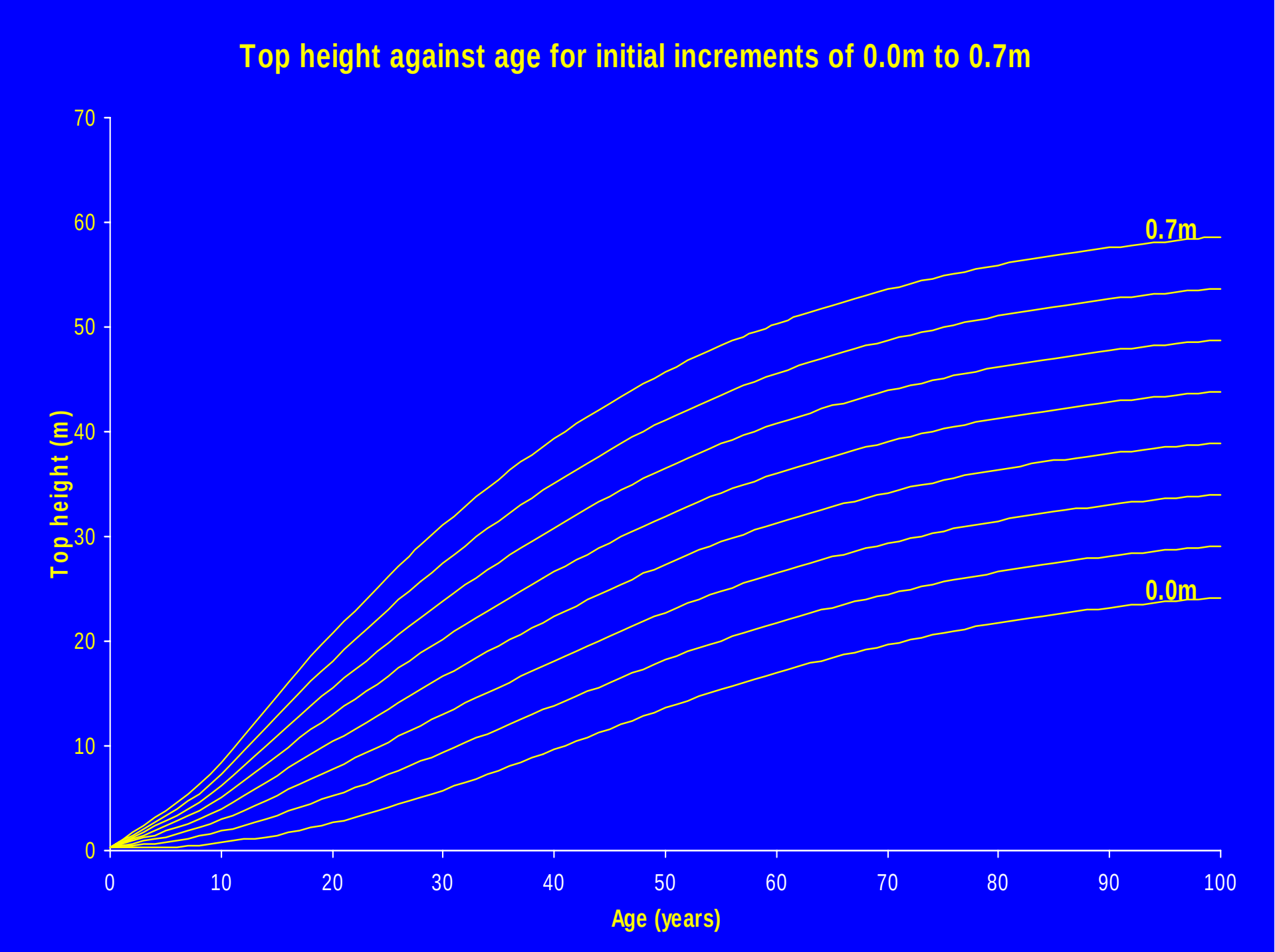
1. Even-age, pure species stands
2. Production forecasting
3. Non standard spacing and thinning
4. Even-age mixed species stands
5. Mixed-age, pure species stands
6. Mixed-age, mixed species stands
7. Impacts of environment and management on wood quality
8. Impacts of management on bio-diversity
9. Interactions between growth and site/environment
10. Economic impact of environmental perturbations

YIELD MODEL STRUCTURE

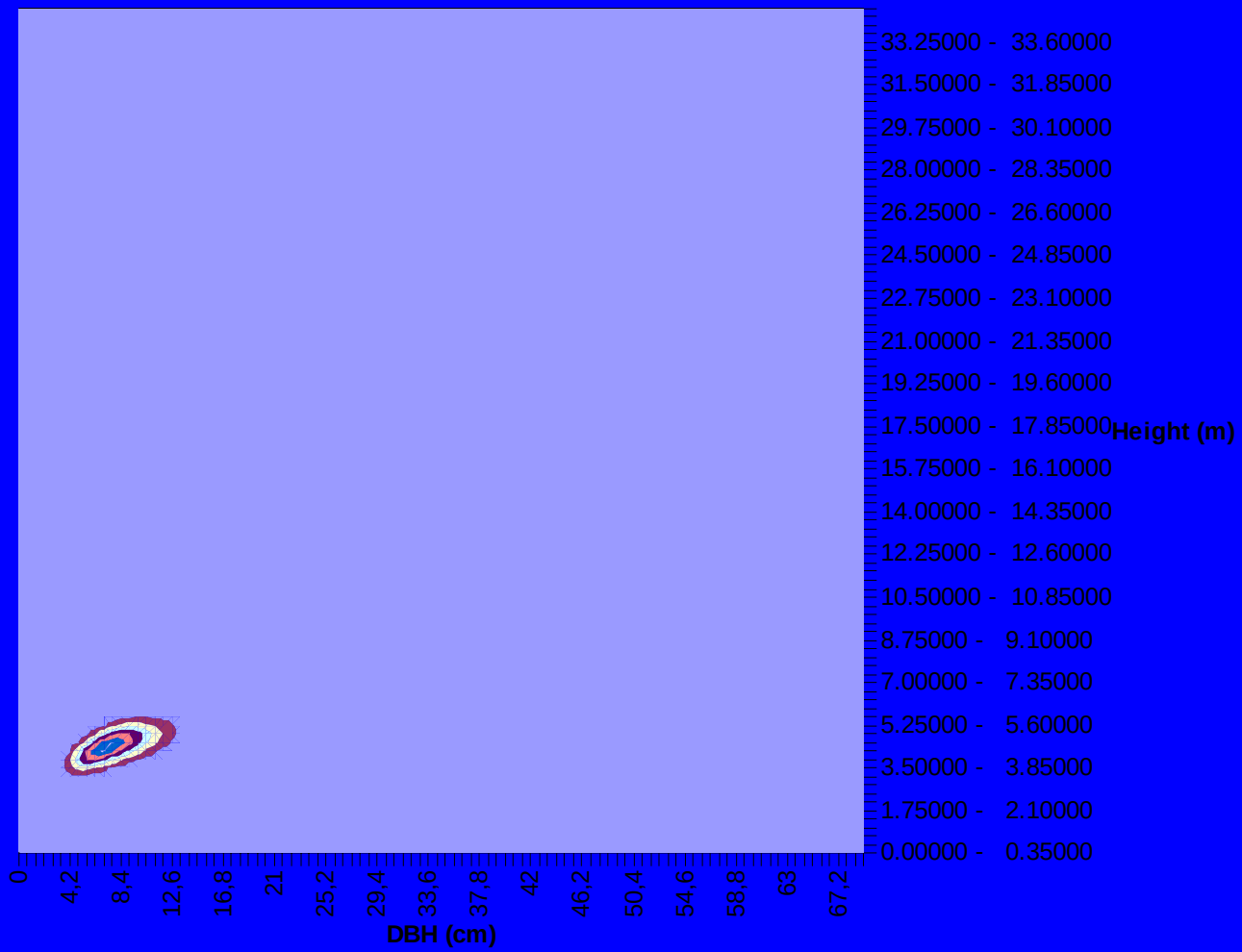




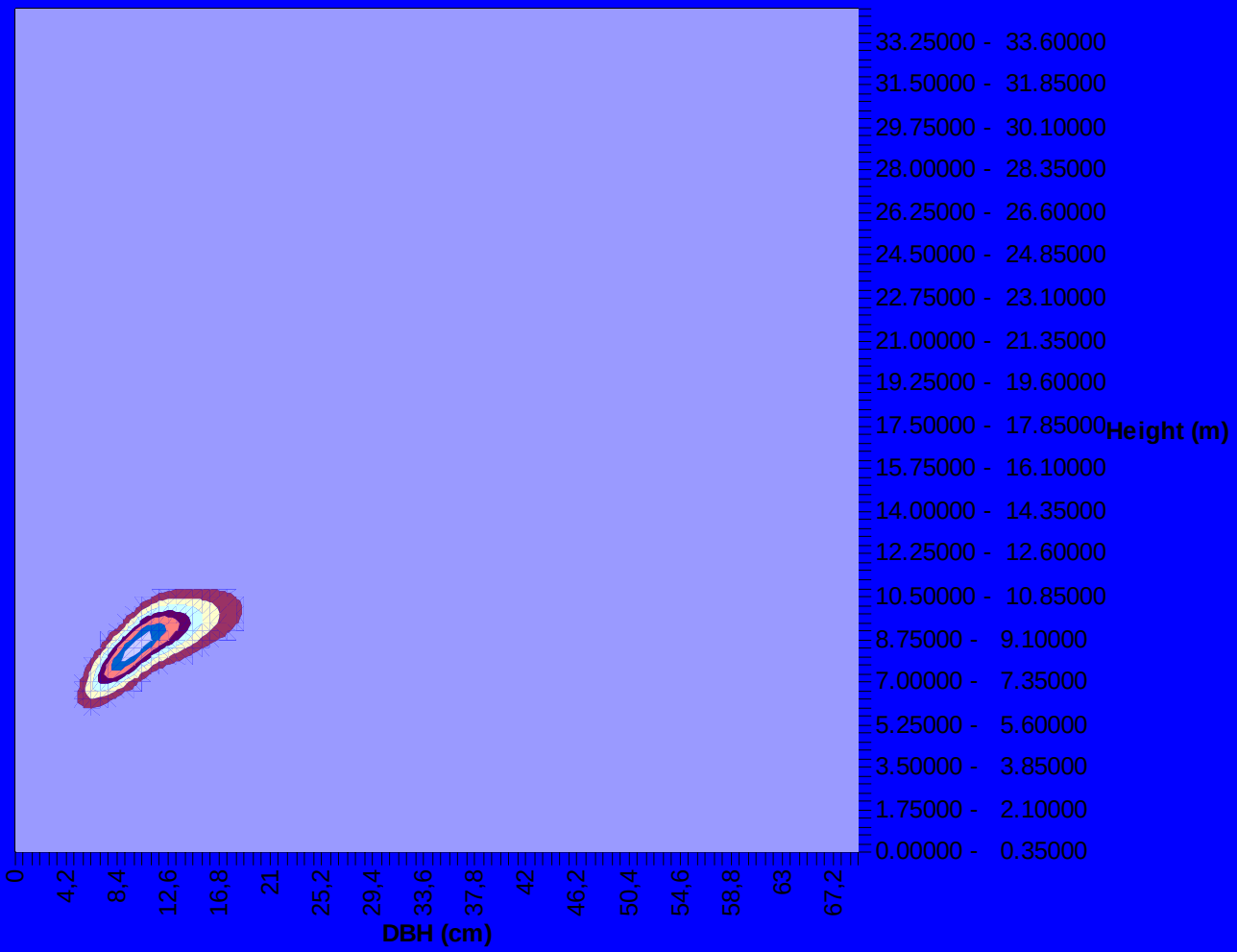



Top height against age for initial increments of 0.0m to 0.7m
Top height (m)
Age (years)
0.7m
0.0m
0
10
20
30
40
50
60
70
80
90
100

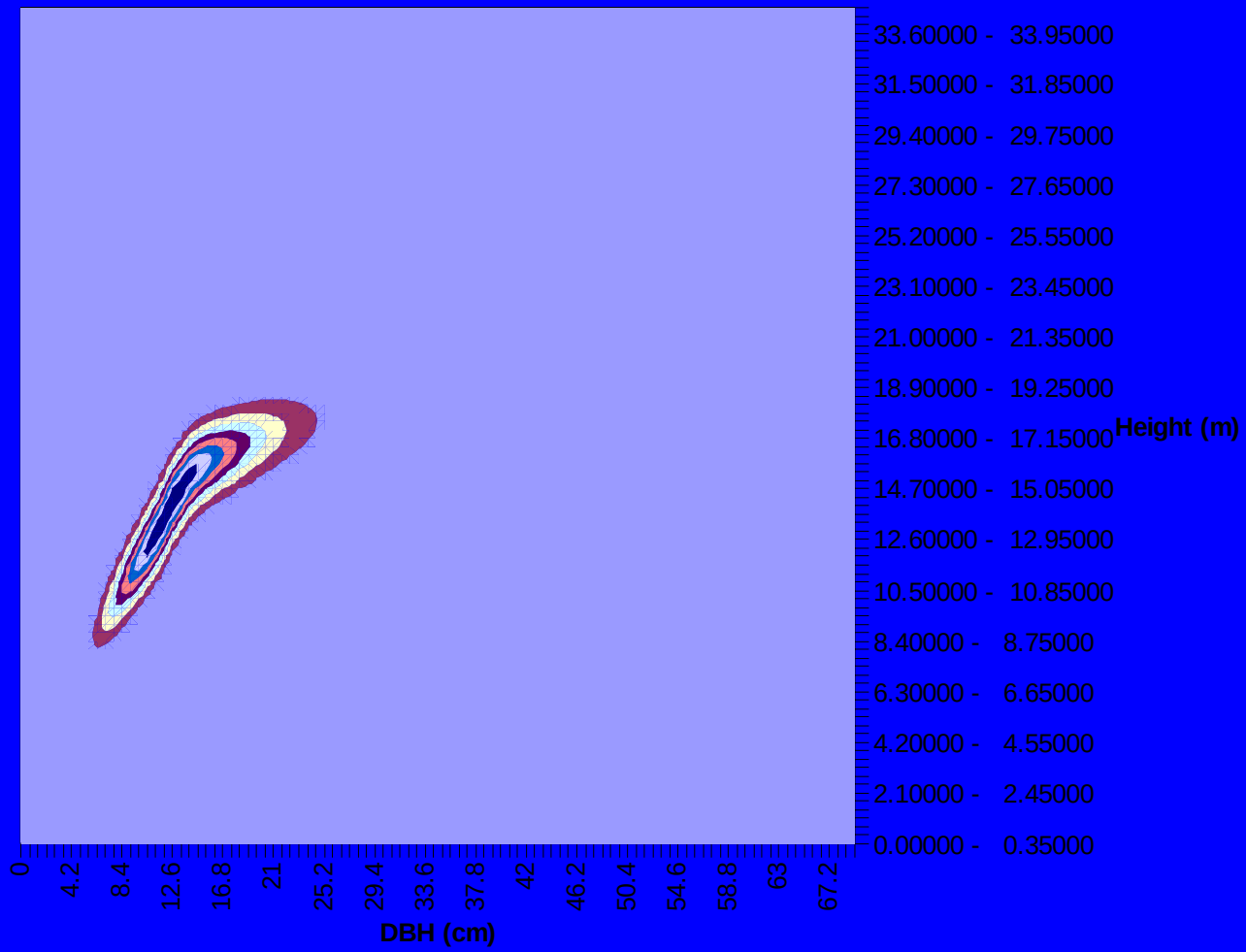
1.5m Spacing, 0.2m Site Index, Height / Diameter Probability Contour Graph after 15 Years



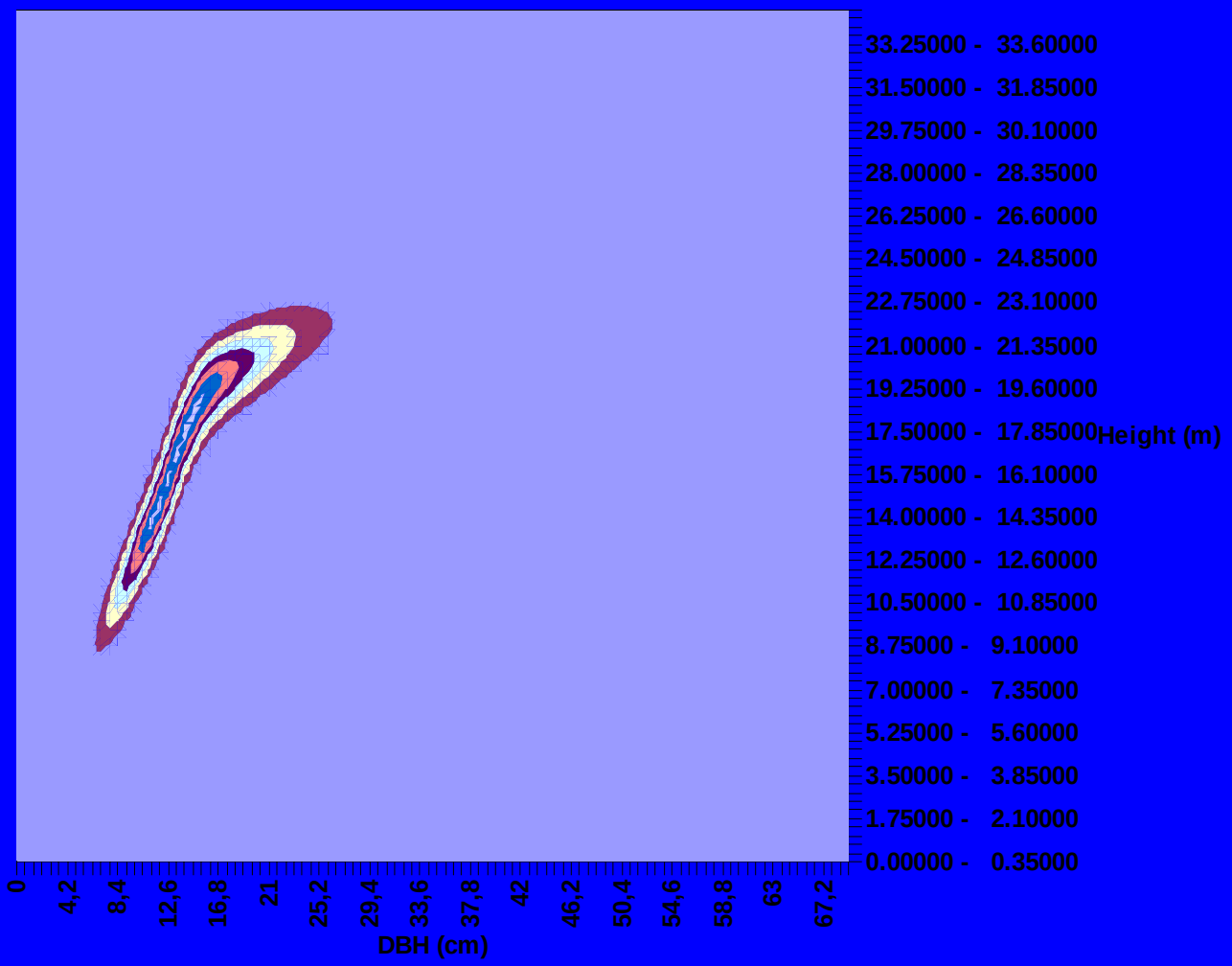
1.5m Spacing, 0.2m Site Index, Height / Diameter Probability Contour Graph after 25 Years

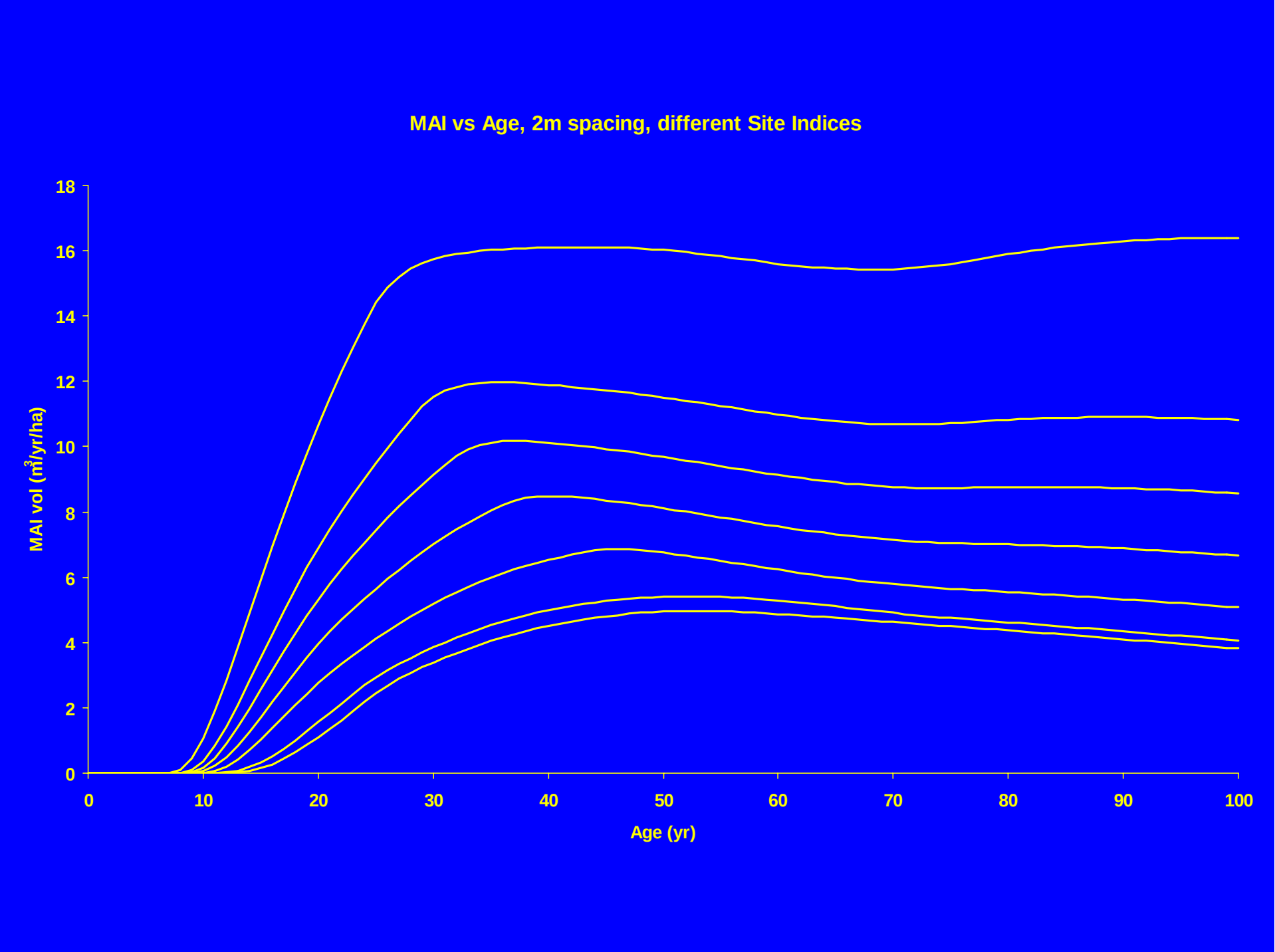


1.5m Spacing, 0.2m Site Index, Height / Diameter Probability Contour Graph after 40 Years



1.5m Spacing, 0.2m Site Index, Height / Diameter Probability Contour Graph after 50 Years




MAI vs Age, 2m spacing, different Site Indices
MAI vol (m3/yr/ha)
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
Age (yr)

NATIONAL SCENARIO MODELS

CFLOW-98

- Age class/area structure accounted for
- Simplistic but defendable soil sub-model

Assumes

- All UK forests either unthinned Sitka spruce or silviculturally thinned beech
- All Sitka spruce or beech forests are of ‘average’ productivity
- All spruce or beech forests are clear felled at the same age
- Constant allometric ratios
- Wood product mix does not change with stand age

NATIONAL SCENARIO MODELS

CARBINE

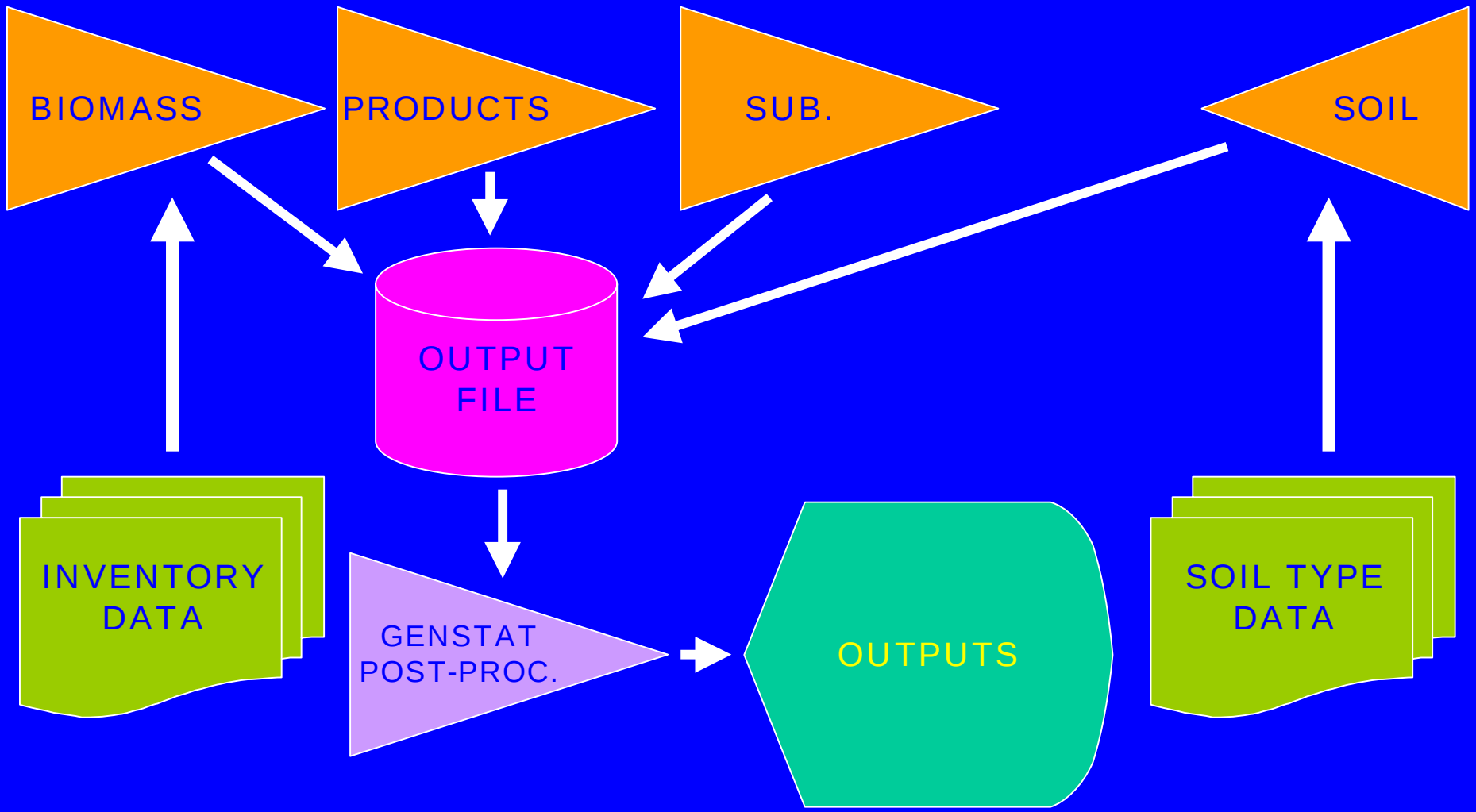
Accounts for

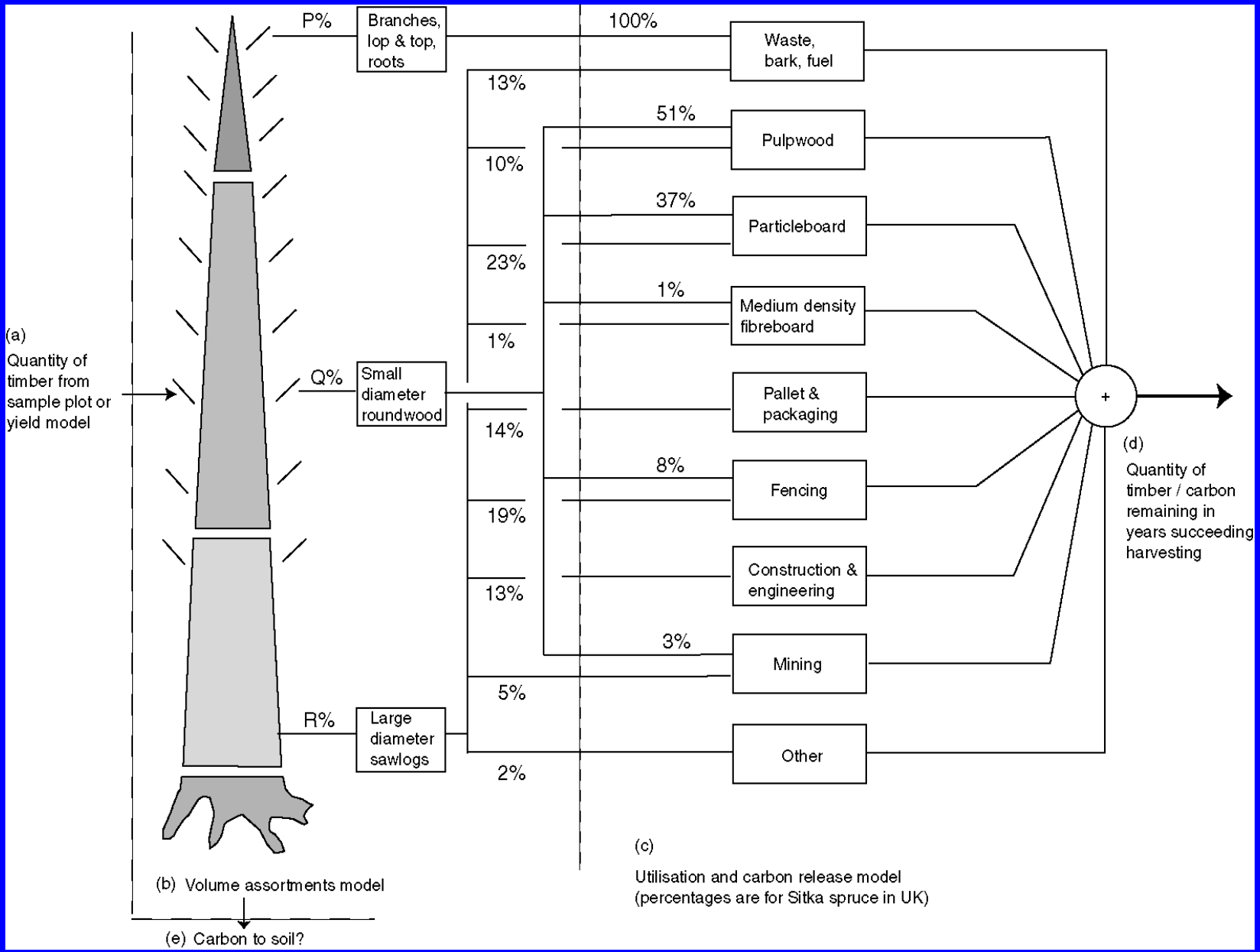
- Age class/area structure
- Species mix (UK forest inventory)
- Variations in rotation
- Changes in product mix
- Energy sector impacts

Assumes

- All stands are of ‘average’ productivity for species
- Unvalidated allometric functions
- Over-simplistic soil sub-model

STRUCTURE OF CARBINE




(a)
Quantity of timber from sample plot or yield model
P%
Branches, lop & top, roots
Q%
Small diameter roundwood
R%
Large diameter sawlogs
(b) Volume assortments model
(e) Carbon to soil?
100%
13%
10%
23%
1%
14%
19%
13%
5%
2%
51%
37%
1%
8%
3%
Waste, bark, fuel
Pulpwood
Particleboard
Medium density fibreboard
Pallet & packaging
Fencing
Construction & engineering
Mining
Other
(c)
Utilisation and carbon release model
(percentages are for Sitka spruce in UK)
+
(d)
Quantity of timber / carbon remaining in years succeeding harvesting

CARBON IN WOOD PRODUCTS

Table 2b.1 Summary of reported estimates of wood products carbon stocks for significant localities, countries and regions. (Estimates apply to various years in the range 1990 to 1997)

Locality, country or region	Source	Method of calculation	Pools included[1]			Estimate of Stocks (PgC)		
						From original source	Based on UK and Finnish inventories	
			Primary	Secondary	Landfill		+FAO timber consumption statistics	+ population statistics
UK	Alexander (1998)	Inventory[2]				0.08	-	-
UK	Alexander (1998)					0.29	-	-
Finland	Pingoud *et al.* (2000)					0.017	0.018	0.007
Finland	Pingoud *et al.* (1996)					0.031	*0.065*	*0.025*
Netherlands	Nabuurs and Mohren (1993)	Accounting Model				0.015	0.026	0.021
Germany	Burschel *et al.* (1993)					0.128	-	-
Canada	Kurz *et al.* (1993)					0.282	-	-
Oregon and Washington, USA	Harmon *et al.* (1996)					0.396	-	-
USA	Matthews *et al.* (1996)					2	-	-
USA	Skog and Nicholson (1998)					2.7	*3.01*	*1.25*
Russia	Krankina *et al.* (1996)					2.9	-	-
New Zealand	Maclaren and Wakelin (1991)					0.022	0.011	0.005
World	Matthews *et al.* (1996)					3	3	*7*
World	Matthews *et al.* (1996)					15	*11*	*25*
World	Buchanan and Levine (2000)					8	*3*	*7*

[1] Wood products carbon pools considered by study
[2] Landfill estimates produced by accounting models.

ENERGY/CARBON BUDGETING MODELS

ERGO (Forest Research)

Matthews, Vials, Campbell

RECAP (ETSU)

Turnbull, O'Brien

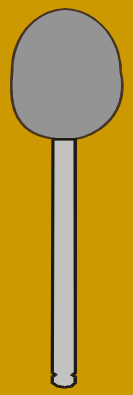
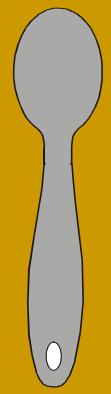
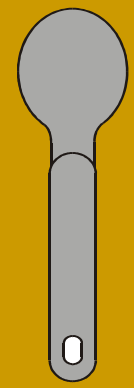
Provide basic estimates for models like CARBINE and GORCAM

Similar to GEMIS?

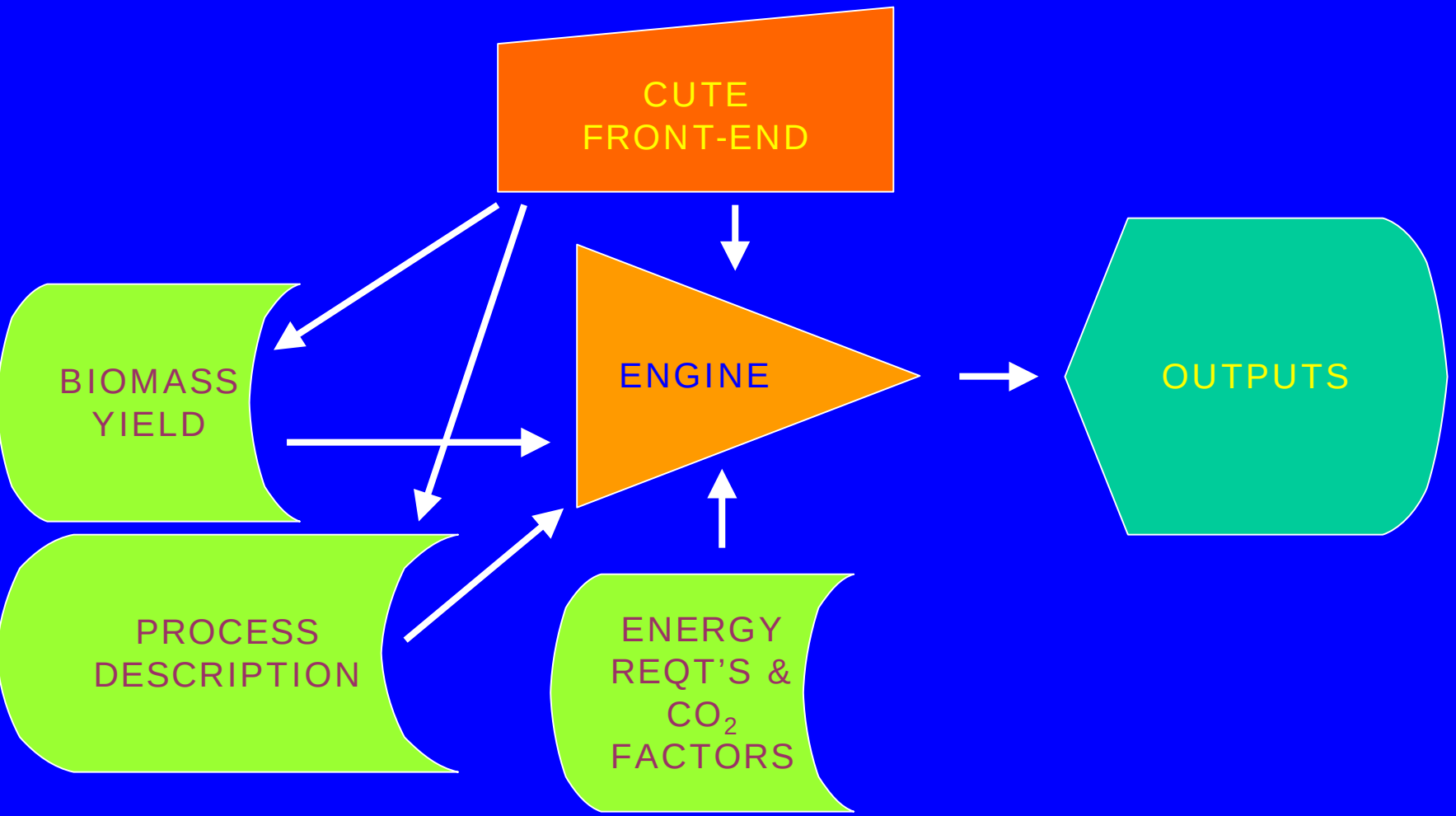
ENERGY/CARBON BUDGETING

Table 2b.4 Summary of reported estimates of carbon dioxide emissions factors for wood fuel production systems

Source	Country	Production system	Emissions factor (gCO_2 MJ^{-1})	
			Energy inputs due to transport to point of use:	
			not included	included
Turhollow and Perlack (1991)	USA	Short rotation forestry	-	4.8
Born (1992)	Germany	'Wood'	-	3
Boman and Turnbull (1997)	USA	Short rotation forestry	-	3.9
Boman and Turnbull (1997)	USA	Harvesting residues		3.3
Dubuisson and Sintzoff (1998)	Belgium	Short rotation forestry	4.8 to 8.4	6.2 to 9.9
Hektor (1998)	Sweden	Short rotation forestry	-	50
Hektor (1998)	Sweden	Whole tree thinning	-	40
Hektor (1998)	Sweden	Harvesting residues	-	68
Korpilahti (1998)	Finland	Harvesting residues	0.92	1.1 to 1.6
Schwaiger and Schlamadinger (1998)	European Union	'Wood logs'	-	0.51 to 1.3
Schwaiger and Schlamadinger (1968)	European Union	'Wood chips'	-	1.1 to 2.4
Matthews (2000)	United Kingdom	Short rotation forestry	4.7	-
Matthews and Mortimer (2000)	United Kingdom	Short rotation forestry	-	3.6
Matthews and Mortimer (2000)	United Kingdom	Harvesting residues	-	3.1
Matthews and Mortimer (2000)	United Kingdom	Whole tree thinning/Harvesting residues	-	2.9

		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

STRUCTURE OF ERGO



WHAT HAS BEEN DONE ?

CARBINE/CFLOW-98

- Policy options analysis
- National estimates and forecasts

CARBINE

- Support to wood products inventory

ERGO

- Process energy analysis (SRC biofuel, forest residues, other crops?)

WHAT NEXT ? - INTEGRATION

CFLOW-98 – ROTH-C

CARBINE – CFLOW-98

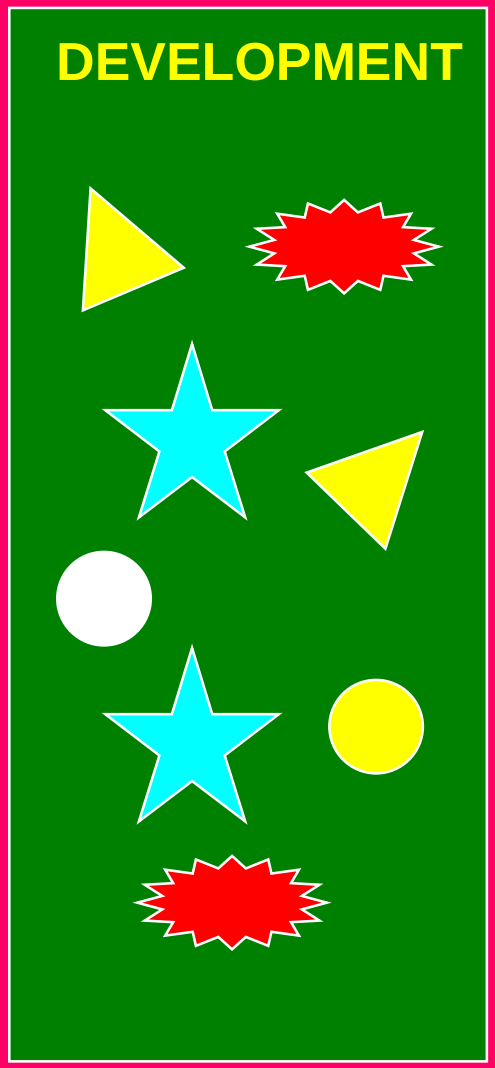
M3 – FORESTER

M3 – ASORT

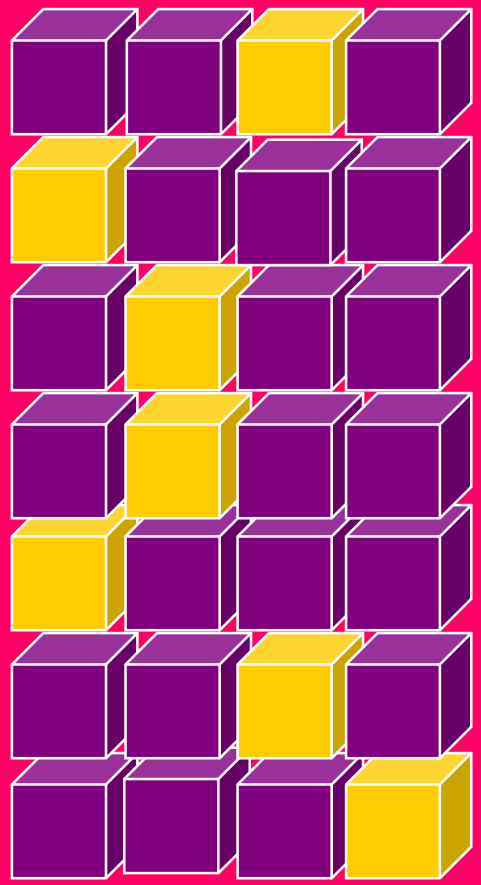
M5 -ERGO – (CARBINE/CO_2fix) – EFISCEN ?

M3 – GROMIT ... M5 (FC CORE MODEL)

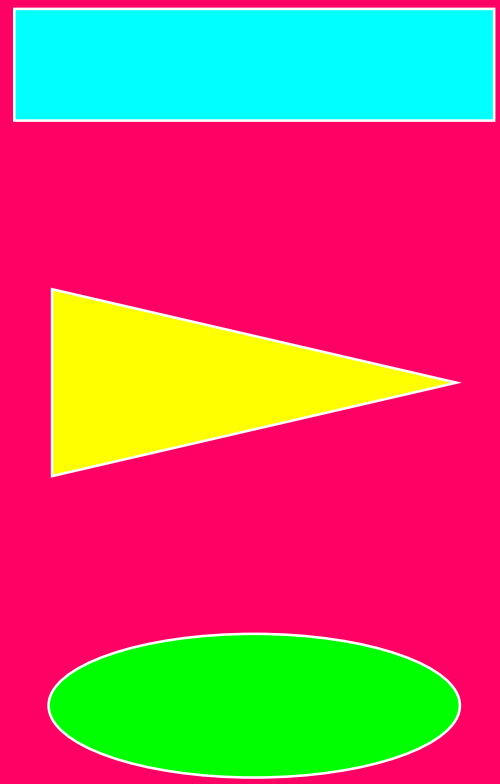
MODELLING SYSTEMS GROUP - CORE MODEL WORKSHOP



RESEARCH TOOL



USER APPLICATION



TRANSLATE FLEXIBLY

WHY DEVELOP M3 ?

UK growth models are:

- Static (inflexible)
- Internally inconsistent
- Do not represent UK forests
- Biased

M3 needed to solve these problems

STRUCTURE OF M3