

# CO2FIX – Stand-level carbon simulator

Markku Kanninen  
3.5.2023



# CO2FIX - Stand-level carbon simulator

ECOLOGICAL  
MODELLING

Ecological Modelling 164 (2003) 177–199

[www.elsevier.com/locate/ecolmodel](http://www.elsevier.com/locate/ecolmodel)

## Modeling carbon sequestration in afforestation, agroforestry and forest management projects: the CO2FIX V.2 approach

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<sup>d</sup> ALTEIRA, P.O. Box 47, 6700 AA Wageningen, The Netherlands

<sup>e</sup> El Colegio de la Frontera Sur, Apdo. Postal 1042, C.P. 86100, Admin. de Correos 2, Col Atasta, Villahermosa, Tab, Mexico

<sup>f</sup> Forest Ecology and Forest Management Group, Department of Environmental Sciences, Wageningen University,  
P.O. Box 342, 6700 AH Wageningen, The Netherlands

<sup>g</sup> Finnish Forest Research Institute, P.O. Box 68, FIN 80101 Joensuu, Finland

## Coffee-agroforestry in Costa Rica



Canopy layer: *Cordia alliodora*

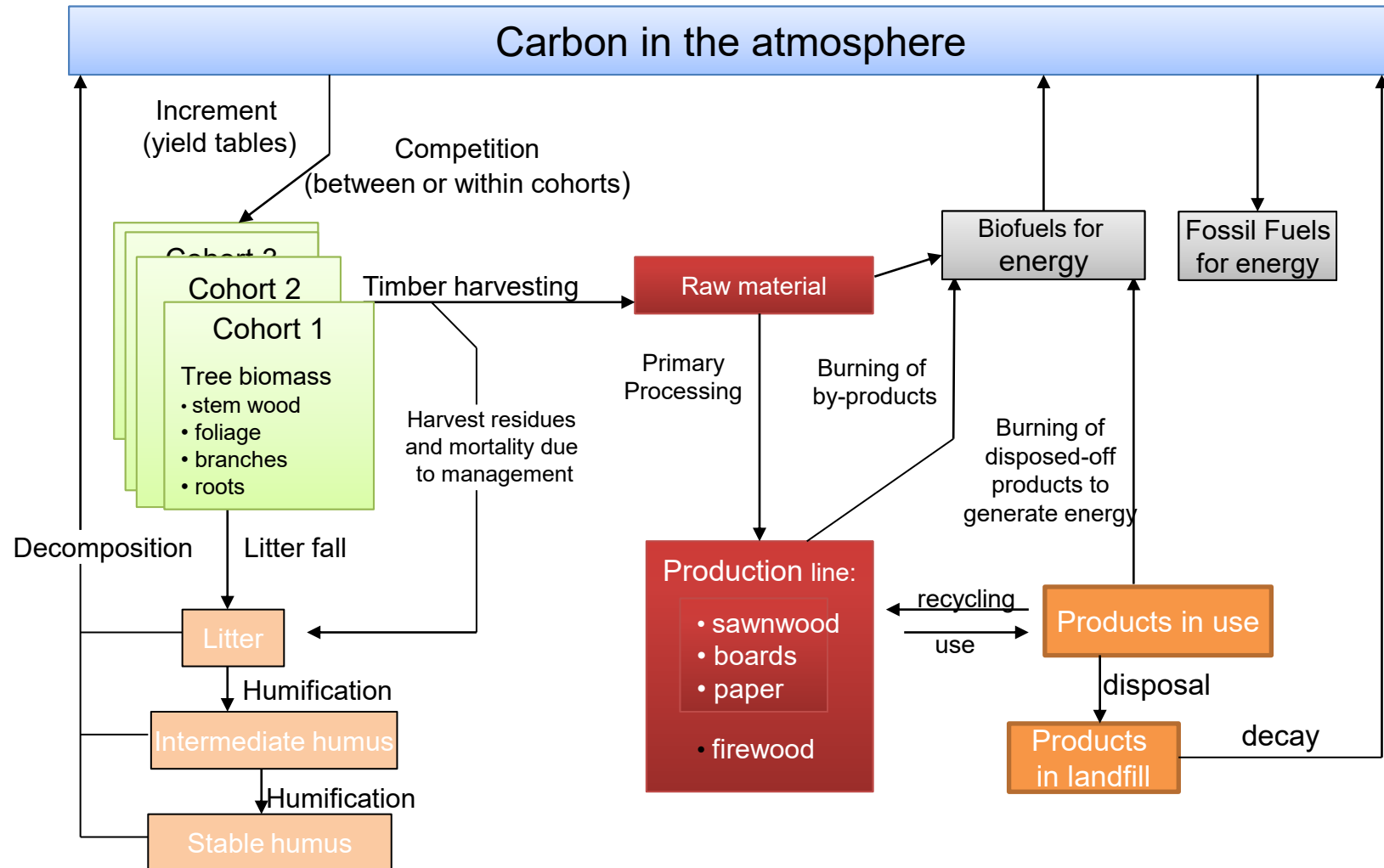
Service tree: *Erythrina poeppigiana*

Cash crop = *Coffea arabica*

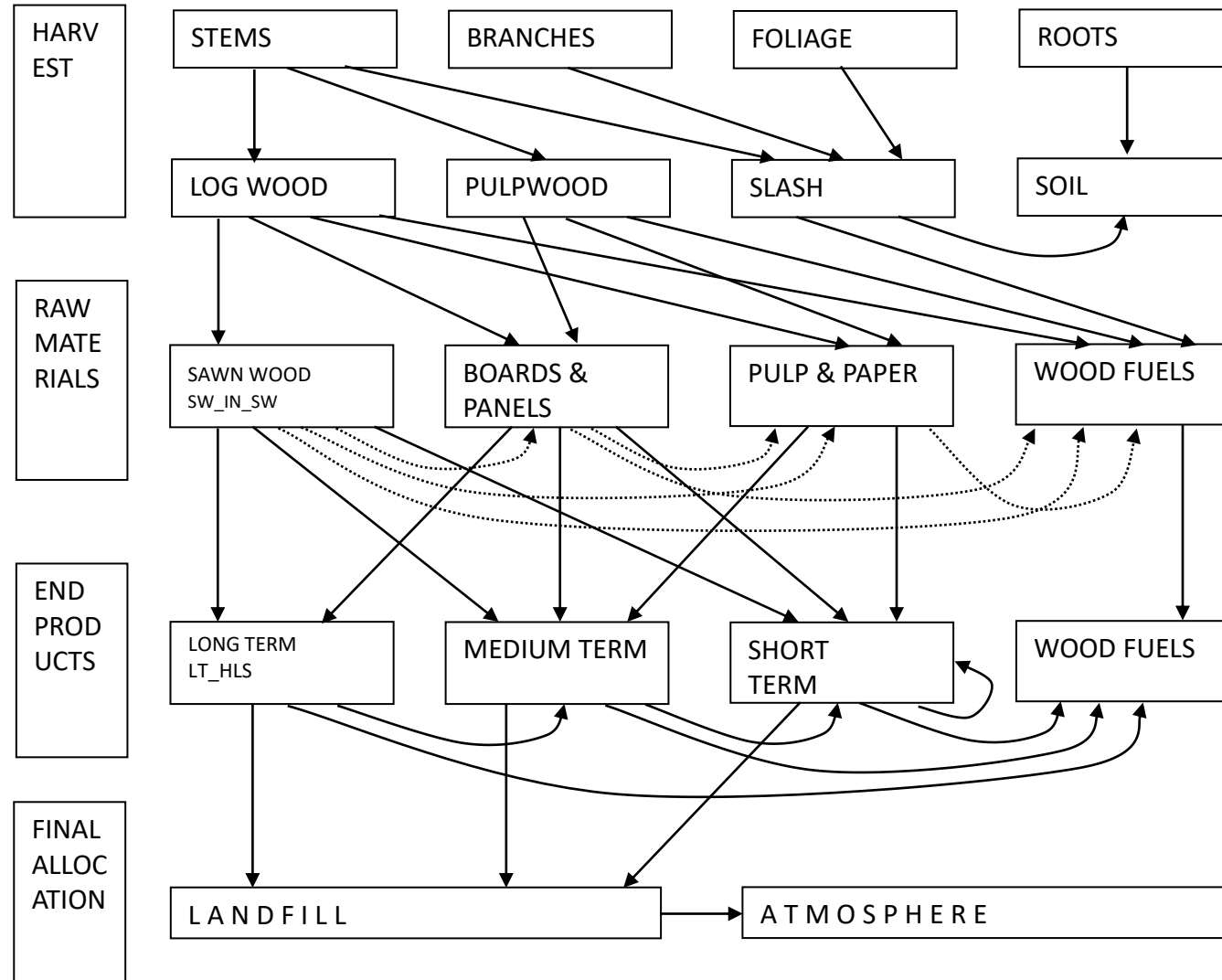
The most commonly used patch-scale  
C-simulator globally

<http://dataservices.efi.int/casfor/models.htm>

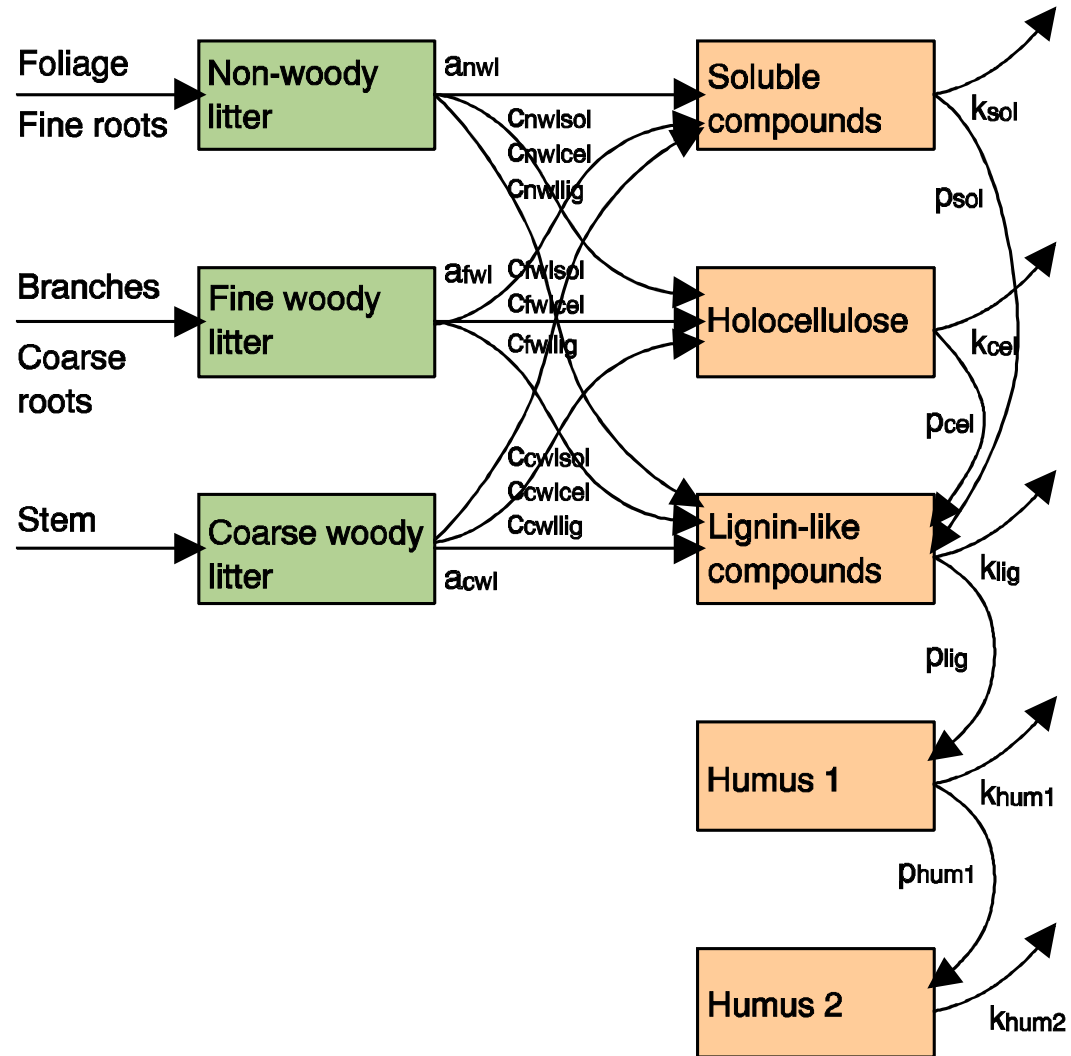
# CO2FIX: model structure



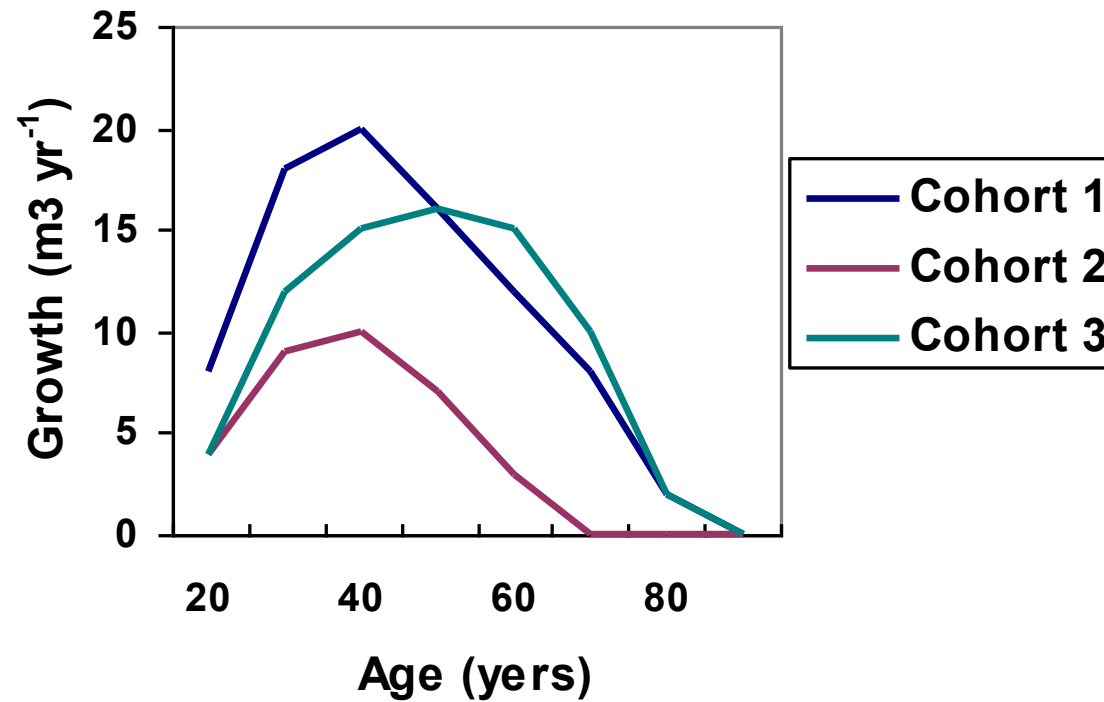
# CO2FIX: products module



# CO2FIX: soil module

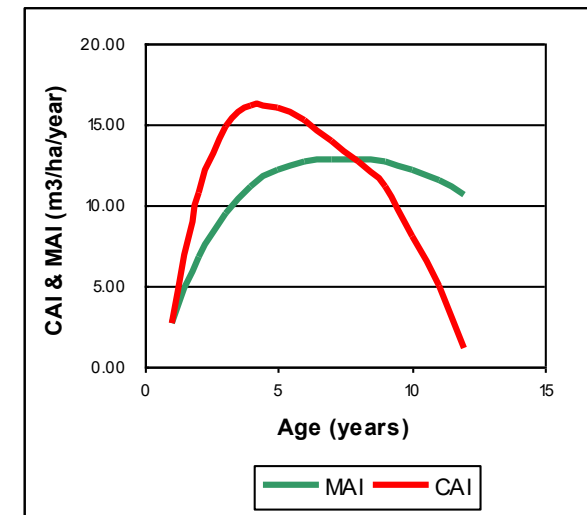
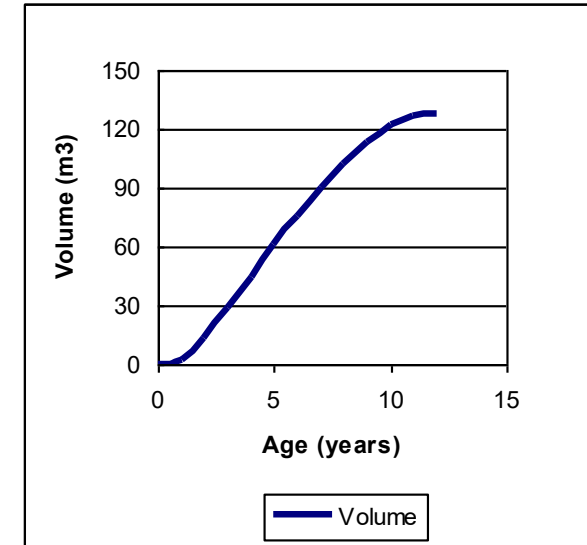


# Growth as a function of tree size



# Yield tables -> input data for growth

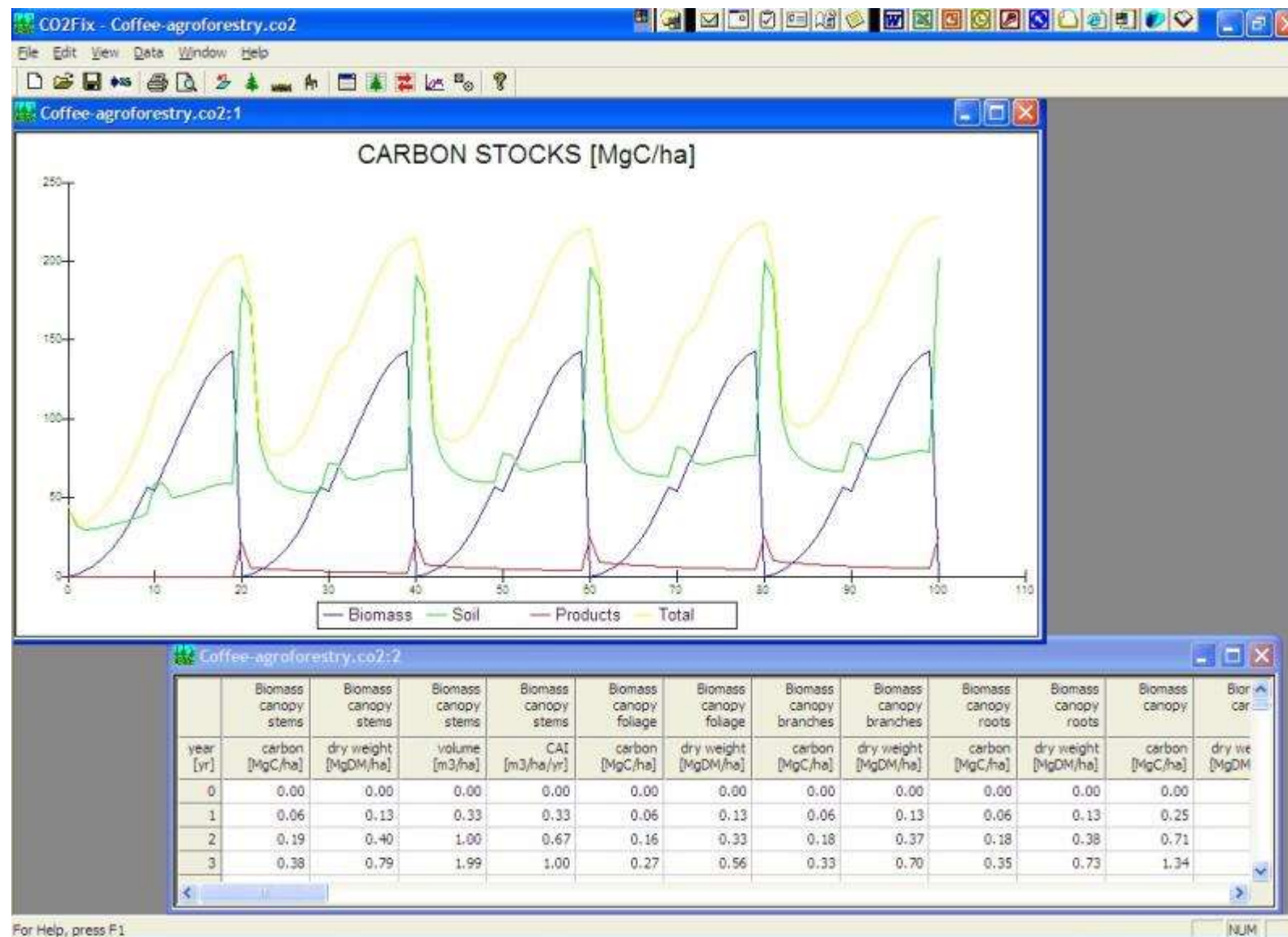
Age	Volume	MAI	CAI
0	0		
1	2.7	2.70	2.7
2	13.5	6.75	10.8
3	28.4	9.47	14.9
4	44.6	11.15	16.2
5	60.6	12.12	16
6	75.8	12.63	15.2
7	89.8	12.83	14
8	102.5	12.81	12.7
9	113.7	12.63	11.2
10	121.8	12.18	8.1
11	126.8	11.53	5
12	128	10.67	1.2



MAI = Mean annual increment  
CAI = Current annual increment

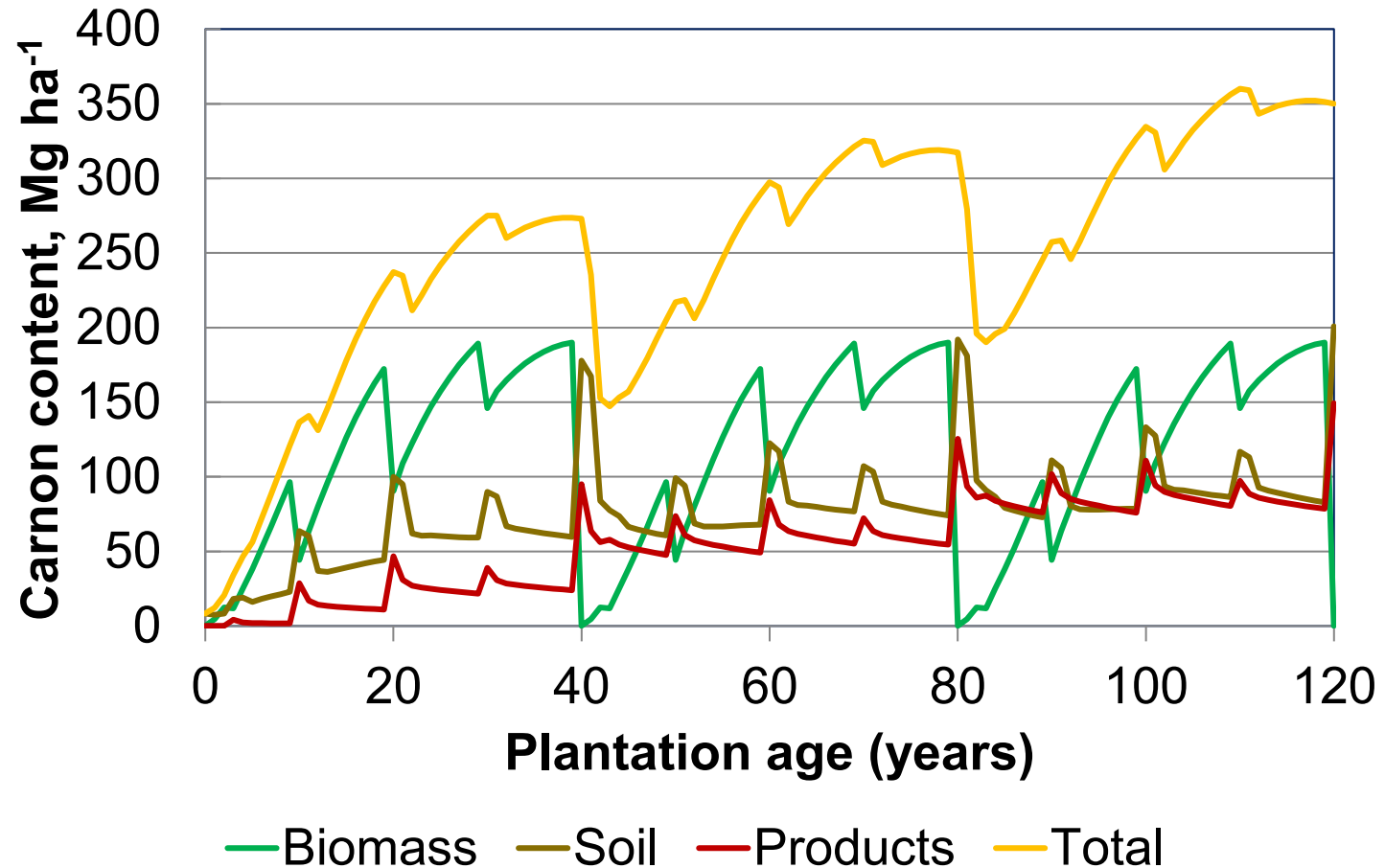


# Multi-strata coffee agroforestry





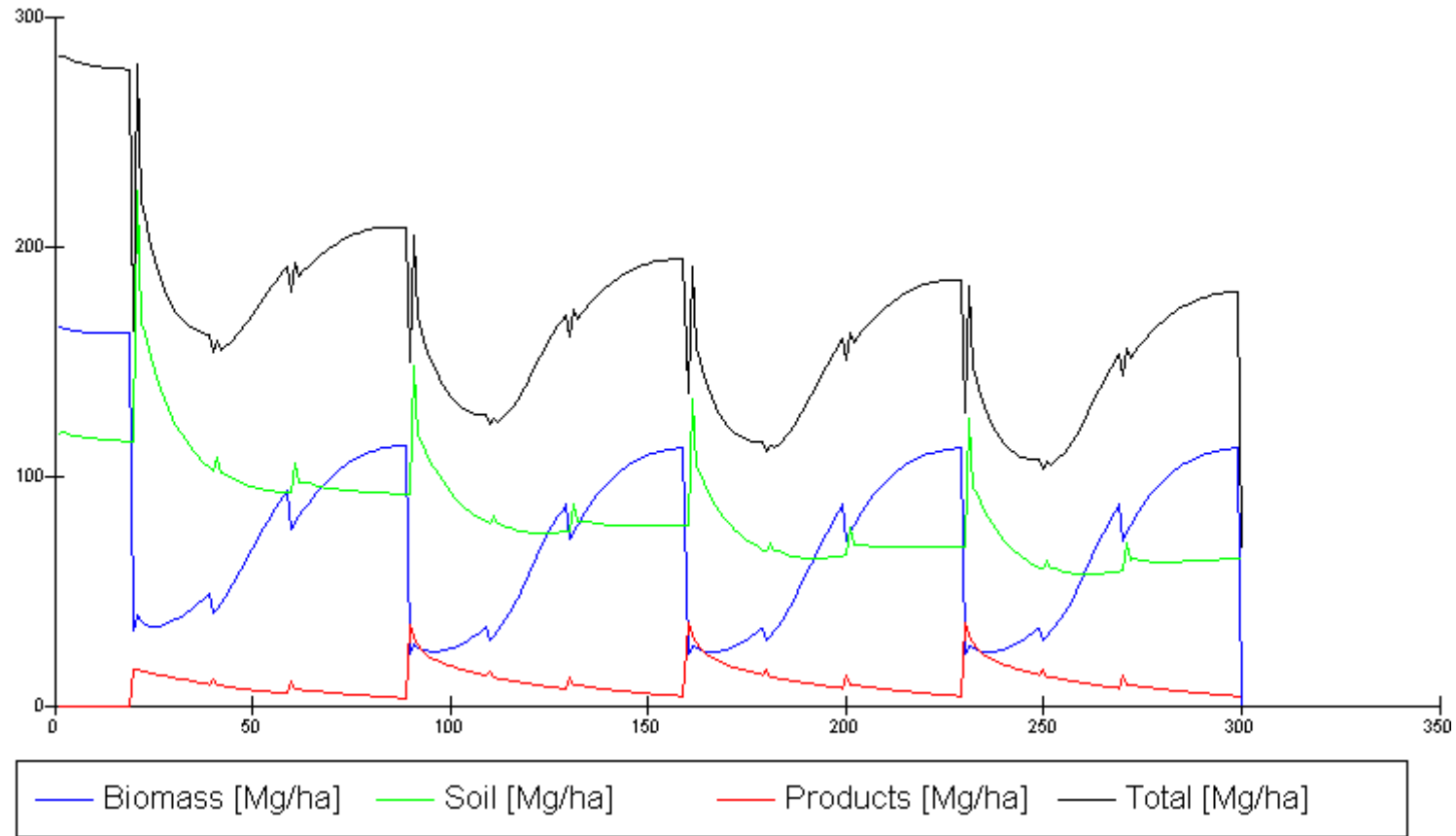
# Carbon dynamics in a teak plantation (data from Costa Rica)



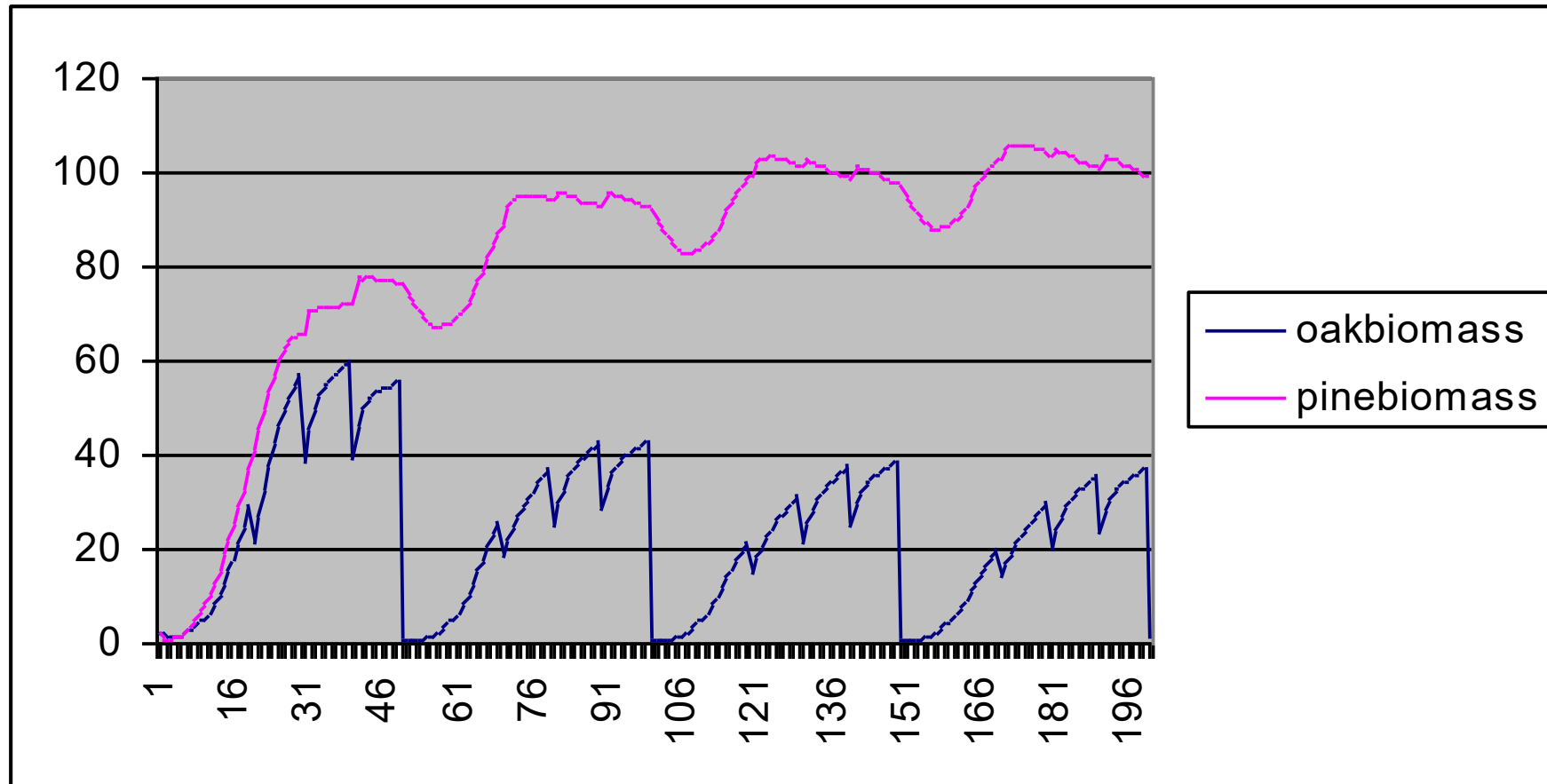
MAI<sub>Vol</sub> =  
12  $\text{m}^3\text{h}^{-1}\text{year}^{-1}$

Masera et al. 2003

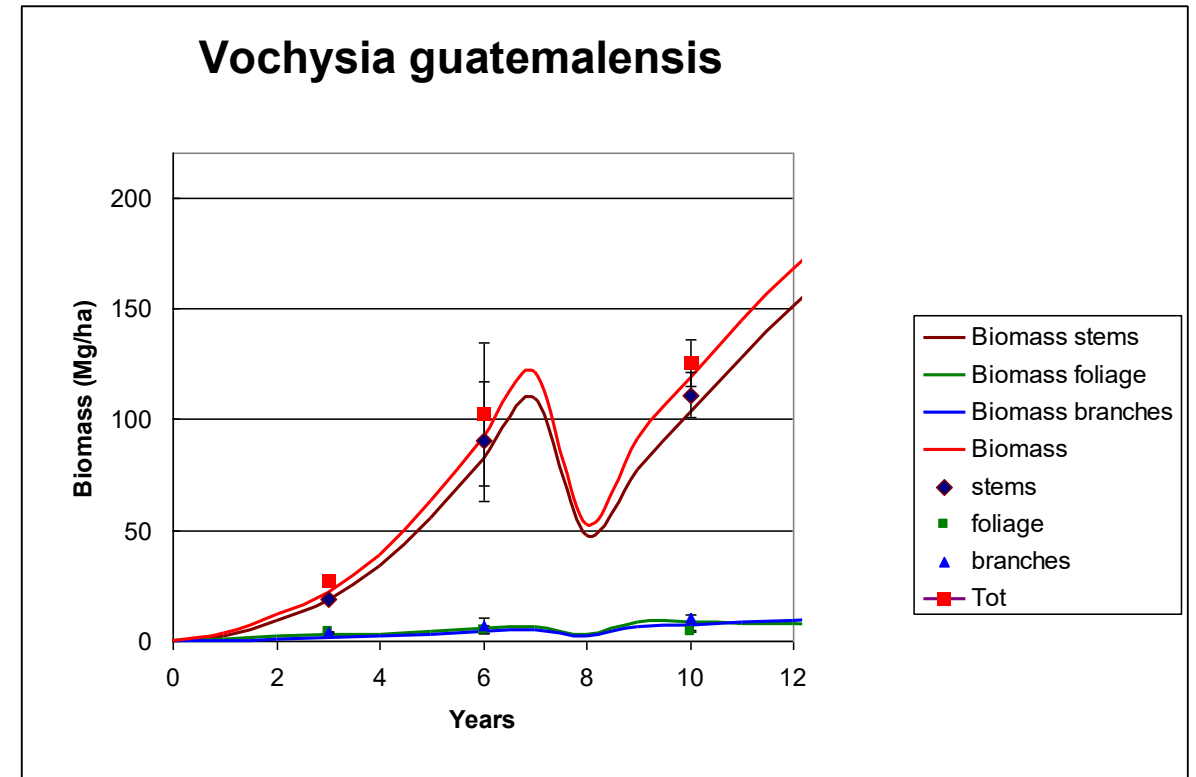
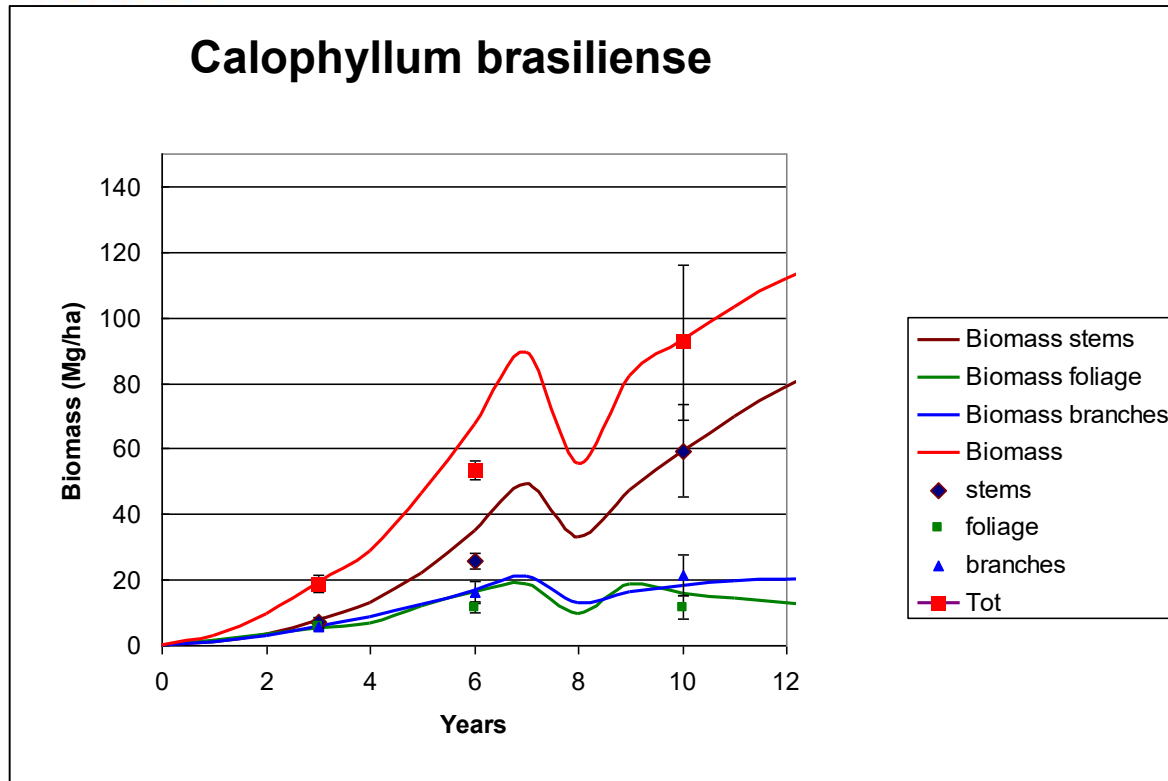
# Natural forest (data from Costa Rica)



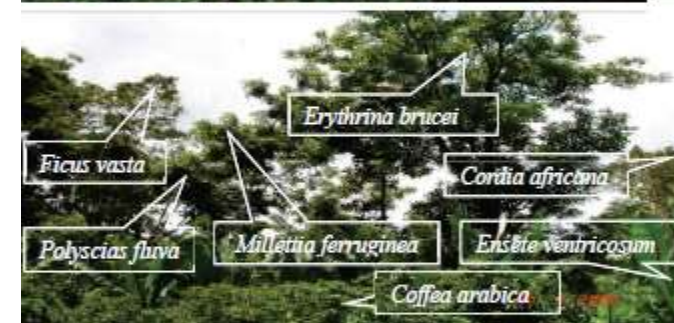
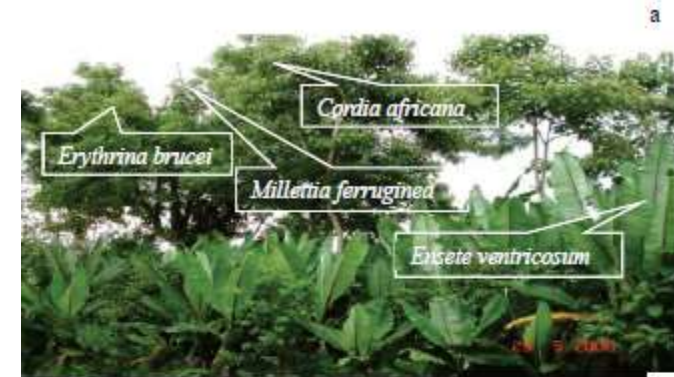
# Pine-oak forest in Mexico



# CO2Fix – validation with independent data

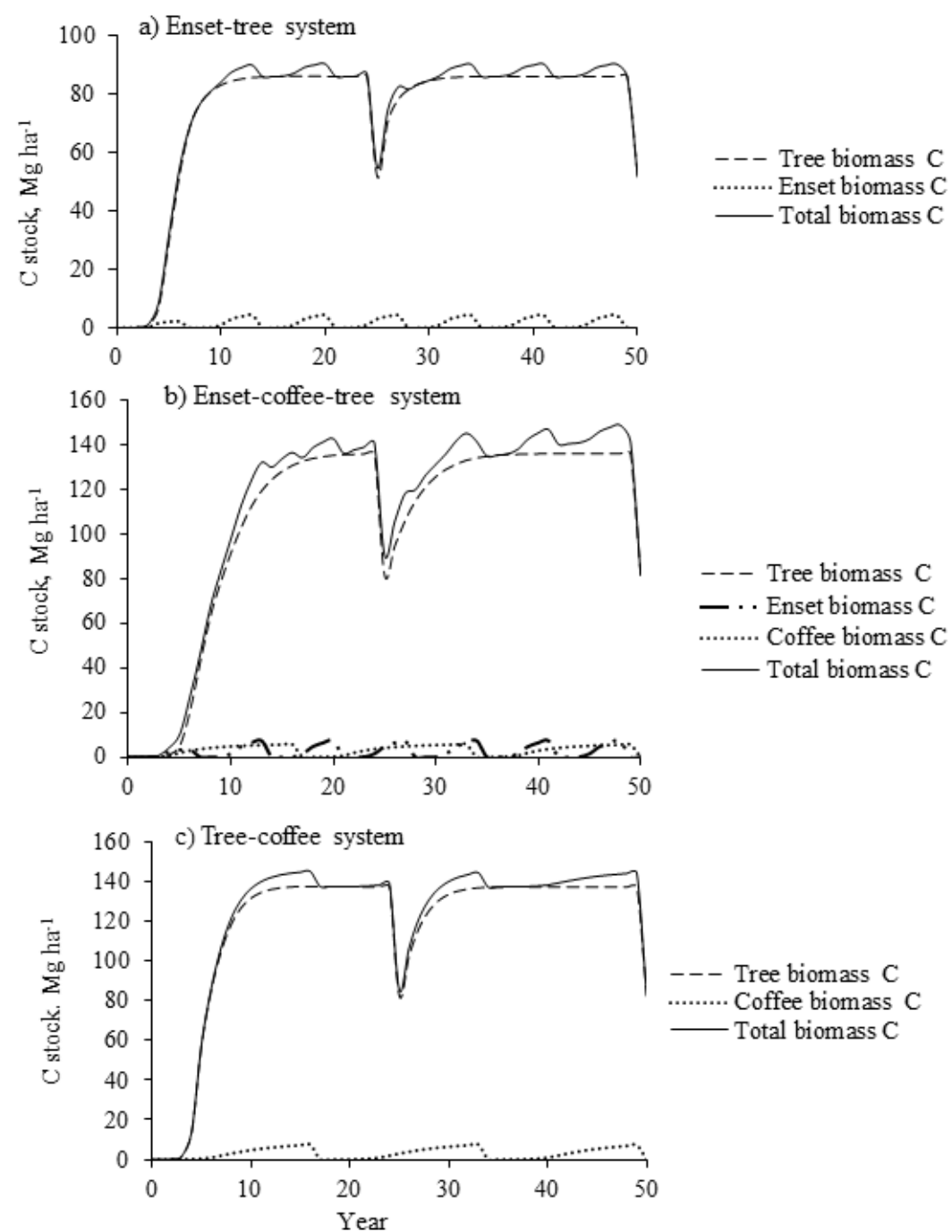


# CO2FIX modelling in Enset (*Ensete ventricosum*) agroforestry systems, Ethiopia



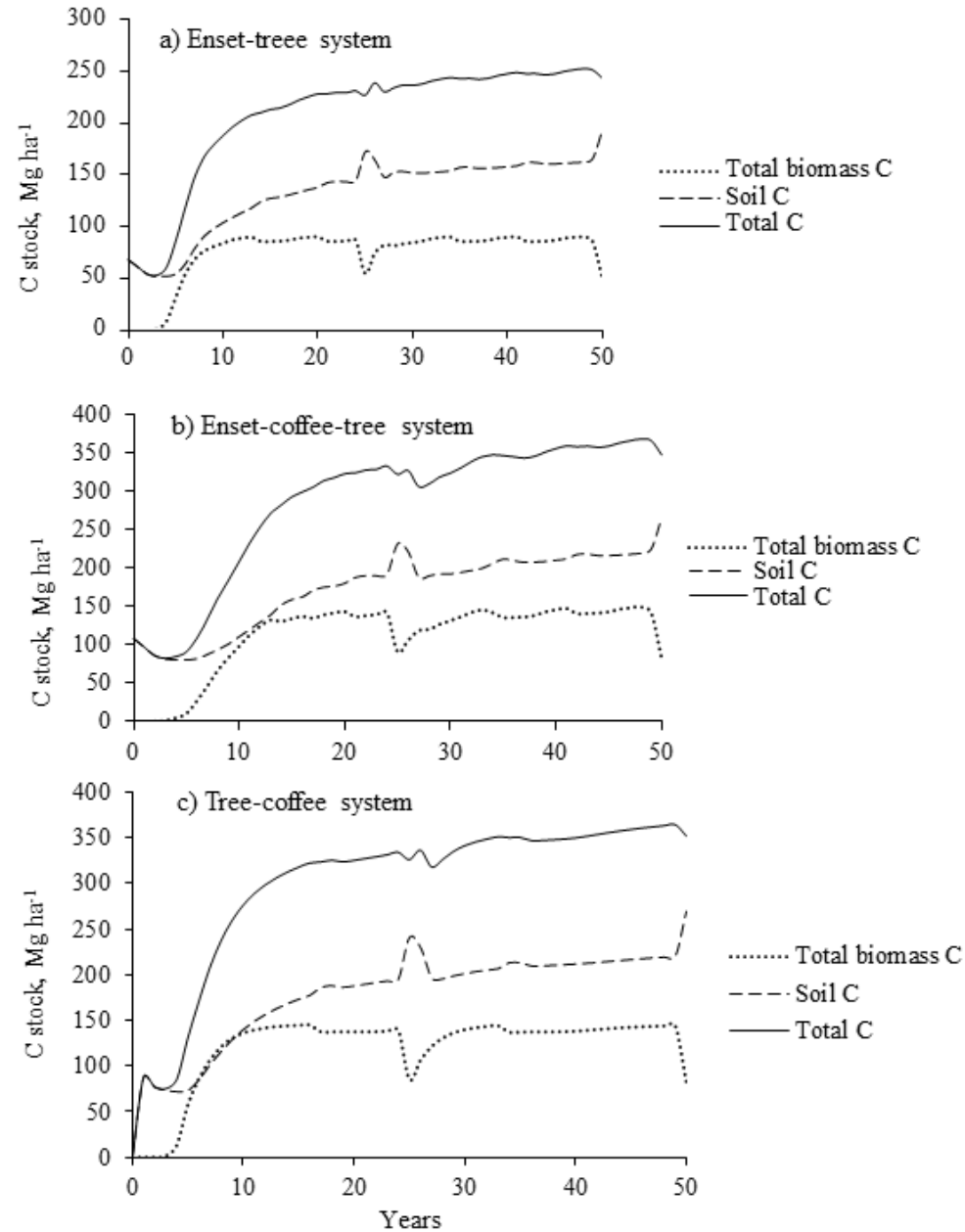
# Simulated above-ground C stocks (Mg C ha<sup>-1</sup> year<sup>-1</sup>) over 50 year period

Negash & Kanninen (2015)



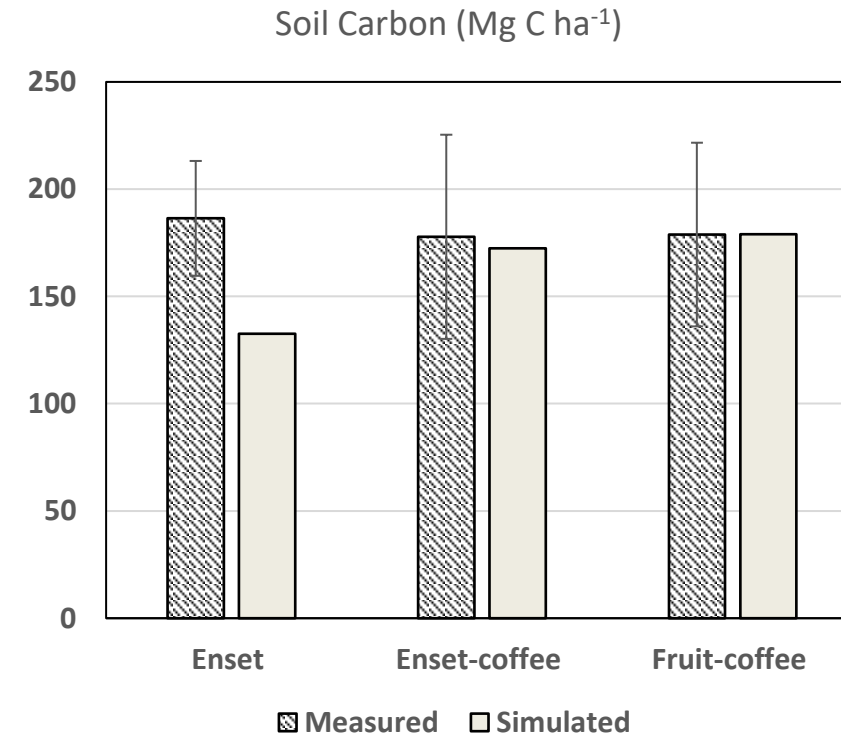
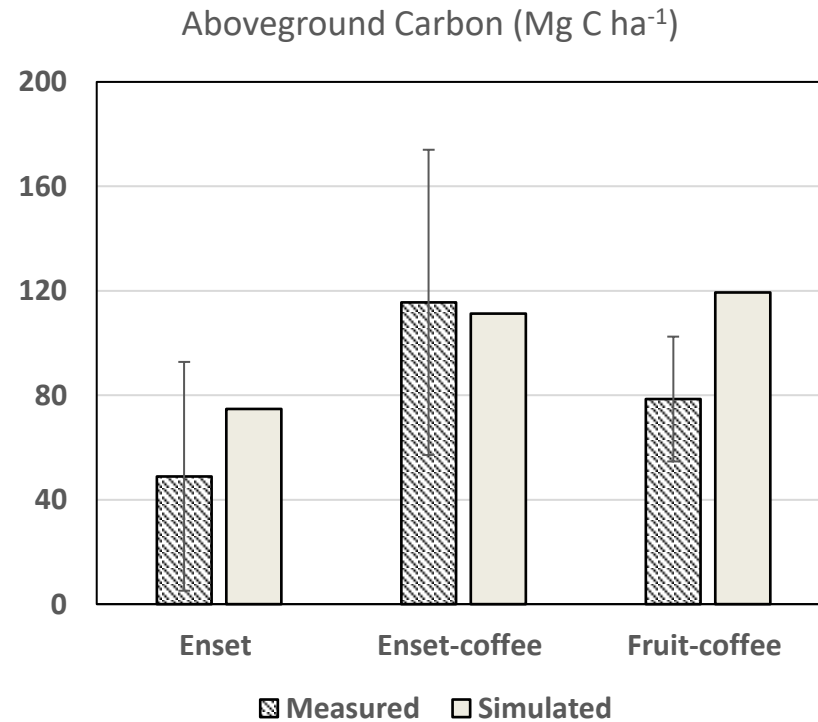


# Simulated total & above-ground & soil C stocks (Mg C ha<sup>-1</sup> year<sup>-1</sup>) over 50 year period



Negash & Kanninen (2015)

# Measured vs. Simulated carbon stocks (ages 10– 40 years)



# Example from India (2010)

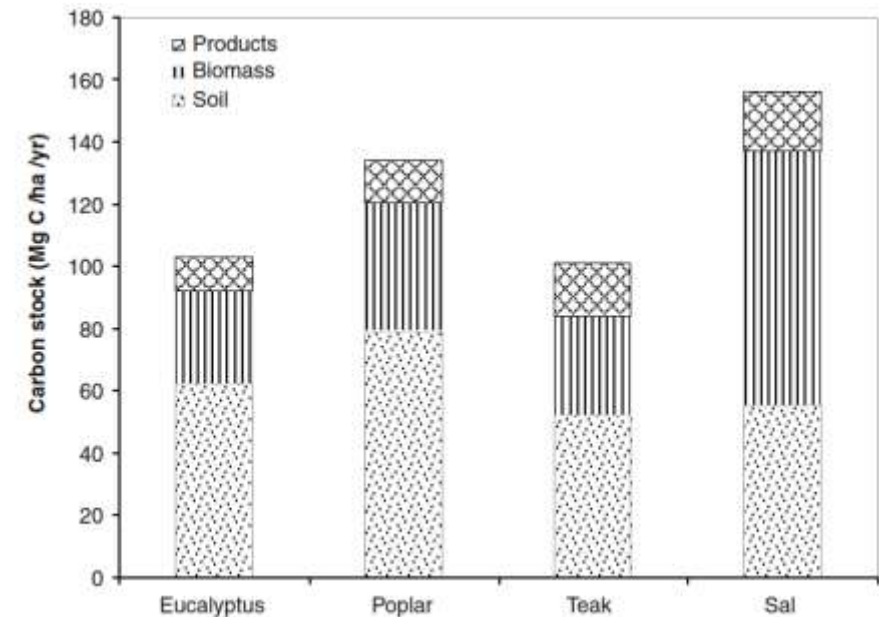
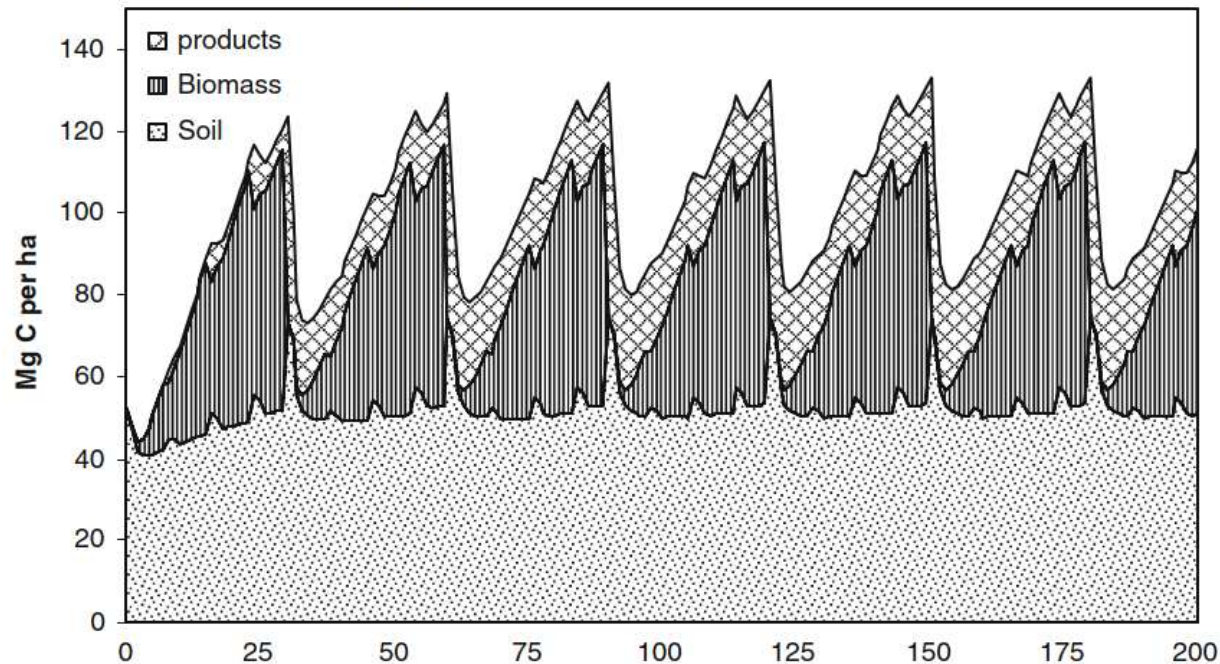
Mitig Adapt Strateg Glob Change  
DOI 10.1007/s11027-010-9230-5

ORIGINAL ARTICLE

## Carbon storage and sequestration potential of selected tree species in India

Meenakshi Kaul • G. M. J. Mohren • V. K. Dadhwal

c) Carbon stocks in the Teak forest

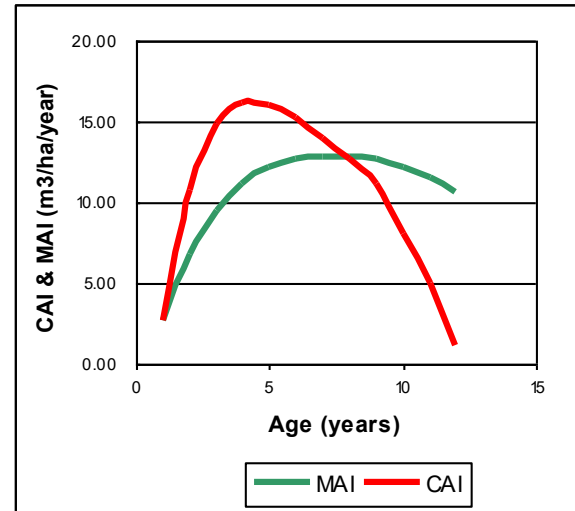
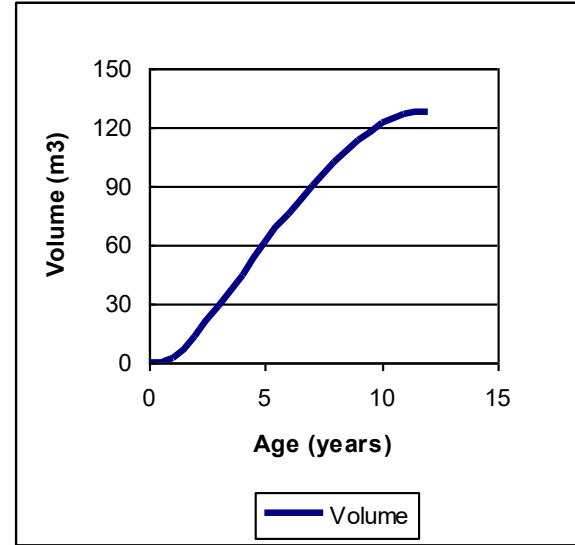




# How to get data for CO2FIX?

Age	Volume	MAI	CAI
0	0		
1	2.7	2.70	2.7
2	13.5	6.75	10.8
3	28.4	9.47	14.9
4	44.6	11.15	16.2
5	60.6	12.12	16
6	75.8	12.63	15.2
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9	113.7	12.63	11.2
10	121.8	12.18	8.1
11	126.8	11.53	5
12	128	10.67	1.2

MAI = Mean annual increment  
CAI = Current annual increment



NOTE !!!

Input data for CO2FIX is

Current annual increment  
(CAI) of stem wood  
volume per hectare



# Data for CO2FIX – example from Vietnam

Data source

*Journal of Tropical Forest Science* 33(2): 137–148 (2021)  
<https://doi.org/10.26525/jtfs2021.33.2.137>

*Arvola AM et al.*

## **FINANCIAL ATTRACTIVENESS OF WOOD PRODUCTION IN SMALLHOLDER PLANTATIONS OF CENTRAL VIETNAM IN THE CONTEXT OF DEVELOPING CARBON MARKETS**

**Arvola AM<sup>1</sup>, Ha HT<sup>2</sup>, Kanninen M<sup>1</sup>, Malkamäki A<sup>3</sup> & Simola N<sup>4</sup>**

<sup>1</sup>*Viikki Tropical Resources Institute, Latokartanonkaari 7, University of Helsinki, Finland A*

<sup>2</sup>*University of Agriculture and Forestry, Phung Hung Street 102, Hue University of Agriculture and Forestry, Vietnam*

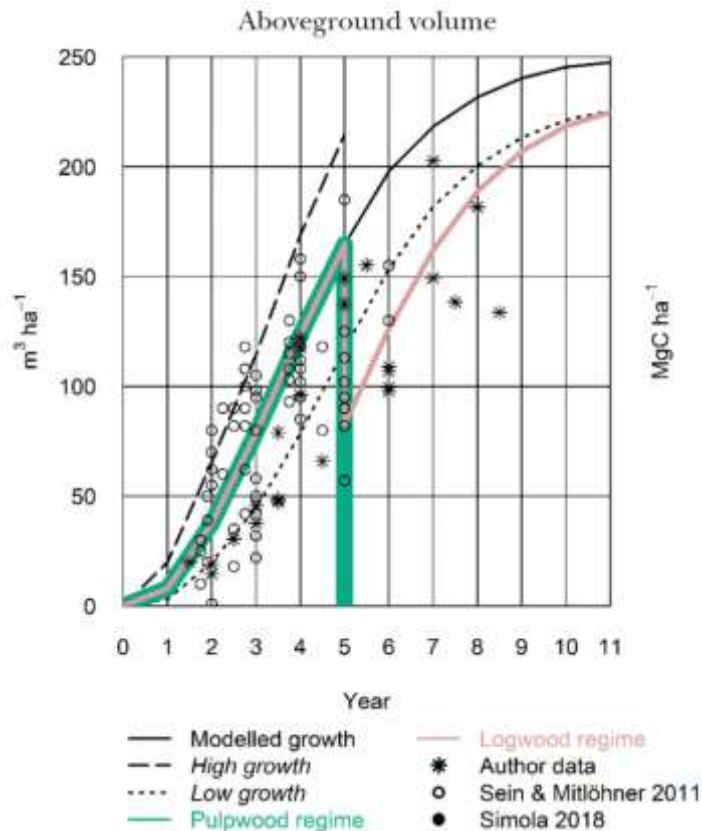
<sup>3</sup>*Helsinki Institute of Sustainability Science, Yliopistonkatu 3, University of Helsinki, Finland*

<sup>4</sup>*Finnish Agri-Agency for Food and Forest Development (FFD), Simonkatu 6, Helsinki, Finland*

\**anne.arvola@helsinki.fi*

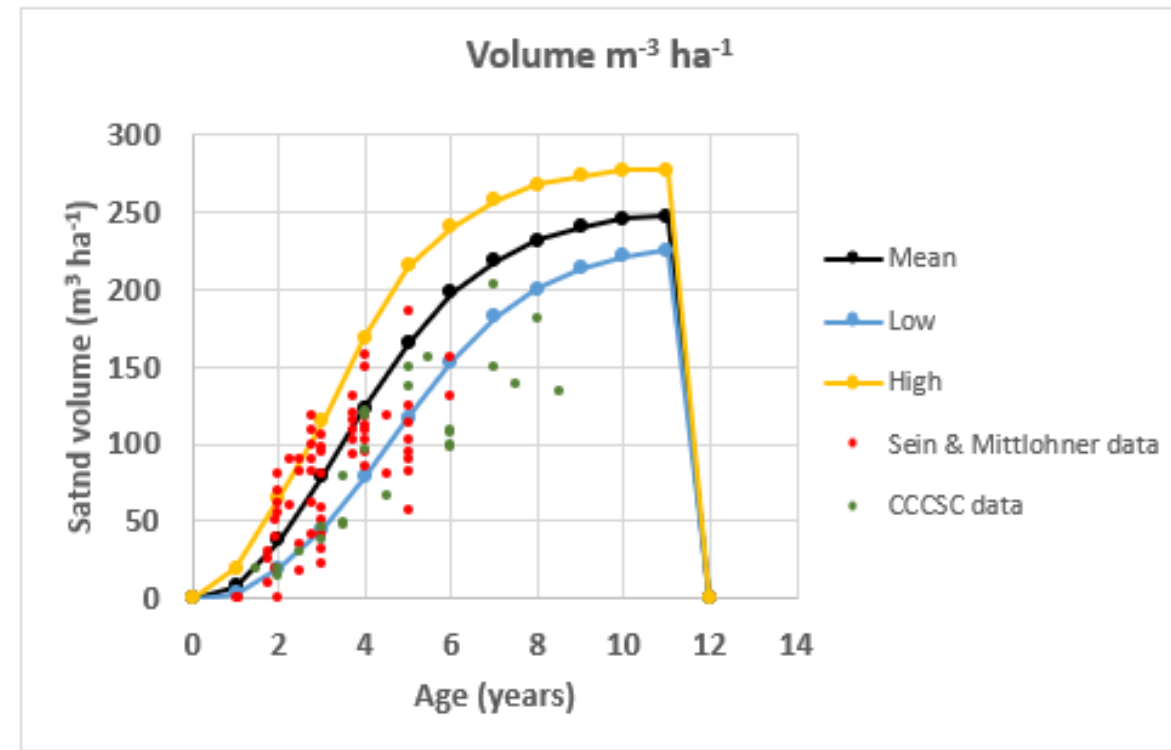
*Submitted April 2020; accepted August 2020*

# Acacia hybrid plantations in Vietnam, Thua Thien Hue and Quang Ngai provinces



**Volume ( $\text{m}^3 \text{ha}^{-1}$ )**

Age	Mean	Low	High
0	0	0	0
1	8	3	20
2	37,84	19,94	65,6
3	79,08	44,54	114,69
4	123,5	78,65	168,92
5	164,68	117,08	214,86
6	197,87	153,33	239,96
7	218,29	181,82	257,1
8	231,64	200,41	267,47
9	240,38	213,31	273,32
10	245,41	221,29	276,53
11	247,49	225,46	277,14
12	0	0	0

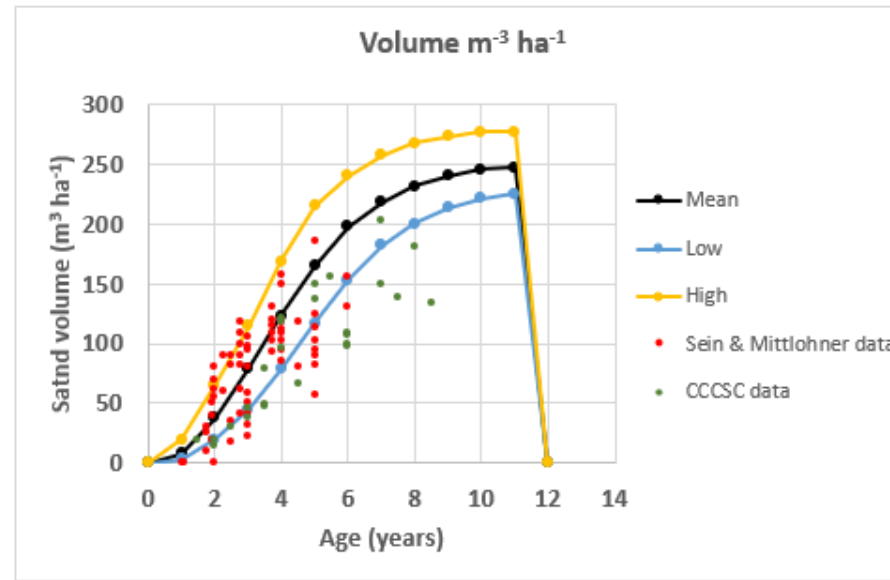






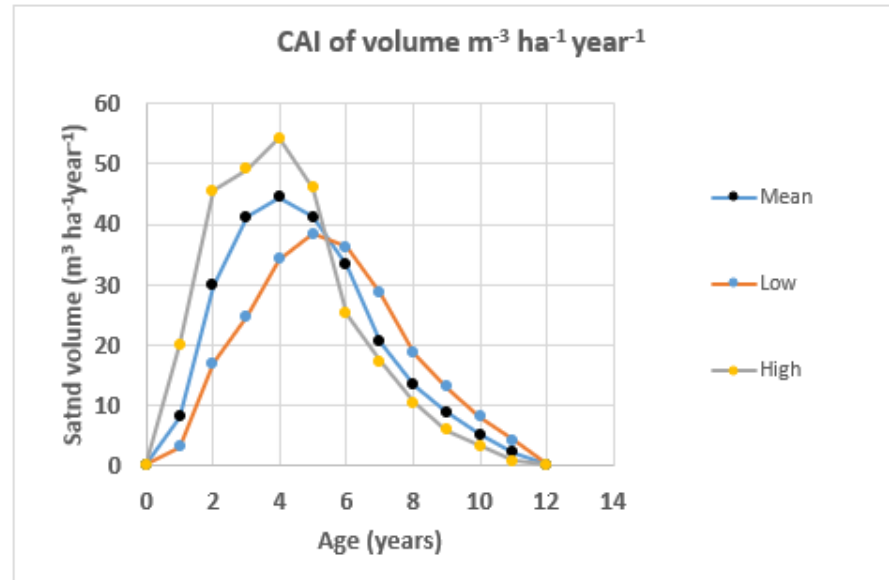
## Volume ( $\text{m}^3 \text{ha}^{-1}$ )

Age	Mean	Low	High
0	0	0	0
1	8	3	20
2	37,84	19,94	65,6
3	79,08	44,54	114,69
4	123,5	78,65	168,92
5	164,68	117,08	214,86
6	197,87	153,33	239,96
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10	245,41	221,29	276,53
11	247,49	225,46	277,14
12	0	0	0

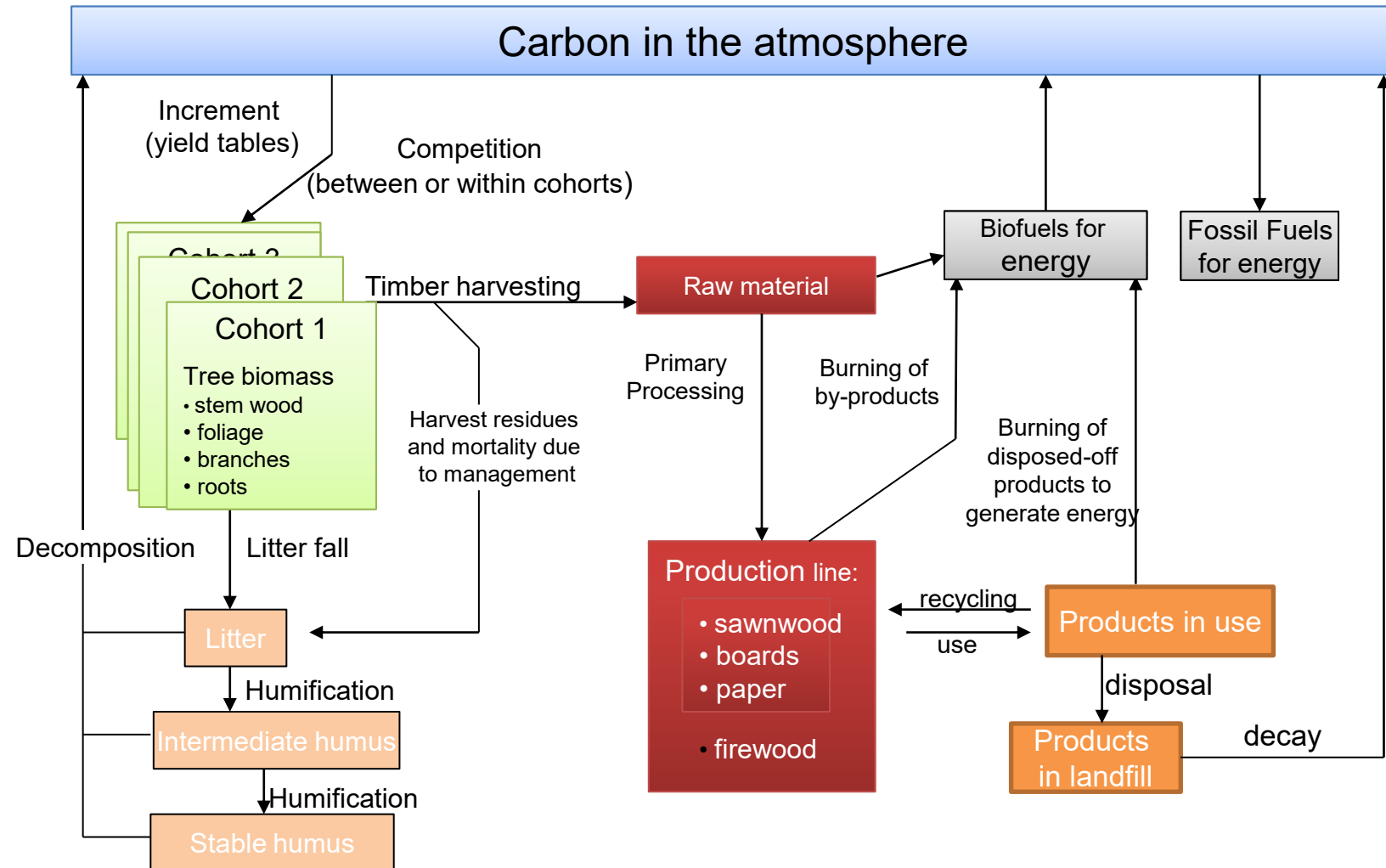


## Current Annual Increment (CAI) of Volume ( $\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$ )

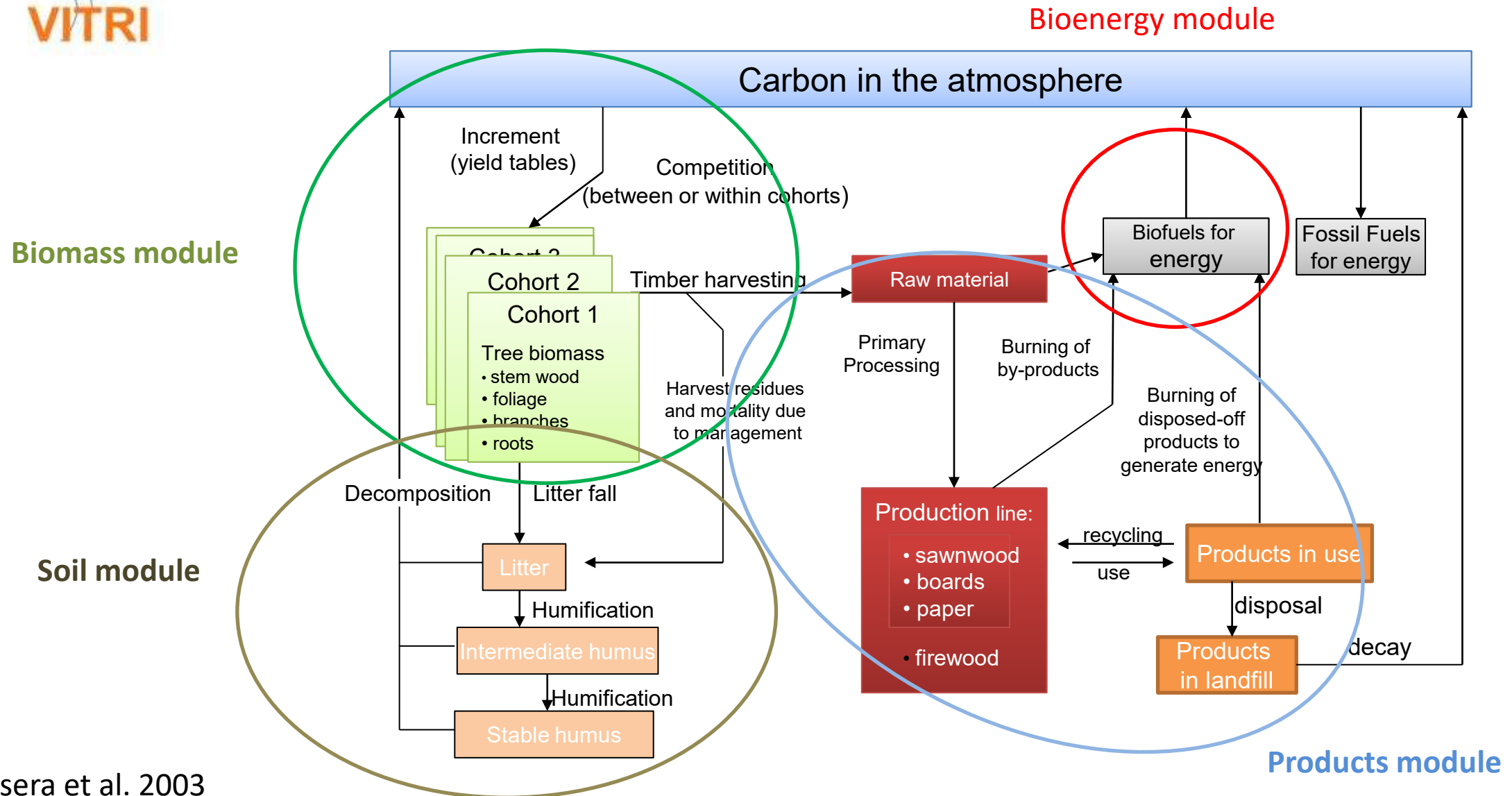
Age	Mean	Low	High
0	0	0	0
1	8	3	20
2	29,84	16,94	45,6
3	41,24	24,6	49,09
4	44,42	34,11	54,23
5	41,18	38,43	45,94
6	33,19	36,25	25,1
7	20,42	28,49	17,14
8	13,35	18,59	10,37
9	8,74	12,9	5,85
10	5,03	7,98	3,21
11	2,08	4,17	0,61
12	0	0	0



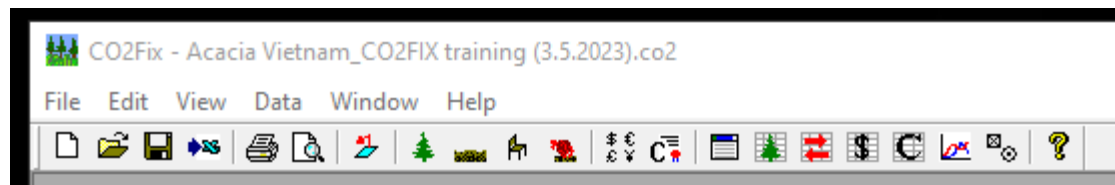
# CO2FIX: model structure



# CO2FIX: model structure



# Data input to CO2FIX



General parameters

Biomass module

Soil module

Products module

Bioenergy module

# Data input – Biomass module

Biomass

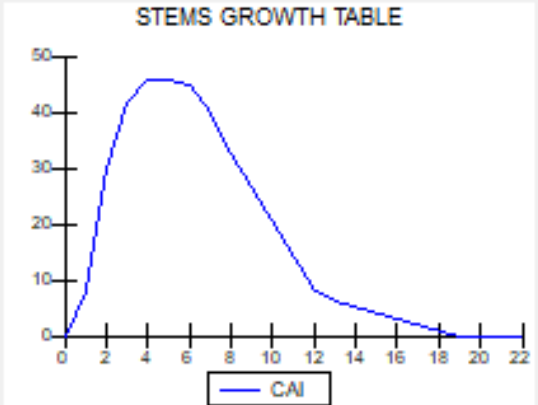
Stems | Foliage | Branches | Roots | Mortality | Competition | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium

Carbon content [MgC/MgDM]: 0.466  
 Wood density [MgDM/m3]: 0.455  
 Initial carbon [MgC/ha]: 0

Age [yr]	CAI [m3/ha/...]
0	0
1	8
2	30
3	42
4	46
5	46

STEMS GROWTH TABLE



OK Cancel Apply Help

# Data input to CO2FIX

Section

Biomass

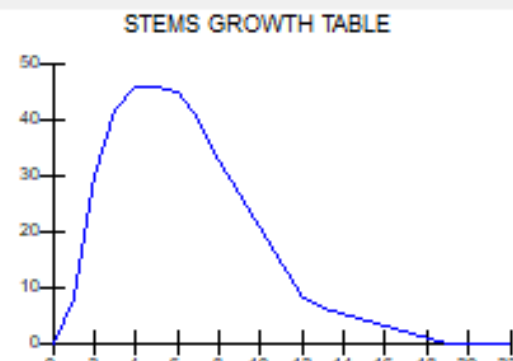
Stems | Foliage | Branches | Roots | Mortality | Competition | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium

Carbon content [MgC/MgDM]: 0.466  
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 Initial carbon [MgC/ha]: 0

Age [yr]	CAI [m3/ha/...]
0	0
1	8
2	30
3	42
4	46
5	46

STEMS GROWTH TABLE



OK Cancel Apply Help



# Data input to CO2FIX

Section → **Biomass**

Scenario (site class) → **Scenario 1 - Mean**

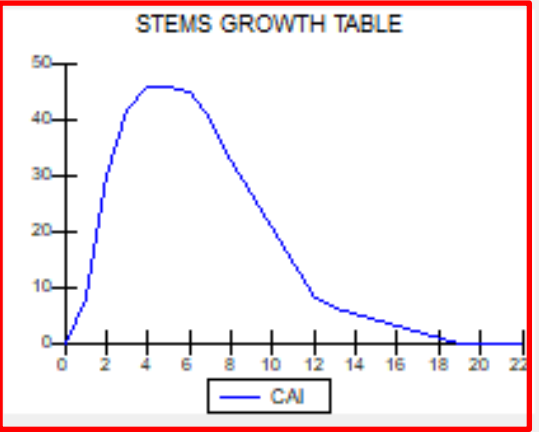
Cohort (species) → **acacia mangium**

Basic wood properties

Age [yr]	CAI [m3/ha/...]
0	0
1	8
2	30
3	42
4	46
5	46

Data input table

Interactive graph



The graph displays the Carbon Area Index (CAI) over a 22-year period. The y-axis represents CAI from 0 to 50, and the x-axis represents time in years from 0 to 22. The curve starts at 0, rises sharply to a peak of approximately 46 around year 4, and then gradually declines to near zero by year 22.

# Data input to CO2FIX

Section

Biomass Foliage Stems Branches Roots Mortality Competition Management mortality Thinning-Harvest

Scenario Scenario 1 - Mean Cohort acacia mangium

Carbon content [MgC/MgDM] 0.466

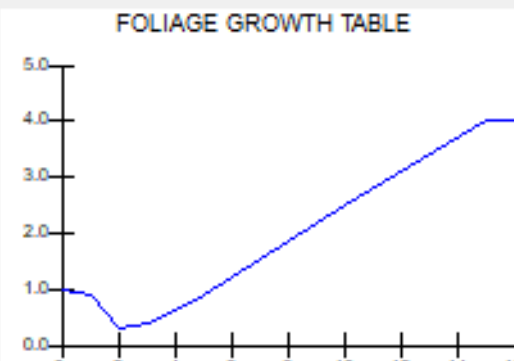
Initial carbon [MgC/ha] 0

Growth correction factor 1

Turnover rate [1/yr] 1

Age [yr]	Relative gro...
0	1
1	0.9
2	0.3
3	0.4
4	0.6
5	0.9

FOLIAGE GROWTH TABLE



— RELATIVE TO STEM GROWTH

OK Cancel Apply Help

# Data input to CO2FIX

Section



Biomass

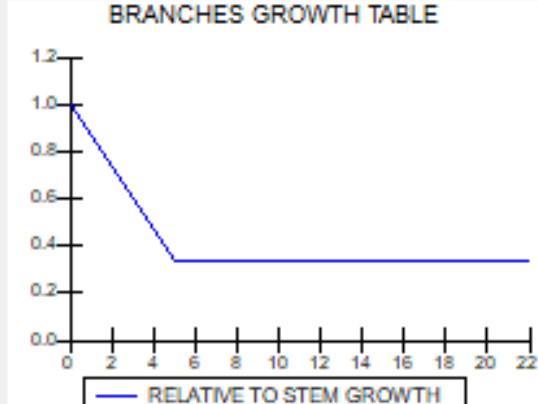
Stems | Foliage | **Branches** | Roots | Mortality | Competition | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium

Carbon content [MgC/MgDM]: 0.466  
 Initial carbon [MgC/ha]: 0  
 Growth correction factor: 1  
 Turnover rate [1/yr]: 0.05

Age [yr]	Relative gro...
0	1
5	0.34
19	0.34

BRANCHES GROWTH TABLE



OK Cancel Apply Help

# Data input to CO2FIX

Section



Biomass

Stems | Foliage | Branches | **Roots** | Mortality | Competition | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium

Carbon content [MgC/MgDM]: 0.507

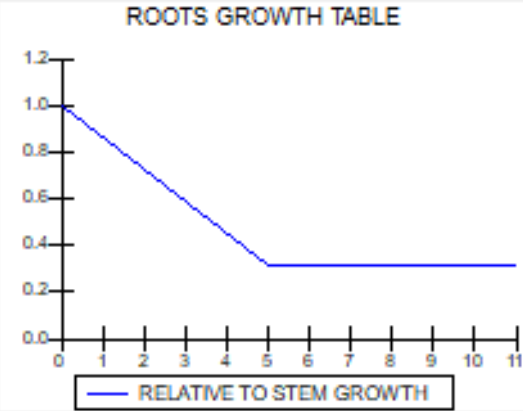
Initial carbon [MgC/ha]: 0

Growth correction factor: 1

Turnover rate [1/yr]: 0.07

Age [yr]	Relative gro...
0	1
5	0.31
10	0.31

ROOTS GROWTH TABLE



OK Cancel Apply Help

# Data input to CO2FIX

Section



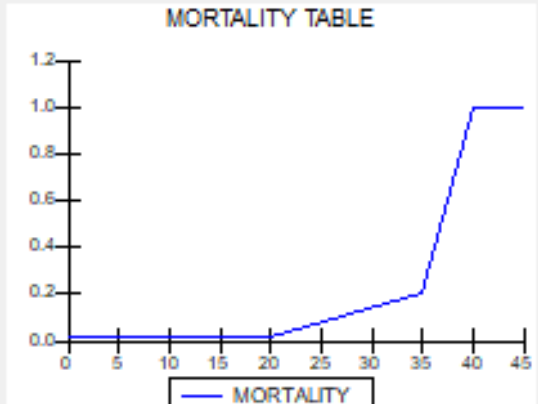
Biomass

Stems | Foliage | Branches | Roots | **Mortality** | Competition | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium

Age [yr]	Mortality
0	0.02
20	0.02
35	0.2
40	1

MORTALITY TABLE



OK Cancel Apply Help

# Data input to CO2FIX

Section



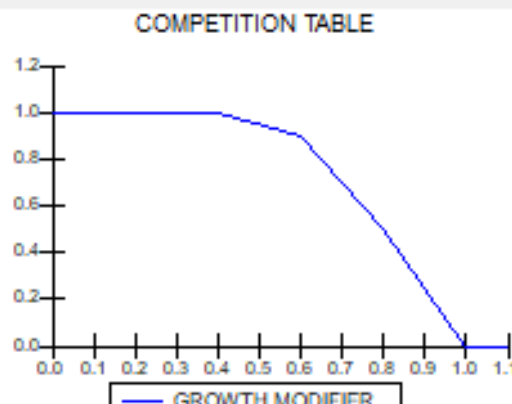
Biomass

Stems | Foliage | Branches | Roots | Mortality | **Competition** | Management mortality | Thinning-Harvest

Scenario: Scenario 1 - Mean Cohort: acacia mangium Maximum above ground biomass in the whole stand [MgDM/ha]: 220

Bio/Ma...	Growth modi...
0	1
0.4	1
0.6	0.9
0.8	0.5
1	0

COMPETITION TABLE



OK Cancel Apply Help





X

Management mortality

# Data input to CO2FIX

Section



Biomass

Stems | Foliage | Branches | Roots | Mortality | Competition | Management mortality | **Thinning-Harvest**

Scenario: Scenario 1 - Mean Cohort: acacia mangium Rotation length [yr]: 12

Age [yr]	Fraction Remov...	Stems LogW...	Stems PulpPap	Stems Slash	Branches LogW...	Branches PulpPap	Branches Slash	Foliage Slash	Slash FireWo...	Slash Soil
12	1	0.6	0.4	0.00	0	0	1.00	1.00	0	1.00

OK Cancel Apply Help



**THANK YOU FOR YOUR ATTENTION**