Forest and timber quality in Europe

Modelling and forecasting yield and quality in Europe

PROJECT EXTENSION REPORT

1 July 2004 – 31 December 2004

PROJECT QLK5-CT-2001-00345

Project Progress Summary

<table>
<tr><td colspan="2">Section 1: PROJECT IDENTIFICATION</td><td colspan="2">NOT CONFIDENTIAL</td></tr>
<tr><td colspan="4">Title of the project
FORECASTING THE DYNAMIC RESPONSE OF TIMBER QUALITY TO MANAGEMENT AND ENVIRONMENTAL CHANGE: AN INTEGRATED APPROACH</td></tr>
<tr><td colspan="4">Acronym of the project
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<tr><td colspan="2">Type of contract
RS (Research and Technological Development Project)</td><td colspan="2">Total project cost (in euro)
2 131 087 EUR</td></tr>
<tr><td>Contract number
QLK5-CT-2001-00345</td><td colspan="2">Duration (in months)
36 months + 6</td><td>EU contribution (in euro)
1 483 041 EUR</td></tr>
<tr><td colspan="2">Commencement date
1 July 2001</td><td colspan="2">Period covered by the progress report
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<tr><td colspan="4">World wide web address
www.efi.fi/projects/mefyque</td></tr>
<tr><td colspan="4">List of participants
See attached table</td></tr>
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Section 2: Project Progress Report	*NOT CONFIDENTIAL*

Objectives:

The overall objective of MEFYQUE is to increase understanding of the relationships between site conditions and growth, yield and timber quality for current and future scenarios of atmospheric change. This objective will be achieved by developing a prototype modelling system operating at an appropriate forestry management scale (the forest stand) to forecast timber growth, yield, quality and marketability suitable for application in the EU. The system will also predict and quantify reversible and irreversible energy fluxes to and from the forest, including those due to fossil fuel consumption. Such a forecasting system must account for the reshaping of European forestry through policies aimed at the optimisation of sustainable management, the provision of renewable resources and the protection of the global and local environment, in particular the role of forestry in the carbon cycle. Thus, a fully integrated approach to pre- and post-production activities is required to develop a tool suitable for use both by the timber industry and national/governmental policy decision-makers.

THE PRINCIPAL DELIVERABLE OF THE PROJECT IS AN INTEGRATED MODELLING SYSTEM THAT WILL ASSIST FOREST MANAGERS, THE TIMBER INDUSTRY AND POLICY MAKERS TO DECIDE WHETHER MANAGEMENT OF FORESTS SHOULD BE PRIMARILY FOR PRODUCTION, CONSERVATION OR AMENITY OUTPUTS, WITHIN THE CONTEXT OF MULTI-PURPOSE FOREST MANAGEMENT.

In order to achieve this overall objective the project has the following specific objectives:

1. to increase understanding of the relationship between tree growth, timber quality, site conditions and stand management using a network of traditional mensuration sample plots and supplementary information on structure, quality, environment and physiology;
2. to increase understanding of the influence of climate and atmospheric composition (climate change) on timber quality through manipulative experiments and the analysis of wood properties for material grown under ambient and enhanced CO_2 concentrations. This will be obtained through a combination of the analysis of existing plant material from previous experiments and new material from specific manipulative experiments;
3. to construct and validate a coupled empirical-process model of timber growth, yield, quality and carbon sequestration including non-harvestable fractions, operating at the stand scale. This will be achieved using data collected under objectives 1 and 2, and additional validation being provided by flux experiments at monitored sites. This model will be based on widely accepted functions in an innovative modular structure;
4. to simulate the impacts of future scenarios of atmospheric composition (climate change) on timber growth, yield and carbon sequestration at different spatial scales (stand and regional). The most up-to-date Global Climate Model outputs and predictions of atmospheric composition change will be used as drivers for the model developed under objective 3;
5. to simulate and quantify the impact of forest management on timber growth, yield and quality allowing the optimisation of economic return and/or carbon sequestration and energy cost: benefits through sustainable practices of production;
6. to simulate and quantify the impact of forest management on the industrial energy and production and forestry as an important land use system.

Results and Milestones:

Most key results and milestones foreseen by the Technical Annex have been successfully completed.

The main results for the project, and its database are presented in a separate final report document and accompanying CDs.

<u>Results</u>

Timber growth and quality assessments on forest stands located across the European Union.
New knowledge on the variation of selected anatomical wood properties across project sites and of manipulation of environmental conditions.
New knowledge on the variation of selected biochemical wood properties across project sites and of manipulation of environmental conditions.
New knowledge on the variation of selected wood physico-mechanical properties across project sites and of manipulation of environmental conditions.
New stand scale timber growth and quality model.
New model for analysing 3-D log scans and simulating optimised cutting cycles.
Integration of sub-modules and with a project database.
A review of forestry working practices, wood processing methods and implicit fossil energy inputs.
Two computer-based models of fossil energy and carbon-based balances available as source code, or executable user-friendly interface. The second model was not originally foreseen in the Technical Annex.
Project WWW page updates.
Third Annual Report.

<u>Milestones</u>

<u>Data collection</u>. Completed data collection programme across a large range of data types from the project experimental sites.
<u>Development of project database</u>. Development of project database containing data collected from project experimental sites.
<u>Stand scale quality model</u>. Development and partial validation of a stand scale model simulating the growth of key parameters determining timber quality.
<u>3-D log shape and processing model</u>. Development of a 3-D model reconstructing log shape from scanning data integrated with a module optimising log processing and cutting cycles.
<u>Model integration</u>. Development of linkage between growth, cross-cutting, batten cutting and grading models.
<u>Upscaling and Scenario Anaylsis</u>. Application of the regional scale forest products and energy model to various socio-economic scenarios for a selected region.
<u>Third Annual Report</u>. Completion of annual report to European Commission.
<u>Final Report</u>. Completion of the final report to the European Commission
<u>Database.</u> Completion and submission of the consortium database
<u>International Conference.</u> An international conference to disseminate project results was held in Edinburgh 28-30 September 2004.

Benefits and Beneficiaries:

Publications in peer-review literature for the benefit of scientists.
The timber industry.

Future Actions (if applicable):

Project completed.

Progress Report

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MEFYQUE OBJECTIVES AND EXPECTED ACHIEVEMENTS

The overall objective of the project is to increase understanding of the relationships between site conditions and growth, yield and timber quality for current and future scenarios of atmospheric change. This objective will be achieved by developing a prototype modelling system operating at an appropriate forestry management scale (the forest stand) to forecast timber growth, yield, quality and marketability suitable for application in the EU. The system will also predict and quantify reversible and irreversible energy fluxes to and from the forest, including those due to fossil fuel consumption. Such a forecasting system must account for the reshaping of European forestry through policies aimed at the optimisation of sustainable management, the provision of renewable resources and the protection of the global and local environment, in particular the role of forestry in the carbon cycle. Thus, a fully integrated approach to pre- and post-production activities is required to develop a tool suitable for use both by the timber industry and national/governmental policy decision-makers.

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- to simulate the impacts of future scenarios of atmospheric composition (climate change) on timber growth, yield and carbon sequestration at different spatial scales (stand and regional). The most up-to-date Global Climate Model outputs and predictions of atmospheric composition change will be used as drivers for the model developed under objective 3;
- to simulate and quantify the impact of forest management on timber growth, yield and quality allowing the optimisation of economic return and/or carbon sequestration and energy cost: benefits through sustainable practices of production;
- to simulate and quantify the impact of forest management on the industrial energy and carbon balances as a significant contribution towards a full life cycle assessment of wood timber production and forestry as an important land use system.

1.1 INTRODUCTION

Project components. The Technical Annex provides significant amounts of background information concerning sites, methodologies and techniques used in MEFYQUE that for brevity will not be repeated here. Where required, this report only outlines changes to activities foreseen in the Technical Annex.
As described in the Technical Annex (October 2000) the MEFYQUE project is separated into 5 major components:

The monitoring component

The manipulative component

The laboratory component

The modelling component

The management component. This component is described in Section 4.

Each component is being delivered through achievement of scheduled milestones and deliverables assigned to one of 11 Work-Packages (Table 1). Progress against each project components is described in the sections below.

Table 1. *Integration between project components and work-packages.*

Project Component	Work-package Number	Work-package Title
Monitoring	WP1	Stand growth and yield data in field conditions for a range of management practices at primary and secondary sites
Monitoring	WP2	Analyses of qualitative properties in standing timber
Manipulative	WP3	Analyses of qualitative properties in manipulative experiments
Laboratory	WP4	Analyses of wood anatomical properties in laboratory conditions
Laboratory	WP5	Analyses of wood biochemical properties in laboratory conditions
Laboratory	WP6	Analyses of wood physico-mechanical properties in laboratory conditions
Modelling	WP7	Modelling of wood quality and tree growth at stand scale for representative sites across Europe
Modelling	WP8	Development of the energy budget sub-model
Modelling	WP9	Protocol for model integration and upscaling
Modelling	WP10	Validation and application of model integration and upscaling
Management	WP11	Database development and project co-ordination

1.2 MILESTONES, DELIVERABLES AND TIMETABLE.

To assess progress against project deliverables, the following tables are provided below.

Table 2. Planned Participant Contribution and Timetable.
Table 3. List of Project Milestones
Table 4. List of Project Deliverables

Table 2. *Planned Participant Contribution and Timetable. This table identifies contribution to working steps led by each Partner only.*

		1st year												2nd year												3rd year											
	Title of Working Step	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Participant 1	1a Establishment of permanent sampling plots at primary sites						■	■																													
	1b Primary site plot sampling protocol					■																															
	1e Growth & yield data collection from primary and secondary sites		■	■							■	■	■	■									■	■	■	■											
	2a Development & training in Timber Quality Assessment protocol						■			■																											
	2b Standing timber quality assessment										■	■											■	■													
	7c Plot scale model validation and application																		■	■	■								■	■	■	■	■				
	7e Modelling productivity of wood products at the plot scale																													■	■	■					
	11a Development of consortium database and data exchange protocols								■	■	■																										
	11b Data exchange											■												■											■	■	
	11c International workshop																																			■	
	11e Annual and Final Reports												■	■											■	■								■	■	■	■
Participant 2	1c Secondary site plot sampling protocol					■																															
	1d Monitoring and data collection from secondary sites	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
	7a Plot scale model modelling protocols						■	■																													
	7b Plot scale model development and calibration	■	■	■	■	■											■	■																			
	7d Modelling carbon sequestration at the plot scale																															■	■	■			
Participant 3	8a Energy budget sub-model modelling protocols				■	■	■																														
	8b Energy budget sub-model development and calibration						■	■	■																												
	9a Prototype integrated system modelling protocols							■	■	■																											
	9b Development of the prototype integrated model at regional scale									■	■	■	■	■	■																						
	9c Application of climate change scenarios																															■	■	■			
	9d Application of socio-economic scenarios																																■	■	■		
	10a Prototype regional integrated model validation and application																	■	■	■	■	■											■	■	■		
	11d Web site updates			■											■												■										■
Participant 4	4a Wood anatomy protocol						■	■																													
	4b Wood anatomical laboratory studies (existing and new material)			■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■						■	■	■	■	■	■			
	5a Wood chemistry protocol		■	■																																	
	5b Wood chemical laboratory analyses (existing and new material)			■	■							■	■	■	■	■								■	■	■	■	■									
Participant 5	3a Tertiary site sampling protocol		■																																		
	3b Monitoring and data collection from tertiary sites										■	■											■	■					■	■							
A Participant 6	6b Wood physico-mechanical analyses (existing & new material)					■	■	■						■	■	■										■	■	■									
Participant 7	6a Wood physico-mechanical protocol				■	■																															
All	11f Consortium meetings	1										2				3							4					5						6			
All	11g Milestones		I				II-III			IV		V		VI			VII							VIII-X						XI		XII		XIII-XIV		XV-XIX	

Table 3. *List of Project Milestones*

Milestone No	Associated WPs	Title	Delivery Date	Participants		Description
				Lead	Assoc.	
		Project WWW site	Month 3	P3		Interactive WWW site for use both by partners in the consortium and external browsers
	1,2,3,4	Sampling and analytical protocols	Month 6	P5	P1, P2	Completion of sampling protocols for primary, secondary and tertiary sites
	5,6	Laboratory and analytical protocols	Month 6	P4	AP6, P7	Completion of laboratory and analytical protocol for wood anatomy, wood chemistry and wood physico-mechanical properties
	8	Energy budget model	Month 8	P3	P1, P7	Carbon and energy book-keeping model to quantify the fossil fuel energy inputs and associated CO_2 emissions of individual forest operations and timber conversion procedures.
		First Annual Report	Month 12	P1	P2, P3, P4, P5, AP6, P7	Completion of annual report to European Commission
	1,2,3,4,5,6	Completion of Phase 1 sampling programme	Month 13	All		Completion of all sampling programme for year 1 at the primary, secondary and tertiary sites.
	7	Prototype mechanistic dynamic model at plot scale	Month 16	P2	P1, P3, P4, P5, AP6, P7	A prototype coupled mensuration mechanistic dynamic model of tree growth, timber production and wood quality operational at the stand scale
		Scientific Papers	Month 24	All		Completion of 6 scientific papers for publication in peer-reviewed journals
		Technical Papers	Month 24	All		Completion of 6 technical papers for publication in national timber industry journals
		Second Annual Report	Month 24	P1	P2, P3, P4, P5, AP6, P7	Completion of annual report to European Commission
	1,2,3,4,5,6	Completion of Phase 2 sampling programme	Month 30	All		Completion of all sampling programme for year 2 at the primary, secondary and tertiary sites.
	5,6	Completion of laboratory studies	Month 32	P4	AP6, P7	Completion of all laboratory studies on wood anatomy, wood chemistry and wood physico-mechanical properties.
	9	Regional scale model	Month 34	P3	P1, P2, P4, P7	An integrated model which accounts for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the regional scale.
		International Workshop	Month 35	P1	P2, P3, P4, P5, AP6, P7	International workshop on “Forecasting the dynamic response of timber quality to management and environmental change from the site to the regional scale: experimental and modelling approaches”.

Milestone No	Associated WPs	Title	Delivery Date	Participants		Description
				Lead	Assoc.	
		Scientific Papers	Month 36	All		Completion of 6 scientific papers for publication in peer-reviewed journals
		Technical Papers	Month 36	All		Completion of 6 technical papers for publication in national timber industry journals
	1,2,3,4,5,6	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Month 36	P1	P2, P3, P4, P5, AP6, P7	Unified relational database with all monitoring, experimental, laboratory and manipulative data collected during the programme.
	9,10	Database of modelling scenarios	Month 36	P3	P1, P2, P5	Portfolio of model predictions at the regional scale
		Final Report	Month 36	P1	P2, P3, P4, P5, AP6, P7	Completion of final report to European Commission

Table 4. *List of Project Deliverables*

Work-Package No.	Deliverable No.	Deliverable title	Delivery Date	Nature [1]	Dissemination Level [2]	Dissemination Target [3]
1.	1.	Standardised methodology for site characteristics, physiological, eco-physiological and mensurational data for observed forest stands	Month 6	O	CO	C
	2.	Database of site characteristics, physiological, eco-physiological and mensurational data for a range of species, environmental conditions and management options	Month 36	O	CO	C S P
	3.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; growth and yield	Month 36	O	CO	C
2.	4.	Standardised methodology for timber quality assessment for forest stands, applicable across the European Union.	Month 6	O	CO	C S I
	5.	Database on timber quality assessment for forest stands for a range of species, environmental conditions and management options	Month 22	O	CO	C S I
	6.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; qualitative properties in standing timber	Month 24	O	CO	C
3.	7.	Standardised methodology for assessing growth patterns and allocation of juvenile plants grown in manipulative experimental conditions.	Month 30	O	CO	C
	8.	Database on growth patterns and allocation from individuals for a range of species, environmental conditions, management options and atmospheric change	Month 32	O	CO	C S I
	9.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; manipulative experiments	Month 34	O	CO	C
4.	10.	Standardised methodology for determining selected anatomical wood properties.	Month 6	O	CO	C S
	11.	Data incorporated into a database on the anatomical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change	Month 34	O	CO	C S I
	12.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; anatomical properties	Month 34	O	CO	C S
5.	13.	Standardised methodology for determining selected biochemical wood properties.	Month 6	O	CO	C S
	14.	Data incorporated into a database on the biochemical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change	Month 27	O	CO	C S I
	15.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; biochemical properties	Month 31	O	CO	C
6.	16.	Standardised methodology for determining selected wood physico-mechanical properties.	Month 6	O	CO	C

[1] **Nature of Deliverables:**
R = Report
P = Prototype
D = Demonstrator
O = Other
[2] **Dissemination Level:**
PU = Public
RE = Restricted to group specified by Consortium (including Commission Services)
CO = Confidential, only for members of the Consortium (including Commission Services)
[3] **Target audience of potential users/beneficiaries of the deliverable:**
C = Restricted to group specified by Consortium (including Commission Services)
CO = Commission Services
S = Scientific users
I = Industry users

Work-Package No.	Deliverable No.	Deliverable title	Delivery Date	Nature [1]	Dissemination Level [2]	Dissemination Target [3]
	17	Database on the physico-mechanical properties of wood from trees for a range of species, environmental conditions, management options, climate and atmospheric change	Month 27	O	CO	C S I
	18.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.	Month 29	O	CO	C
7.	19.	Protocol for integration of sub-modules.	Month 6	O	CO	C
	20.	A prototype coupled mensuration mechanistic dynamic model of tree growth, timber production and wood quality operational at the stand scale.	Month 16	p	CO	C
	21.	A user-friendly version of the model available as a prototype decision support system.	Month 18	P	PU	C S I
	22.	Predictions of timber production accounting for tree quality across a representative range of sites and silvicultural regimes in participating countries, also accounting for scenarios of future environmental change.	Month 32	R	PU	C S I
	23.	Predictions of environmental impact in terms of current and future forest stand composition and structure, its nutrient status and dynamics, and ecosystem carbon balance across a representative range of sites and silvicultural regimes in participating countries, also accounting for scenarios of future environmental change.	Month 33	R	PU	C S I
8.	24.	A review of forestry working practices, wood processing methods and implicit fossil energy inputs.	Month 6	O	CO	C
	25.	A computer-based model of fossil energy and carbon-based balances Available as source code, or executable user-friendly interface.	Month 8	p	PU	C
	26.	Sub-model within integrated model to evaluate impacts of environmental and silvicultural changes on fossil energy requirements and greenhouse gas balances of wood production processes.	Month 18	p	CO	
9.	27.	Protocol for model integration and upscaling	Month 14	R	CO	C
	28.	An integrated model accounting for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the scale of EU Member States.	Month 29	P	CO	C S I
	29.	Database integrated with the model of plausible future Environmental socio-economic and management scenarios applicable to the EU forestry and wood products sector.	Month 30	O	PU	C S I
	30.	Validation of model outputs against empirical databases of processes observed in the monitoring and manipulative components of the project.	Month 34	O	PU	C
	31.	A portfolio of plausible future environmental socio-economic and management scenarios applicable to the EU forestry and wood products sector.	Month 36	O	PU	C
	32.	A portfolio of model predictions for all variables listed above, (listed in deliverable 28) produced by running the above model using empirical data from earlier work-packages and simulation data from the stand- scale model as input.	Month 36	O	PU	C
10.	33.	Standardised model assessment tools incorporated into the integrated model software to assess uncertainty in model predictions associated with output sensitivity to input parameters and scaling effects.	Month 34	R	PU	C
	34.	A selection of environmental, socio-economic and management scenarios for the EU forestry and wood products sector.	Month 35	O	PU	C S I
	35.	A portfolio of model predictions for all variables listed above (listed in deliverable 28), produced by running the improved upscaling model using empirical data from earlier work-packages and simulation data from the stand- scale model as input with an associated uncertainty interval.	Month 35	O	PU	C S I
Other	36.	Papers in peer-reviewed scientific journals.	Month 18-36	R	PU	C S
	37.	Reports at international and national scientific meetings.	Month 18-36	R	PU	S
	38.	Reports in forestry and timber-processing industry journals in participating countries and international bulletins.	Month 18-36	R	PU	I
Manag	39.	First Annual Report	Month 13	R	CO	CO
	40.	Second Annual Report	Month 26	R	CO	CO
	41	Final Report	Month 36	R	CO	CO
	42..	International Workshop	Month 35	O	PU	S I
	43.	WWW page	Month 3	O	PU	S I

1.3 PROJECT DESCRIPTION OVERVIEW

Introduction

The project can be separated into 4 major components:

- the monitoring component
- the manipulative component
- the laboratory component
- the modelling component

Each is outlined in overview in the paragraphs below, and the methodology, deliverables and milestones associated with each component are described in detail in the individual work-packages.

1.3.1 The Monitoring Component

The **MONITORING COMPONENT** is designed to characterise the relationships between site conditions, growth, yield prediction and timber quality and how this varies as a function of multi-purpose forest management practices. It will combine field measurements of site conditions, forest growth, and of quality for standing timber, together with an assessment of forest product usage.

Primary sites. Existing monitoring protocols will be carried out as prescribed in the relevant technical manual of the UN/ECE ICP Forests Level II Forest Health Monitoring Network. A summary of the measurements carried out under this programme is given in the table below:

Mensurational	Climate	Pedological	Foliage	Site characteristics
Diameter at breast height (DBH) of all trees to the nearest 0. 1 cm	Automated meteorological weather stations for collection of sub-hourly data on: Temperature Precipitation Wind-speed Solar radiation Relative humidity OR Standard climatic weather stations providing the same parameters	Soil water content	Foliar chemical analysis	Species composition
Total height of (a) 100 largest trees by diameter per ha (b) 10 trees selected through the diameter distribution		Water release curve	Crown condition	Crop details: (a) Planting year (b) Establishment year (c) Crop history (brashing, thinning) (d) Windblows
Tree shape, e.g. swelling, leaning, forked		Soil profile description	Litter fall quantification	Major soil type (FAO classification)
Crown width and depth	Atmospheric deposition	Soil solution sampling analysis	Phyto-pathological observations	Row spacing
Stem form		Rooting depth	Phenology	Aspect, slope
Branching habit		Soil chemical analysis	Ground vegetation analysis	Altitude

Sampling frequency and analysis of existing data.

		Frequency	
	Start year	Sampling	Analysis
Foliar analysis	1995	2 years	2 years
Soil analysis	1995	10 years	10 years
Growth increment	1995-96	5 years	5 years
Crown condition	1995	1 year	
Meteorology	1994	Hourly	Automatic
		Daily	Manual
Ground vegetation	1998	3 years	3 years
Litter fall	1998	2 weeks (autumn) 4 weeks (rest of year)	2 weeks (autumn) 4 weeks (rest of year)
Soil solution	1995	2 weeks	4 weeks
Phenology	1998	2 weeks	

Additionally, the following data will be collected:

	UK		Belgium		Germany		Italy	
	1/0	Timestep	1/0	Timestep	1/0	Timestep	1/0	Timestep
Tree height	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3
Root depth	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3
Needle/leaf mass ha^{-1}	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3
DBH	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3	X	Yrs 1, 3
Root mass		Yrs 1,3	X	Yrs 1,3				Yrs 1,3

A protocol designed to describe the quality of timber applicable to the processing industry will be added to these existing measurements, to provide comprehensive data sets of stand characteristics that will be used to calibrate and validate the coupled empirical-process model of stand growth and quality. An indication of the approach that will be adopted is given in the following section.

<u>Quality assessment of standing timber at primary and secondary sites</u>.
Assessment of stem straightness will be carried out at primary and secondary sites, which specifies that:

Bow should not exceed 1 cm for every 1m length, and that this is in one plane and one direction only.

Bow is measured as the maximum deviation at any point of a straight line joining centres at each end of the log from the actual centre line of the log.

The full assessment protocol for timber quality is based on four log length categories that are associated with different value wood products, to ensure the straightness measure would indicate product potential.

Score	Maximum log length observed	Quality Assessment
1	No straight logs < 2 m	Lengths are generally too short for high volume saw-milling and are more suitable for industrial processing, e.g. pulp and panel board manufacture. New technology enables shorter lengths to be joined together to make longer logs.
2	2 m+ and less than 3 m (1 or 2 logs per stem)	The main market for straight logs of these lengths is fencing, pallets and packaging. They are usually too short for processing into carcassing timber but have some potential for studding. New technology enables shorter lengths to be joined together to make longer logs.
3	>= 3 m and < 4 m (1 log per stem)	Straight logs of these lengths can be marketed to the construction market although they are less sought after, but they also have market potential in the fencing and packaging industry.
4	>= 4 m (1 only per stem)	Straight logs of these lengths are important for the structural timber and carcassing markets and further expansion into these markets will depend on the ability to produce a significant volume of these lengths.

Field restrictions.
The stem straightness assessment is restricted to the first 6 m butt section of standing trees, because the butt section is the most important for higher value products. In practice, it is difficult to see clearly above 6 m, particularly in unthinned stands. Using this method there are six possible combinations of log lengths, as shown stylistically in Figure 1.

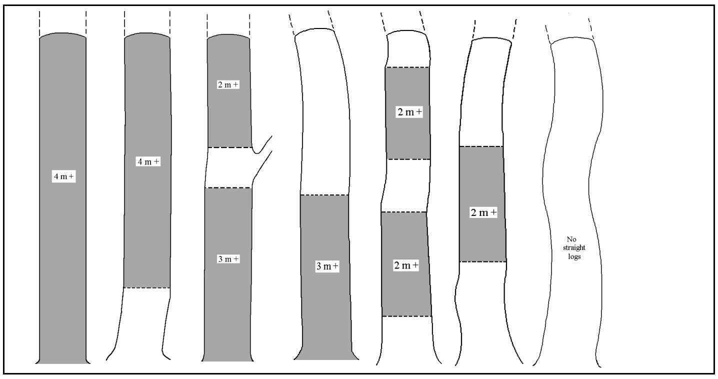


Figure 1. *Different combinations of log lengths in the basal 6 m showing a gradual reduction in quality from left to right. A 4 m+ can only occur on its own; a 3 m+ can only occur on its own or in combination with a 2 m+; a 2m+ can occur on its own or in combination with a 2 m+ or a 3 m+.*

Preliminary field trials and the statistical evaluation of field assessments against observed outputs of log lengths at a commercial sawmill indicate that the scoring system is able to detect potential quality differences in stands of trees of the same species and in different locations.

Secondary sites.
Eddy- covariance measurements are performed at all secondary sites, with data on fluxes of water, carbon and energy exchanges continuously measured above the forest canopy in real time, and stored together with meteorological data at sub-hourly intervals. A comprehensive suite of physiological parameters is also available for all sites, whilst individual studies of hydrological and carbon balance are available at most. These data-sets will be collated to validate and inform the process level sub-models (photosynthesis, respiration and transpiration) of the integrated modelling system.

1.3.2 The Manipulative Component

The **MANIPULATIVE COMPONENT** at the tertiary sites will use existing facilities, consisting of open top chambers and closed growth chambers together with appropriate methods of experimental control. The experimental protocols used at these facilities are well documented and their success in providing the necessary parameters for modelling activities is widely accepted. Three specific activities will be carried out in these facilities:

- induce the individual and combined treatment effects of CO_2**,** temperature and precipitation using established experimental infrastructure;
- produce new juvenile plant material grown under ambient (≅350-370 µmol mol^{-1}) and enhanced CO_2 atmospheres (≅700 µmol mol^{-1}) with individual and combined effects of temperature and precipitation for use in assessing timber growth and quality;
- produce new information to inform model parameterisation, calibration and validation on growth through non-destructive monthly measurements of physiological growth parameters, annual measurements of mensurational parameters and destructive sampling of biomass from tree compartments to develop allometric mass distribution ratios.

1.3.3 The Laboratory Component

The **LABORATORY COMPONENT** will use established laboratory infrastructure and procedures to assess whether the anatomy, biochemical composition and mechanical properties of wood vary as a result of growth conditions (climate and CO_2 concentration). Laboratory procedures will be used to assess these characteristics for:

- new plant material from the monitoring and manipulative experiments;
- existing plant material produced in previous manipulative experiments;
- over-mature standing timber, to contrast properties for timber grown at ambient (≅350-370 µmol mol^{-1}) and elevated CO_2 concentrations (≅700 µmol mol^{-1}).

Anatomical	Biochemical	Mechanical
Lumen diameter	Non-structural and structural carbohydrate content	Wood density
Vessel/fibre length	Total lignin, cellulose and hemicellulose content	Mechanical stress
Tissue wall thickness of early and latewood	Total N content (also for other compartments e.g. leaf, branch, stem, fine and coarse roots)	Drying distortion
Ratio between tissue types		Knot area
Annual ring widths		Slope of grain / spiral grain
Compression/reaction wood		Juvenile and compression wood area
Wood decomposition by saprophytic fungi and micro-organisms		Micro-fibre angle

This component will provide invaluable information on the likely effects of enhanced atmospheric CO_2 concentrations on a suite of biochemical, anatomical and mechanical properties that are directly relevant to the modelling of timber quality, and its coupling to the modelling of growth and yield.

1.3.4 The Modelling Component

The **MODELLING COMPONENT** of the research will build upon existing state-of-the-art empirical and process-based models available in the consortium, simulating timber yield at the forest stand scale under current and future scenarios of atmospheric composition, integrated with:

- a coupled empirical-process sub-model of timber quality as affected by ambient and modified atmospheric composition, environmental change and management;
- sub-models for estimating the productivity of a range of wood products;
- energy budget sub-model for the energy costs of production and exploitation of wood products.

In turn, the forest growth-quality stand scale model will inform an existing and upgraded large-scale scenario model which up-scales stand features to the forest management scale.

1.3.4.1 The Stand Scale Growth-Quality Model

In the model, microclimate state variables (T_{min}, T_{max}, total radiation and PPFD, precipitation, relative humidity, wind speed) and biophysical variables (photosynthesis, soil water balance, stomatal conductance, transpiration, carbon balance, crown growth, cambial activity, height and diameter growth for above and below ground parts) will be simulated at a daily time step.

Weather generator.

A stochastic-deterministic weather generator will be used to downscale monthly- time step inputs. The model requires a minimum of five inputs to produce estimates at different timescales (daily, hourly or smaller) of up to 18 weather variables. Time series of the model outputs are estimated from climatic statistics derived from instrumental data, and have the same 'intrinsic' properties as the instrumental meteorological data from which they are derived. Monthly instrumental weather data for mean temperature, precipitation and wind speed are input into a first-order Markov chain, coupled to an auto-correlation intensity factor, to generate daily scale estimates of mean, maximum and minimum temperature and wind speed. The same approach is used in a two-state domain to estimate the mean amount of precipitation on a rain day. Algorithms are used to estimate precipitation intensity and duration, and relative humidity. Total, direct and diffuse solar radiation is approximated using a spherical geometry approach, corrected for altitude and latitude. The model will be validated for a representative number of sites within Europe, illustrating a range of climates. The model will be used to simulate transient climates as developed by General Circulation Models (GCMs), for which monthly-time step data are available at the European scale at a 0.5 degree resolution.

Soil water balance.

Soil water balance will be calculated by a daily-time step, multi-horizon capacity model where the spatial and temporal variability of soil water content is determined by changes in soil hydraulic conductivity, soil water storage capacity and the pathways of water movement through the soil and across soil types. Soil water content will be simulated at horizon level; limits on the amount of drainage from one horizon to the next allows the formation of temporary perched water tables, lateral drainage, matric potential and surface runoff. Simulations have shown that the capacitance-type model provides good approximations of point-scale experimental data under a range of soil, climate and drainage management conditions in temperate latitudes. Simulations are close to those developed by a mechanistic model, suggesting that the capacity model can be applied to describe the water balance of multi-horizon soil profiles. The modelling approach used is considered to be applicable to the wide range of soil lower boundary conditions, ranging from free-draining to impermeable, which occur in Europe.

Growth model.

In this model, a tree will be represented by five principal compartments: foliage, branches, stem, structural roots and fine roots, arranged according to a simple model of tree shape. A process-based physiological model of carbohydrate productivity simulates carbon production, where assimilation will be assumed to be proportional to individual tree crown size. Partitioning of dry matter will be based on the model of tree shape, which is used to estimate the relative sizes of different tree compartments and therefore their respiration and demand for assimilates for growth. Changes in tree shape and the relative sizes and growth rates of tree compartments will be determined internally by reference to the pipe theory and externally by competition. Diameter growth will be driven by the pipe theory, while height growth is based on a simplistic model of the relationship between foliage accumulation and branch increment. Growth of structural roots will depend on the quantity of fine roots that needs to be sustained, which in turn depends directly on the quantity of active foliage. Tree stem volume will be integrated from sectional diameters estimated at different heights of the stem. These variables act as an efficient description of the gross shape of individual trees, and their development through time are a record of the effects of environmental and competitive influences upon each tree. For example, a detailed representation of the crown may be generated from $h_{u,t}$, $h_{l,t}$ and $d_{c,t}$, , and their progression through time summarise changes in crown development and interaction with neighbours through time. Although mensurational variables are less well defined below ground, in principle the system of variables described above could be extended to the root systems of trees. In the current version of the model, gross root dimensions are represented by two variables (d_r and h_r).

Figure 2. *Simple model of tree morphology based on mensuration variables.*

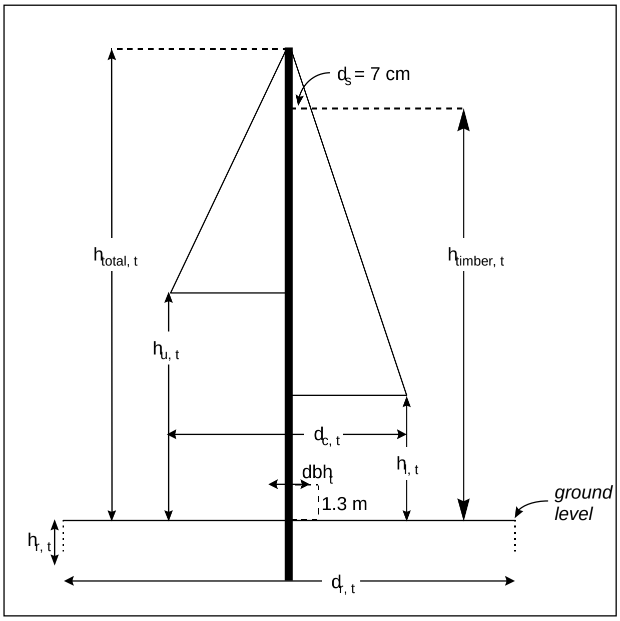


Figure 2 shows a simplistic representation of a coniferous tree in terms of fundamental mensuration variables as implemented, with the following interpretation:
$h_{total,t}$ = total height of tree from ground at time *t* (m);
$h_{timber,t}$ = height to point on main stem that is 7 cm diameter over bark (m);
$h_{u,t}$ = ‘upper crown’, height of lowest complete live whorl of branches (m);
$h_{l,t}$ = ‘lower crown’, height of lowest live branch (m);
dbh_t = ‘diameter at breast height’, stem diameter 1.3 m from ground (cm);
$d_{c,t}$ = average projected diameter of crown (m);
$d_{r,t}$ = average diameter of structural root plate at time *t* (m);
$h_{r,t}$ = average depth of structural root plate (m).

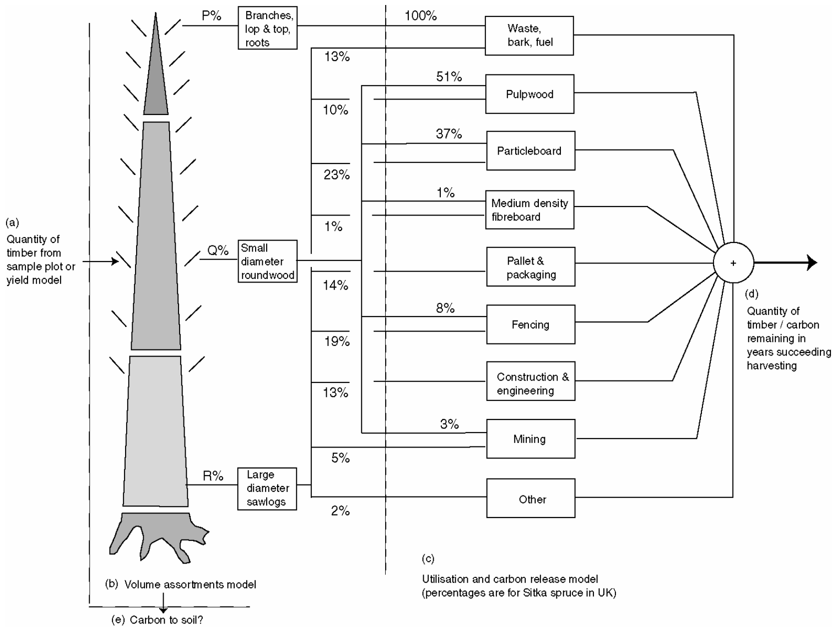
Carbon production*.*
The model for CO_2 uptake and conversion into carbohydrate ‘building blocks’ allocated to tree compartments will be a coupled solution to assimilation, stomatal conductance, net radiation, transpiration and leaf temperature. In the model CO_2 demand by photosynthetic tissues will be balanced by CO_2 supply describing inter-cellular CO_2 diffusion from the atmosphere via the stomata and cuticle to the sites of photosynthesis; nitrogen effects on photosynthesis are also described. An additional sub-model will describe the response of stomata to physiological and environmental variables.
Cambial growth.
The cambial processes of division, enlargement, wall thickening and functional specialisation of a row of xylem cells within an annual growth ring, at different development stages (cambial initial, maturing and fully mature), are regulated by crown growth rate, photosynthetic activity and stem water potential, as determined by stomatal resistance. Processes controlling cell growth result in variations in cell size and wall thickness as the cell matures until its death at full maturation. Functional specialisation of cell types (support, conductive and reserve tissues) will be introduced into the model based on empirical probability ratios derived from the laboratory phase, which will link the field data developed through manipulative experimentation and modelling. Timing of growth will be regulated by bud burst that is driven by a phenology sub-model.
Linking growth with quality**.**
The proposed research will integrate the stand growth model with growth-related quality sub-models predicting:
- profiles of annual ring development along the stem of the tree, with the potential to allow for inter-annual variation;
- inception year, position and distribution of primary branches along the stem of the tree, as well as branching angle and branch diameter;
- gross stem curvature, presence of ‘stops’ or forks and more complex departures from straightness.

Wood products sub-model.
A wood product out-turn sub-model will be developed, building on existing models of tree architecture adapted to predict aspects of stem quality, such as ring width, knot distribution and branching characteristics, as an integral component of the growth and yield model. One component of this sub-model will be used to predict stress grade yields from measured growth characteristics. Complementary methods of practical field assessment will be developed for use as input to model forecasts.

1.3.4.2 Energy Budget Sub-Model.
A policy-level energy and carbon accounting sub-model, linked explicitly to the wood product sub-model and integrated with a process energy analysis sub-model, as well as appropriate databases underpinning sub-model operation, will be developed. The modelling approach is summarised in

diagrammatic form in Figure 3. The model will predict energy inputs and flows of carbon related at the stand scale, accounting for stand management and harvesting operations, as well as energy costs related to production and processing of specific wood products and product mixes. The energy budget sub-model will be nested within the large-scale scenario model to permit up-scaling of these estimates to regional level. Simulation of European cross-sector energy budgets in relation to policy and economic scenarios is beyond the scope of the proposed research and is specifically excluded.

Figure 3. *Diagrammatic representation of a typical energy budget sub-model*.



Model parameterisation.
The essential data required to inform the parameters required by the forest stand model will, in part, be obtained from previous and ongoing experiments that represent the state-of-the-art and developed by individual partners in the consortium. However the successful coupling of the sub-models will rely heavily upon new data, to be obtained both from the monitoring and the manipulative components of the project. Data from the primary sites will be used in the model development and calibration, whilst data from the secondary sites, where growth measurements in enhanced CO_2 will be made, will be used for model validation for scenarios of future atmospheric composition.
Prototype.
The forest stand scale model for predicting timber yield and quality will be developed into a prototype system with improved information as to the sensitivity of the response of production forests and of timber quality to current and future scenarios of atmospheric change and management.
The Upscaling Model.
The upscaling model incorporates an existing forest inventory database, held by Partner 3, which includes forest area, standing volume and increment from 30 European countries; these data are queried by country, region, owner class, site class, tree species and age class. Forest area covered in the database is 146.4 millions ha, distributed across 2527 forest types; the level of detail varies between countries. Outputs of the up-scaling model will inform policy advisors as to the sensitivity of the response of production forests and of timber quality to current and future scenarios of atmospheric change and management.
Description of EFISCEN.
EFISCEN is a forest resource assessment model, especially suitable for strategic, large scale (> 10,000 ha), long-term (20–70 years) analysis. EFISCEN 2.0 is suitable for assessments of the future state of forest under assumptions of future felling levels. EFISCEN 2.0 consists of a module for even aged forests and one for uneven aged forests.
The core of the growth simulator of the even aged part of EFISCEN 2.0 (European Forest Information Scenario) model is based on a model developed by Ola Sallnäs at the Swedish University of Agricultural Sciences for even-aged forests. The original aim was to develop a forest growth model that could be incorporated into a forest sector model. During the early 1990's this model was modified and used by IIASA (International Institute for Applied Systems Analysis) to study the effect of air pollution on European forests.

EFISCEN is currently in use and under further development at the European Forest Institute (EFI) for developing new forest resource projections at the European level and in the Russia. At the EFI the model has been validated with historical data (Nabuurs et al. 2000). The main advantage of this model is that it is not very data intensive, requiring rather basic forest inventory data which most of the European countries have available in a harmonised way. This makes the model suitable for use in a large number of countries.
The basic input data of the EFISCEN 2.0 even aged model are forest area, growing stock and increment by age classes, i.e. data that are gathered in most national forest inventories. The basic output of the model consists of forest states at five years interval, in terms of e.g. growing stock, increment, felling and age class distribution. If additional input data about growth change in future is provided, the model can adjust the growth of the forest inventory. Furthermore, if data of distribution of biomass and litter production is provided, the model can calculate the forest carbon budget.
In the even aged part of EFISCEN 2.0 the following adaptations have been introduced into the model:
Thinnings have been incorporated in a different way in the model, resulting in more realistic growth after thinning;

- The growth rates at high growing stocks have been modified;
- All calculations are now carried out for five-year age classes;
- Transient growth rate changes due to e.g. environmental changes can now be incorporated;
- Full forest biomass balance can be calculated, including soil carbon.

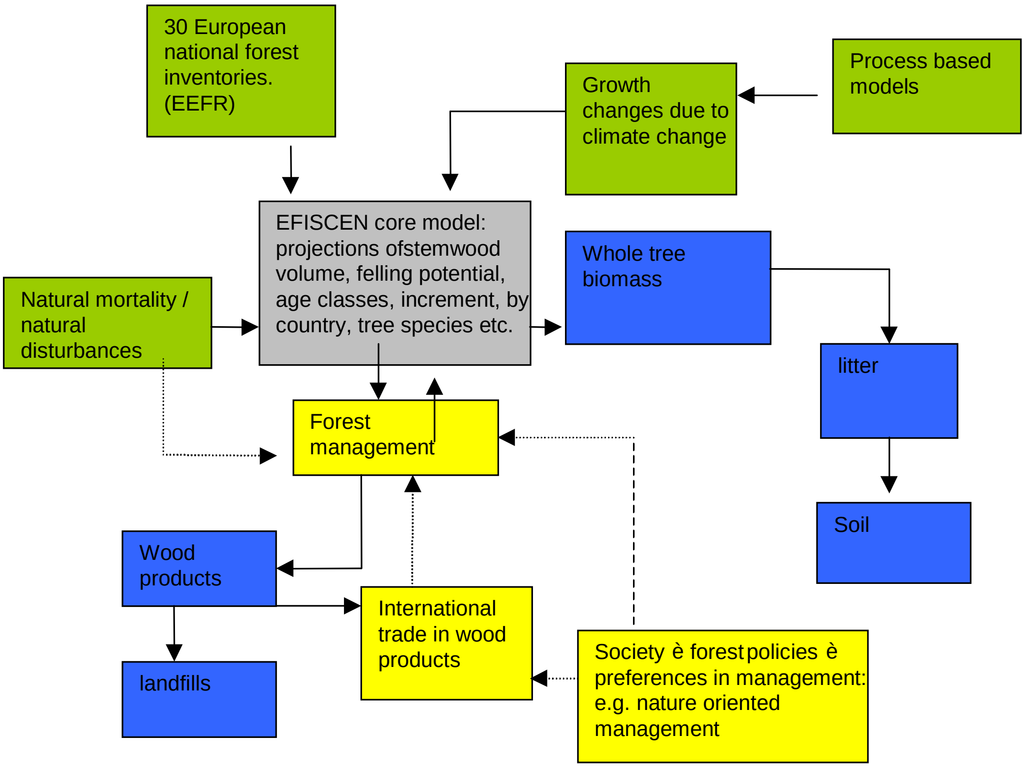
Some countries in Europe gather their forest inventory data by diameter classes. This so-called uneven-aged approach is in use for parts of Belgium, France and Italy and the whole of Spain.
The EFISCEN model is under constant development and version 3.0 will incorporate natural mortality rates and a stochastic approach for natural disturbances. EFISCEN version 4.0 will incorporate a multi country module that links the countries through consumption rates and wood products trade flows.
For the LTEEF-II project, the model has been adjusted to calculate the carbon budgets of the trees, the forest soil and wood products. With this adapted model, it is also possible to adjust forest growth under changing climatic conditions according to predictions of process based models. For the carbon budget calculations, biomass distribution parameters, weather data and litter production data are also needed.

Forest management in EFISCEN is provided for in terms of thinning and final felling regimes, and total volumes to be thinned and clear-cut by tree species group. Final felling is expressed as a probability, dependent on the stand age or actual standing volume. These probabilities are converted into a proportion of the area in each cell that can be felled. The actual area felled in a cell depends of the requested volume to be harvested and volume available in the species group. A felled area is moved to a bare-forest-land class. Regeneration is regarded as transition of area from the bare-forest-land class to the first volume and age class. The amount of area that is regenerated is regulated by a parameter that expresses the intensity of the regeneration (young forest coefficient). This parameter is a percentage of the area in the bare-forest-land class that will move to the first volume and age class during the following five years.

Harvested timber is processed into products in a wood products sub-model. This model keeps track of the products until they are removed from use and the carbon in the products then is released back into the atmosphere. The conversion of timber into wood products is based on product/timber units typical for the wood processing industry. The final products are divided into eight usage categories to describe the use of raw material in production and the use of products. At the end of its primary use, products can be recycled, burned to generate energy or disposed of into landfills. In landfills, disposed products decompose slowly, releasing carbon into the atmosphere. Running the model with harvesting data dated from 1960 initialises the wood product model.

Carbon stocks and stock changes in tree biomass, soil and products are calculated per region but are usually presented by country. In order to allow comparison with flux measurements and flux modelling, gross primary production (GPP, net primary production plus respiration of tree biomass), net primary production (NPP, net tree biomass carbon balance plus litter production and timber harvesting), net ecosystem exchange (NEE, = NPP plus net soil carbon balance), net biome production (NBP, = NEE minus timber harvesting), net product exchange (NPE, net product carbon balance), and net sector exchange (NSE, = NBP plus NPE) are calculated. Carbon budgets are presented as average values per hectare (average for the area) or for the whole area in consideration.

Figure 4. *Outline of the EFISCEN model. The EFISCEN model can simulate development of forest resources and forest sector carbon budget on a regional and country levels with given input data and scenarios (forest inventory data as input, possible changes in the increment, biomass allocation and litter production, management regimes).*

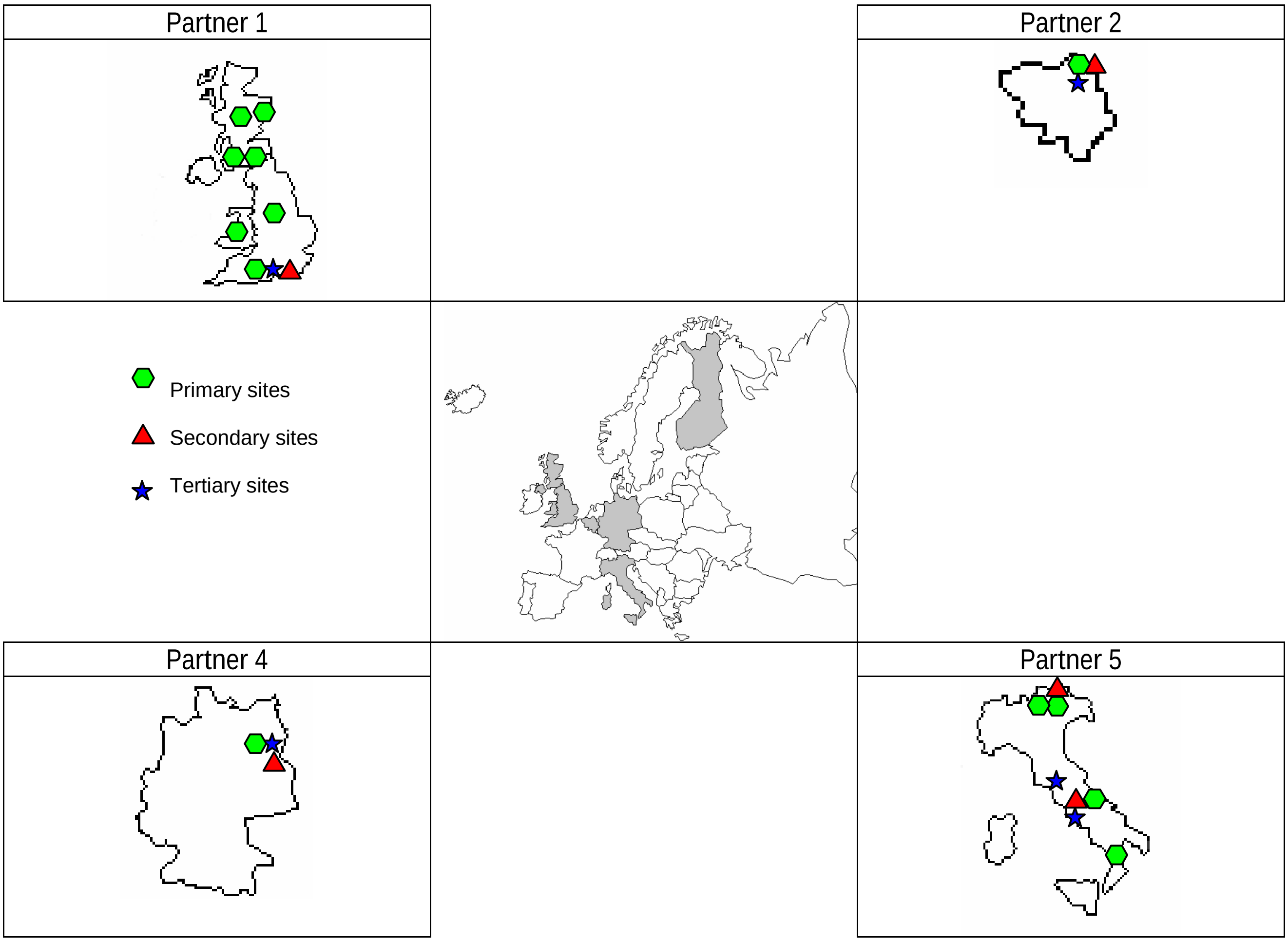


1.3.4.3 Model integration.

The stand scale process-based model will inform the projections of the up-scaling model of forecasted changes in growth, timber yield and quality at stand scale resulting from the combined effects of environmental change and management practices by explicitly simulating those physical, biophysical and biological processes associated with plant growth. When integrated with existing and new data on growth response to management practices, standing volume, increment/yield projection and quality functions will be developed for a number of production species in Europe, namely oak (OK), beech (BE), poplar (PO), Scots pine (SP), Sitka spruce (SS) and Norway spruce (NS). The formal coupling with the large-scale scenario model will be achieved through the increment/yield projection and quality functions for each species. By coupling the new yield/quality functions to the existing database on standing volume and increment held within the up-scaling model, this 'nested' approach permits the prediction of changes of both wood productivity and quality resulting from future environmental change and management practice at the regional levels. This approach will be applied to the regions/countries studied as part of this project and tested under current climates using available forest statistics, life cycle analysis data and wood products inventories.

The Sites

Figure 5. *Distribution map of primary, secondary and tertiary sites.*



Site responsibilities

	Number of Sites		
Responsible Partner	Primary	Secondary	Tertiary
1. Forestry Commission – UK	9	1	1
2. Antwerpen – Belgium	1	1	1
4. Berlin – Germany	1	1	2
5. Tuscia – Italy	4	2	2
TOTAL	15	5	6

1.3.5.1 Primary Sites

At each site sample plots will be established within existing spacing, thinning and fertiliser experiments in managed forests. In these plots standing trees will be assessed, using a standard protocol across all partners, to generate data for growth and quality model calibration and validation. To maximise the use of existing data, selected sites from the UN/ECE ICP Forests Level II Forest Health Monitoring Network in the Partners' member states will also be used, where data collection is ongoing[4]. A quality protocol will be introduced to assess timber quality potential of standing trees. Primary sites also provide the sources for additional field observations and locations for monitoring. Samples of plant material will be taken for anatomical, chemical and structural analyses to identify climatic/latitudinal, management and treatment effects on wood quality. Sites have been selected to represent a limited number of productive species in Europe, namely oak (OK), beech (BE), poplar (PO), Scots pine (SP), Sitka spruce (SS) and Norway spruce (NS).

[4] Approval has already been granted by the Intensive Monitoring Programme of Forest Ecosystems in Europe Programme (DG VI) for this project to use the experimental sites and historical data collected in long-term monitoring plots.

Partner 1. Two series of primary sites are listed below. Paired UN/ECEICP Level II plots (for oak, Scots pine and Sitka spruce) are available for single species model calibration and validation. In addition, two experimental stands have been selected to enable the effect of management intervention on stand growth and quality to be investigated. Whilst these experimental sites do not have the same intensive environmental monitoring activities as at the Level II plots, they were all established as permanent mensuration sample plots over 50 years ago. Thus, a long run of increment data is available and will demonstrate the effect of management on a mature crop. Sites have been selected to allow both model calibration and validation.

(1) *Site 1* **(Straits – UK)** is a relatively homogenous and mono-specific forest block planted with oak in the 1930s covering an area of approximately 70 ha. There are UN/ECEICP Forests Level I and II forest health plots within the block. Other species (mostly ash, *Fraxinus excelsior*) make up 10% of the tree cover and the understorey is dominated by hazel *(Corylus avellana),* hawthorn *(Crataegus monogyna), Rubus* spp. and various grass and herbaceous species. The soil is a pelo-stagnogley with a depth of 80 cm to the C horizon of the Cretaceous clay. The pH is 4.6 and 4.8 in the organic and mineral horizons respectively. Top height and DBH were 19.3 m and 25.9 cm respectively in 1995 at a density of 606 trees per hectare resulting in a basal area of 22 m^2 ha^{-1}; general yield class is 6 and the site was last thinned in 1995 (and 1991). Daily meteorological data are available from 1955 (within 5 km of the stand), and an automatic weather station was installed in 1994. Total nitrogen deposition was 9.1 and 7.4 kg ha^{-1} in 1996 and 1997, respectively, and a continuous pollution record (hourly concentrations of SO_2, NO_x, O_3) is available from 1987, and NH_3 (monthly values) from 1996. Mean annual rainfall is 780 mm, and mean annual temperature 10.6 °C.
(2) *Site 2* **(Coalburn – UK)** is a Sitka spruce plantation established in 1974 and designated an UN/ECEICP Level II forest health monitoring plot in 1994. It is part of a large upland (300 m a.s.l.) production coniferous forest Mean top height is 10.9 m, DBH 27.1 cm, stocking density 2118 trees per hectare resulting in a basal area of 47.1 m^2 ha^{-1}. General yield class is 18 and the site is unthinned. The soil type is a cambic stagnohumic gley; with an effective rooting depth of 35 cm. Ground vegetation is limited to mosses and lichens. The area has been the subject of a catchment study of water quality and quantity since 1971, and automatic weather station data are available from 1980, with a long-term weather (1959) and pollution (1974) data-set available for a site within 20 km and 50 m altitude. Annual rainfall is approximately 1200 mm and total nitrogen deposition (after REF. 70) was 11.9 and 10.2 kg ha^{-1} in 1996 and 1997, respectively.
(3) *Site 3* **(Tummel – UK)** is a Sitka spruce plantation (400 m a.s.l.) established in 1969. Mean top height is 14.7 m, DBH 15.8 cm, stocking density 2747 trees per hectare, resulting in a basal are of 59.2 m^2 ha^{-1}. General yield class is 16 and the site was thinned in 1997. The site was designated an UN/ECE ICP Level II tree health monitoring plot in 1995. The soil type is a ferric podzol with an effective rooting depth of 50 cm. Ground vegetation is absent. Annual rainfall is approximately 1500 mm. Long term weather records are available for a site 30 km distant and the data from the automatic weather station at Site 4 (see below) is applicable to this site, given their proximity. Total nitrogen deposition is approximately 6 kg ha^{-1} a^{-1}.
(4) *Site 4* **(Rannoch – UK)** is an unthinned upland Scots pine plantation (470 m a.s.l.) established in 1965. Mean top height is 11.1 m, DBH 12.7 cm, stocking density 2776 trees per hectare, resulting in a basal area of 32.8 m^2 ha^{-1}. General yield class is 8. Annual rainfall is approximately 1500 mm, and an automatic weather station was installed in 1997. The site was designated an UN/ECE ICP Level II tree health monitoring plot in 1995. The soil is a humo-ferric gley podzol with an effective rooting depth of 85 cm, and grasses and mosses dominate 100% ground cover. Nitrogen deposition and climate are similar to that at site 3.
(5) Site 5 **(Grizedale – UK)** is an oak plantation (120 m a.s.l.) established in 1920. The plot is within a mixed species forest with rolling/mountainous topography. Mean top height is 18.4 m, DBH 30.2 cm, and stocking density 310 trees per hectare (under-stocked at present) resulting in a basal area of 20 m^2 ha^{-1}. The soil is a brown podzol with an effective rooting depth of 50 cm. Mean annual precipitation is 1800 mm. Understorey vegetation cover is approximately 50%, and is dominated by grasses, bilberry, bracken and mosses. A long-term weather station is located within 2 km, and an above canopy weather station was installed in 1998. The site was designated as an UN/ECEICP Level II tree health monitoring plot in 1995 and a pilot study to upgrade the Level II protocol to enable process modelling of tree growth has been in operation for two years. General yield class is 4, and total nitrogen deposition approximately 19 kg ha^{-1} a^{-1}.

(6) *Site 6* **(Thetford – UK)** is a Scots pine plantation (30 m a.s.l.) established in 1967 in a flat lowland area. Mean top height is 12.7 m, DBH 15 cm and stocking density 1720 trees per hectare resulting in a basal area of 37 m^2 ha^{-1}. The site was thinned in 1994 when it was established as a Level II plot. Ground vegetation cover is complete and is dominated by grasses, bracken, mosses and nettles. In addition to Scots pine, the canopy includes a scattering of other species *(Pinus strobus,* sycamore and oak). The soil is a brown calcareous sand with an effective rooting depth of 80 cm. Annual rainfall is 600 mm and nitrogen deposition is 15 kg ha^{-1} a^{-1}. Long-term weather data are available within 1 km of the stand.
(7) *Site 7* **(Clunes – UK)** is a Norway spruce plantation (76 m a.s.l.) planted in 1935 and with an average stocking density of 1145 trees per hectare. The site is a permanent mensurational plot that has been assessed in 1969, 1973, 1976, 1981, 1986, 1991, 1996 and 2003. The soil is a surface water gley. No ground vegetation is recorded.
(8) *Site 8* **(Sawley – UK)** is a Sitka spruce plantation (230 m a.s.l.) planted in 1943 with a 2.7 m spacing interval and three thinning regimes. The site is a permanent mensurational plot that has been assessed in 1974, 1979, 1984, 1989 and 1997. Ground vegetation is sporadic, with occasional *Deschampsia,* mosses and ferns. The site is a moorland plateau, and the soil type is a brown earth with an effective rooting depth of 40 cm.
(9) *Site 9* **(Hope – UK)** is a Scots pine plantation (265 m a.s.l.) planted in 1952. Soil type is a sandy podzol. There are some *Fagus sylvatica* and *Quercus petreae*, and the ground vegetation is primarily *Prunus serotina* and *Sorbus aucuparia*. Annual rainfall is 960 mm. The site was designated an UN/ECE ICP Level II tree health monitoring plot in 1995.

<u>Partner 2</u>.
(1) *Site 10* **(Brasschaat – Belgium)** is at 15 m a.s.l. The site is on moderately wet sandy soils with a tendency to podsol, planted with 70 year old mixed pine-deciduous vegetation comprising *Pinus sylvestris L., Quercus robur* L. and *Fagus sylvatica* L. Understorey species mainly include *Rhododendron ponticum, Prunus serotina* Ehrh. and *Molinia caerulea. The* average stand height is 23 m and the annual volume increment of the Scots pine is 7 m^3 per year. The total area of the forest is over 150 ha. Mean annual temperature is 10°C and annual precipitation is 750 mm. The site is an UN/ECE ICP Level II observation plot of the European programme for Intensive Monitoring of Forest Ecosystems.

<u>Partner 4</u>.
(1) Site 11 **(Grünewald – Germany)** is at ca. 50 m a.s.l. The soil is a Ferric Cambisol developed on alluvial sand with a tendency to Podsol; pH is in the range of 3.0 - 4.8. The site is indicated as a 140 an old *Pino-Quercetum,* but dendrochronological analyses have identified only a few *Pinus sylvestris* L. and *Quercus robur* L. individuals older than 100 as. Dominant species are *Pinus sylvestris* L. and *Quercus robur* L., with subdominant individuals of *Fagus sylvatica* L. and *Quercus petreae* (Matt.) Lieb.; the shrub layer is composed of *Prunus serotina* Ehrh. and *Sorbus aucuparia* L. Herbaceous layer is dominated by seedlings of *Acer pseudoplatanus L., Avellana (Deschampsia) flexuosa* (L.) Parl., *Agrostis tennuis* Sibth., *Luzula campestris* (L.) DC., *Rumex acetosella* L. and *Hypericum perforatum* L. Mean tree height is 21.9 m for pine and 10.5 m for oak, with a max rooting depth of 4.5 m and 196 pine and 973 oak trees in the research plot. Mean annual increment of stem and branch wood is 1,573 kg ha^{-1} a^{-1} for pine and 849 kg ha^{-1} a^{-1} for oak, respectively; needle dry mass is 5.9 t ha^{-1} and leaf dry mass is 3.3 t ha^{-1}. The site has been part of UNESCO's MAB programme since 1987 and the EU Forest Ecosystem Research Network since 1988.

<u>Partner 5</u>.
(1) *Site 12* **(Collelongo – Italy)** is at ca. 1500 m a.s.l. The site is on calcareous brown earth and is a natural regeneration stand of approximately 100-yr old *Fagus sylvatica.* The stand is within a 3000 ha community forest that is part of a wider forest area, included in a national park. The stand has been studied for tree biomass distribution above- and below-ground, stem growth (stem analysis) and biomass productivity. Biomass study involved the felling and analysis of 25-30 trees distributed over the diameter range of the forest trees. Below-ground biomass was investigated on 6 of those trees; results indicated that 25% of a total woody biomass of 280.8 t ha^{-1} is made up from roots, while root/shoot ratio is 0.33. Mean annual increment of total biomass is 2.81 t ha^{-1} a^{-1} and that of root is not negligible, reaching about 0.7 t ha^{-1} a^{-1}. Dominant beech trees are still growing in height and this is true also for dominated trees, although to a lesser extent. Aboveground net primary production (stem, leaves, branches) is around 578 g m^2 a^{-1}. Below ground NPP is *ca.* 1016 g m^2 a^{-1}, divided into 106 g m^2 a^{-1} for main root apparatus increment and 910 g m^2 a^{-1} for total fine root turnover. In total, the NPP reached

1594 g m^2 a^{-1} with more than 60% allocated to below-ground components. The mean annual temperature of the site is 6.2°C, while the mean annual precipitation is 1100 mm. Absolute maximum temperature can be higher than 30 °C, while absolute minimum can reach –25°C. Snow cover can last 3.5 months, from the end of December to mid April. The growing season is between early May and early October (140-160 days). The climate is montane-mediterranean, and the occurrence of summer water stress is not unusual. The environmental and structural conditions of the stand are representative of the region's beech forests. Since the early 1990s structural studies have been conducted out in 7 sampling sites in two different and contrasting areas. *Area 1* (1600 m a.s.l.), with trees covering the upper zone of the mountain with flat areas alternating with more or less steep slopes, and *Area 2* (1300-1500 m a.s.l.), a fairly steep, fresh and north facing valley. At both sites several stands will be identified with different structure and developmental stage, as well as stands growing on different mountain aspects and slopes. *Area 1* is an UN/ECE ICP Level II observation plot of the European programme for Intensive Monitoring of Forest Ecosystems.
(2) Site 13 **(Catena Costiera – Italy)** at ca. 1500 m a.s.l. This site offers an optimum environment for *Fagus sylvatica.* Some of the stands have been recently thinned. *Area 1* (915 m a.s.l.) is an UN/ECE ICP Level II observation plot of the European programme for Intensive Monitoring of Forest Ecosystems, managed by the Ministry of Agricultural Policies. Within these forests a representative forest stand will be identified and described for its structure, species composition, stem form and quality.
(3) Site 14 **(Tesino – Italy)** *is* from 800 to 1600 m a.s.l. The community forests covers a total area of about 10,000 ha and are composed mainly of mixed coniferous stands of *Picea abies* L. and *Abies alba* Mill., with a small proportion of *Fagus sylvatica* L. These are all managed forests with an uneven age structure and a MAI of about 5 t ha^{-1} a^{-1}. Within these forests a representative forest stand will be identified and described for its structure, species composition, stem form and quality.
(4) Site 15 **(Renon – Italy)** is at ca. 1700 m a.s.l. The existing research area has a surface area of 9000 m^2 and it is inside a forest of *Picea abies* L. with the sporadic presence of *Pinus cembra and Larix decidua.* The understorey is rich in small shrubs, mainly blueberries *(Vaccinium myrtillus* L. and *V. vitis-idaea* L.), and herbs *(Melampaum sylvaticum L., Homogyne alpina L., Hieracium sylvaticum).* Sampling all the trees with a DBH greater than 12.5 cm, showed that the forest stand has a density of 270 trees ha^{-1}, with a basal area of 25.7 m^2 ha^{-1} and a standing volume of 241.3 m^3 ha^{-1}. The mean height of the 10 larger trees is 24.8 m. Mean age of the stand is 80 years. The stand is of natural origin and is managed through selective fellings, although less intensively in recent years. In terms of stem volume, larch and pine are present in the same proportion (8.3%), while the dominance of spruce is confirmed (83.5%). The distribution in diameter classes is homogenous for spruce, indicating an uneven aged structure; pine is characterised by the presence of very few large specimens, while larch is present with large trees and an absence of a regeneration layer. In the vicinity of this site is an UN/ECE ICP Level II observation plot of the European programme for Intensive Monitoring of Forest Ecosystems. Within this site a representative forest stand will be identified and described for its structure, species composition, stem form and quality.

1.3.5.2 Secondary Sites

Secondary sites will be located at existing monitoring sites where flux data from standing forests are currently being collected under ongoing EU projects which involve partners from the current project, to generate data for short term validation of the growth model.

<u>Partner 1</u>
(1) Site 1 described above. A system for measuring CO_2 and H_2O and energy fluxes was installed in March 1998, and a continuous record is available from May 1998. Net ecosystem flux from June 1998-May 1999 was 3.3 t C ha^{-1} with leaf area index of the over canopy rising to 4.7 in mid-summer.

<u>Partner 2</u>
(1) *Site 10* described above. A 40 m tall self-supported square tower is installed at the site, with an eddy covariance flux measuring system (three-dimensional sonic anemometer and fast-response gas analyser) and an extensive set of meteorological sensors above and within the canopy installed on the tower. Fluxes of water, carbon and energy exchanges are continuously being measured above the canopy in real time, and stored together with meteorological data at half hour intervals.

Partner 4
(1) Site 11 described above. The field station is equipped with gas exchange measuring instrumentation, a tower and a mast for microclimatic measurements. Gas exchange measurements at different heights in the canopy have been conducted since 1997.

Partner 5
(1) *Site 12* is a site where eddy covariance measurements are performed as part of ongoing EU projects. Data were collected for a whole year between spring 1993 and spring 1994 and some daily campaigns were collected in 1995. Since 1996 data have been collected continuously.
(2) *Site 16* **(Selva Piana – Italy)**. The site is fully equipped with micrometeorological sensors and all the instrumentation required, measuring canopy fluxes of carbon and water vapour.

1.3.5.3 Tertiary Sites

Tertiary sites are located at, or close to, the established centres of field research participating in this project, where existing facilities for experimental manipulation of CO_2, temperature, water supply and fertilisation are available. These sites will be used to generate new data for the growth and quality model calibration and validation under conditions of enhanced CO_2. Tertiary sites will be used for experimental observation, where samples of plant material will be taken for anatomical, chemical and structural analyses to identify single and combined effects of enhanced CO_2, temperature and droughtiness effects on wood quality. To maximise the use of existing data, plant material generated from past and ongoing manipulative experiments will also be used to develop new model calibration and validation data.

Partner 1.
(1) *Site 17* **(Headley Nursery – UK)**. 16 open top chambers were installed in 1985 and modified to allow manipulation of soil moisture, CO_2 and ozone concentrations in 1994. The chambers are 4 m tall, 3 m in diameter, and airflow is adjusted to two air changes per minute. The soil within the chambers is a heavily cultivated humo-ferric podzol with a pH of approximately 4.0. Chambers are covered to allow more precise manipulation of available water. Ventilation is maintained by removing one layer of glass from the-side walls. Available plant material from completed elevated CO_2 experiments includes the following species: *Pinus sylvestris, Fraxinus excelsior, Quercus petraea, Q. robur and Q. rubra.* Seeds of *Q. robur, Fagus sylvatica, Nothofagus obliqua, Acer pseudoplatanus, Pinus nigra* (var. *maritima*) and *Pseudotsuga menzeii* have been sown in a greenhouse at 600 ppm CO_2 and will be planted in the open top chambers in March 2000. All chambers will receive ambient or ambient precipitation reduced by 25% and ambient or 600 ppm CO_2. This will therefore allow the effect of rising atmospheric CO_2 and drought on wood quality parameters for six lowland forest tree species to be investigated. Plant material (currently held elsewhere) is also available from an identical facility where *Alnus glutinosa, Pinus sylvestris, Picea abies, Picea sitchensis and Betula pendulans* were exposed to combinations of elevated CO_2 concentrations and nutritional regimes.
Partner 2.
(1) Site 18 **(Antwerpen – Belgium)**. Several open top chambers are being used for impact studies of increased levels of atmospheric CO_2 on different tree species. Each decagonal open top chamber has a usable ground area of 7.1 m^2 and air volume is changed nearly twice per minute. Two different atmospheric CO_2 concentrations are supplied to the chambers, i.e. one at ambient CO_2 concentration (ca. 350 • mol mol^{-1}) and one at elevated CO_2 concentration (ambient + 400 • mol mol^{-1}). In the past impact studies have been carried out for three years on different poplar clones, while since 1996 Scots pine seedlings have been monitored under both CO_2 concentrations. Three-year-old seedlings of local provenance were planted in the open top chambers in March 1996 and have been treated continuously in the open top chambers since April 1996. To reduce boundary effects, each open top chamber is surrounded by seedlings of the same provenance and seed lot. Measurements of growth, physiology, development and productivity have been made over the last three years and will continue in the future. Long-term treatments with different CO_2 concentrations are being envisaged for the future continuation of the experiment.

Partner 4
(1) Site 19 **(Berlin – Germany)**. Six acrylic glass mini-greenhouses covering an area of 0.8x0.8 m^2 over a 0.4 m^3 nutrient rich garden soil block have been used since 1996 to investigate responses of juvenile stands to elevated CO_2 concentrations (698±10 • mol mol^{-1}) for beech and pedunculate oak. All greenhouses are acclimatised to the ambient microclimate (temperature variation ± 0.5°C, relative humidity ± 15%; wind speed within the 0.2 - 0.5 m s^{-1} range). Three greenhouses serve as ambient air

controls (360±34 • mol mol^{-1} CO_2). Four greenhouses were planted with beech and 2 with 1.5-yr old oak saplings. Soil water content is maintained constant manually at a volume of 20% and soil water content is monitored at 3 different depths using the TDR technique. The aerial parts of the greenhouses are replaced each year in order to follow stand growth, and are currently ca. 3 m^3. Four adjacent open plots have the same number of saplings (starting number = 48 per plot, n = 36 in the 2nd and n = 25 in the 3rd year, respectively). Continuous monitoring Of CO_2 gas exchange rates in the stand, including the rooted soil compartment has been monitored continuously since planting.
(2) Site 20, located near site 18 **(Berlin – Germany)**. Ten phytotron cabinets have been established to investigate the combined temperature and CO_2 effects on growth, morphology and anatomy of potted beech, pedunculate oak and Scots pine. The facility houses automated equipment for measuring and regulating CO_2, temperature and relative air humidity. Using the local 1909-1969 baseline, for minimum monthly nightly and maximum daily air temperature, temperature levels are adjusted each month. A new experiment has started using CO_2 concentrations of 390 and 700 • mol mol^{-1}, with 5 replicates per experiment, each with 10 beech and 6 Scots pine saplings in 10-litre pots with homogenised medium fertile garden soil; these plants will be used as part of the research proposed under this proposal.

Partner 5.
(1) Site 21 **(Montalto di Castro – Italy)**. The site is a CO_2 enriched experimental site in a Mediterranean evergreen forest ecosystem. Dominant trees of *Quercus ilex L.* are 4 to 6 m high, with accompanying woody shrubs *Phillaea angustifolia L., Matus communis* L. and *Pistacia lentiscus* L. making up a dense, multi-layer canopy. Woody plants are clumped in a typical structure, where the crowns of the dominant trees *(Q. ilex)* intermix with *P. angustifolia,* emerging from a lower layer of *P. lentiscus. The* low palatability of *P. lentiscus* leaves for mammals present in the study ecosystem, suggests a strong interaction between forest structure development and herbivory. The climate of the area is typically temperate-Mediterranean, with rainfall distribution peaking in February and in November. Maximum temperature in summer can be greater than 35°C and is associated with a long dry season. Minimum temperature, generally in January, can be less than -5°C. In this forest, six large open top chambers (OTC) were installed in early spring 1992 to test the effect of atmospheric CO_2 enrichment at community level. Three chambers were randomly assigned to the enriched treatment that consists of a constant addition of 350 • l l^{-1} of incoming air. The resulting doubled atmospheric CO_2, is around 710 • mol mol^{-1}. The remaining three chambers were treated with air at ambient CO_2 concentration. In each OTC, the woody vegetation clump (about 30-years old) is made up on average, of 2xQ. *ilex* trees, 4xP. *angustifolia* and 7x*P. lentiscus shrubs.*

(2) Site 22 **(Viterbo – Italy)** is at an altitude of 25 m a.s.l., where a FACE system has been developed not far from a CO_2 production plant. The main objective of this experimental site is to determine the functional responses of a cultivated, agro-forestry system, a poplar plantation, to current and future atmospheric CO_2 concentrations, and to assess the interactive effects of this anthropogenic perturbation with the other natural environmental constraints on key biological processes and structures. In the context of this research programme, poplar plantations represent a particular type of intensively managed ecosystem where the emphasis is placed on maximising biomass production over a relatively short time-scale. At the experimental site, six FACE rings, each 20 m in diameter, have been installed. CO_2 experimental treatments are enriched and ambient: in the enriched treatment, in three replicate rings CO_2 is being added to reach a concentration of 550 • mol mol^{-1}, which corresponds to the anticipated value for ca. 2050; in the ambient treatment no additional CO_2 is being supplied. Poplar trees are grown under short rotation intensive culture at high density (2x1 m^2 and 1x1 m^2); the first harvest will occur at the 3rd year when trees will be approximately 10 m tall. Within the rings, spacing among trees is close enough to achieve (1) a sufficient number of trees available to conduct the various experimental measurements, and (2) the development of a full canopy after one year from planting. Each ring will be partitioned in two halves corresponding to two different nitrogen-fertilisation treatments. Each fertilisation plot will be divided in three slices (subplots), each planted with a different poplar clone.

Description of the experimental infrastructure held by each Partner.

Country	Species	Age	STRUCTURE OTC	STRUCTURE Phytotron	STRUCTURE FACE rings	Natural/Planted	Size	Air flow rate
BELGIUM	Pinus sylvestris	7 yrs	4			Planted	3 m diameter x 6 m height	5000 $m^3 h^{-1}$
GERMANY	Fagus sylvatica, Quercus robur	1.5 yrs	6			Planted	0,8 x 0,8 m^2	
	Fagus sylvatica, Quercus robur, Pinus sylvestris			10				
ITALY	Quercus ilex, Phillyrea angustifolia, Pistacia lentiscus	30 yrs	16			Natural	4 m diameter x 6 m height	12000 $m^3 h^{-1}$
	Populus nigra, P. alba, P.x euramericana	2 yrs			6	Planted	350 m^2 each	
UK	Pinus sylvestris, Fraxinus excelsior, Quercus petraea, Q. robur and Q. rubra	4 yrs	6			Planted	3 m diameter x 4 m height	

Description of the treatments available at the experimental infrastructure held by each Partner.

Country	Treatment No.	Name	CO_2 ppm	Temperature change	Nutrient status	Water status	Ozone status	Enclosed
BELGIUM	OTC 1.	Ambient CO_2	Ambient	0	Moderate	Moderate	-	Yes
	OTC 1.	Elevated CO_2	Ambient+400	0	Moderate	Moderate	-	Yes
GERMANY	OTC 1.	Ambient CO_2	360 ± 34	0		Low		Yes
	OTC 2.	Elevated CO_2	698 ± 10	0		Low		Yes
	OTC 3.	External control		0		Low		No
	Phytotron 4.	Ambient CO_2	390	-4, -2, 0 = basis, +2, +4				Yes
	Phytotron 5.	Elevated CO_2	700	-4, -2, 0 = basis, +2, +4				Yes
ITALY	OTC 1.	External control	360	0	Low	Low	Low	No
	OTC 2.	Ambient CO_2	360	0	Low	Low	Low	Yes
	OTC 3	Elevated CO_2	710	0	Low	Low	Low	Yes
	FACE 1.	Ambient CO_2	350	0	Low	Low	Low	No
	FACE 2.	Elevated CO_2	550	0	Low	Low	Low	No
UK	OTC 1.	Ambient CO_2	350	0	Low	Low	Low	Yes
	OTC 2.	Ambient CO_2+ O_3	350	0	Low	Low	High	Yes
	OTC 3.	Elevated CO_2+ O_3	700	0	Low	Low	High	Yes
	OTC 4.	Elevated CO_2	700	0	Low	Low	Low	Yes
	OTC 5.	External control	350	0	Low	Low	Low	No

2. ANNUAL WORKPLANS

2.1 WORKPLAN YEAR 1

Year 1 of the MEFYQUE project has primarily focussed on site establishment and field data collection, initial model and database development.

Progress on delivery. To assess progress against project deliverables, the following tables are provided below.

- **Table 5**. Timetable of Project Work-Packages for Year 1.
- **Table 6**. Participant Contribution and Timetable of Activities for Year 1.
- **Table 7**. List of Milestones for Year 1.
- **Table 8**. List of Deliverables for Year 1.

Each table includes a column detailing progress against each task, milestone or deliverable.

Table 5. *Timetable of Project Work-Packages for Year 1*

Work Package	Title of Working Step	Partners	1st year: Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02	Apr 02	May 02	Jun 02	Delivery	Complete
1	a. Establishment of permanent sampling plots at primary sites	**P1** (P2, P4, P5)													Begun Aug 01 and ongoing	
	b. Primary site plot sampling protocol	**P1** (P5)													Version 1 delivered Sep 01, version 8 delivered Jan 02	ó
	c. Secondary site plot sampling protocol	**P2** (P1, P5)													Completed Nov 01	ó
	d. Monitoring and data collection from secondary sites	**P2** (P1, P5)													Ongoing	
	e. Growth & yield data collection from primary and secondary sites	**P1** (P2, P4, P5)													Little training required as plot sampling protocol comprehensive	ó
2	a. Development & training in Timber Quality Assessment protocol	**P1** (P5, AP6, P7)													Little training required as plot sampling protocol comprehensive	ó
	b. Standing timber quality assessment	**P1** (P2, P5, AP6, P7)													Ongoing with site measurement	
3	a. Tertiary site sampling protocol	**P5** (P1, P2, P4)													Completed Oct 01	ó
	b. Monitoring and data collection from tertiary sites	**P5** (P1, P2, P4)													Begun Nov 01 on existing material only	
4	a. Wood anatomy protocol	**P4** (AP6, P7)													First version Jul 01, final version May 02	ó
	b. Wood anatomical laboratory studies (existing and new material)	**P4** (AP6, P7)													Ongoing on new and existing material	
5	a. Wood chemistry protocol	**P4** (P7)													First version Jul 01, final version May 02	ó
	b. Wood chemical laboratory analyses (existing and new material)	**P4** (P7)													Ongoing as material is collected	
6	a. Wood physico-mechanical protocol	**P7** (AP6)													Draft Jul 01	
	b. Wood physico-mechanical analyses (existing & new material)	**AP6** (P7)													Delayed	
7	a. Plot scale model modelling protocols	**P2** (P1, P5)													Completed Jul 02	ó
	b. Plot scale model development and calibration	**P2** (P1, P5)													Ongoing	
8	a. Energy budget sub-model modelling protocols	**P3** (P1, P7)													Completed Feb 02	ó
	b. Energy budget sub-model development and calibration	**P3** (P1, P7)													Completed Mar 02	ó
9	a. Prototype integrated system modelling protocols	**P3** (P1, P2, P5)													Begun Jun 02 and ongoing	
11	a. Development of consortium database and data exchange protocols	**P1** (P2, P3, P4, P5, AP6, P7)													First version Mar 02 and ongoing	ó
	b. Data exchange	**P1** (P2, P3, P4, P5, AP6, P7)													Begun May 02 and ongoing	
	d. Web site updates	**P3** (P1, P2, P4, P5, AP6, P7)													Web site developed Oct 01 and updated Jul 02	
	e. Annual Report	**P1** (P2, P3, P4, P5, AP6, P7)													Completed Aug 02	ó
	f. Consortium meetings	**P1** (P2, P3, P4, P5, AP6, P7)	1										2		Consortium meetings held in Jul 01 (UK) and May 02 (Germany)	ó
	g. MILESTONES		I					II-III			IV		V		See Table 4	ó

Table 6. *Participant Contribution and Timetable of Activities for Year 1*

	Title of Working Step	1st year Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02	Apr 02	May 02	Jun 02	Delivery	Location in 1st Annual Report
Participant 1 FR (UK)	1a Establishment of permanent sampling plots at primary sites													Begun Aug 01 and ongoing	Location maps at Annexes B, C and E
	1b Primary site plot sampling protocol													Version 1 delivered Sep 01, version 8 delivered Jan 02	Annex D
	1e Growth & yield data collection from primary and secondary sites													Delivery to project database begun in May 02	
	2a Development & training in Timber Quality Assessment protocol													Version 1 delivered Sep 01, version 8 delivered Jan 02 Little training required as plot sampling protocol comprehensive	Annex B
	2b Standing timber quality assessment													Ongoing with site measurement	
	11a Development of consortium database and data exchange protocols													First version Mar 02 and ongoing	
	11b Data exchange													Begun May 02	
	11e Annual Report													Completed Aug 02	
Participant 2 UIA (B)	1c Secondary site plot sampling protocol													Completed Nov 01	Annex B
	1d Monitoring and data collection from secondary sites													Ongoing	
	7a Plot scale model modelling protocols													Completed Jul 02	
	7b Plot scale model development and calibration													Ongoing	Annex H
Participant 3 EFI (FIN)	8a Energy budget sub-model modelling protocols													Completed Feb 02	
	8b Energy budget sub-model development and calibration													Completed Mar 02	Annex I
	9a Prototype integrated system modelling protocols													Begun Jun 02 and ongoing	
	9b Development of the prototype integrated model at regional scale													Begun Jun 02 and ongoing	
	11d Web site updates													Web site developed Oct 01 and updated Jul 02	http://www.efi.fi/projects/mefyque
Participant 4 TUB (D)	4a Wood anatomy protocol													First version Jul 01, final version May 02	Annex F
	4b Wood anatomical laboratory studies (existing and new material)													Ongoing on new and existing material	
	5a Wood chemistry protocol													First version Jul 01, final version May 02	
	5b Wood chemical laboratory analyses (existing and new material)													Ongoing as material is collected	
Participant 5 UNITUS (I)	3a Tertiary site sampling protocol													Completed Oct 01	
	3b Monitoring and data collection from tertiary sites													Begun Nov 01 on existing material only	
A Participant 6 RUG (B)	6b Wood physico-mechanical analyses (existing & new material)													Delayed	
Participant 7 BRE(UK)	6a Wood physico-mechanical protocol													Draft Jul 01	Annex G
All	11f Consortium meetings	1											2	Consortium meetings held in Jul 01 (UK) and May 02 (Germany)	
All	11g Milestones	I					II-III			IV		V		S	see Table 4

Table 7. *List of Milestones for Year 1*

Milestone No	Associated WPs	Title	Delivery Date	Participants		Description	Delivery
				Lead	Assoc.		
I.		Project WWW site	Sep 01	P3		Interactive WWW site for use both by partners in the consortium and external browsers	Established Oct 01 Last update Jul 02
II.	1,2,3,4	Sampling and analytical protocols	Dec 01	P5	P1, P2	Completion of sampling protocols for primary, secondary and tertiary sites	Version 1 Sep 01 Version 8 Jan 02
III.	5,6	Laboratory and analytical protocols	Dec 01	P4	AP6, P7	Completion of laboratory and analytical protocol for wood anatomy, wood chemistry and wood physico-mechanical properties	First version Jul 01 Final version May 02
IV.	8	Energy budget model	Feb 02	P3	P1, P7	Carbon and energy book-keeping model to quantify the fossil fuel energy inputs and associated CO_2 emissions of individual forest operations and timber conversion procedures.	Mar 02
V.		First Annual Report	Aug 02	P1	P2, P3, P4, P5, AP6, P7	Completion of annual report to European Commission	Aug 02

Table 8. *List of Deliverables for Year 1*

Work-Package No.	Deliverable No.	Deliverable title	Planned Delivery Date	Nature [5]	Dissemination Level [6]	Dissemination Target [7]	Actual Delivery Date
1.	1	Standardised methodology for site characteristics, physiological, eco-physiological and mensurational data for observed forest stands	Dec 01	O	CO	C	First version Sep 01 Final version Jan 02
2.	4	Standardised methodology for timber quality assessment for forest stands, applicable across the European Union.	Dec 01	O	CO	C S I	Sep 01
4.	10	Standardised methodology for determining selected anatomical wood properties.	Dec 01	O	CO	C S	First version Dec 01 Final version May 02
5.	13	Standardised methodology for determining selected biochemical wood properties.	Dec 01	O	CO	C S	Nov 01
6.	16	Standardised methodology for determining selected wood physico-mechanical properties.	Dec 01	O	CO	C	Draft version Jul 01
7.	19	Protocol for integration of sub-modules.	Dec 01	O	CO	C	Completed Nov 01
8.	24	A review of forestry working practices, wood processing methods and implicit fossil energy inputs.	Dec 01	O	CO	C	Completed Mar 02
	25	A computer-based model of fossil energy and carbon-based balances available as source code, or executable user-friendly interface.	Feb 02	P	PU	C	Mar 02 available as executable user-friendly interface
Manag	39	First Annual Report	Aug 02	R	CO	CO	Aug 02
	43	WWW page	Sep 01	O	PU	S I	First version Oct 01 Last update Jun 02

[5] Nature of Deliverables:
R = Report
P = Prototype
D = Demonstrator
O = Other
[6] Dissemination Level:
PU = Public
RE = Restricted to group specified by Consortium (including Commission Services)
CO = Confidential, only for members of the Consortium (including Commission Services)
[7] Target audience of potential users/beneficiaries of the deliverable:
C = Restricted to group specified by Consortium (including Commission Services)
CO = Commission Services
S = Scientific users
I = Industry users

2.2 WORKPLAN YEAR 2

Year 2 of the MEFYQUE project has focussed on the continuing collection of site data, the laboratory analysis of samples and continued development of the models

Progress on delivery. To assess progress against project deliverables, the following tables are provided below.

Table 9. Timetable of Project Work-Packages for Year 2.

Table 10. Participant Contribution and Timetable of Activities for Year 2.

Table 11. List of Milestones for Year 2.

Table 12. List of Deliverables for Year 2.

Each table includes a column detailing progress against each task, milestone or deliverable.

Table 9. *Actual Timetable of Project Work-Packages for Year 2*

Work Package	Title of Working Step	Partners	2nd year												*Delivery*	*Complete*
			Jul 02	Aug 02	Sep 02	Oct 02	Nov 02	Dec 02	Jan 03	Feb 03	Mar 03	Apr 03	May 03	Jun 03		
1	a. Establishment of permanent sampling plots at primary sites	P1 (P2, P4, P5)													Completed Sep 02	Yes
	b. Primary site plot sampling protocol	P1 (P5)													Completed Year 1	Yes
	c. Secondary site plot sampling protocol	P2 (P1, P5)													Completed Year 1	Yes
	d. Monitoring and data collection from secondary sites	P2 (P1, P5)													Ongoing until end of Year 3	
	e. Growth & yield data collection from primary and secondary sites	P1 (P2, P4, P5)													Ongoing, due to adverse weather conditions in Italy	
2	a. Development & training in Timber Quality Assessment protocol	P1 (P5, AP6, P7)													Completed year 1	Yes
	B. Standing timber quality assessment	P1 (P2, P5, AP6, P7)													Ongoing, due to adverse weather conditions in Italy & sharing of single lean measurement instrument	
3	a. Tertiary site sampling protocol	P5 (P1, P2, P4)													Completed Year 1	Yes
	B. Monitoring and data collection from tertiary sites	P5 (P1, P2, P4)													Ongoing at UK & Berlin tertiary site until end of year 3	
4	a. Wood anatomy protocol	P4 (AP6, P7)													Completed Year 1	Yes
	b. Wood anatomical laboratory studies (existing and new material)	P4 (AP6, P7)													Ongoing, to be completed end of year 3	
5	a. Wood chemistry protocol	P4 (P7)													Completed Year 1	Yes
	b. Wood chemical laboratory analyses (existing and new material)	P4 (P7)													Ongoing, to be completed during year 3	
6	a. Wood physico-mechanical protocol	P7 (AP6)													Completed Year 1	Yes
	b. Wood physico-mechanical analyses (existing & new material)	AP6 (P7)													Delayed from Year 1. Task now ongoing, to be completed during Year 3	
7	a. Plot scale model modelling protocols	P2 (P1, P5)													Completed Year 1	Yes
	b. Plot scale model development and calibration	P2 (P1, P5)													Completed Year 2	Yes
	c. Plot scale model validation and application	P1 (P2, P5)													Ongoing, to be completed Sep 03	
	d. Modelling carbon sequestration at the plot scale	P2 (P1, P4, P5)													Ongoing, to be completed Sep 03	
	e. Modelling productivity of wood products at the plot scale	P1 (P1, P2, P3, P5)													Ongoing, to be completed Sep 03	
8	a. Energy budget sub-model modelling protocols	P3 (P1, P7)													Completed Year 1	Yes
	b. Energy budget sub-model development and calibration	P3 (P1, P7)													EFI model completed Year 1. BRE model completed year 2	
9	a. Prototype integrated system modelling protocols	P3 (P1, P2, P5)													Completed year 2	Yes
	b. Development of the prototype integrated model at regional scale	P3 (P1, P2, P5)													Ongoing, to be completed year 3	
	c. Application of climate change scenarios	P3 (P1, P2, P5)													Year 3 activity, with scenarios agreed Year 2	
	d. Application of socio-economic scenarios	P3 (P1, P2, P5)													Year 3 activity, with scenarios agreed Year 2	
10	a. Prototype regional integrated model validation and application	P3 (P1, P2, P5, P7)													Ongoing, to be completed year 3.	
11	a. Development of consortium database and data exchange protocols	P1 (P2, P3, P4, P5, AP6, P7)													Completed year 1	Yes
	b. Data exchange	P1 (P2, P3, P4, P5, AP6, P7)													Ongoing, to be completed end of year 3	
	c. International workshop	P1 (P2, P3, P4, P5, AP6, P7)													Re-scheduled for Sep 03	
	d. Web site updates	P3 (P1, P2, P4, P5, AP6, P7)													Ongoing, to be completed end of year 3	
	e. Annual and Final Reports	P1 (P2, P3, P4, P5, AP6, P7)													Ongoing, with Report 1 submitted mid-Aug 02	
	f. Consortium meetings	P1 (P2, P3, P4, P5, AP6, P7)					3							4	Meetings held as scheduled. Task ongoing until end of Year 3.	
	g. MILESTONES				VI			VII						VIII-X		

Original timetable | Delayed (low risk) | Delayed (medium risk)

Table 10. *Participant Contribution and Timetable of Activities for Year 2*

	Title of Working Step	Jul 02	Aug 02	Sep 02	Oct 02	Nov 02	Dec 02	Jan 03	Feb 03	Mar 03	Apr 03	May 03	Jun 03	Delivery	Location in 2nd Annual Report
		2nd year													
Participant 1 FR (UK)	1a Establishment of permanent sampling plots at primary sites													Completed Sep 03	Report Year 1 - Location maps at Annexes B, C and E
	1b Primary site plot sampling protocol													Completed Year 1	Report Year 1 - Annex D
	1e Growth & yield data collection from primary and secondary sites													Ongoing, due to adverse weather conditions in Italy	
	2a Development & training in Timber Quality Assessment protocol													Completed Year 1	Report Year 1 - Annex B
	2b Standing timber quality assessment													Ongoing, due to adverse weather conditions in Italy & sharing of single lean measurement instrument	
	11a Development of consortium database and data exchange protocols													Completed Year 1	
	11b Data exchange													Ongoing	
	11e Annual Report													Completed Jul 03	
Participant 2 UIA (B)	1c Secondary site plot sampling protocol													Completed Year 1	Report Year 1 - Annex B
	1d Monitoring and data collection from secondary sites													Ongoing for duration of project	
	7a Plot scale model modelling protocols													Completed Year 1	
	7b Plot scale model development and calibration													Ongoing, to be completed Sep 03	Report Year 1 - Annex H
Participant 3 EFI (FIN)	8a Energy budget sub-model modelling protocols													Completed Year 1	
	8b Energy budget sub-model development and calibration													EFI model completed Year 1. BRE model completed Nov 02	Report Year 1 - Annex I
	9a Prototype integrated system modelling protocols													Completed Nov 02	
	9b Development of the prototype integrated model at regional scale													Begun Jun 02 and ongoing	
	11d Web site updates													To be updated Sep 03	http://www.efi.fi/projects/mefyque
Participant 4 TUB (D)	4a Wood anatomy protocol													Completed Year 1	Report Year 1 - Annex F
	4b Wood anatomical laboratory studies (existing and new material)													Ongoing on new and existing material	
	5a Wood chemistry protocol													Completed Year 1	
	5b Wood chemical laboratory analyses (existing and new material)													Ongoing as material is collected	
Participant 5 UNITUS (I)	3a Tertiary site sampling protocol													Completed Year 1	
	3b Monitoring and data collection from tertiary sites													Ongoing	
A Participant 6 RUG (B)	6b Wood physico-mechanical analyses (existing & new material)													Ongoing but delayed during year 1. Delay is rapidly being absorbed.	
Participant 7 BRE(UK)	6a Wood physico-mechanical protocol													Completed Year 1	Report Year 1 - Annex G
All	11f Consortium meetings						3						4	Consortium meetings held in Nov 02 (B) and Jun 03 (I)	
All	11g Milestones				VI			VII					VIII-X		See Table 4

Table 11. *List of Milestones for Year 2*

Milestone No	Associated WPs	Title	Planned Delivery Date	Delay	Participants		Delivery	Remarks
					Lead	Assoc.		
VI.	1,2,3,4,5,6	Completion of Phase 1 sampling programme	Jul 02	Yes	All		Completion of all sampling programme for year 1 at the primary, secondary and tertiary sites.	Sampling remains ongoing at 2 sites in Italy, due to adverse weather conditions. Lean measurements to be completed at some 4 UK sites.
VII.	7	Prototype mechanistic dynamic model at plot scale	Oct 02	Yes	P2	P1, P3, P4, P5, AP6, P7	A prototype coupled mensuration mechanistic dynamic model of tree growth, timber production and wood quality operational at the stand scale	Completed in Mar 03
VIII		Scientific Papers	Jun 03	Yes	All		Completion of 6 scientific papers for publication in peer-reviewed journals	14 scientific papers completed or submitted, 5 currently in draft
IX.		Technical Papers	Jun 03	Yes	All		Completion of 6 technical papers for publication in national timber industry journals	2 technical papers completed
X.		Second Annual Report	Jul 03	No	P1	P2, P3, P4, P5, AP6, P7	Completion of annual report to European Commission	Completed

Table 12. *List of Deliverables for Year 2*

Work-Package No.	Deliverable No.	Deliverable title	Planned Delivery Date	Actual Delivery date & Remarks	Nature [8]	Dissemination Level [9]	Dissemination Target [10]
2.	5	Database on timber quality assessment for forest stands for a range of species, environmental conditions and management options	Month 22	Ongoing and to be completed in Jun 04	O	CO	C S I
	6	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; qualitative properties in standing timber	Month 24	Version 2 to be completed in Sep 03	O	CO	C
7.	21	A user-friendly version of the model available as a prototype decision support system.	Month 18	Version 1 completed in Mar 03	P	PU	C S I
8.	26	Sub-model within integrated model to evaluate impacts of environmental and silvicultural changes on fossil energy requirements and greenhouse gas balances of wood production processes.	Month 18	EFI model completed in Mar 02 BRE model completed in May 03	p	CO	
9.	27	Protocol for model integration and upscaling	Month 14	Completed Nov 02	R	CO	C
Other	36	Papers in peer-reviewed scientific journals.	Month 18-36	Ongoing	R	PU	C S
	37	Reports at international and national scientific meetings.	Month 18-36	Ongoing	R	PU	S
	38	Reports in forestry and timber-processing industry journals in participating countries and international bulletins.	Month 18-36	None completed to date	R	PU	I
Manag	40	Second Annual Report	Month 26	Completed Jul 03	R	CO	CO

[8] Nature of Deliverables:
R = Report
P = Prototype
D = Demonstrator
O = Other
[9] Dissemination Level:
PU = Public
RE = Restricted to group specified by Consortium (including Commission Services)
CO = Confidential, only for members of the Consortium (including Commission Services)
[10] Target audience of potential users/beneficiaries of the deliverable:
C = Restricted to group specified by Consortium (including Commission Services)
CO = Commission Services
S = Scientific users
I = Industry users

2.3 WORKPLAN YEAR 3

Year 3 of the MEFYQUE project has primarily focussed on field data collection, laboratory analysis and model and database development. The project has been granted a 6 month extension, thus some work packages have yet to be completed.

Progress on delivery. To assess progress against project deliverables, the following tables are provided below.

- **Table 13**. Timetable of Project Work-Packages for Year 3.
- **Table 14**. Participant Contribution and Timetable of Activities for Year 3.
- **Table 15**. List of Milestones for Year 3.
- **Table 16**. List of Deliverables for Year 3.

Each table includes a column detailing progress against each task, milestone or deliverable.

Table 13. *Timetable of Project Work-Packages for Year 3*

Work Package	*Title of Working Step*	*Partners*	3rd year Jul 03	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Mar 04	Apr 04	May 04	Jun 04	*Delivery*	*Complete*
1	a. Establishment of permanent sampling plots at primary sites	**P1 (**P2, P4, P5)													Completed Sep 02	Yes
	b. Primary site plot sampling protocol	**P1** (P5)													Completed Year 1	Yes
	c. Secondary site plot sampling protocol	**P2** (P1, P5)													Completed Year 1	Yes
	d. Monitoring and data collection from secondary sites	**P2** (P1, P5)													Completed Year 3	Yes
	e. Growth & yield data collection from primary and secondary sites	**P1** (P2, P4, P5)													Completed Year 3	Yes
2	a. Development & training in Timber Quality Assessment protocol	**P1** (P5, AP6, P7)													Completed year 1	Yes
	b. Standing timber quality assessment	**P1** (P2, P5, AP6, P7)													Completed Year 3	Yes
3	a. Tertiary site sampling protocol	**P5** (P1, P2, P4)													Completed Year 1	Yes
	b. Monitoring and data collection from tertiary sites	**P5** (P1, P2, P4)													Completed Year 3	Yes
4	a. Wood anatomy protocol	**P4** (AP6, P7)													Completed Year 1	Yes
	b. Wood anatomical laboratory studies (existing and new material)	**P4** (AP6, P7)													Ongoing, to be completed end of year 3	
5	a. Wood chemistry protocol	**P4** (P7)													Completed Year 1	Yes
	b. Wood chemical laboratory analyses (existing and new material)	**P4** (P7)													Ongoing, to be completed during year 3	
6	a. Wood physico-mechanical protocol	**P7** (AP6)													Completed Year 1	Yes
	b. Wood physico-mechanical analyses (existing & new material)	**AP6** (P7)													Delayed from Year 1. Task now ongoing, to be completed during Year 3	
7	a. Plot scale model modelling protocols	**P2** (P1, P5)													Completed Year 1	Yes
	b. Plot scale model development and calibration	**P2** (P1, P5)													Completed Year 2	Yes
	c. Plot scale validation and application	**P1** (P2, P5)														
	d. modelling carbon sequestration at plot scale	**P2** (P1, P4, P5)														
	e. modelling productivity of wood products at plot scale	**P1** (P2, P3, P5)														
8	a. Energy budget sub-model modelling protocols	**P3** (P1, P7)													Completed Year 1	Yes
	b. Energy budget sub-model development and calibration	**P3** (P1, P7)													Completed	Yes
9	a. Prototype integrated system modelling protocols	**P3** (P1, P2, P5)													Completed year 2	Yes
	b. Development of Prototype integrated model at regional scale	**P3** (P1, P2, P5)													Completed Year 3	Yes
	c. Application of climate change scenarios	**P3** (P1, P2, P5)													Largely Completed, Scenarios agreed	
	d. Application of socio-economic scenarios	**P3** (P1, P2, P5)													Largely Completed, Scenarios agreed	
10	a. Prototype regional integrated model validation and application	**P3** (P1, P2, P5, P7)													Ongoing, to be completed	
11	a. Development of consortium database and data exchange protocols	**P1** (P2, P3, P4, P5, AP6, P7)													Completed Year 1	Yes
	b. Data exchange	**P1** (P2, P3, P4, P5, AP6, P7)													Ongoing, until end of project	
	d. Web site updates	**P3** (P1, P2, P4, P5, AP6, P7)													Ongoing, to be completed end of year 3	
	e. Annual Report and Final Report	**P1** (P2, P3, P4, P5, AP6, P7)													Ongoing, Report 2 submitted Sept 03	
	f. Consortium meetings	**P1** (P2, P3, P4, P5, AP6, P7)							5				6		Ongoing, Full meetings Held Jan 04 Edinburgh, May 04 Helsinki	
	g. MILESTONES						XI		XII		XIII-XIV		XV-XIX		Ongoing, to be completed end of year 3	

Completed   In Progress   Planned   Ongoing – low Risk   Ongoing or Delayed – Medium Risk

Table 14. *Lead Participant Contribution and Timetable of Activities for Year 3*

	Title of Working Step	3rd year Jul 03	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Mar 04	Apr 04	May 04	Jun 04	**Delivery**	**Location in 3rd Annual Report**
Participant 1 FR (UK)	1a Establishment of permanent sampling plots at primary sites													Completed Year 1	Annexes B, C and E
	1b Primary site plot sampling protocol													Completed Year 1	Annex D
	1e Growth & yield data collection- primary and secondary sites													Completed Year 3	
	2a Development & training in Timber Quality Assessment protocol													Completed Year 1	Annex B
	2b Standing timber quality assessment													Completed year 3	
	7c Plot scale Validation and application													Ongoing – Delayed by technical problems & delayed data	
	7e Modelling productivity of wood products at plot scale													Ongoing – Delayed by technical problems & delayed data	
	11a Development of database and data exchange protocols													Completed Year 1	
	11b Data exchange													Ongoing until end of project. All Data received	
	11e Annual Report													Completed year 3	
Participant 2 UIA (B)	1c Secondary site plot sampling protocol													Completed Year 1	Annex B
	1d Monitoring and data collection from secondary sites													Completed Year 3	
	7a Plot scale model modelling protocols													Completed Year 1	
	7b Plot scale model development and calibration													Completed Year 2	Annex H
	7d Modelling carbon sequestration at plot scale													Ongoing – Delayed by delayed data & plot model	
Participant 3 EFI (FIN)	8a Energy budget sub-model modelling protocols													Completed Year 1	
	8b Energy budget sub-model development and calibration													EFI model completed Year 1. BRE model completed Year 2	Annex I
	9a Prototype integrated system modelling protocols													Completed Year 2	
	9b Development of prototype integrated model at regional scale													Completed Year 3	
	9c Application of climate change scenarios													Ongoing – Delayed by plot scale model	
	9d Application of socio-economic scenarios													Ongoing – Delayed by plot scale model	
	11d Web site updates													updated Feb 04	http://www.efi.fi/projects/mefyque
Participant 4 TUB (D)	4a Wood anatomy protocol													Completed Year 1	Annex F
	4b Wood anatomical laboratory studies (existing and new material)													Ongoing on new and existing material – slightly delayed due to late samples. Delay rapidly being absorbed	
	5a Wood chemistry protocol													Completed Year 1	
	5b Wood chemical laboratory analyses (existing and new material)													Ongoing as material is collected- slightly delayed due to late samples. Delay rapidly being absorbed	
Participant 5 UNITUS (I)	3a Tertiary site sampling protocol													Completed Year 1	
	3b Monitoring and data collection from tertiary sites													Completed Year 3	
Assoc. P 6 RUG (B)	6b Wood physico-mechanical analyses (existing & new material)													Ongoing - delayed during project. Delay is rapidly being absorbed.	
Participant 7 BRE(UK)	6a Wood physico-mechanical protocol													Completed Year 1	Annex G
All	11f Consortium meetings							5				6		Consortium meetings held in Jan 04 (Finland). and May 04 (UK)I)	
All	11g Milestones							XI		XII		XIII-XIV		XV-XIX	See Table 4

Progressing work | Completed Work

Table 15. *List of Milestones for Year 3*

Milestone No	Associated WPs	Title	Planned Delivery Date	Delay	Participants		Delivery	Remarks
					Lead	Assoc.		
XI.	1,2,3,4,5,6	Completion of Phase 2 sampling programme	Dec 03	yes	All		Completion of all sampling programme for year 2 at the primary, secondary and tertiary sites.	Now completed
XII.	5,6	Completion of laboratory studies	Feb 04	yes	P4	AP6, P7	Completion all laboratory studies on wood anatomy, wood chemistry and wood physico-mechanical properties	Near completion
XIII	9	Regional scale model	Apr 04	yes	P3	P1, P2, P4, P7	An integrated model which accounts for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the regional scale.	Delayed due to delay in stand level model validation and revision caused by incomplete data.
XIV.		International workshop	May 04	yes	P1	P2, P3, P4, P5, AP6, P7	International workshop on 'Forecasting the dynamic response of timber quality to management and environmental change from the site to the regional scale: experimental and modelling approaches.	Conference scheduled for September 04 - Edinburgh
XV.		Scientific papers	Jun 04		All		Completion of 6 scientific papers for publication in peer reviewed journals.	Completed > 20
XVI.		Technical papers	Jun 04		All		Completion of 6 technical papers for publication in national timber industry journals.	2 Completed
XVII.	1,2,3,4,5,6	Unified database of data from the monitoring, experimental and manipulative components	Jun 04	yes	P1	P2, P3, P4, P5, AP6, P7	Unified relational database with all monitoring, experimental, laboratory and manipulative data collected during the programme	Near completion, awaiting final data
XVIII	9,10	Database of modelling scenarios	Jun 04	yes	P3	P1, P2, P5	Portfolio of model predictions at regional scale.	Largely completed awaiting model simulations
XIX.		Final Report	Jun 04	yes	P1	P2, P3, P4, P5, AP6, P7	Completion of final report to the European commission.	Final report deferred due to 6 month extension on project.

Table 16. *List of Deliverables for Year 3*

Work-Package No.	Deliverable No.	Deliverable title	Delivery Date	Nature [11]	Dissemination Level [12]	Dissemination Target [13]
1.	2.	Database of site characteristics, physiological, eco-physiological and mensurational data for a range of species, environmental conditions and management options	Month 36	O	CO	C S P
	3.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; growth and yield	Month 36	O	CO	C
3.	7.	Standardised methodology for assessing growth patterns and allocation of juvenile plants grown in manipulative experimental conditions.	Month 30	O	CO	C
	8.	Database on growth patterns and allocation from individuals for a range of species, environmental conditions, management options and atmospheric change	Month 32	O	CO	C S I
4.	11.	Data incorporated into a database on the anatomical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change	Month 34	O	CO	C S I
	12.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; anatomical properties	Month 34	O	CO	C S
5.	14.	Data incorporated into a database on the biochemical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change	Month 27	O	CO	C S I
	15.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality; biochemical properties	Month 31	O	CO	C
6.	17	Database on the physico-mechanical properties of wood from trees for a range of species, environmental conditions, management options, climate and atmospheric change	Month 27	O	CO	C S I
	18.	Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.	Month 29	O	CO	C
7.	22.	Predictions of timber production accounting for tree quality across a representative range of sites and silvicultural regimes in participating countries, also accounting for scenarios of future environmental change.	Month 32	R	PU	C S I
	23.	Predictions of environmental impact in terms of current and future forest stand composition and structure, its nutrient status and dynamics, and ecosystem carbon balance across a representative range of sites and silvicultural regimes in participating countries, also accounting for scenarios of future environmental change.	Month 33	R	PU	C S I
9.	28.	An integrated model accounting for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the scale of EU Member States.	Month 29	P	CO	C S I

[11] **Nature of Deliverables:**
R = Report
P = Prototype
D = Demonstrator
O = Other
[12] **Dissemination Level:**
PU = Public
RE = Restricted to group specified by Consortium (including Commission Services)
CO = Confidential, only for members of the Consortium (including Commission Services)
[13] **Target audience of potential users/beneficiaries of the deliverable:**
C = Restricted to group specified by Consortium (including Commission Services)
CO = Commission Services
S = Scientific users
I = Industry users

Work-Package No.	Deliverable No.	Deliverable title	Delivery Date	Nature [11]	Dissemination Level [12]	Dissemination Target [13]
9.	29.	Database integrated with the model of plausible future Environmental socio-economic and management scenarios applicable to the EU forestry and wood products sector.	Month 30	O	PU	C S I
	30.	Validation of model outputs against empirical databases of processes observed in the monitoring and manipulative components of the project.	Month 34	O	PU	C
	31.	A portfolio of plausible future environmental socio-economic and management scenarios applicable to the EU forestry and wood products sector.	Month 36	O	PU	C
	32.	A portfolio of model predictions for all variables listed above, (listed in deliverable 28) produced by running the above model using empirical data from earlier work-packages and simulation data from the stand- scale model as input.	Month 36	O	PU	C
10.	33.	Standardised model assessment tools incorporated into the integrated model software to assess uncertainty in model predictions associated with output sensitivity to input parameters and scaling effects.	Month 34	R	PU	C
	34.	A selection of environmental, socio-economic and management scenarios for the EU forestry and wood products sector.	Month 35	O	PU	C S I
	35.	A portfolio of model predictions for all variables listed above (listed in deliverable 28), produced by running the improved upscaling model using empirical data from earlier work-packages and simulation data from the stand- scale model as input with an associated uncertainty interval.	Month 35	O	PU	C S I
Other	36.	Papers in peer-reviewed scientific journals.	Month 18-36	R	PU	C S
	37.	Reports at international and national scientific meetings.	Month 18-36	R	PU	S
	38.	Reports in forestry and timber-processing industry journals in participating countries and international bulletins.	Month 18-36	R	PU	I
Manag	40.	Second Annual Report	Month 26	R	CO	CO
	41	Final Report	Month 36	R	CO	CO
	42.	International Workshop	Month 35	O	PU	S I

2.4 WORKPLAN – Project Extended Period

The project has been granted a 6 month extension,
This period has primarily focussed on the small amount of laboratory analysis to be completed, and the stand and wood-chain models requiring further development. Additionally the database continues to be populated.

The project has now concluded and overall results are presented in the final report.

Progress on delivery. To assess progress against project deliverables, the following tables are provided below.

- **Table 17**. Project Work-Packages for the extended period.
- **Table 18**. Participant Contribution and Timetable of Activities for the extended period.
- **Table 19**. List of Milestones for the extended period.

Each table includes a column detailing progress against each task, milestone or deliverable.

Table 17. *Timetable of Project Work-Packages for Extended Period*

Work Package	***Title of Working Step***	***Partners***	**Jul 04**	**Aug 04**	**Sep 04**	**Oct 04**	**Nov 04**	**Dec 04**	***Delivery***	***Complete***
1	a. Establishment of permanent sampling plots at primary sites	**P1 (**P2, P4, P5)							Completed Sep 02	Yes
	b. Primary site plot sampling protocol	**P1** (P5)							Completed Year 1	Yes
	c. Secondary site plot sampling protocol	**P2** (P1, P5)							Completed Year 1	Yes
	d. Monitoring and data collection from secondary sites	**P2** (P1, P5)							Completed Year 3	Yes
	e. Growth & yield data collection from primary and secondary sites	**P1** (P2, P4, P5)							Completed Year 3	Yes
2	a. Development & training in Timber Quality Assessment protocol	**P1** (P5, AP6, P7)							Completed year 1	Yes
	b. Standing timber quality assessment	**P1** (P2, P5, AP6, P7)							Completed Year 3	Yes
3	a. Tertiary site sampling protocol	**P5** (P1, P2, P4)							Completed Year 1	Yes
	b. Monitoring and data collection from tertiary sites	**P5** (P1, P2, P4)							Completed Year 3	Yes
4	a. Wood anatomy protocol	**P4** (AP6, P7)							Completed Year 1	Yes
	b. Wood anatomical laboratory studies (existing and new material)	**P4** (AP6, P7)							Completed During Extension	Yes
5	a. Wood chemistry protocol	**P4** (P7)							Completed Year 1	Yes
	b. Wood chemical laboratory analyses (existing and new material)	**P4** (P7)							Completed During Extension	Yes
6	a. Wood physico-mechanical protocol	**P7** (AP6)							Completed Year 1	Yes
	b. Wood physico-mechanical analyses (existing & new material)	**AP6** (P7)							Completed During Extension	Yes
7	a. Plot scale model modelling protocols	**P2** (P1, P5)							Completed Year 1	Yes
	b. Plot scale model development and calibration	**P2** (P1, P5)							Completed Year 2	Yes
	c. Plot scale validation and application	**P1** (P2, P5)							Completed for limited sites/species	Partial
	d. modelling carbon sequestration at plot scale	**P2** (P1, P4, P5)							Completed for limited sites/species	Partial
	e. modelling productivity of wood products at plot scale	**P1** (P2, P3, P5)							Completed for limited sites/species	Partial
8	a. Energy budget sub-model modelling protocols	**P3** (P1, P7)							Completed Year 1	Yes
	b. Energy budget sub-model development and calibration	**P3** (P1, P7)							Completed	Yes
9	a. Prototype integrated system modelling protocols	**P3** (P1, P2, P5)							Completed year 2	Yes
	b. Development of Prototype integrated model at regional scale	**P3** (P1, P2, P5)							Completed Year 3	Yes
	c. Application of climate change scenarios	**P3** (P1, P2, P5)							Completed for limited sites/species	Partial
	d. Application of socio-economic scenarios	**P3** (P1, P2, P5)							Completed During Extension	Yes
10	a. Prototype regional integrated model validation and application	**P3** (P1, P2, P5, P7)							Completed to Saw-mill outturn	Partial
11	a. Development of consortium database and data exchange protocols	**P1** (P2, P3, P4, P5, AP6, P7)							Completed Year 1	Yes
	b. Data exchange	**P1** (P2, P3, P4, P5, AP6, P7)							Ongoing, until end of project	Yes
	d. Web site updates	**P3** (P1, P2, P4, P5, AP6, P7)							Ongoing to end of project	Yes
	e. Annual Report and Final Report	**P1** (P2, P3, P4, P5, AP6, P7)							Ongoing, Final report Submitted Sept 05, Additional Report Sept 05	Yes
	f. Consortium meetings	**P1** (P2, P3, P4, P5, AP6, P7)							International conference held Edinburgh, September 2004	Yes

Table 18. *Lead Participant Contribution and Timetable of Activities for Extended Period*

	Title of Working Step	**Jul 04**	**Aug 04**	**Sep 04**	**Oct 04**	**Nov 04**	**Dec 04**	**Delivery**	Location in **Final Report (separate Document)**
Participant 1 FR (UK)	1a Establishment of permanent sampling plots at primary sites							Completed Year 1	Chapter 2
	1b Primary site plot sampling protocol							Completed Year 1	Appendix B
	1e Growth & yield data collection- primary and secondary sites							Completed Year 3	Chapter 2, 8
	2a Development & training in Timber Quality Assessment protocol							Completed Year 1	Appendix C
	2b Standing timber quality assessment							Completed year 3	Chapter 2, 8
	7c Plot scale Validation and application							Delayed by technical problems & delayed data	Chapter 6
	7e Modelling productivity of wood products at plot scale							Delayed by technical problems & delayed data	Chapter 6
	11a Development of database and data exchange protocols							Completed Year 1	Chapter 8
	11b Data exchange							Completed at end of project	Chapter 8; Database CD
	11e Annual Report							Final report and Extension report Competed Sept 05	
Participant 2 UIA (B)	1c Secondary site plot sampling protocol							Completed Year 1	Appendix C
	1d Monitoring and data collection from secondary sites							Completed Year 3	Chapter 2
	7a Plot scale model modelling protocols							Completed Year 1	Chapter 5
	7b Plot scale model development and calibration							Completed Year 2	Chapter 5, 6; Appendix I, J
	7d Modelling carbon sequestration at plot scale							Delayed by delayed data & plot model	Chapter 5, 6; Appendix H
Participant 3 EFI (FIN)	8a Energy budget sub-model modelling protocols							Completed Year 1	Appendix H
	8b Energy budget sub-model development and calibration							EFI model completed Year 1. BRE model completed Year 2	Appendix H
	9a Prototype integrated system modelling protocols							Completed Year 2	Chapter 5
	9b Development of prototype integrated model at regional scale							Completed Year 3	Chapter 5, 6
	9c Application of climate change scenarios							Delayed by plot scale model – limited application	Chapter 7
	9d Application of socio-economic scenarios							Delayed by plot scale model – limited application	Chapter 7
	11d Web site updates							updated at end of project	http://www.efi.fi/projects/mefyque
Participant 4 TUB (D)	4a Wood anatomy protocol							Completed Year 1	Appendix F
	4b Wood anatomical laboratory studies (existing and new material)							Completed during Extension	Chapter 3
	5a Wood chemistry protocol							Completed Year 1	Appendix F
	5b Wood chemical laboratory analyses (existing and new material)							Completed during Extension	Chapter 3
Participant 5 UNITUS (I)	3a Tertiary site sampling protocol							Completed Year 1	Appendix D
	3b Monitoring and data collection from tertiary sites							Completed Year 3	Chapter 2, 8
Assoc. P 6 RUG (B)	6b Wood physico-mechanical analyses (existing & new material)							Completed during Extension	Chapter 4
Participant 7 BRE(UK)	6a Wood physico-mechanical protocol							Completed Year 1	Appendix G
All	11f Consortium meetings							International Conference held Edinburgh September 2004	Abstracts on CD

Progressing work   Completed Work

Table 19. *List of Milestones for extended period (Carried over)*

Milestone No	Associated WPs	Title	Planned Delivery Date	Delay	Participants		Delivery	Remarks
					Lead	Assoc.		
XI.	1,2,3,4,5,6	Completion of Phase 2 sampling programme	Dec 03	yes	All		Completion of all sampling programme for year 2 at the primary, secondary and tertiary sites.	Now completed
XII.	5,6	Completion of laboratory studies	Feb 04	yes	P4	AP6, P7	Completion all laboratory studies on wood anatomy, wood chemistry and wood physico-mechanical properties	Completed
XIII	9	Regional scale model	Apr 04	yes	P3	P1, P2, P4, P7	An integrated model which accounts for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the regional scale.	Partially completed – to a limited degree.
XIV.		International workshop	May 04	yes	P1	P2, P3, P4, P5, AP6, P7	International workshop on ‘Forecasting the dynamic response of timber quality to management and environmental change from the site to the regional scale: experimental and modelling approaches.	Conference Held September 04 - Edinburgh
XV.		Scientific papers	Jun 04		All		Completion of 6 scientific papers for publication in peer reviewed journals.	>30 Published, Accepted, or Submitted
XVI.		Technical papers	Jun 04		All		Completion of 6 technical papers for publication in national timber industry journals.	2 Published
XVII.	1,2,3,4,5,6	Unified database of data from the monitoring, experimental and manipulative components	Jun 04	yes	P1	P2, P3, P4, P5, AP6, P7	Unified relational database with all monitoring, experimental, laboratory and manipulative data collected during the programme	Now Completed
XVIII	9,10	Database of modelling scenarios	Jun 04	yes	P3	P1, P2, P5	Portfolio of model predictions at regional scale.	Completed subject to limitations
XIX.		Final Report	Jun 04	yes	P1	P2, P3, P4, P5, AP6, P7	Completion of final report to the European commission.	Final Report Completed.

2.5 PROJECT WORK PACKAGES

2.5.1 The Monitoring Component

OBJECTIVES

The **MONITORING COMPONENT** is designed to characterise the relationships between site conditions, growth, yield prediction and timber quality and how this varies as a function of multi-purpose forest management practices. It combines field measurements of site conditions, forest growth, and of quality for standing timber, together with an assessment of forest product usage.

MAIN RESULTS – YEAR 1

This component encompasses two types of sites:

Primary sites. A total of 17 primary sites have been selected as part of MEFYQUE and a total of 15 plots established at selected sites. Species at the remaining site are primarily deciduous and, given the nature of measurements carried out as part of MEFYQUE require visibility of the top of each measured tree, experimental plots will be established during the leafless season (winter 2002).
Comprehensive data have been collected at established primary sites to measure non-destructive and destructive growth and quality in accordance with the MEFYQUE sampling protocol (Annex 1-D). Data are currently being quality assured for inclusion in the project database. At a number of these sites sample trees have been felled and have been transferred to a mill for 3-D scanning and subsequent milling.
Due to the delay in the project start date, some sites originally proposed for use in this project (see Technical Annex) were no longer available for research purposes. Abandoned sites have been replaced with new sites and key changes to the monitoring network are described below.
At the majority of sites monitoring is also carried as prescribed in the relevant technical manual of the EC/ICP Pan-European Monitoring Programme On Forest Ecosystems (Level II sites). Authority has been granted for data from Level II sites to be made available to MEFYQUE by the EC data holding centre (FIMCI, Herenveen, The Netherlands) and data are currently being requested for inclusion in the project database.

Figure MON-1. *The Brasschaat primary site*

Figure MON-2. *Trees at the Brasschaat site*

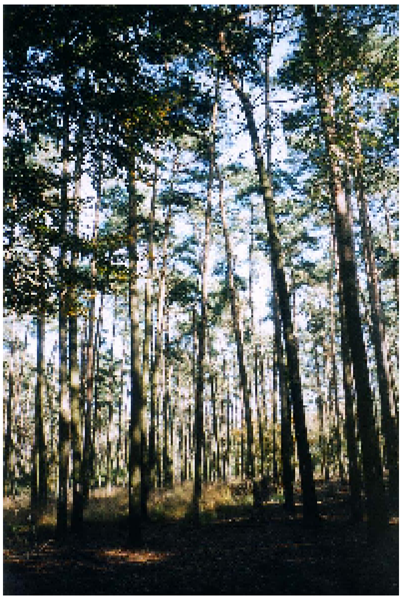


Figure MON-3. *Selecting a sample tree for felling.*

Figure MON-4. *Measuring stem lean for timber quality assessment.*

Figure MON-5. *Measuring stem lean (detail).*

Figure MON-6. *Cutting 1 metre logs and discs.*

Figure MON-7. *Marking N-S orientation on 1-metre logs.*

Figure MON-8. *Colour marking of logs at sawmill prior to 3-Dscanning.*

Figure MON-9. *Measuring the weight of canopy sections*

Figure MON-10. *Measuring branch length.*

Figure MON-11. *Example of three-dimensional scanning of logs at sawmill*

Figure MON-12. *Root sampling using 1 metre corer.*

Figure MON-13. *Extraction of soil core containing root sample*

<u>Secondary sites</u>. A total of 4 secondary sites are currently available for use by MEFYQUE that coincide with the location of primary sites. Again, due to the delay in the project start date, 1 site originally proposed for use in this project (Grünewald, Germany) was no longer available for research purposes.
At these sites eddy- covariance measurements are routinely performed, with data on fluxes of water, carbon and energy exchanges continuously measured above the forest canopy in real time, and stored together with meteorological data at sub-hourly intervals. A comprehensive suite of physiological parameters is available for all sites, whilst individual studies of hydrological and carbon balance are available at most. These data are currently being collated into the project database and will be used to inform and validate the process level sub-models (photosynthesis, respiration and transpiration) of the integrated modelling system.

Figure MON-14. *Litter collectors at a primary site.*

Figure MON-15. *41-metre scaffold tower at the Brasschaat site from which*

Figure MON-16. *Meteorological monitoring in Grünewald Forest and co-located with a MEFYQUE primary site.*

Figure MON-17. *Poplar plantation, scaffold tower and CO_2 containers at the Collelongo site.*

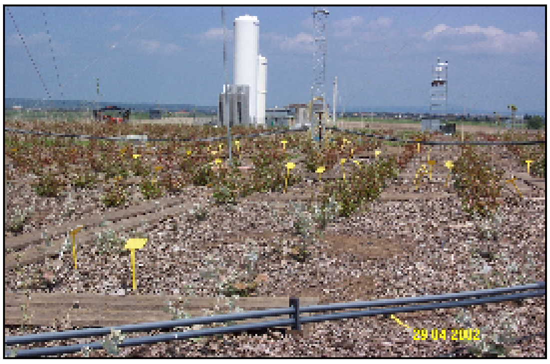


Figure MON-18. *Free air carbon enrichment equipment for CO_2 fumigation at the Collelongo poplar plantation.*

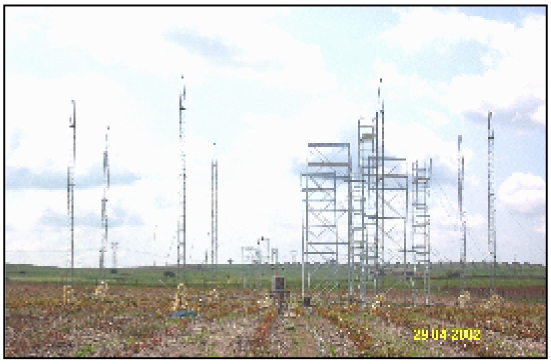
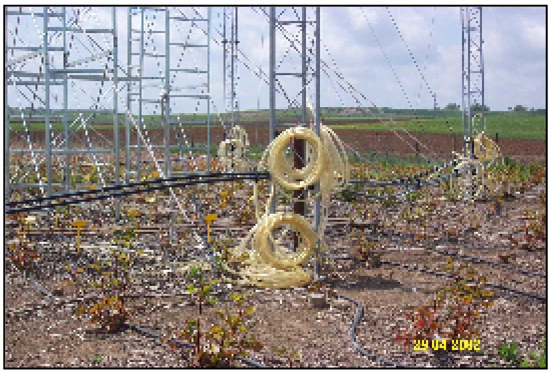


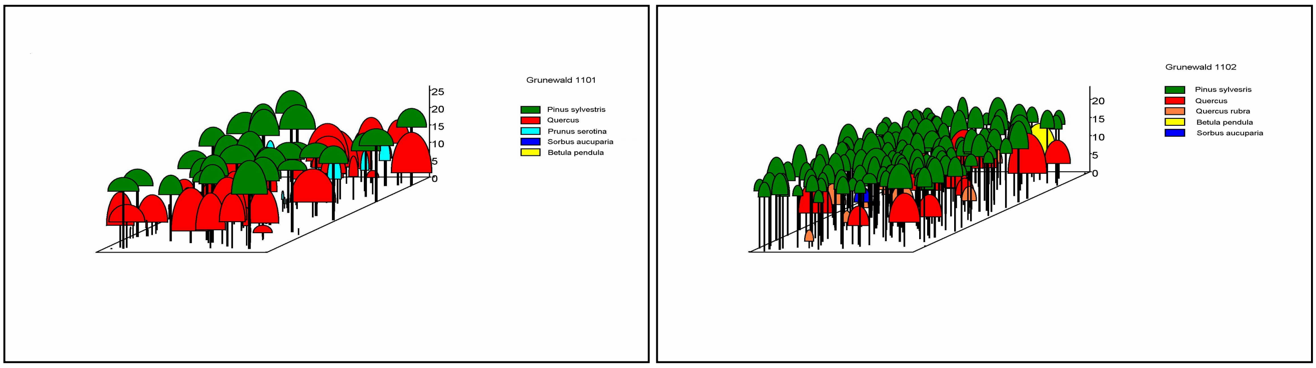
Figure MON-19. *Details of the free air carbon enrichment and water irrigation equipment at the Collelongo site*.



Data collection at MEFYQUE sites. The main results achieved in the first year of MEFYQUE for the monitoring component at primary and secondary sites are provided in tables MON-1 to MON-3 below. These tables summarise the key characteristics of the MEFYQUE project sites where monitoring plots have been established. Location map of MEFYQUE primary sites and secondary sites are provided at Appendices 1-B and 1-C, respectively.

For illustrative purposes, and using the data collected at two primary sites, the crown and structure projections for 2 plots located in Grünewald forest can be represented in three dimensions [14] as shown in figures MON-20,21, with crown cover planimetry and diameter class distribution shown at Figures MON-22, respectively. Figure MON-23 illustrates the diameter at breast height increments for the period 1986-2000 at various intervals, with Figure MON-24 outlining the biomass increments per tree compartment for ICP/ECE plot 1102 over the same period (data supplied by ICP/ECE FIMCI Data Co-ordination Centre).

Figure MON-20. *Three-dimensional structure of MEFYQUE monitoring plots in the Grünewald forest*



[14] Plot generated using the Bestand software developed by Dr Anette Degenhardt, Landesamt für Forstwirtschaft Brandenburg, Abt. Waldwachstum, Eberswalde, Germany. (Anette.Degenhardt@LFE-E.Brandenburg.de) tel. +49-33341-65279.

Figure MON-21. *Crown cover at the MEFYQUE monitoring plots in the Grünewald forest.*

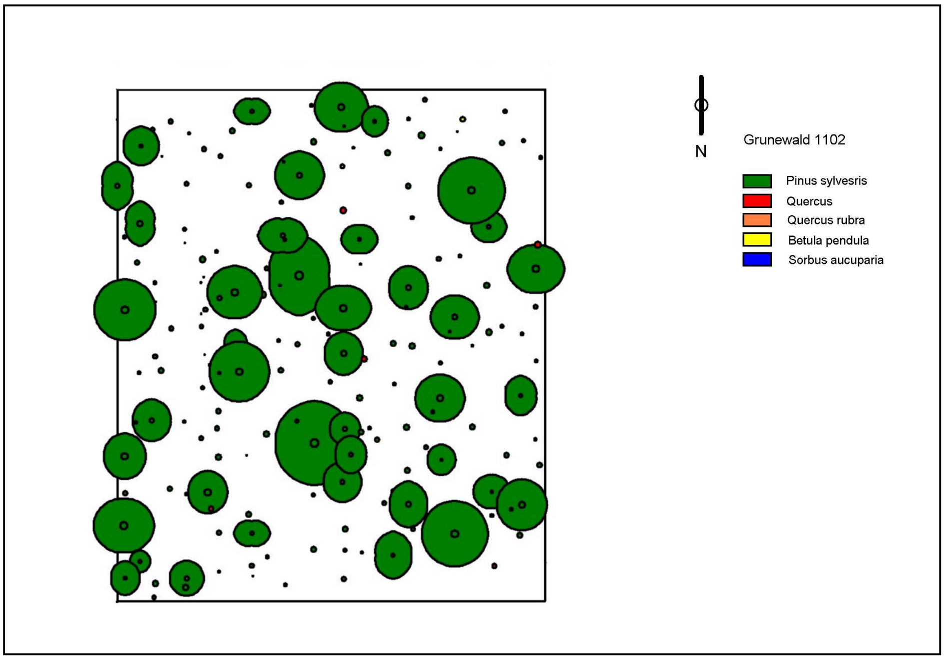
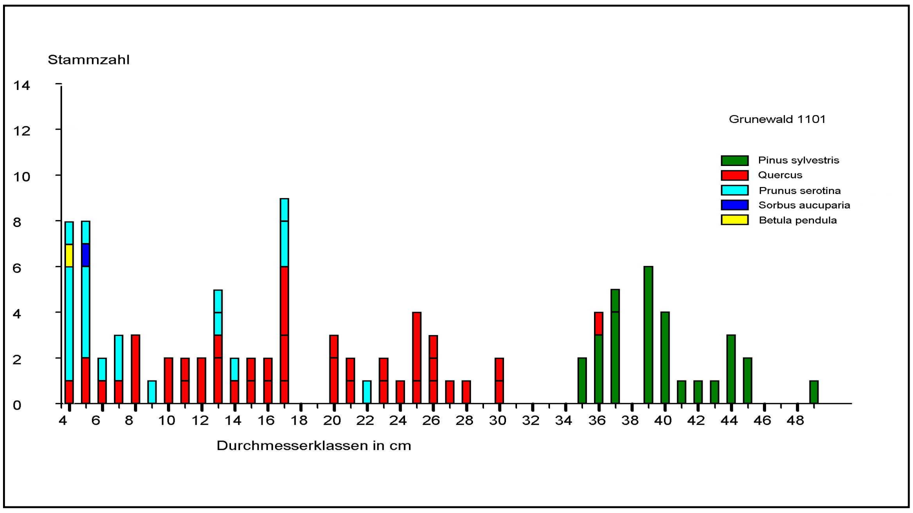


Figure MON-22. *Number of trees in each diameter class at the MEFYQUE monitoring plots in the Grünewald forest.*



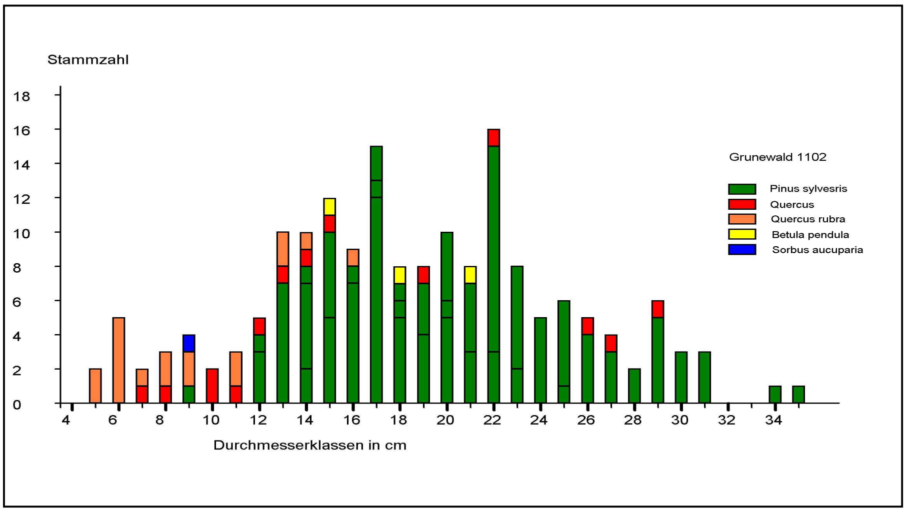


Figure MON-23. *DBH increments at the MEFYQUE monitoring plots in the Grünewald forest in the period 1986-2000*

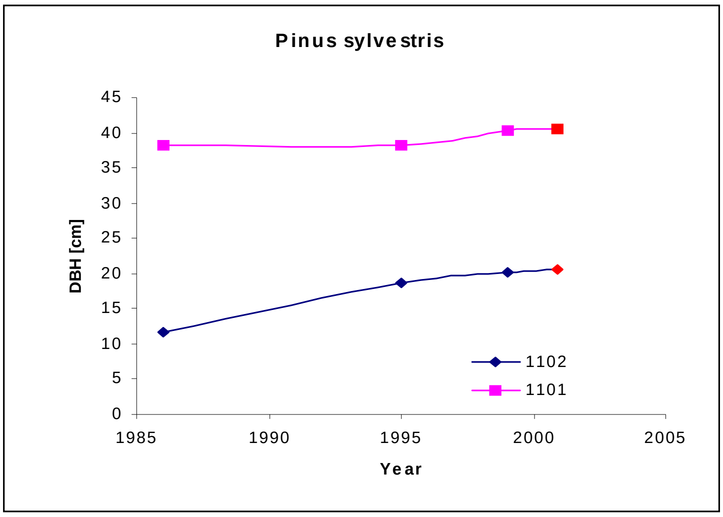
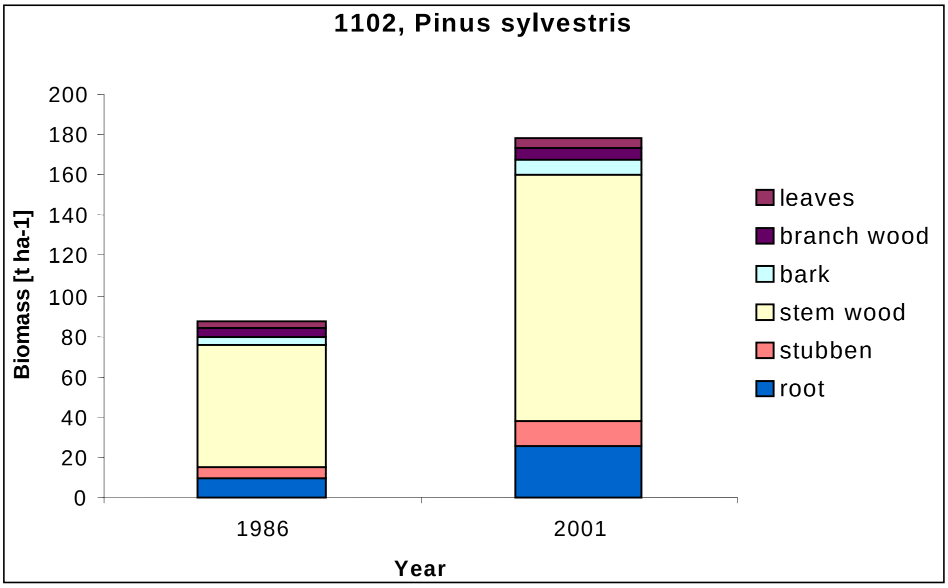


Figure MON-24. *Biomass increments in tree compartments in Plot 1102 at the MEFYQUE monitoring plots in the Grünewald forest for 1986 and 2000.*



3-Dimensional scanning of logs from felled trees. Logs resulting from harvesting of softwood trees selected for destructive sampling will be scanned using 3-D scanners in industrial sawmills based in Scotland. The sawmill industry will also assist with the conversion of the sawlogs that are large enough to produce structural battens and will be required to complete WP6. Following some initial difficulties in collaboration with an industrial sawmill (BSW Carlisle), negotiations with Howie Forest Products, Scotland resulted in an offer for assistance with the scanning and conversion of the first batches of logs. To date 5 batches of logs have been delivered to this sawmill and these have been marked with a colour spray system on both ends of the logs (Figure MON-8). As the sawmilling system is automatic (Figure MON-9) and can process 10 logs per minute, this is a necessary procedure to allow identification of individual logs during 3D scanning and conversion.
The marking system adopted by MEFYQUE is as follows:

- Top end of log -
- A background colour linking a particular group of trees to a known stand.
- A number stencil colour for all the logs of a particular tree
- A numbered stencil identifying the logs and their order in the tree from the butt end
- The north point was marked to record the orientation of the log during scanning

- Butt end of log -
- 4 quadrants of different colours (same for all logs) with same colour quadrant starting at the north point. This is necessary for the log saw operator to attempt to cut all logs with their north point vertical. Where this does not prove possible the colour quadrant system will give the information necessary to reconstruct the orientation of cut battens.

Logs are currently ready for scanning and conversion and await installation of new additional software to the sawmill's scanning system that will output true log shape (Figures MON-25 to MON-27). The current system only provides accurate log cross-sectional profiles at the top, bottom and mid-point of each log; MEFYQUE requires accuracy at 10 cm intervals (Figure MON-27). Given the speed at which the scanning system and log conversion operates it is anticipated that, once installed, scanning and conversion will take place immediately.

Figure MON-25. *3D Laser Scanner.*

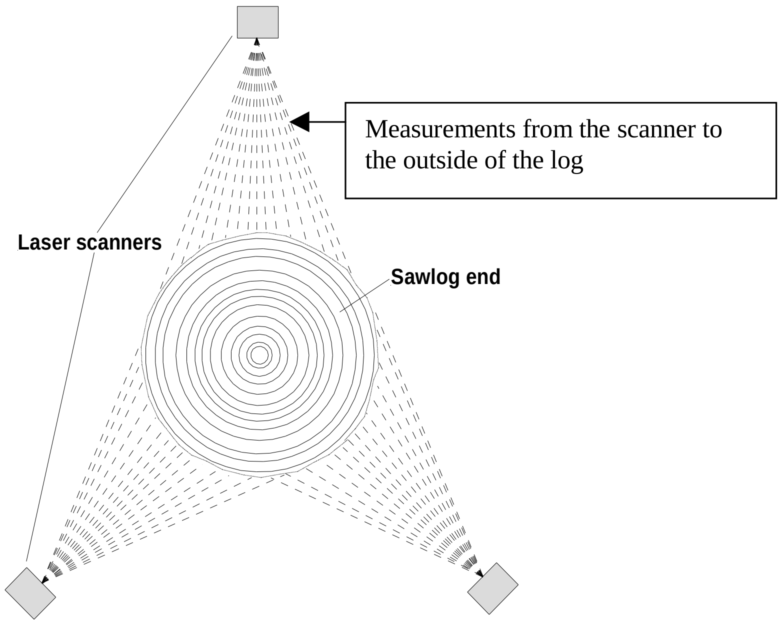


Figure MON-26. *Stacked scans*

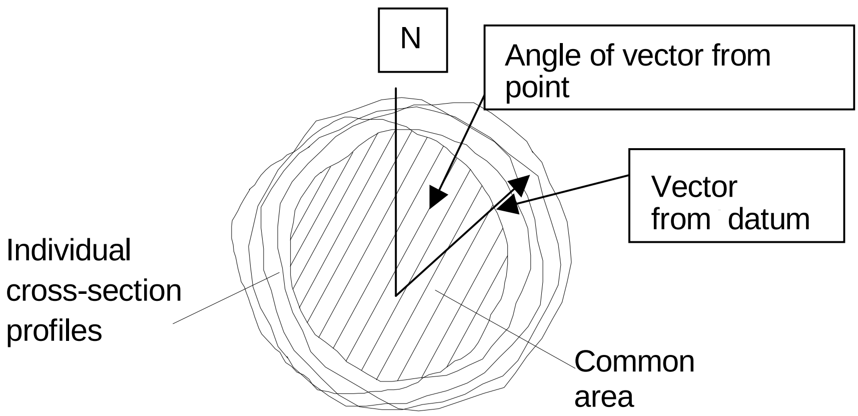
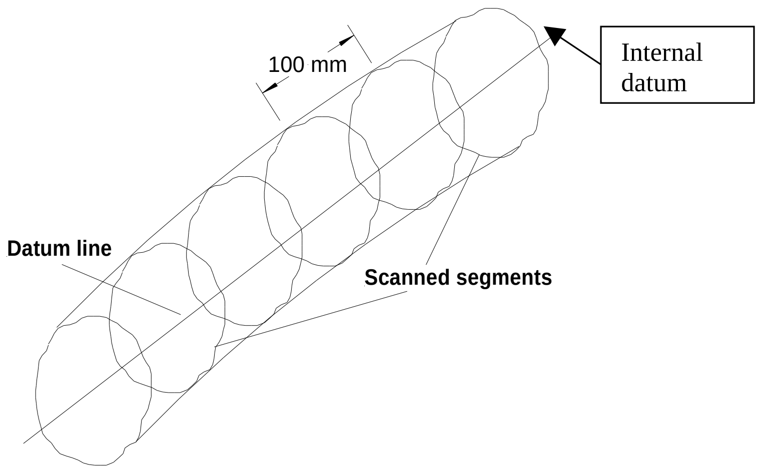


Figure MON-27. *Complete 3D log picture.*



The industrial scanning system described above cannot cope with stems < 75mm diameter, nor can it deal with hardwood logs. It is therefore currently intended to scan stems portions < 75 mm in diameter, the tops of trees from the primary and secondary sites, all sampled material from tertiary sites and all hardwood logs at BRE, Watford (UK). At this location accurate log stem measurement and conversion will also be carried out. To this end a new low cost system, that uses of 'off the shelf' components, is being developed that is expected to be operational in mid-October 2002. Initial trials of this new system are proving successful. Financial support for this equipment is being provided jointly by MEFYQUE, another EU project (COMPRESSION WOOD) and a UK national programme. As the new device has patent possibilities, no further details will be provided here. Following scanning of logs, small material will then be milled to produce small strength and stiffness assessment samples for use in WP6.

Table MON-1. *Primary Site details*.

Level II number	MEFYQUE Site number	Site location	Country	Research site area (m^2)	Forest area (ha)	Elevation (m)	Mean precipitation (mm)	Soil characteristics	MEFYQUE plot established and measured	Co-located with MEFYQUE Secondary site
06-512	1	Straits Enclosure	UK	2916	70	80	780	Pelo-stagnogley	ü	ü
06-919	2	Coalburn	UK	2988		300	1200	Cambic stagnohumic gley	ü	
06-920	3	Tummel	UK	3051		400	1500	Ferric podzol	ü	
06-717	4	Rannoch	UK	3052		470	1500	Humo-ferric gley podzol	ü	
06-517	5	Grizedale	UK	2954		115	1800	Brown podzol	ü	
06-715	6	Thetford	UK	3030		20	600	Calcareous sand	ü	
not Level II	7a	Clunes	UK	991		76	1780	Brown earth		
not Level II	7b	Clunes	UK	996		76	1780	Surface water gley		
not Level II	7c	Clunes	UK	1085		76	1780	Brown earth		
not Level II	7d	Clunes	UK	1012		76	1780	Brown earth		
not Level II	8a	Sawley	UK	973		225	1000	Brown earth	ü	
not Level II	8b	Sawley	UK	1041		225	1000	Podzol	ü	
not Level II	8c	Sawley	UK	1131		225	1000	Brown earth	ü	
06-716	9	Hope (Sherwood)	UK	3081		265	960	Podzol (sandy)	ü	
02-015	10	Brasschaat	Belgium		150		750		ü	ü
1101	11	Grünewald	Germany	1600				Ferric cambisol	ü	
1102	12	Grünewald	Germany						ü	
	13	Grünewald	Germany						ü	
	14	Collelongo	Italy		3000	1500	1100	Calcareous brown earth		ü
	15	Monte Amiata	Italy							
	16	Pieve Tesino	Italy		10000	800-1600				
	17	Renon	Italy	9000		1700			ü	ü

Table MON-2. *Tree details at Primary Sites*.

Level II number	MEFYQUE Site no	Site location	Planting year (average)	Dominant species	Other tree species	Understorey species and ground vegetation	Date of last measurement assessment	Average density of trees/ha	Mean height (m)	Dominant DBH (cm)	Mean DBH (cm)
06-512	1	Straits Enclosure	1935	OK	Fraxinus excelsior	Corylus avellana, Cratagus monogyna, rubus spp	Mar-2001	495	19.9	29	24.5
06-919	2	Coalburn	1974	SS		Mosses, Lichens	Mar-2000	1850	14.5	32.6	20.7
06-920	3	Tummel	1969	SS		None	Nov-1999	2082	15.2	31.2	19.3
06-717	4	Rannoch	1965	SP		Grasses, Mosses	Nov-1999	2270	10.4	21.4	14.4
06-517	5	Grizedale	1920	OK		Grasses, Bilberry, Bracken, Mosses	Feb-2000	230	17.4	43.7	34.9
06-715	6	Thetford	1967	SP		Grasses, Bracken, Mosses, Nettles	Mar-2000	978	14.9	28.5	20.4
	7a	Clunes	1935	NS			Feb-1996	1463	25	41.4	26.5
	7b	Clunes	1935	NS			Feb-1996	1145	26.2	44.2	30.4
	7c	Clunes	1935	NS			Feb-1996	1143	25.6	45.7	30.5
	7d	Clunes	1935	NS			Feb-1996	1146	23.6	43.4	29.4
	8a	Sawley	1943	SS		Deschampsia, Mosses, Ferns	Apr-2002	154	30.8	65.1	59.8
	8b	Sawley	1943	SS		None	Apr-2002	893	26.7	43.5	30.7
	8c	Sawley	1943	SS		Rhododendron ponticum, Prunus serotina, Molinia caerulea	Apr-2002	239	29.5	52.6	46.8
06-716	9	Hope (Sherwood)	1952	SP	Fagus sylvatica, Quercus petreae	Prunus serotina, Sorbus aucuparia	Feb-2000	1125	16.4	29.3	21.9
02-015	10	Brasschaat	1929	SP/OK/BE			2001		23		
1101	11	Grünewald	1900	SP/OK/BE			2001				
1102	12	Grünewald	post-1945	ESF/SP			2001				
	13	Grünewald	post-1945	ESF			2001				
	14	Collelongo	1902	BE	Fagus sylvatica				25		
	15	Monte Amiata		BE	Pinus cembra, Larix decidua	Vaccinium myrtillus, V. vitis-idaea, Melampaum sylvaticum, Homogyne alpina, Hieracium sylvaticum					
	16	Tesino	Uneven	NS/ESF							
	17	Renon	1920	NS			Aug-2000	270	24.8		

Species key: OK: Oak SS: Sitka spruce SP: Scots pine NS: Norway spruce BE: Beech ESF: European silver fir

Dominant and mean DBH are quadratic means:

$$\sqrt{\frac{\left(\sum x^2\right)}{n}}$$

Table MON-3. *Secondary Site details.*

MEFYQUE Site n°	1	10	14	17
Site location	Straits	Brasschaat	Collelongo	Renon
Country	UK (south)	Belgium (north)	Italy (central)	Italy (north)
Elevation		16 m	1500 m	
Mean temp.	10.6 °C	10.0 °C	6.2 °C	
Mean precipitation	780 mm	750 mm	1100 m	
Forest area	70 ha	150 ha		
Stand age	72 yrs	73 yrs	100 yrs	
Dominant species	Oak (Quercus robur) + ash (Fraxinus excelsior)	Scots pine (Pinus sylvestris)	Beech (Fagus sylvatica	
Other species	Hazel (Corylus avellana), hawthorn (Crataegus monogyna) & Rubus spp	Oak (Quercus robur); beech (Fagus sylvatica); Rhododendron spp, Prunus serotina		
Tree height	19.3 m (1995)	23 m (2001)	25 m	
Soil characteristics	Pelo-stagnogley; 80 cm deep, pH 4.7	Wet sandy soil to podsol; pH	Brown earth; 80 cm deep	
Meteorological data	Since 1955, and at the site since 1994	Since 1996		
Eddy flux data	Since 1999(?)	Since 1996	Since 1994 (?)	Since 2001 (?)
Other programmes	UN/ECE ICP Level I and Level II	UN/ECE ICP Level II EU CarboEuroflux project	UN/ECE ICP Level II	
Other information	Continuous pollution records (7.4 kg/ha N in 1997)	Continuous pollution records since 1996	GPP, NPP, NEP and other carbon budget terms	

MAIN RESULTS – YEAR 2

Primary sites, where tree and stand characteristics are measured and wood material sampled, according to the project Sample Plot Protocol. A total of 17 project plots have been established. Data collection at the majority of primary sites is now completed, as shown at Table MON-4. Due to adverse weather conditions, sampling at 2 sites in Italy was delayed until spring 03, with sampling now ongoing. Data for these sites are not yet included in the project database.

Table MON-4. *Primary sites. Number of trees measured for each mensuration parameter at the project sites*

Site	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08.1	FR08.2	FR10	IT01	IT02	IT03	IT04	TUB01	TUB02	UIA01
Stem form	6	7	0	0	6	9	2	6	4	9	63	61			102	175	79
Stem lean	6	8	0	0	6	9	3	6	4	9	61	61			102	175	70
Dominance class	0	0	0	0	0	0	0	0	0	0	63	61			102	179	9
Dbh	6	8	5	9	6	9	3	8	4	9	63	61			102	176	79
Total height	6	8	9	9	6	9	9	8	4	9	18	34			62	41	79
Tim height	6	8	9	9	4	9	9	8	4	9	0	29			62	0	9
Height of 1st dead branch	4	8	7	9	3	9	9	8	4	9	3	3			0	0	0
Height of lower crown	6	8	9	9	5	0	9	8	4	9	10	29			62	41	4
Height of upper crown	1	8	9	9	2	9	9	8	4	9	10	29			62	41	4
Crown width	0	0	0	0	0	0	0	0	0	0	10	30			62	40	0

Table MON-5 outlines the progress in the data collection of on destructive biomass and biochemical samples taken from felled trees at each project sites. Due to adverse weather conditions, sampling at 2 sites in Italy was delayed until spring 03, with sampling now ongoing. Data for these sites are not yet included in the project database. Data from other sites has yet to be inputted into the project database.

Table MON-5. *Progress in the data collection of on destructive biomass and biochemical samples taken from felled trees at each project sites*

Measurement type	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08	FR10	IT01	IT02	IT03	IT04	TUB01	TUB02	UIA01
C/N data (bark)	ü		ü	ü	ü		ü	ü	ü						ü	ü
C/N data (branches)	ü	ü	ü	ü	ü	ü		ü	ü						ü	
C/N data (cones)															ü	
C/N data (heartwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü						ü	ü
C/N data (leaves)	ü				ü											
C/N data (needles)		ü	ü	ü		ü	ü	ü	ü						ü	
C/N data (roots)	ü	ü	ü	ü		ü		ü	ü						ü	ü
C/N data (sapwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü						ü	ü
C/N data (transient zone)	ü				ü			ü	ü							
Green/dry weights (Branch)	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Green/dry weights (Disk)	ü	ü			ü	ü	ü	ü	ü							
Green/dry weights (Leaves)	ü				ü											
Green/dry weights (Needles)		ü	ü	ü		ü	ü	ü	ü							
Green/dry weights (Root)	ü	ü			ü		ü	ü	ü							
Tree branch lengths	ü		ü	ü	ü	ü	ü		ü							
Tree branch weights	ü		ü	ü	ü		ü		ü							
Tree crown width										ü	ü			ü	ü	

Measurement type	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08	FR10	IT01	IT02	IT03	IT04	TUB01	TUB02	UIA01
Tree DBH	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü			ü	ü	ü
Tree diameters (sections)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü
Tree dominance										ü	ü			ü	ü	
Tree ht to 1st dead branch										ü	ü					
Tree logs	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Tree lower crown	ü	ü	ü	ü	ü		ü	ü	ü	ü	ü					ü
Tree stem form	ü	ü			ü	ü		ü	ü	ü	ü			ü	ü	
Tree stem lean	ü	ü			ü	ü	ü	ü	ü	ü	ü			ü	ü	
Tree timber height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü
Tree total height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü			ü	ü	ü
Tree upper crown	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü

Examples of data collection undertaken in the current year are illustrated in Figures MON-28,29 below, outlining data for 2 Italian primary sites.

Figure MON-28. *DBH distribution at the Amiata primary site.*

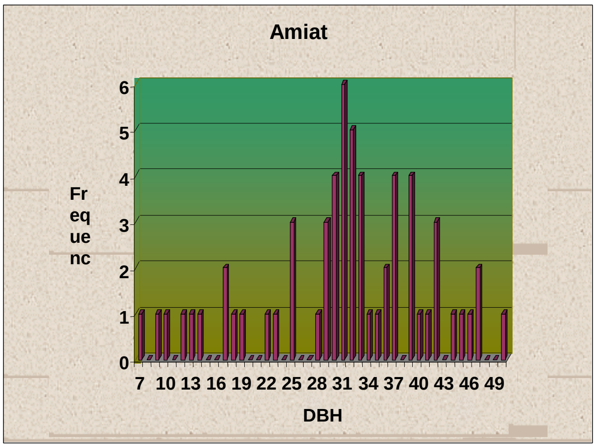


Figure MON-29. *DBH distribution at the Collelongo primary site.*

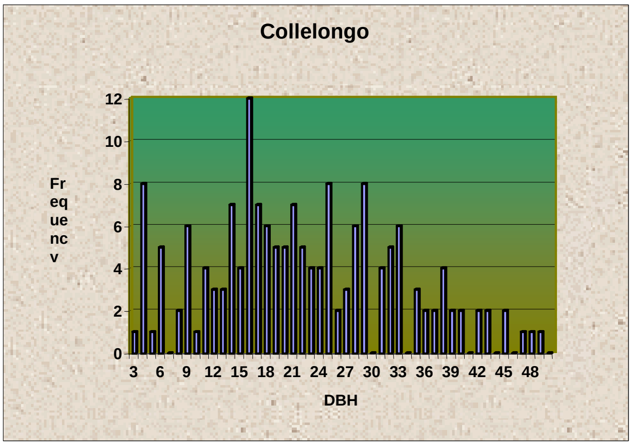


Figure MON-30. *Stem quality score distribution at the Amiata primary site.*

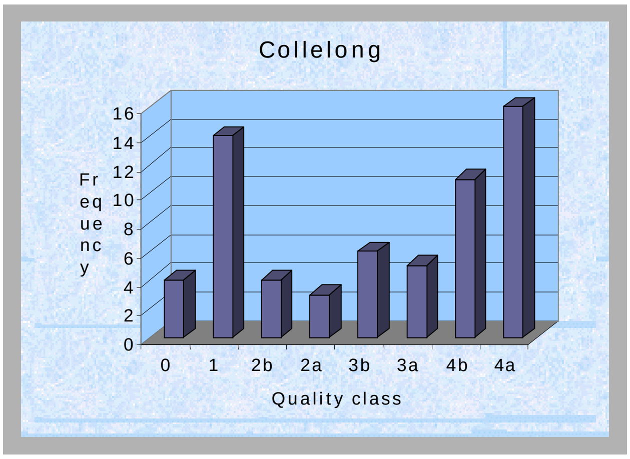
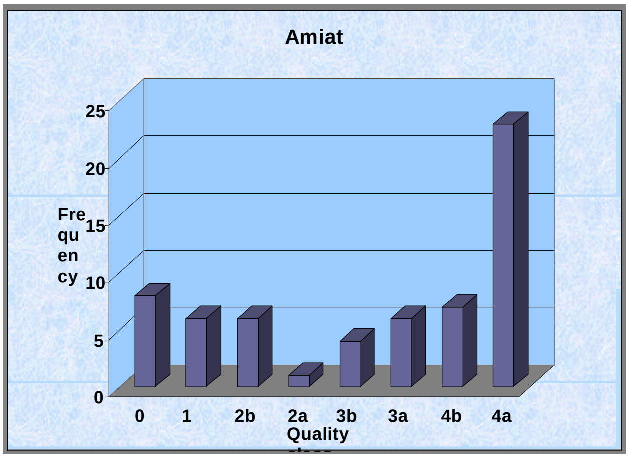


Figure MON-31. *Stem quality score distribution at the Collelongo primary site.*



Detailed evaluation of the log quality scores has been carried out at the Collelongo site, as shown in Figures MON-32,33 below.

Figure MON-32. *Trend on log quality score per tree at the Collelongo site*

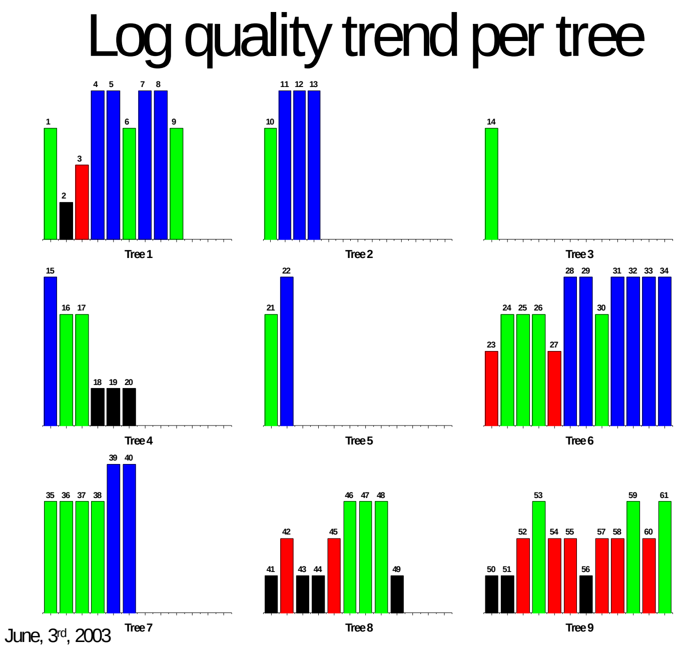
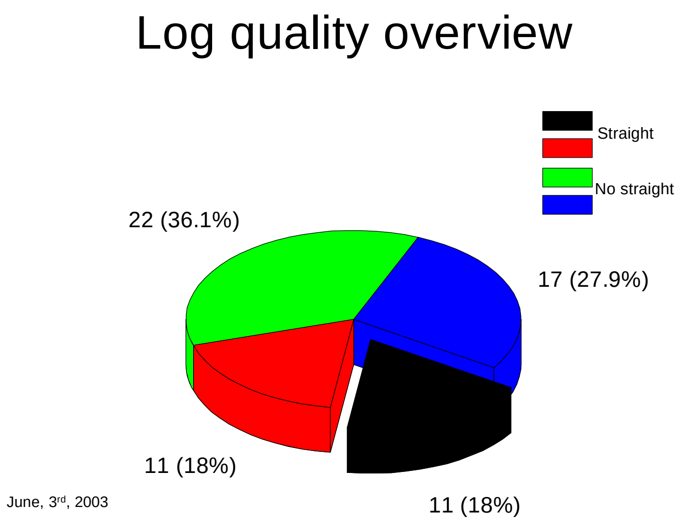


Figure MON-33. *Overview of log quality scores for the Collelongo site.*



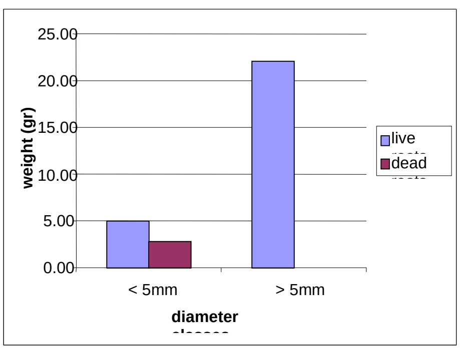
In accordance with the sampling protocol, data are being collected on below-ground biomass, as illustrated below in Figures MON-34 to MON-36 for the Monte Amiata site.

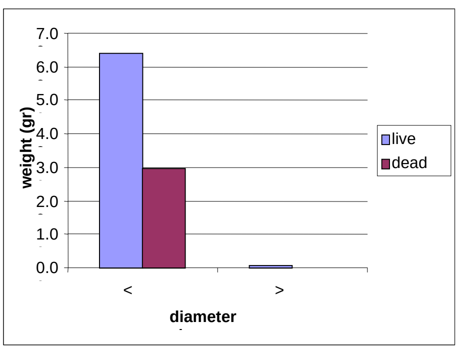
Figure MON-34. *Sample A1 (10 cm from tree). Root weight and diameter classes (dead and green roots).*

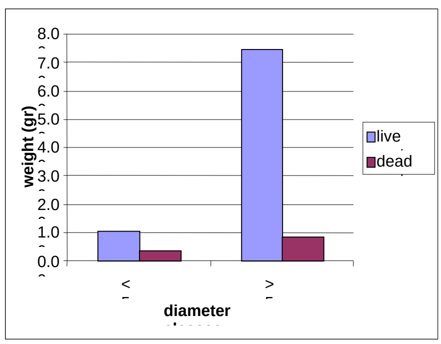
Figure MON-35. *Sample A2 (50 cm from tree). Root weight and diameter classes (dead and green roots).*

Figure MON-36. *Sample A3 (100 cm from tree). Root weight and diameter classes (dead and green roots).*

Roots weight of sample A1:				Roots of sample A2:				Roots weight (g) horiz A3:			
Live roots		Dead roots		Live roots		Dead roots		Live roots		Dead roots	
<5mm	>5mm	<5mm	>5mm	<5mm	>5mm	<5mm	>5mm	<5mm	>5mm	<5mm	>5mm
5.00	21.97	2.83	0.00	6.40	0.07	2.97	0.00	1.06	7.44	0.37	0.88



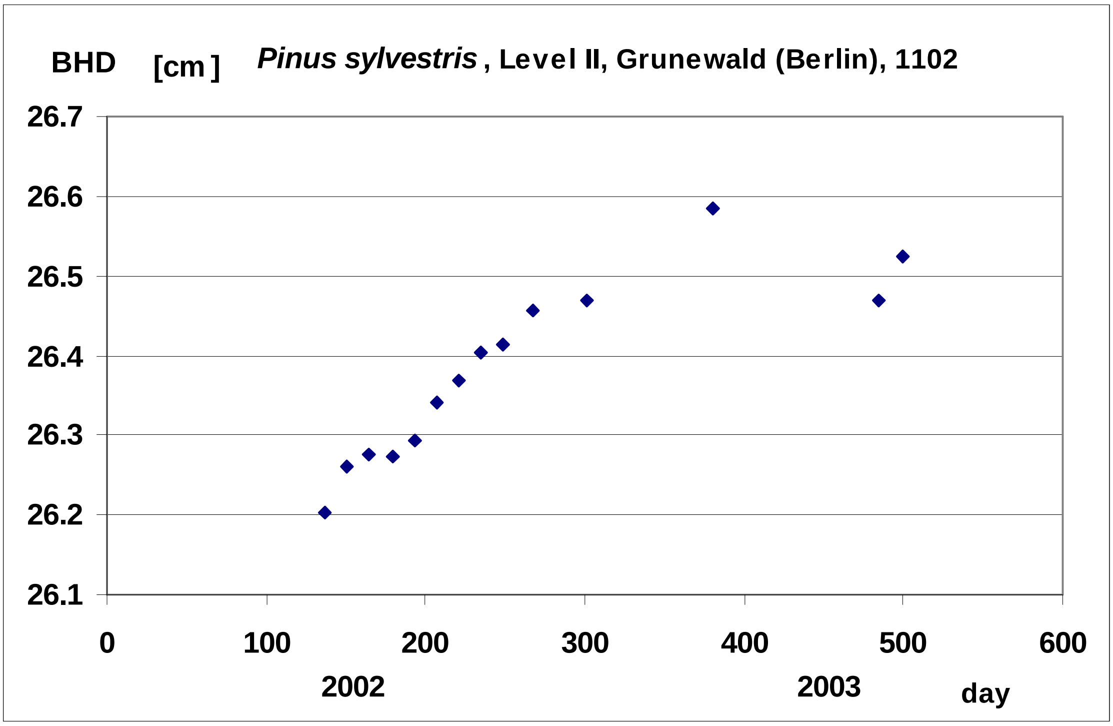




Secondary sites. A total of 4 secondary sites are available for use by MEFYQUE that coincide with the location of 4 primary sites. At the sites eddy- covariance measurements are routinely performed, with data on fluxes of water, carbon and energy exchanges continuously measured above the forest canopy in real time, and stored together with meteorological data at sub-hourly intervals. These data have been used to inform and validate the process level sub-models (photosynthesis, respiration and transpiration) of the integrated modelling system. Data collection at these sites is ongoing and available data are held on a project CD-ROM.

Some additional studies have been undertaken at primary sites. At the Grünewald site stem circumferences at breast height were continued in the older mixed pine-oak stand (1101, 120-year-old pines) and in the 50-year-old pine stand (1102) monthly. Figure MON-37 below shows as an example the development of the BHD of *Pinus sylvestris* on the plot 1102; the reduction of stem circumference in winter 2002/2003 is due to stem shrinking. In addition samples were taken every two weeks with a special small corer to sample the last 4 tree rings at the 50-year-old pine-stand (1002). Samples were embedded for further anatomical analyses; measurements have yet to be performed on these samples.
At the same site, results from the mensurational measurements at the very beginning of the project were evaluated and compared with data from 1986 obtained in the same stands. Although 15 years are only a short moment in tree life span and in forest succession some slight changes are visible. In the older stand growth limit of Scots pine is reached. Oak could only slightly expand its stand wood volume at the cost of its high mortality. It can be assumed that at this stand strong competitive power maintained equilibrium in competition. In the younger Scots pine stand that is still in its fast growing phase, oak could fill gaps and provide a gene resource for natural regeneration. Nevertheless, it was found that the portion of oak in the dominant layer is decreasing. We, therefore, postulate that in both stands pedunculate oak might become a dominant tree species after senescence of the pine layer only.

Figure MON-37. *Monthly course of stem diameter at breast height at the primary site with ~50-year-old Scots pines during the previous and the current year in Grünewald forest, Berlin, Germany.*



BRE Progress with log scanning
Appendix 2-A includes tables showing progress with this WP.

3-D Log scanning. Logs were due to be scanned at Howies Forest Products Ltd early in this reporting period. However, Howie's and BRE were misinformed about the demonstration software to be provided. The general understanding had been that the new software would give 36 accurate points to describe each cross-section. However, the industrial system only gave 12 points, thus introducing a delay in the scanning phase of the project. It therefore became essential to move the scanning operation to a near by sawmill. The managing director of James Jones and Son (JJ), the 2nd biggest saw-millers of the UK accommodated the project logs at Lockerbie. The sawmill scanned and cut the logs large enough for their system; badly twisted and small logs, some of which were from Belgium, were put to one side to return to BRE for further assessment. Unfortunately a significant amount of time elapsed after which (JJ), on cleaning up the sawmill yard, were destroyed the project's remaining small distorted logs, though clearly marked. James Jones (JJ) have since apologised but the event has caused a loss of some entity to the project.

Due to pressure of business (JJ) could no longer scan or cut any more of the project logs. The next batch was therefore cut at Adam Wilson and Son Ltd [15]. All future scanning and sawing will be carried out at BRE. A scanner has been developed and built and BRE are currently scanning the outstanding logs. The scanner is a shared cost development but has been mainly used by the MEFYQUE project. The scanner is a low cost device using off-the-shelf components that has required considerable additional programming effort.

The theory of 3-D scanning has been reported in Year 1. Some practical results of the new scanner are reported below.

A camera, as shown in Figure MON-38, with the image processed to give the result shown in Figure MON-38, views a laser line round a log.

Figure MON-38. *The straight line laser view at an angle by the camera.*

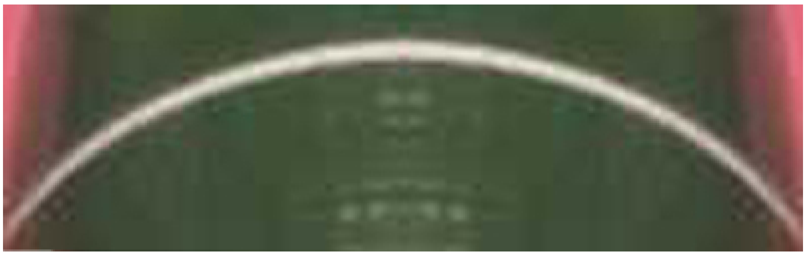
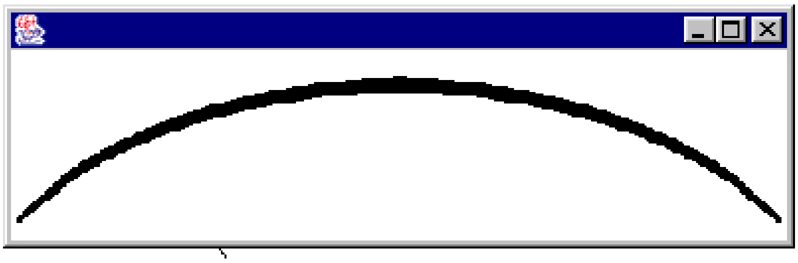


Figure MON-39. *Processed image in rectangle co-ordinates*.



The true shape is then derived by geometric equations, as shown in Figure MON-40.

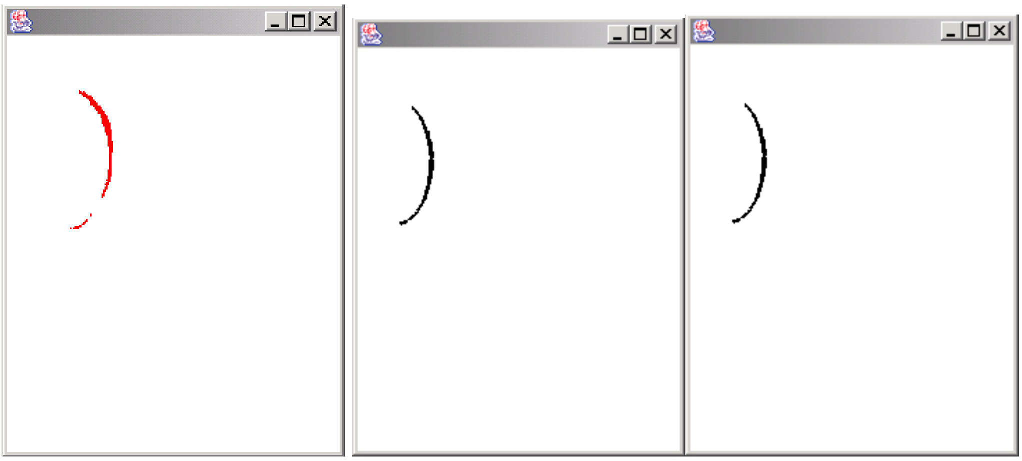
Figure MON-40. *True shape of arc of log.*

As outlined in the Year 1 report, the scanner uses three laser lines and three cameras to see round the log. Figures MON-41 and 42 show the scans and 3 arcs of one cross-section.

[15] This was a special favour to BRE. BRE are indeed grateful to both sawmills for making their facilities available on Saturday mornings. This is an industry showing a real interest in the project.

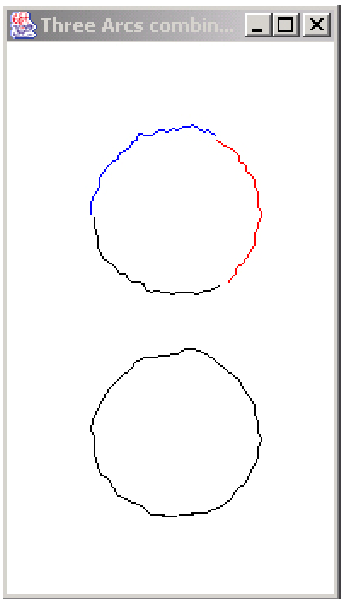
Figure MON-41. *Three laser scans*.

Figure MON-42. *Scans converted into arcs by the computer software.*



Images are then processed to give the cross-section, as shown in Figure MON-43 below.

Figure MON-43. *The 3 scans are processed and combined to give log cross-section.*

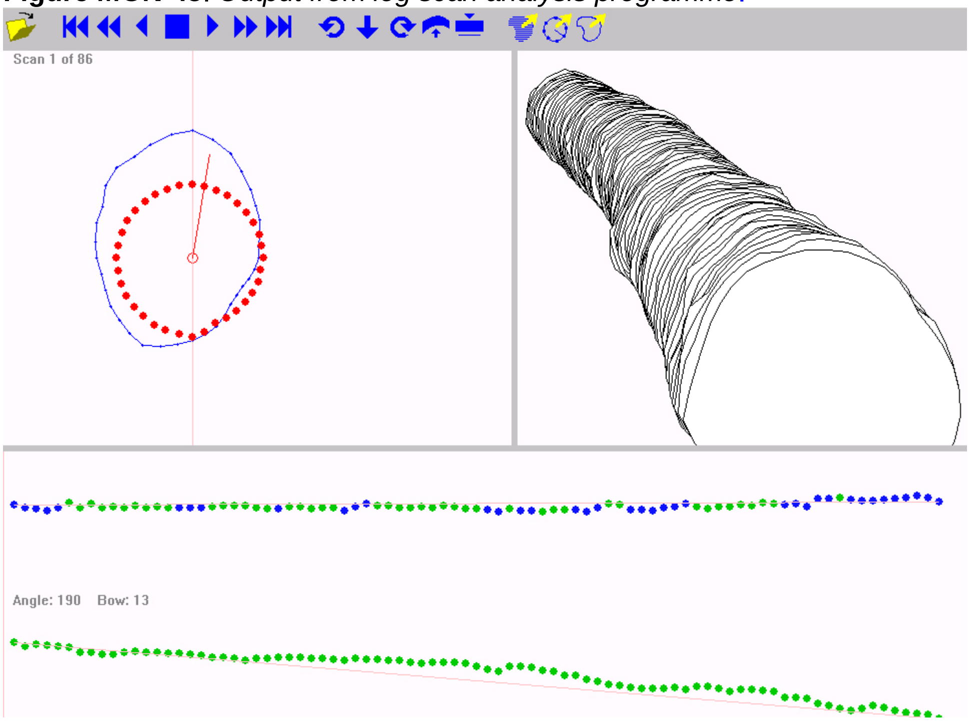


Software has been developed to read both the output from the industrial and BRE scanners to view and analyse the scans and build them into logs. The industrial data was very noisy and special software had to be developed to clean up the output. Figure MON-44 shows scans of a log stacked to give the common area. The significance of the common area is discussed below.

Figure MON-44. *Stacked clean spans to give the common area.*

The developed software not only reads all the scans and cleans up the data, it also allows the log to be turned through 360 degrees, in 10 degree intervals, increment and it calculates maximum log bow and it rotational position (Figure MON-45 below). Also, it outputs the data in mm strip rectangular co-ordinates for the common area and each cross-section for 36 rotations. Simulation programmes to derive optimum cutting patterns described in Section 2.2.4.1 use these data as input.

Figure MON-45. *Output from log scan analysis programme*.



MAIN RESULTS • YEAR 3

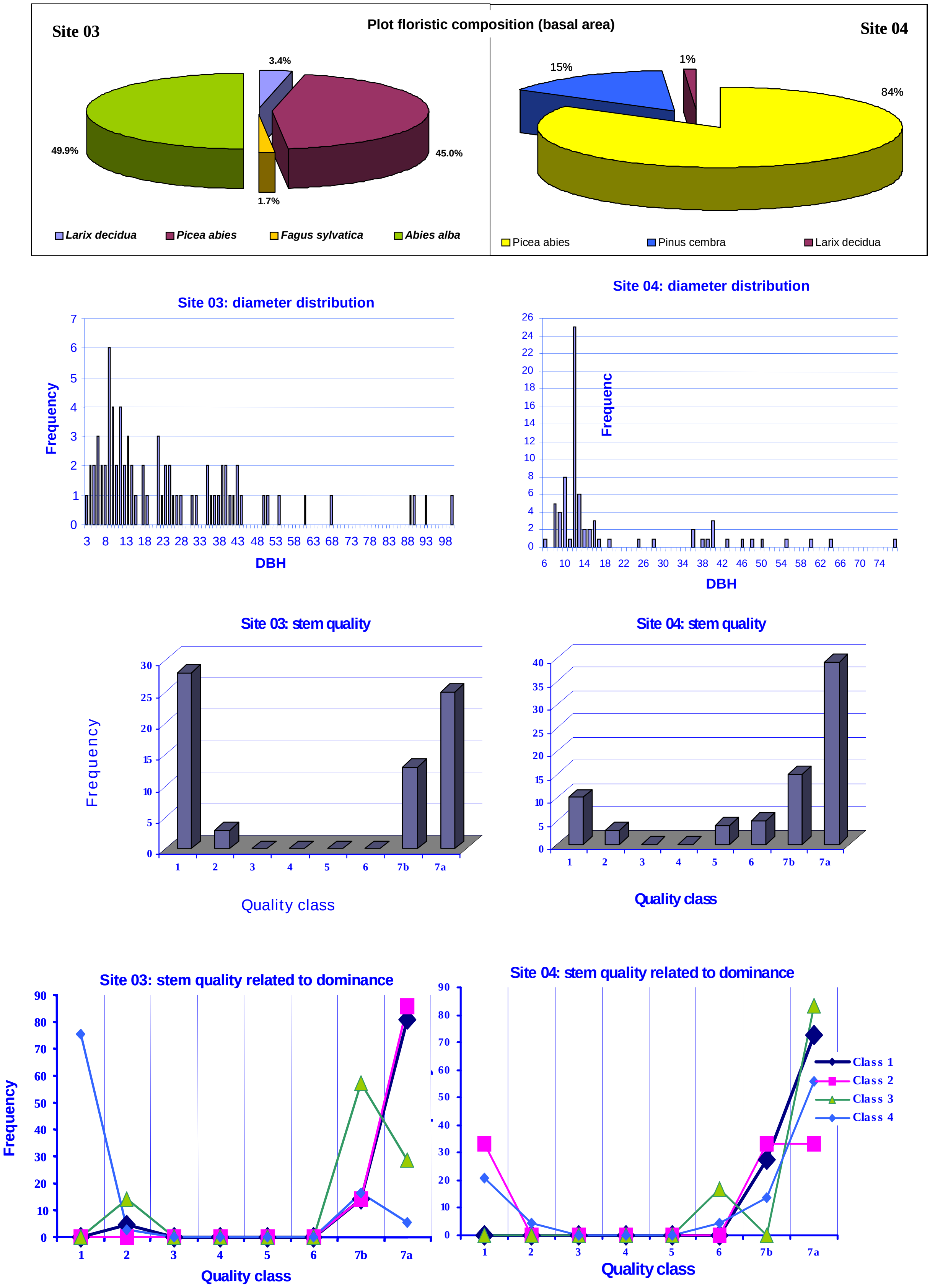
All field measurements included in the sampling protocol about sites 01 (Collelongo), 02 (Monte Amiata) 03 (Cinte Tesino) and 04 (Renon) are complete and the data have been sent to the Partner 01. During the 2004 season sampling was mainly carried out on sites 03 and 04.

The following features were measured for all stand trees:

1) stem form
2) stem lean

3) dominance score
4) dbh
5) total height
6) top height
7) deviation

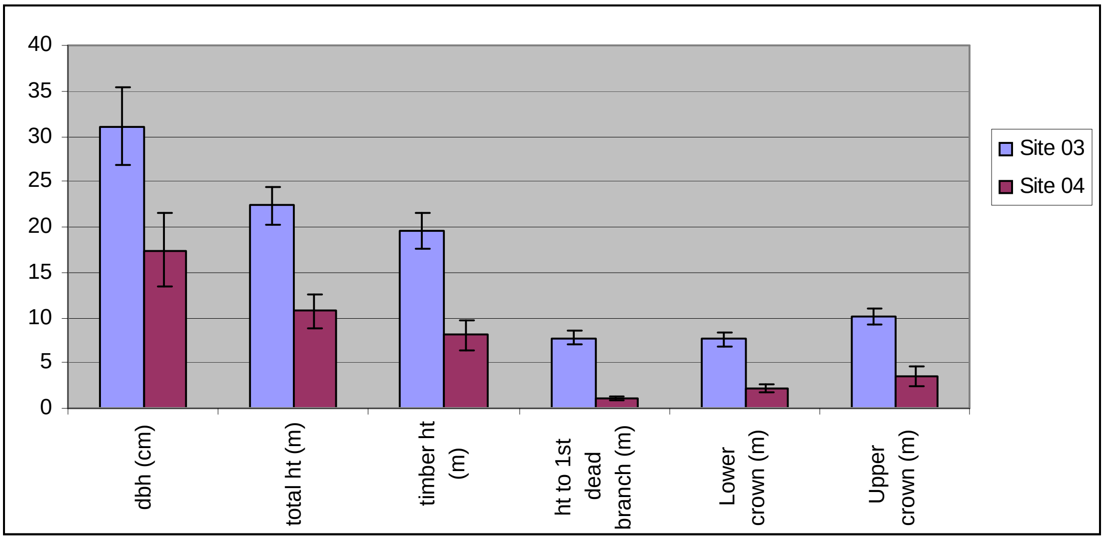
Figure MON-46. *Summary results sites 03 and 04*



For 30 selected trees in site 03 and 10 in site 04, the following were additionally measured:

- dbh
- timber height
- lower crown
- upper crown
- crown width

Figure MON-47. *Mean data from 30 and 10 selected trees sites 03 and 04*

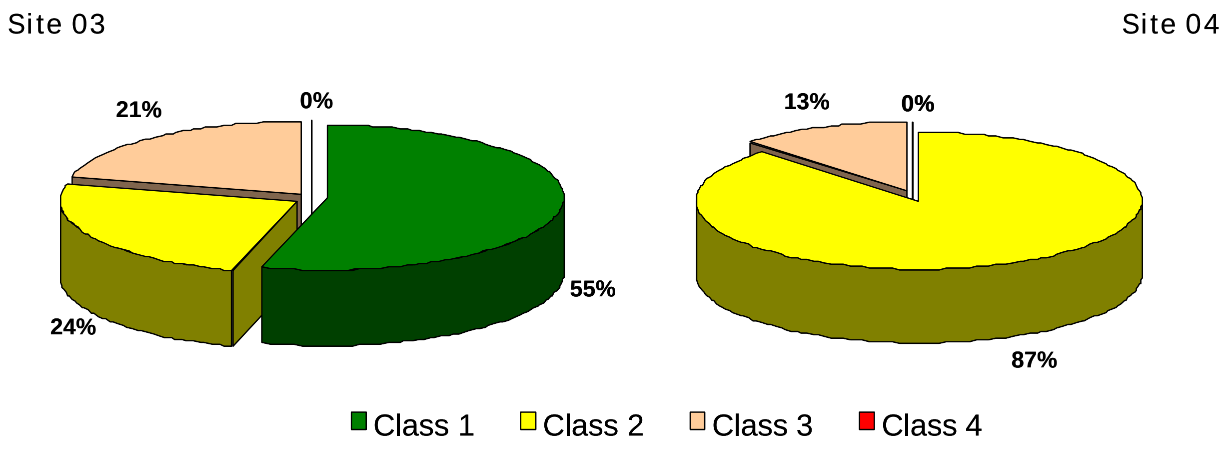


On the 9 felled trees for each plot were measured:

- total tree length
- timber height
- height of first live whorl
- height of first whole dead branch
- taper at one metre intervals up the stem
- tree quality, visually assessed using the scoring system provided by the sampling protocol

From the bole 2.5 metres long logs were produced.
Logs were visually assessed for quality using the scoring system provided by the sampling protocol; preliminary results are shown below:

Figure MON-48. *Log quality overview*



The logs were sent to the Partner 7 and the discs to Partner 6 and 4 as agreed.

Three additional trees were selected, felled and measured at each plot and for each tree three soil cores were extracted; results are shown below:

Figure MON-49. *Above ground biomass*

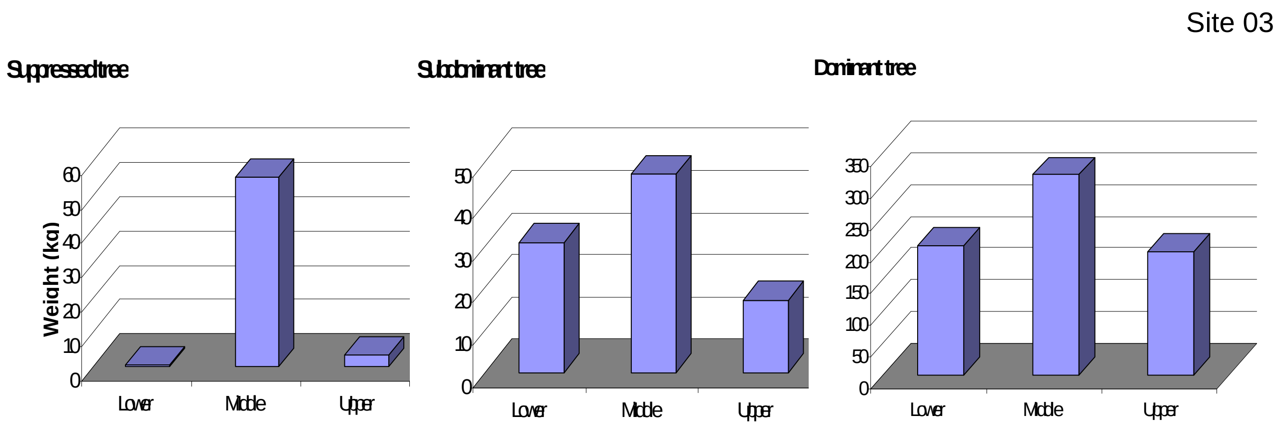
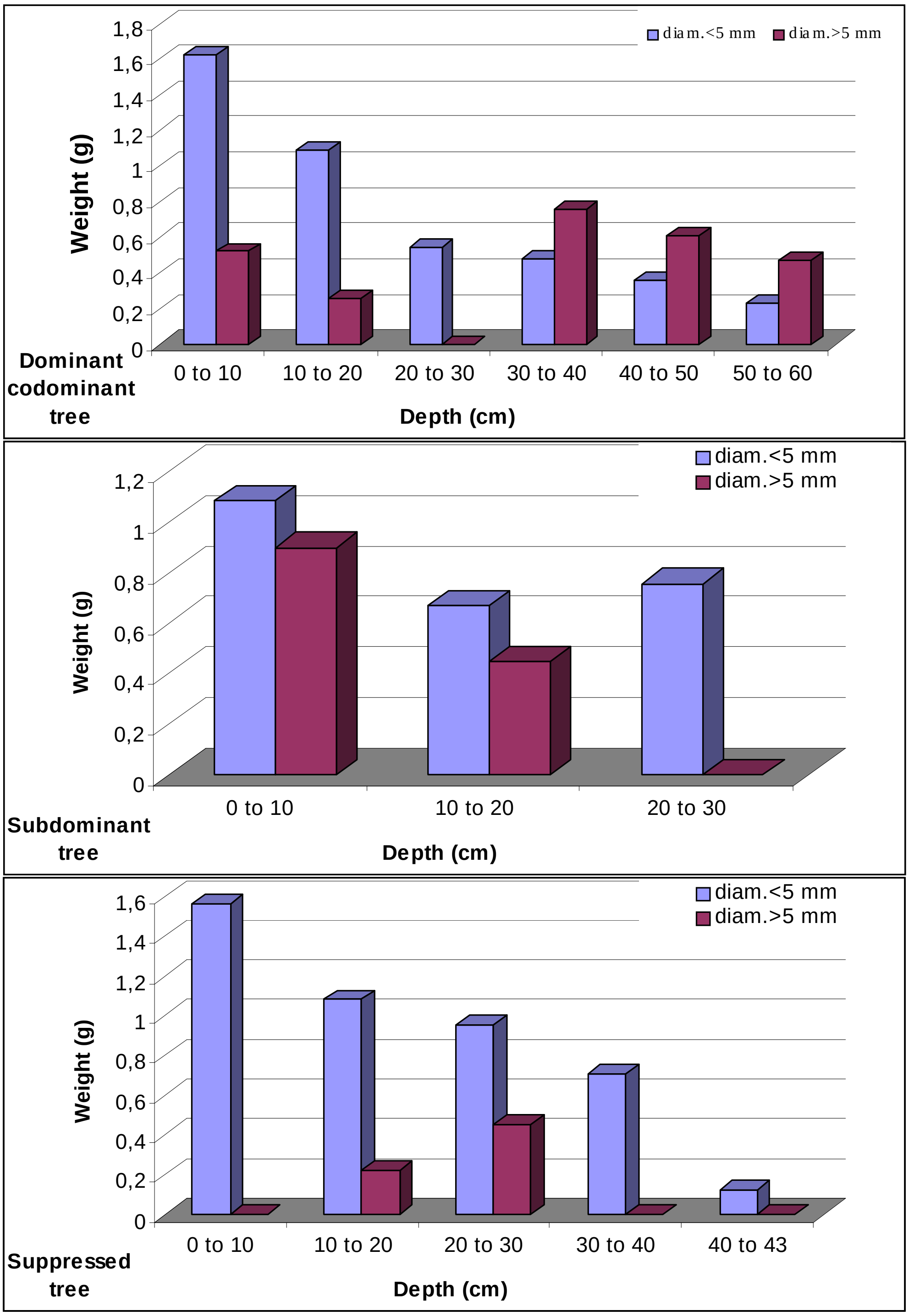


Figure MON-50. *Below ground biomass*



One main activity was carried out during this year: continuation of eddy covariance data collection on the meteorological tower. These data have been processed (gap-filled and corrected). Furthermore the data have been fully analysed resulting in the publication of one paper and a second paper recently submitted (see publication list).

The data (from the previous years) were integrated into the database, as our contribution towards deliverables 2 (completed database) and 3 (data available for validation of the model).

Mensuration data from felled trees

Primary Sites

These primary sites were used to assess the growth and quality of the standing trees. The sites were of known spacing, thinning and fertiliser levels so that direct correlation could be formulated between growth conditions and timber quality. Nine tress were selected from each plot (three dominant, three sub-dominant and three suppressed trees) for anatomical, chemical and structural analysis to determine the climate/latitude, management and treatment effects on the quality of the felled timber. The sites selected were used to represent a number of different species, Scots pine (SP), Sitka spruce (SS), Norway spruce (NS), oak (OK), beech (BE) and poplar (PO).

BRE's role with this material was to assess the timber quality of the felled trees. This included 3D scanning of the felled logs, batten conversion, drying distortion (twist, bow, spring and cup), batten grain angle, presence of compression wood, batten distance from pith, knot area ratio, density, moisture content, rate of growth, machine grading stiffness, MOE and MOR values.

By the close of the second year, 50% of the selected logs from the primary sites had been scanned and processed. Primary processing was undertaken at Adam Wilson and Sons, Troon, and BSW, Lockerbie, both sawmills being located in Scotland. The sawn material was subsequently kiln dried and sent to BRE for the assessment of growth and mechanical characteristics. Assessments were initiated as soon as the material was received.

By the close of the third year, all the battens received at BRE were assessed for distortion (twist, bow, spring and cup), grain angle, the presence of compression wood, distance from the pith, knot area ratio, density, moisture content, growth rate and were then machine stress graded.

At the beginning of the third year, BRE received a number of logs from the Italian forests, Collelongo, Monte Aminata and Pieve Tesino. These logs were scanned at BRE, using the in-house log scanner. The logs were then processed on site, to produce as many 50 x 100 mm dimension battens as possible. All the processed battens were then kiln dried to 12% and assessed using the same protocol developed during previous assessments.

All assessment data was input into the BRE log database (developed at the beginning of the project) as the data was collected. Although, the database is still being finalised, during the remaining period of the project, all the remaining assessment data will be input for all trees. This database forms an important element of the project and will be used to compare important growth and structural parameters and aid the development of predictive models.

Tertiary sites
The tertiary sites used to assess the effects of climate change on the tree growth. These sites consist of both open and closed top chambers that have highly controlled environments. The sites were used for experimental observations, where samples of plant material were assessed for anatomical, chemical and structural analysis to determine single and combined effects of enhanced CO_2, temperature and doughtiness effects on timber quality.

BRE's role in the analysis of the tertiary sites was to assess the density, volume and strength for the different species, for each growth conditions. However, due to the young age of the trees and in turn the high spread of strength data obtained from this material it was not cost effective to continue measuring this variable.

The material collected from the tertiary sites was received at BRE during the second year. Due to work pressures dealing with the logs from the primary sites, material from the tertiary sites was retained in a freezer to ensure the material remained 'green' until testing could commence.

During the first half of the third year, assessments (volume and density measurements) were initiated on the tertiary material. Measurements were also recorded of the top, middle and base diameters, in order to calculate the whole tree volume. A small disc was also removed from each stem in order to calculate the whole tree density.

All the measurements on tertiary material are now complete, and the database for this material fully compiled. During the last stage of the project, the results will be analysed to compare density and volume for each species and different growth conditions.

MAIN RESULTS • YEAR 3 - Extension

The monitoring component of the project was completed by the end of year 3 of the project; hence there is no new material to report for the extended period. Table MON-6 Summarises the data collected, both from the monitoring and laboratory work.

The Table MON-6 below summarises the Measurement types stored in the database from the different sites.

Table MON-6: Summary of data collected.

Measurement type	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08	FR10	IT01	IT02	IT03	IT04	UIA01	TUB01	TUB02
C/N data (bark)	ü		ü	ü	ü		ü	ü	ü					ü		ü
C/N data (branches)	ü	ü	ü	ü	ü	ü		ü	ü							ü
C/N data (cones)																ü
C/N data (heartwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (leaves)	ü				ü											
C/N data (needles)		ü	ü	ü		ü	ü	ü	ü							ü
C/N data (roots)	ü	ü	ü	ü		ü		ü	ü			ü		ü		ü
C/N data (sapwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (transient zone)	ü				ü			ü	ü							
Green/dry weights (Branch)	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Green/dry weights (Disk)	ü	ü			ü	ü	ü	ü	ü							
Green/dry weights (Leaves)	ü				ü											
Green/dry weights (Needles)		ü	ü	ü		ü	ü	ü	ü							
Green/dry weights (Root)	ü	ü			ü		ü	ü	ü							
Log data - bark thickness	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü				
Log data - mid diameter	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü			
Log data - quality score	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Stress test - Bow		ü	ü			ü	ü	ü	ü			ü				
Stress test - MOE		ü	ü			ü	ü	ü	ü			ü				
Stress test - Moisture content		ü	ü			ü	ü	ü	ü			ü				
Stress test - MOR		ü	ü			ü	ü	ü	ü			ü				
Stress test - reaction load		ü	ü			ü	ü	ü	ü			ü				
Stress test - Spring		ü	ü			ü	ü	ü	ü			ü				
Stress test - Twist		ü	ü			ü	ü	ü	ü			ü				
Tree bow												ü	ü			
Tree branch lengths	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Tree branch weights	ü		ü	ü	ü		ü		ü							
Tree crown width										ü	ü				ü	ü
Tree DBH	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree diameters (sections)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree dominance						ü	ü	ü		ü	ü	ü	ü	ü	ü	ü
Tree ht to 1st dead branch										ü	ü	ü	ü			
Tree lower crown	ü	ü	ü	ü	ü		ü		ü	ü	ü	ü	ü	ü		
Tree ring data	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü				
Tree stem form	ü	ü			ü	ü		ü	ü	ü	ü	ü	ü		ü	ü
Tree stem lean (measured)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree stem lean (scores)	ü	ü			ü	ü	ü	ü	ü						ü	ü
Tree timber height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree total height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree upper crown	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Wood anatomy parameters				ü										ü		

2.5.1.1 WP1: Stand growth and yield data in field conditions for a range of management practices at primary and secondary sites

Work-package number:	1						
Start Date:	Planned Jun 01			Status: No change			
Completion Date:	Planned Dec 03			Status: Delay to Feb 04			
Current Status	completed						
Partners Responsible:	P1, P2, P4, P5			Status: No change			
Person-months per Partner:	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	10	3		3	9		
Year 1 – person-months employed	6	2		2	3		
Year 2 – cumulative person-months employed	9	3		2	7		
Year 3 – cumulative person-months employed	10	6		3	9		
Total including extension	10	6		3	9		

OBJECTIVES
The main objective will be to generate stand growth and yield data in field conditions for a range of management practices at primary and secondary sites. This will be achieved by:
1.1 Collection of historical stand data on growth and yield from the primary monitoring sites.
1.2 Collection of contemporary data on growth and yield from the primary monitoring sites for a range of representative management conditions as practised in the partners' Member States:

- even-age single species [intensive silviculture]
- uneven age single species
- uneven-age multi-species [continuous cover forest]

1.3 Sampling of wood from tree compartments (branch and stem) from timber felled as a result of national forest management practices. Thinning will take place according to standard national forest management practices.
1.4 Generation of CO_2 and H_2O flux datasets using existing infrastructure for validating short-term process models.

METHODOLOGY AND STUDY MATERIALS
Available historical stand and yield data will be integrated with ongoing annual monitoring of stand growth and yield assessments at well characterised primary and secondary sites, for a representative range of management conditions. These data are required to parameterise, validate and calibrate the mensurational sub-module of the forest stand scale model.
A standardised mensurational protocol will be introduced to achieve harmonisation of the experimental protocol and develop a unified set of growth and yield data for selected sites across Europe. Training will be carried out by Partner 1, who has the primary responsibility to ensure standardised application of the mensurational protocol.

The table below outlines the monitoring measurements being carried out at each secondary site, with each Partner responsible for his national sites.

		UK		Belgium		Germany		Italy		
		1/0	Timestep	1/0	Timestep	1/0	Timestep	1/0	Timestep	Remarks
Meteo	Air temperature	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Soil Temperature	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Wind speed	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Vapour pressure	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Wind direction	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Light interception	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Solar radiation	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Net radiation	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
	Throughfall volume	•	30 mins	•	30 mins	•	30 mins	•	30 mins	
Soil Water	30 cm	•	30 mins	•	1 week					
	0-15 cm	•	30 mins	•	1 week	•	1 week	•	1 week	
	15-30 cm	•	1 week	•	1 week	•	1 week	•	1 week	
	30-60 cm	•	1 week	•	1 week	•	1 week	•	1 week	
	60-90 cm	•	1 week	•	1 week	•	1 week	•	1 week	
	90-120 cm	•	1 week	•	1 week					
Physiology	CO_2 flux	•	30 mins	•	30 mins	•	30 mins	•	30 mins	Growing season
	TranspiraH_2O flux	•	30 mins	•	30 mins	•	30 mins	•	30 mins	Growing season
	Transpiration flux	•	15 mins	•	1 g.s.					Growing season
	Girth increment	•	30 mins	•	1 g.s.	•	1 week	•	1 week	

Equipment used for the measurements.

		UK	Belgium	Germany	Italy
Meteo	Air temperature		five heights		24.5,21.18.11.2.0.5 m
	Soil Temperature	30 cm height	5 cm depth	30 cm height	-0.05,-0.2 m
	Wind speed	Sonic and conventional anemometer	Sonic and conventional anemometer	Sonic and conventional anemometer	27,23,21 m
	Vapour pressure	Psychrometer and IRGA	Psychrometer and IRGA	Psychrometer and IRGA	24.5,2,0.5 m
	Wind direction		Sonic anemometer		27 m
	Light interception	Tube solarimeter above and below canopy	Tube solarimeter	Tube solarimeter	
	Solar radiation	Dome solarimeter	Solarimeter	Solarimeter	26 m
	Net radiation		Net radiation	Net radiation	24.5 m
	Throughfall volume				20 automatic samplers
Soil Water	30 cm	Theta probe	Theta probe	Theta probe	
	0-15 cm	TDR probe	TDR probe	TDR probe	TDR probe
	15-30 cm	TDR probe	TDR probe	TDR probe	TDR probe
	30-60 cm	TDR probe	TDR probe	TDR probe	TDR probe
	60-90 cm	TDR probe	TDR probe	TDR probe	TDR probe
	90-120 cm	TDR probe	TDR probe	TDR probe	
Physiology	CO_2 flux	Edisol flux system	Edisol flux system	Edisol flux system	Eddy fluxes
	TranspiraH_2O flux	Edisol flux system	Edisol flux system	Edisol flux system	Eddy fluxes
	Transpiration flux	Granier sap-flow gauges	Energy balance method	Energy balance method	
	Girth increments	Wheatstone bridge strain gauges	Dendrometers		Traditional dendrometers

The following parameters will be measured annually from 10 juvenile trees harvested at the end of the growing season over the 3-year period:

Parameter	UK (n=10)	Germany (n=10)	Italy (n=10)	Belgium (n=10)
stem length	•	•	•	•
stem diameter (2x)	•	•	•	•
number of branches	•	•	•	•
number of buds		•		
number of leaves		•		
leaf area	•	•	•	•
dry mass of stem	•	•	•	•
dry mass of fine roots	•	•	•	•
dry mass of coarse roots	•	•	•	•

DELIVERABLES

1. Standardised methodology and protocol for site characteristics, physiological, eco-physiological and mensurational data for observed forest stands.
2. Database of site characteristics, physiological, eco-physiological and mensurational data for a range of species, environmental conditions and management options
3. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality using flux data, increment and other mensuration datasets.

MILESTONES – YEAR 1

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Primary site plot sampling protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02 Secondary site plot sampling protocol. Completed Nov 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – YEAR 2

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Primary site plot sampling protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02 Secondary site plot sampling protocol. Completed Nov 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Scheduled for completion in Dec 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing. Version 2 to be released in Dec 03.	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – YEAR 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Primary site plot sampling protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02 Secondary site plot sampling protocol. Completed Nov 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completed Feb 04	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02. Version 2 Dec 03. Final Version due Feb 05	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extended period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Primary site plot sampling protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02 Secondary site plot sampling protocol. Completed Nov 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completed Feb 04	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02. Version 2 Dec 03. Final Version completed Feb 05	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP1 - Year 1

Primary sites. It has not yet proved possible to obtain permission from the owners (the Berlin Senate and *Berliner Forsten*) of the primary Grünewald sites (Germany) to fell sample trees, as this is within the boundaries of the Grünewald Nature Reserve. In order to mitigate the impact of data loss on the project, it was decided to extend the primary site network to include 2 new additional sites:

- a young post-1945 two-stored stand with a dominant *Pinus sylvestris* layer and a subdominant *Quercus* layer in Grünewald forest where previous mensurational measurements were carried out. The monitoring plot was established within an existing EU/ICP experiment and differs in management regime from the existing *Pinus* stand included in MEFYQUE.
- a *Fagus sylvatica* stand, adjacent to the original primary site in Grünewald forest.

Negotiations between the MEFYQUE project co-ordinator and the Berlin Senate are ongoing to seek special permissions to fell trees at the younger plots.

Primary/Secondary sites. At the Brasschaat primary/secondary site, in addition to the activities already foreseen by the Technical Annex, the following new activities are being carried out:

- As a ICP Forest level II monitoring site, additional data are collected by Institute for Forestry and Game Management, Belgium (Code 2-15), that will be made available to the MEFYQUE consortium.
- Since January 2001, CO_2 soil efflux was measured with a closed dynamic system (IRGA, CIRAS-1, PP SYSTEMS, UK), in nine plots (different associations of canopy/understorey vegetation) representative of the forest structure.
- Soil C, N and pH analyses have been carried out in two representative forest plots.
- Continuous litter collection in Scots pine and pedunculate oak plots.

Key Changes to WP1 - Year 2

Primary sites. All activities at primary sites have been completed, with the following exceptions:

Completion of stem lean measurements at some UK sites.
Completion of activities at 2 Italian sites due to adverse weather conditions in the Alps. Some delay was also introduced to completion of activities in the Apennine sites (central Italy), but the majority of activities are now complete.

It is foreseen that activity at all primary sites will be complete by Dec 03, in line with the Technical Annex Plan.

Primary/Secondary sites. Monitoring and data collection are ongoing. It is foreseen that activity at all primary/secondary sites will be complete by Dec 03, in line with the Technical Annex Plan.

Key Changes to WP1 - Year 3

Primary sites.
No significant change; all data collected before 04 growing season commenced

Primary/Secondary sites.
No significant change; all data collected before 04 growing season commenced

Key Changes to WP1 - Year 3
none

2.5.1.2 WP2: Analyses of qualitative properties in standing timber

Work-package number:	2						
Start Date:	Planned Jun 01			Status: No change			
Completion Date:	Planned Aug 02			Status: No change			
Current status	Completed						
Partners Responsible:	P5, P1, P2, AP6, P7			Status: No change			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	6	2			4	4(-4)	2 (-2)
Year 1 – person-months employed	3	1		1	2	0	
Year 2 – cumulative person-months employed	5	2		1	3		
Year 3 – cumulative person-months employed	6	2		1	4		
Total including extension	6	2		1	4		

Key change: AP6 person-months have been re-allocated to activities of WP4.
Key change: P7 person months have been re-allocated to activities of WP4.

OBJECTIVES
To apply a standard classification system for assessing quality in forest stands and consistent with sawmill outputs will be used across all the primary sites. This allows an assessment of straightness and quality scoring of both trees and stands and will be employed to develop a database across a range of species at well-characterised sites and for a representative range of management options. These data are required to parameterise, validate and calibrate the standing timber quality sub-module of the stand scale growth-quality model.
The main objective will be to determine the qualitative properties of standing timber. To be achieved by:

- Developing the standardised methodology for timber quality assessment for forest stands, applicable across studied regions.
- Non-destructive single measurement of standing tree characteristics for straightness and branchiness.
- Creating a database on timber quality assessment for forest stands across a range of species, environmental and management perturbations.

METHODOLOGY AND STUDY MATERIALS
An existing system to assess timber quality of forest stands based on an evaluation of stem straightness and branchiness in conifers will be adopted and extended by this project. Log quality is determined principally through stem features, summarised for the following categories:

- Stem form: straightness, sweep, bend, lean
- Branchiness: presence and size of knots, limbs, forks, multi-stems
- Damage: scar defects, browsing, extraction.

The definition of straightness specifies:

- Bow not to exceed 1 cm for every 1 m length and this in one plane and one direction only
- Bow is measured as the maximum deviation at any point of a straight line joining centres at each end of the log from the actual centre line of the log.

At both primary and secondary sites, the quality protocol will be applied on all standing trees present in a surface area of 0.1 ha. It is anticipates the number of trees will vary between 50÷300, as a function of stand age and local management practices. It is further anticipated repeated site visits will be required to modify the protocol and to produce a standard methodology and data-set valid for all sites.

Tree felling.
Felling of trees is not allowed in the permanent Level II sites. Thus a sample of trees, representative of those inside the permanent plot, will be felled from outside the plots. These trees will have to be located

in a position where this will not influence or damage individuals growing inside the permanent plots, so as not to affect the ongoing long-term experiment. It is therefore necessary to identify a plot similar to the permanent plot in terms of site and mensurational characteristics; this will therefore require a new series of measurements to be carried out. It is assumed that all other variables remain constant between the two plots.
Felled trees will be used to:

- Validate the quality assessments made on the standing timber
- Provide the plant material required for the laboratory-based WPs 4-6.

The number of trees to be felled will vary as a function of the number of individuals present, their age and species, the stand characteristics as well as the variability observed in the results of the quality assessment protocol.
Tree felling, sampling of wood material and transportation will be responsibility of individual Partners.

Training.
Training for field staff on the quality protocol is required in order to ensure inter-Partner standardisation and will be provided by Partner 1.

DELIVERABLES

4. Prototype standardised methodology for timber quality assessment for forest stands, applicable across studied regions.
5. Database on timber quality assessment for forest stands for a range of species, environmental conditions and management options.
6. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.

MILESTONES – Year 1

1. New data on the quantification of the standing quality of timber from trees across a range of species, environmental and management options in participating Member States.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Timber quality protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 2

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Timber quality protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Scheduled for completion in Dec 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Timber quality protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completed Feb 04	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 Dec 03 Final version Feb 04	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extension

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Timber quality protocol. Version 1 delivered Sep 01, version 8 delivered Jan 02	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completed Feb 04	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 Dec 03 Final version completed Feb 04	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP2 - Year 1

The main change is the inclusion in WP2 of the 3-dimensional scanning of logs to obtain true shape data. Log scanning is required to allow for the detailed modelling of logs leading to the simulation of sawn yields and to link this with the tree branch, grain angle, density and compression wood information collected in WP6, and modelling of the quality of structural battens and other wood properties. This will, in turn, ease the prediction of stress grading machine stiffness and kiln drying distortion. The inclusion of this additional task brings with it a number of benefits:

1. Enhanced models to assist future planning by the timber industry.
2. The ability to predict likely log supplies and quality.
3. Detailed knowledge of what trees, scored using the MEFYQUE standing timber quality assessment system, will yield in terms of red / green logs and actual volumetric yield.
4. The ability to check and design new log classification systems
5. The ability to carryout an accurate assessment of log measuring systems.
6. The ability to test the effect on yield of changing sawing patterns to reduce drying distortion.

Key Changes to WP2 - Year 2

Work on 3-D log scanning has significantly progressed, but delays in scanning of felled logs continue, and have had a knock-on effect on the work carried out in the Laboratory component of this project. The 3-D scanning programme is now scheduled for completion in Dec 03.

Key Changes to WP2 - Year 3

As indicated in year 2, a delay in the scanning caused a knock-on effect into the laboratory component (WPs 4, 5). Work now completed.

Key Changes to WP2 – Extension

None – work completed

2.5.2 The Manipulative Component

The **MANIPULATIVE COMPONENT** at tertiary sites uses closed growth chambers (CTC) to:
(a) induce the individual and combined treatment effects of CO_2**,** temperature and precipitation using established experimental infrastructure;
(b) produce new juvenile plant material grown under ambient (≅350-370 µmol mol^{-1}) and enhanced CO_2 atmospheres (≅700 µmol mol^{-1}) with individual and combined effects of temperature and precipitation for use in assessing timber growth and quality;
(c) produce new information to inform model parameterisation, calibration and validation on growth through non-destructive monthly measurements of physiological growth parameters, annual measurements of mensurational parameters and destructive sampling of biomass from tree compartments to develop allometric mass distribution ratios.

MAIN RESULTS – YEAR 1
The main results achieved in the first year of MEFYQUE for the monitoring component at tertiary sites are provided in table MAN-1 that summarises the tertiary site characteristics, together with details concerning the experimental facility and design implemented at these sites. A location map of MEFYQUE tertiary sites is provided at Annex 1-E.

For experiments now closed, and prior to and after harvesting a range of measurements have been made in accordance with the MEFYQUE sampling protocol at Annex 1-B.

Table MAN-1. *Summary monitoring at tertiary sites.*

MEFYQUE site number	Location	Species	Eco-physiological measurements	Biomass Measurements	Wood anatomy measurements
20	Berlin – Closed top Chambers	Fagus sylvatica Pinus sylvestris	Leaf photosynthesis, transpiration, stomatal conductance and respiration (at the beginning of darkness) Stem respiration	Stem length, stem diameter, number of leaves, and dry mass of the following compartments fine roots, coarse roots, stems, and leaves	Anatomical measurements
23	Wilrijk	Pinus sylvestris	Leaf photosynthesis, transpiration, stomatal conductance and respiration (at the beginning of darkness)	Stem length, stem diameter, number of leaves, and dry mass of the following compartments fine roots, coarse roots, stems, and leaves	Mechanical wood properties. Anatomical measurements. Wood density. Number of tracheids. Number of resin channels.

Results for wood anatomy studies carried out on material from the Wilrijk site will shortly be appearing in the peer reviewed literature [16].

For illustrative purposes a selection of analyses carried out on the eco-physiological data from the Berlin CTC experiment (MEFYQUE site 20) are shown in Figures MAN-1, MAN-1 below. These data are being used to inform calibration of the project's stand scale process model.

[16] Ceulemans R, Jach ME, van de Velde R, Lin JX and Stevens M (2002). Elevated atmospheric CO_2 alter wood production, wood quality and wood strength of Scots pine (Pinus sylvestris L.) after three year of enrichment. Global Change Biology 8: in press.

Figure MAN-1. *Relative growth of stem length at two CO_2 concentrations and five temperature levels in the 2^{nd}, respectively 3^{rd} season. On the left are means in response to temperature. On the right are means in the course of the season regardless of temperature levels.*
*Black squares: elevated CO_2 (~ 700 µmol mol^{-1}); open circles: ambient air CO_2 concentration (~385 µmol mol^{-1}); *: $p < 0.05$.*

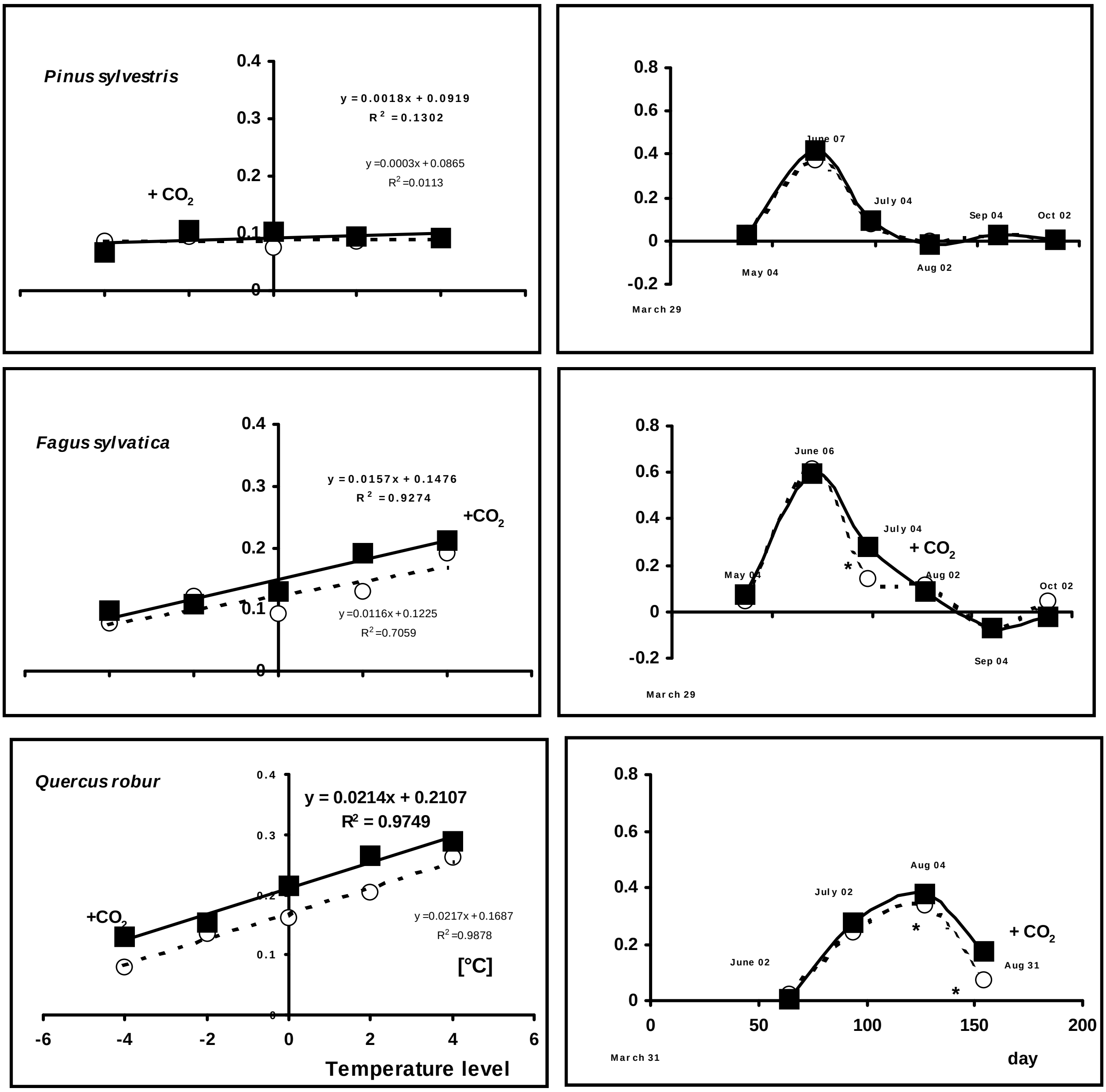
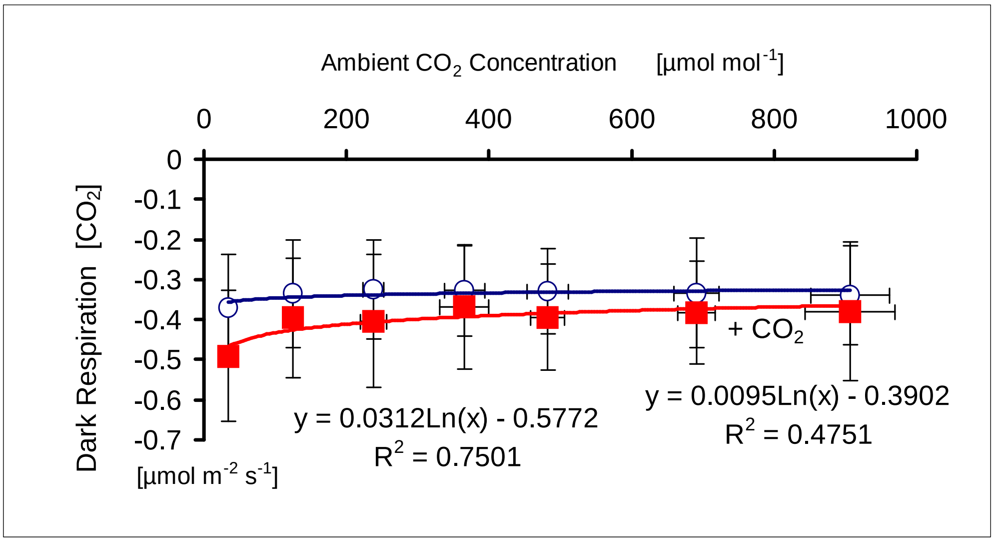


Figure MAN-2. *Dark respiration of beech leaves from saplings grown at elevated CO_2 (~700 µmol mol^{-1} filled squares) and ambient air CO_2 concentration (open circles).*



Results indicate that *Pinus sylvestris* growth responded less intensively on temperature and CO_2 concentration increase than the two *Angiospermae* in the experiment, as both beech and oak reacted positively to CO_2 and temperature increases. Scots pine showed only a slight response on CO_2. At higher temperatures the growth of *Fagus sylvatica* saplings was more enhanced by the additional CO_2 supply than at decreased temperature levels, whereas pedunculate oak reacted to elevated CO_2 concentrations to the same extend at both lower and elevated temperatures. *Fagus* saplings grown at elevated CO_2 had greater CO_2 respiratory losses expressed on leaf area basis. However, saplings from ambient air CO_2 concentration chambers and those from chambers with elevated CO_2 showed no response to sudden changes in CO_2 concentration at the leaf surface. Expressed on dry mass base units, respiration rates of both groups were almost identical.

In addition to the above, a small number of additional eco-physiological studies have also been carried out on the understorey species *Prunus serotina* at the Grünewald primary site. These data will be used to inform calibration of the project's stand scale process model. Initial results are shown below at Figure MAN-3. Net CO_2 assimilation of *Prunus serotina* showed a very low light compensation point, which is almost equal to that of the extremely shade tolerant young beech in the understorey. The initial slope of the light response curve is not as steep as that of a typical shade plant although it is growing in deep shadow. As a result this species is reaching light saturation at comparatively high light intensities and is therefore assessed as having wide ecological amplitude towards the factor light.

Figure MAN-3. *CO_2 net assimilation (A_n) of a Prunus serotina leaf versus photosynthetic photon flux density (PPFD) at the Grünewald forest site (MEFYQUE site 20).*

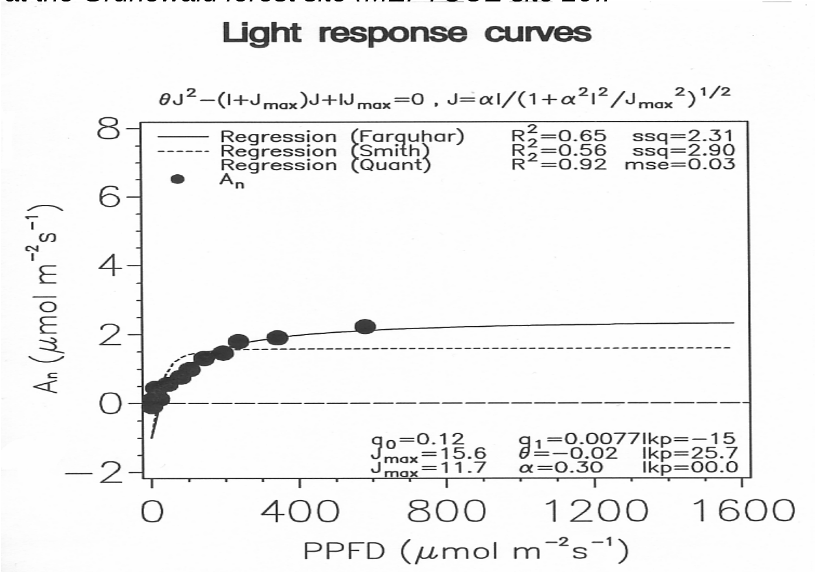


Table MAN-2. *Experimental details at Tertiary Sites. Sites with shading are no longer active.*

MEFYQUE Site n°	18	19	20	21	22	23
Site location	Headley Nursery	Berlin	Berlin	Viterbo-Popface	Montalto di Castro	Wilrijk
Country	UK (south)	Germany	Germany	Italy (central)	Italy (central)	Belgium
Elevated CO_2 concentration (ppm) of treatment	600	700	700	550	710	750
Enrichment typology	OTC	Mini-ecosystems	Phytotron-chambers	FACE	OTC	OTC
Number of replicates per treatment	4	2	5	3	3	4
Size of each enriched plot	8.7 m^2	1 m^2	3.2 m^2	380 m^2	20 m^2	7.1 m^2
Planting year	1999	2001	2000	1999	1970	1993
Age of trees	3 years	3 years at final harvest in 2004	4 years	3 yrs	about 30 yrs	3 yrs
Years of CO_2 enrichment	3	3	3	3	7	3
Control	yes	yes	yes	yes	yes	Yes
Origin	Planted	Planted	Planted	Planted	Natural	Planted
Treated species	Fagus sylvatica, Nothofagus obliqua, Quercus robur, Pinus sylvestris, Fraxinus excelsior, Acer pseudoplatanus	Quercus robur	Fagus sylvatica Pinus sylvestris Quercus robur	Populus alba Populus nigra P. x euramericana	Quercus ilex, Phyllirea angustifolia, Pistacia lentiscus	Pinus sylvestris
Tree height	0.5 – 4 m	In 2002: ~ 0.3 m	Fagus ~ 1.5 m Pinus ~ 1.2 m Quercus ~ 0.3 (2002)	8-9 m	Quercus ~ 5 m Phyllirea and Pistacia ~ 3 m	0.7 m at start of experiment
Harvest date	Nothofagus and Acer in Feb 2002	Fagus and Pinus Autumn 2001			1999	2001
Soil classification	Humo-ferric podsol	Sandy clay, medium rich soil, pH= 6.5	Sandy clay, medium rich soil, pH= 6.5	Clay, nutrient rich soil, pH=5.2	Sandy, nutrient poor soil, pH=8	Originally a heavy loam soil removed to a depth of 0.5 m and replaced by sandy forest soil (N content 0.12% on dry mass basis)
Meteorological data	Available for all of the experiment	Available for all of the experiments	Available for all of the experiments	Available for all of the experiment	Available for all of the experiment	Available for all of the experiment
Other information	Acer and Nothofagus harvested in winter 2001-2002	Experiment started in 2002	Fagus and Pinus harvested in autumn 2001 Quercus planted in 2002	Harvested in 2001, enrichment now on resprouts	Harvested in 1999 and experiment closed down in autumn 2000	Harvested in 2001 and experiment closed down

MAIN RESULTS – YEAR 2

The focus of activity during year 2 has been on the Collelongo poplar FACE experiment and the Berlin CTC experiment.

COLLELONGO FACE EXPERIMENT

Estimating wood density. Poplar wood density was assessed in different tree compartments on harvested material by measuring fresh volume using the water displacement technique. Results for above ground biomass at the end of the 3rd growing season are reported at Tables MAN-3,4. Wood samples obtained from each height growth increment have been powdered for C/N analysis after being dried. In addition, carbohydrate analyses have been carried out on this material to determine glucose, fructose, sucrose and starch. (Table MAN-5). Discs from the three height growth increments have been sent to Berlin University for anatomical assessments. Root samples have been separated between fine and coarse roots, and a sample for each of the two categories has been powdered for all harvested trees both for C/N and carbohydrates analyses.

Table MAN-3. *Analysis of variance (ANOVA) of biomass and production characteristics of three Populus genotypes under control and FACE treatments at the end of three growing seasons. Only the above ground biomass (2000) is reported to the end of the second growing season. Significance (p-values of the ANOVA F-test) of the effects of CO_2 treatment, genotype, and their interaction are indicated as ns: not significant,* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

	treatment	**genotype**	**Treat*genotype**
Ab.ground biomass (2000)	0.05	***	ns
Ab.ground biomass	*	**	ns
Branch biomass	**	***	ns
Stem biomass	**	**	ns
Syll. branch biomass on HGI1	*	***	ns
Prol. branch biomass on HGI1	ns	ns	ns
Syll. branch biomass on HGI2	ns	***	ns
Prol. branch biomass on HGI2	ns	**	ns
Syll. branch biomass on HGI3	ns	0.1	ns
II order branch biomass	*	***	ns
Stump biomass	**	ns	ns
Coarse roots biomass	*	**	ns
Total below ground biomass	**	ns	ns
Total biomass	*	**	ns
Basal density whole tree	ns	**	ns
Basal density HGI1	ns	***	ns
Basal density HGI2	ns	***	ns
Basal density HGI3	ns	ns	ns

Table MAN-4. Biomass distribution within the trees (values per hectare) for three Populus genotypes grown for three growing seasons under control and FACE treatments.

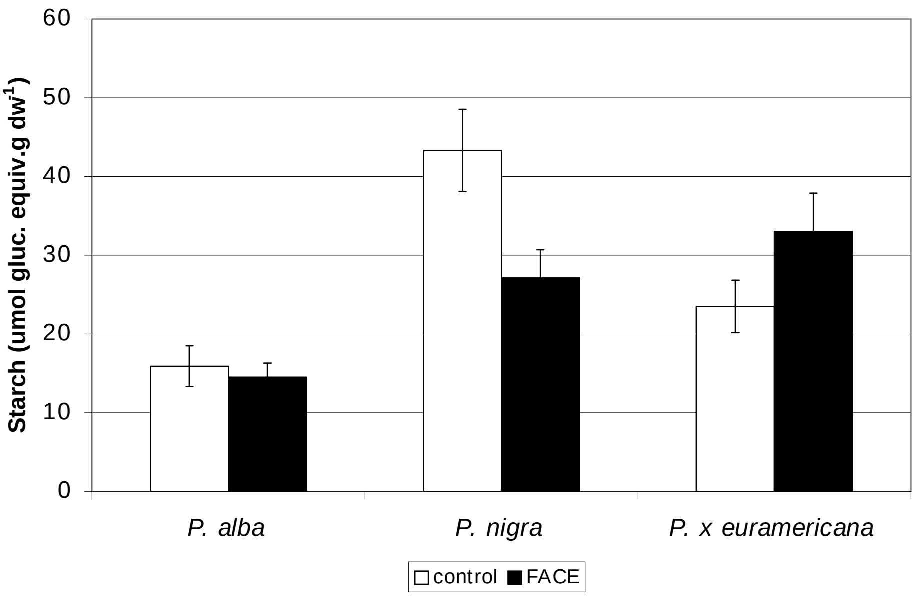
	P.alba		**P.nigra**		**P. x euramerica**	
	control	**FACE**	**control**	**FACE**	**control**	**FACE**
	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)
Syll. Branches on HGI1	1.52	1.70	1.89	3.21	0.60	0.88
Prol. Branches on HGI1	1.58	1.94	1.48	1.62	1.79	2.45
Syll. Branches on HGI2	3.57	3.53	2.52	3.37	0.12	0.44
Prol. Branches on HGI2	1.43	2.04	2.94	2.45	2.66	3.49
Syll. Branches on HGI3	1.33	1.71	1.83	2.08	1.04	1.02
II Branches	2.03	2.24	0.91	1.22	0.25	0.28
Total Branches	11.45	13.15	11.57	13.95	6.45	8.56
Stem	28.87	38.23	42.01	47.78	31.71	39.82
Stump	2.65	4.78	2.73	3.87	2.95	4.46
Coarse roots	4.93	5.68	5.71	6.43	4.92	5.65
Total above-ground biomass	40.32	51.38	53.58	61.73	38.16	48.39
Total below-ground biomass	7.58	10.46	8.44	10.30	7.87	10.11
Total biomass	47.90	61.84	62.02	72.03	46.03	58.50
	(ratio)	(ratio)	(ratio)	(ratio)	(ratio)	(ratio)
Branches/Stem	0.40	0.34	0.28	0.29	0.20	0.22
Root/Shoot	0.19	0.20	0.16	0.17	0.21	0.21

Table MAN-5. Starch in the stem for three years/species at FACE experiment, merging the two CO_2 treatments.

	Year 1	Year 2	Year 3
Mean	34	23.5	21.2
SD	4.457	1.809	1.787

	P. alba	*P. nigra*	*P. x euram.*
Mean	15.2	35.2	28.2
SD	1.559	3.408	3.013

Figure MAN-4. *Stem starch content in FACE experiment distinguishing FACE treatment and species*



BERLIN CTC EXPERIMENT

Work-plan

Evaluation of data from manipulative CO_2 enrichment experiments in Berlin used to determine the pattern of dry mass allocation in juvenile trees have been continued. Data were obtained after a final harvest of experimental trees during the first year of the MEFYQUE programme (beech and Scots pine). Additionally, monthly non-destructive seasonal measurements in a new experiment with oak and beech were continued; i.e. measurements on twigs, branches, stems, fine roots ø <~2mmm and coarse roots ø>~2mm and counting of leaves and buds. Thirdly, measurements of dark respiration of stems were pursued (started during the first year). In addition, dry mass partitioning of the two ~50-year-old Scots pines from the primary site in Grünewald was determined and evaluated.

Deliverables

The allocation pattern of dry mass in juvenile beech was elaborated from the dataset of juvenile beech having grown for three years under ambient and elevated CO_2 (700 µmol mol^{-1}). About 40% of those data are still to be evaluated in detail. All row data from the study on beech were sent to the database at FR together with the outcome of the complete C/N-analyses (compare work-package 5). Some results have been presented in the first Annual Report. Data from the enrichment study on juvenile Scots pine in pots were also completely delivered to the database as row data during the period of this report together with C/N analytical results and partly evaluated (70%). First maintenance respiration measurements on stems took place before bud break of oak in the phytotron chambers of the running experiment in March 2003 at 1 °C; 24 data-sets were stored. In the middle of last season (2002) growth respiration of stems was already measured once at 25 °C, 24 data-sets. These data have not yet been evaluated. Data from the two ~50-year-old Scots pine were sent to the database at FR.

Research activities during the second reporting period

Methods.

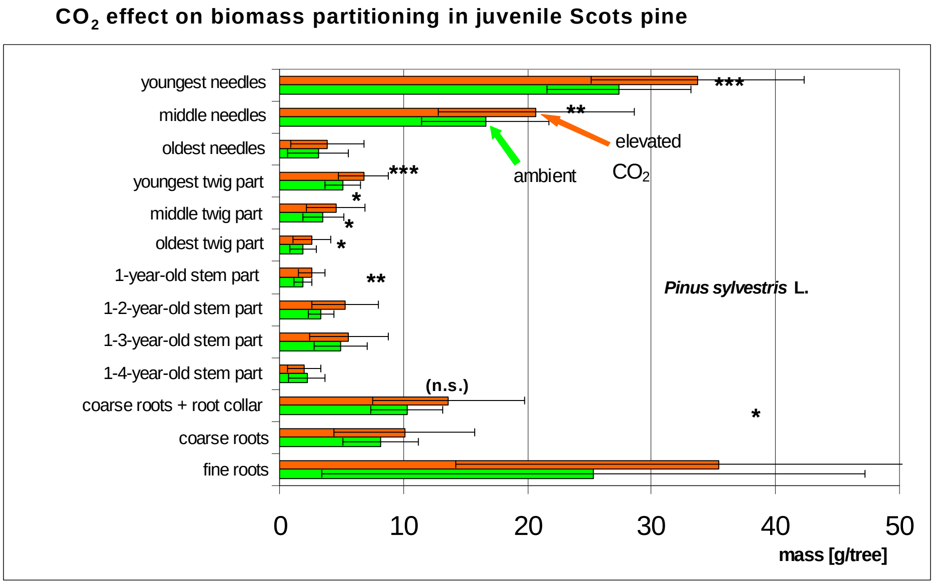
The equipment used during the first year has functioned continuously over the second report period. One piece of equipment is provided with measuring and regulating systems for CO_2, temperature and relative air humidity. On the basis of means of monthly minima of air temperature for the night and maxima for the day in Berlin-Dahlem (1909-1969; Meteorological Institute of the FU-Berlin), 2 x 5 temperature levels are adjusted for each month separately with the following deviations from the means: -4, -2, 0=base, +2, +4 °C (deviation from this theoretical value. ± 0.2 °C): Relative air humidity is regulated in between 50 and 100%. Each phytotron chamber contains 6 oaks and 2 beech saplings in 10 l-pots filled with homogenised medium fertile forest soil. Soil moisture is maintained constant. This experiment is conducted in five chambers at ~390 and in five chambers at 700 µmol mol^{-1} CO_2. A group of 6 pots with oaks and 2 pots with beech are positioned outside and both tree species are growing without restrictions by pot size in the field for comparisons. Classical growth parameters are measured monthly on all plants until the end of the project.

In addition, three model-ecosystems (mini-ecosystems) are used for studying only CO_2 effects on growth of oak. The mini-greenhouses are standing in the field and cover a ground area of 0.8 x 0.8 m and are closed beneath containing a block of 0.4 m^3 medium rich soil. Two of the acrylic greenhouses are supplied with 698 ±µmol mol^{-1} CO_2 and one glasshouse serves as control with ambient air (360 ±34 µmol mol^{-1} CO_2). All mini-greenhouses are acclimatised according to the recorded outside micro-climate (temperature: ±0.5 °C, relative air humidity: ± 15%, wind in the range of 0.5 – 2.5 m s^{-1}). In each of the mini-glasshouses 16 oaks are growing. The aerial parts of the mini-greenhouses were renewed in this second reporting period in order to follow the above-ground growth of saplings. The same parameters as in the ten mini-greenhouses were measured monthly. On samplings from the 10 phytotron chambers stem dark respiration was measured.

Results and conclusions

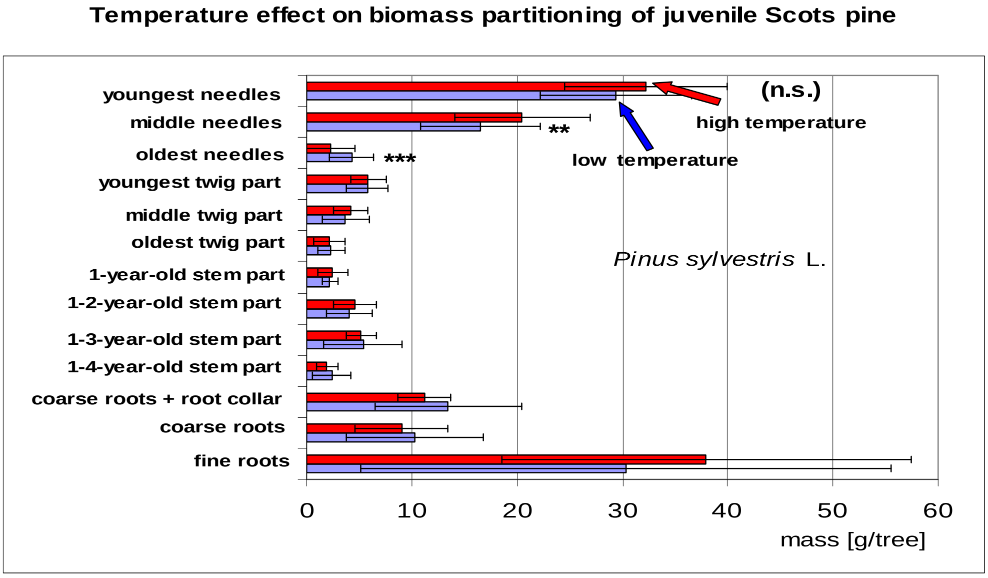
Most data from the initial *Pinus sylvestris* experiment were evaluated during the second reporting period. Regardless of the temperature level at which the pine saplings had grown all data from the elevated CO_2 glasshouses were pooled and those from the other glasshouses in a second data set. Then vertical distributions of biomass were compared and differences caused by elevated CO_2 were tested statistically.
The clearest positive CO_2 effect was found for the youngest needle mass and the mass of the youngest twigs. Also mass production of youngest and the second youngest stem parts were enhanced by elevated CO_2 significantly (Figure MAN-5).

Figure MAN-5. *Biomass allocation in response to CO_2 at the TU-Berlin tertiary site. [***: p<0.001, **: p<0.01, *:p<0.05, (n.s.): p: 0.05-0.1]*



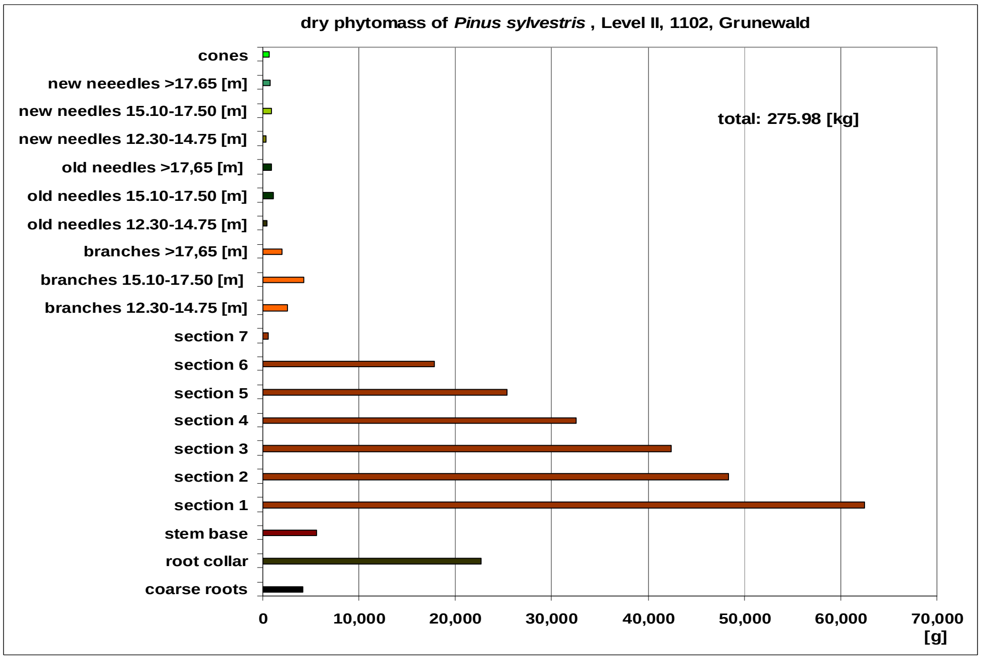
In a second evaluation step all data from the glasshouses below the temperature base were compared with those from the houses above the temperature level base regardless of their CO_2 levels. Statistically significant positive temperature effects could be only shown for the needles from the year before the last year. Temperature effect was negative on the oldest needles (three-year-old needles). Higher temperature during growth resulted in earlier needle loss (Figure MAN-6). In total, it can be concluded that Scots pine reacts upon CO_2 more than upon temperature in the ranges given by the experiment.

Figure MAN-6. *Biomass allocation in response to temperature at the TU-Berlin tertiary site.* [***: p<0.001, **: p<0.01, (n.s.): p : 0.05-0.1]



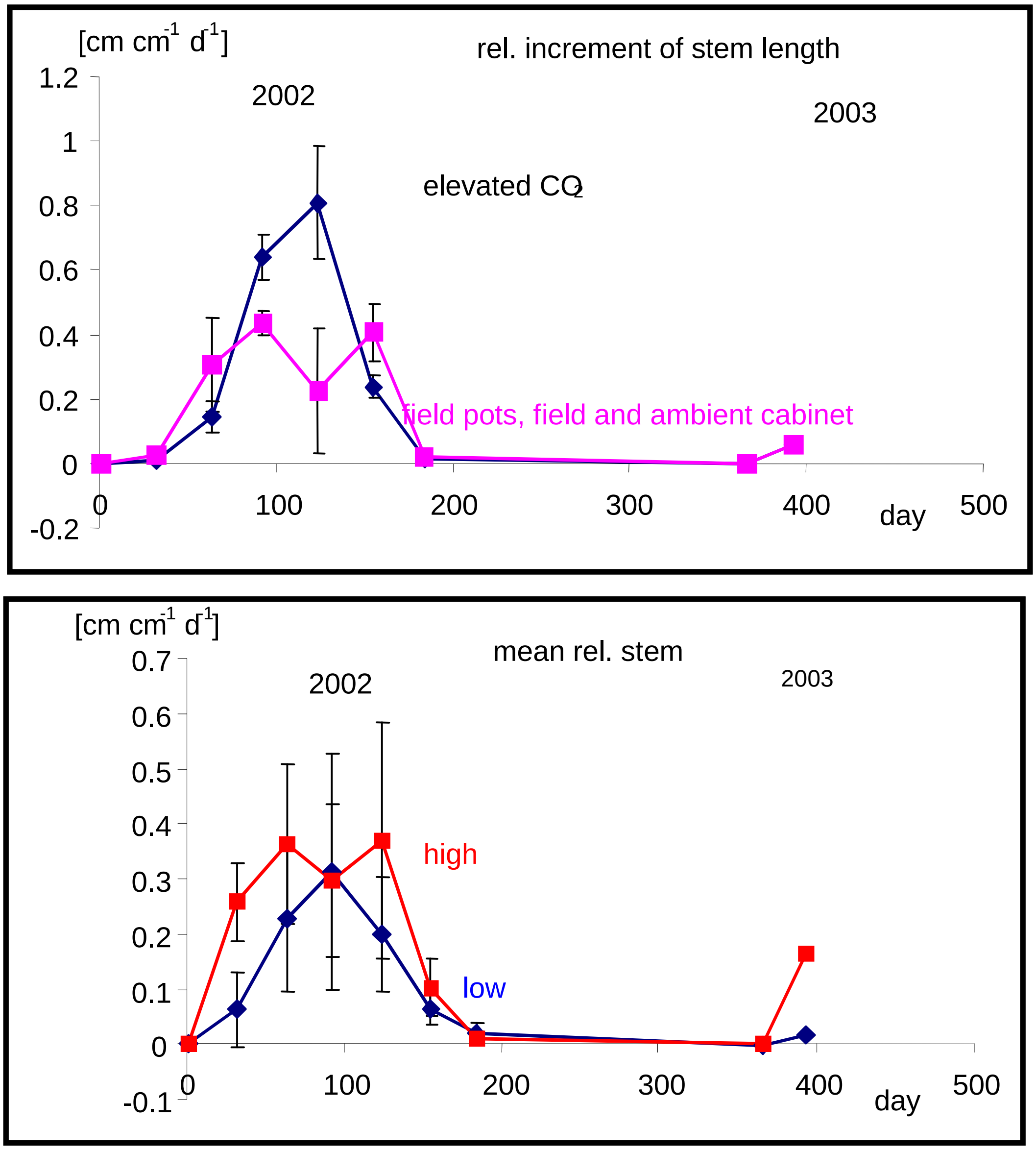
As expected, the biomass partitioning of the 50-year-old Scots pines from the primary site (Grünewald) showed a completely different biomass partitioning from the juvenile trees in the experiment. In the crown more biomass was concentrated in the needles from the year before within the middle of the crown and in the branches there. Figure MAN-7 shows vertical biomass distribution. Mass of fine roots could not be determined precisely enough. Total dry mass of this representative tree amounted to 275.98 kg.

Figure MAN-7. *Biomass allocation of one representative ~50-year-old Scots pine from Grünewald forest in Berlin, harvested at the end of 2002.*



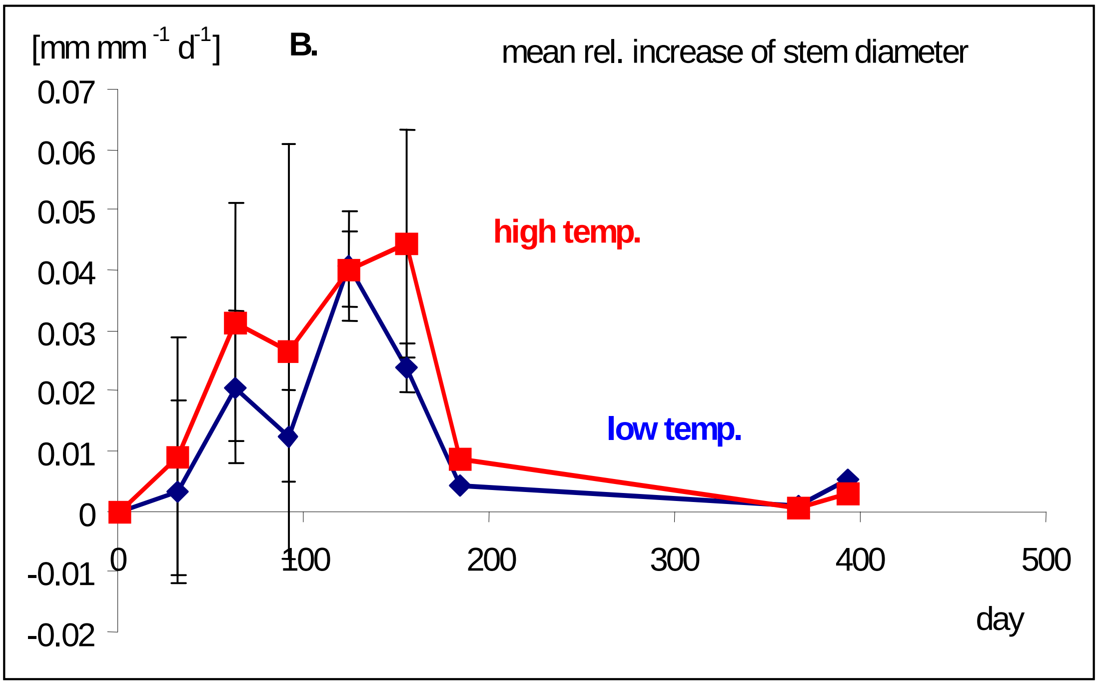
Clear positive CO_2 and temperature effects on stem length of *Fagus sylvatica* saplings could be shown in the phytotron experiment. Stem diameter increment is also enhanced by elevated CO_2 concentration, whereas a lower temperature level delayed stem diameter increase only. Relative stem length growth in *Quercus robur* is significantly enhanced by elevated CO_2 in the middle of the vegetation period. Also higher temperature tends to lead to longer stems (Figures MAN-8a and b).

Figures MAN-8a and b: *CO_2 and temperature effect on growth of stem length of Quercus robur in experiments at the tertiary site of TU-Berlin, Germany.*

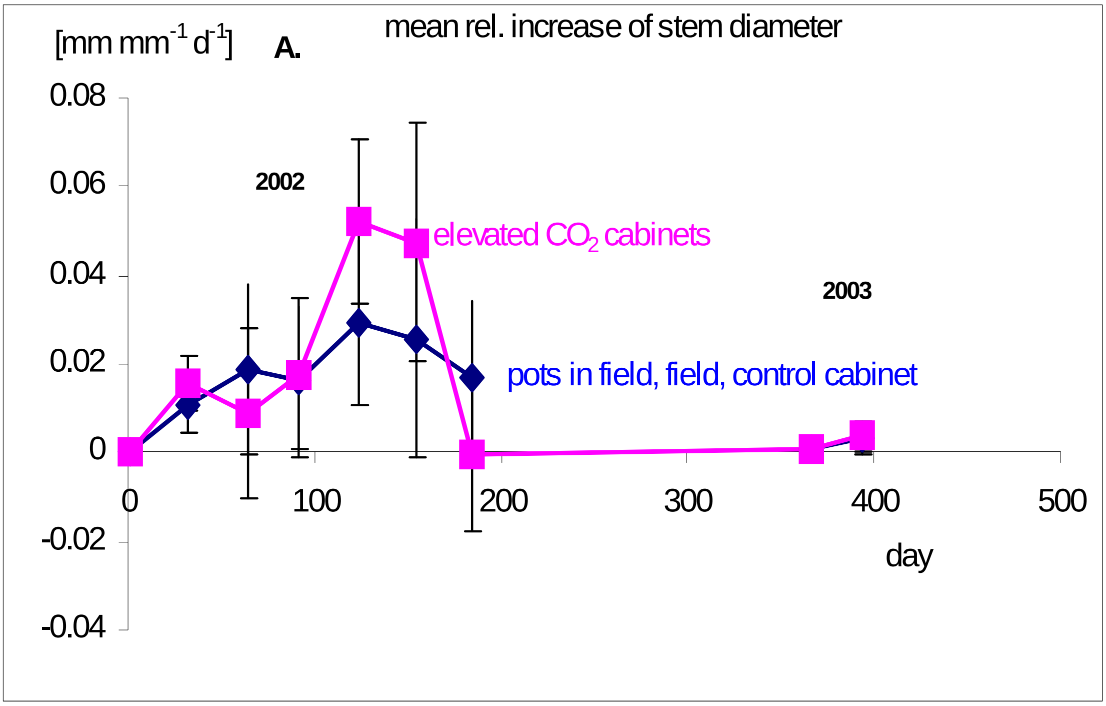


Elevated CO_2 and temperature also caused thicker stems measured 2 cm above ground (Figures MAN-9a and b). During the first season neither CO_2 nor temperature significantly influenced number of leaves per tree.

Figure MAN-9a and b: *CO_2 and temperature effect on relative growth of stem diameter at 2 cm above ground of Quercus robur in experiments at the tertiary site of TU-Berlin, Germany.*

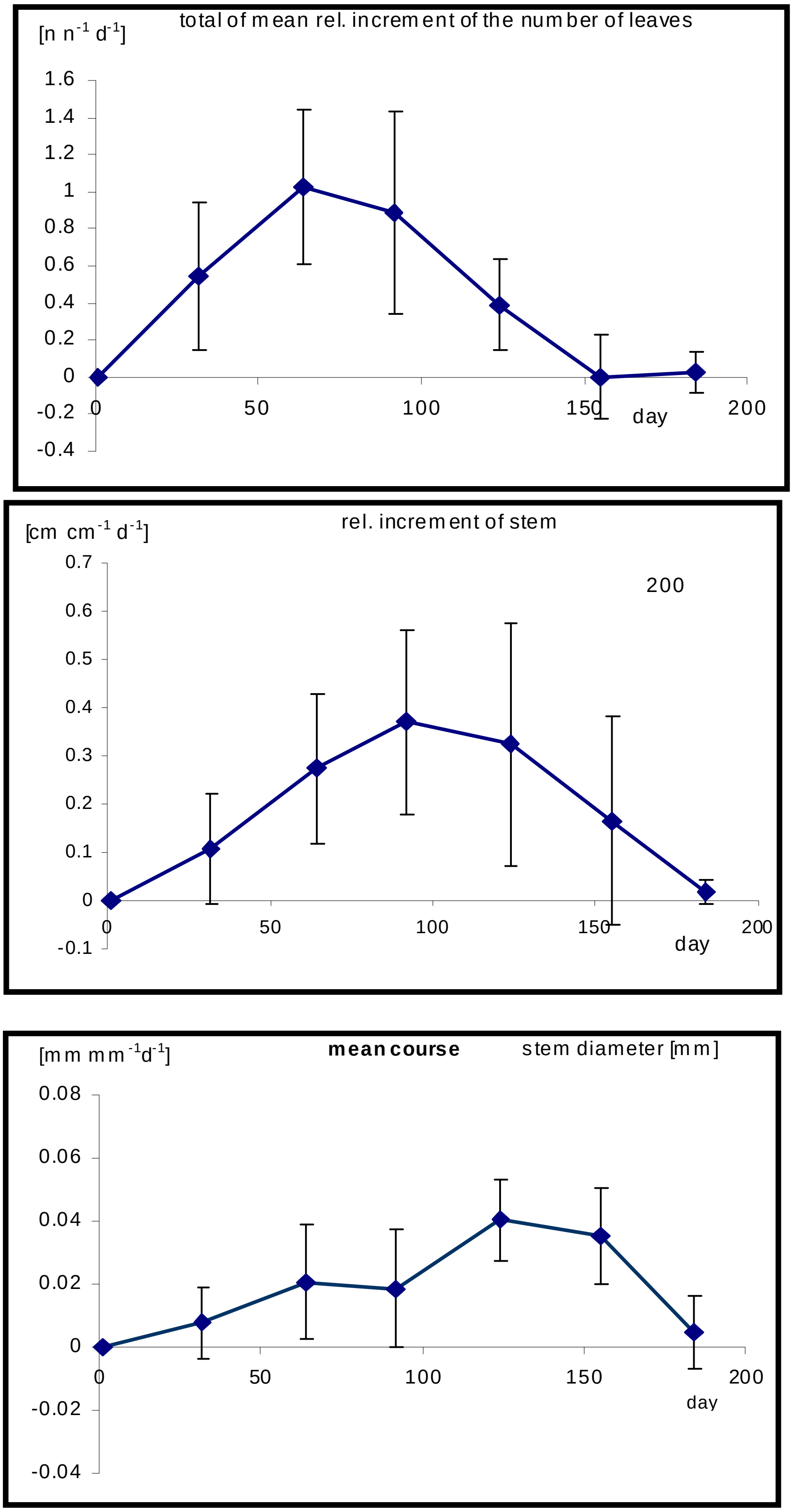


***Quercus robur*, Berlin, tertiary site**



In Figure MAN-10 the shift in time of the growth of main plant organs is documented.

Figure MAN-10. *Mean timely course of unfolding of leaves, stem length growth and stem diameter increment of Quercus robur in experiment at the tertiary site of TU-Berlin, Germany.*



Stem maintenance respiration before bud break varied between 0.22 and 0.27 µmol CO_2 s^{-1} m^{-2}.

Proposed activities in year 3

1. At the end of June 2003 stem respiration measurements on the juvenile oaks in experiment will be repeated. Data will be evaluated at the end of this programme.

2. Regularly non-destructive measurements on the plants in the experiment will be continued until the end of the season and evaluated in parallel.
3. Gas-exchange data (dark of beech and oak measured on leaves and stems) have to be evaluated.

Significant difficulties or delays experienced during the second reporting period
Variability between trees is considerably high in all experiments. This might lead to principal statistical problems and therefore, time for data evaluation might be too short.

MAIN RESULTS YEAR – 3

Flux data
The monitoring measurements in the Italian secondary sites were carried out without significant interruptions.

Table MAN-5. *Daily data sent to Partner 01:*

Site 1

FLUXES	METEOROLOGY
carbon dioxide concentration	precipitation
Water vapour concentration	reflected radiation
atmosphere stability parameter	global radiation
carbon dioxide	net radiation
quality class	diffuse radiation
sensible heat	photosynthetic photon flux density
quality class	light interception
latent heat	air temperature
quality class	pressure
friction velocity	canopy radiative temperature
tree transpiration	bole temperature
canopy heat storage	soil temperature 5 cm
CO2 storage in canopy air layer	soil temperature 30 cm
LATENT HEAT in canopy air layer	soil water content
heat storage in canopy air layer	soil water content
-	soil heat flux
-	soil heat flux
-	relative humidity
-	Wind direction
-	Wind horizontal speed
-	Snow depth
-	Absolute max temp
-	t avg
-	t soil -5
-	t soil –20
-	avg Vv
-	sum of prec
-	VP Avg
-	daylight avgVPD
-	VP 6:00
-	Globrad

Site 4

NET RADIATION
PFD
AIR TEMPERATURE
[CO2]
NEE Fc
Sens heat H
Latent heat LE
Hourly sum PREC
Hourly mean WIND SPEED
Air humidity %
Soil Temp -5cm

Further information and more data can be obtained by contacting:
Giorgio Matteucci, e-mail giorgio.matteucci@ieif.cs.cnr.it for Collelongo (site 01)
Leonardo Montagnani, e-mail leonar@inwind.it for Renon (site 04).

Tertiary site

At the POPFACE site, a harvest was carried out on 144 3 year-old trees (24 trees per clone and per treatment) to determine above- and below-ground biomass. For each tree the stem was divided according to the 3 HGI (height growth increment) and branches were divided into sylleptic and prolepic branches. Poplar wood density was assessed on the harvested material by measuring fresh volume with water displacement technique. Wood samples were obtained from each height growth increment and ground for C/N analysis after being dried. Carbohydrates analysis were also carried out on this material (i.e. glucose, fructose, sucrose and starch).

Root samples were separated between fine and coarse roots, and a sample for each of the two categories was powdered for all harvested trees both for C/N and carbohydrates analysis.

Results did not show a FACE effect on carbohydrate content which was quite different among species (Table MAN-6). On the contrary N concentration was considerably reduced under FACE (Figure MAN-11) for all species. Finally wood density was affected by species and age of the wood but not by FACE treatment (Table MAN-7).

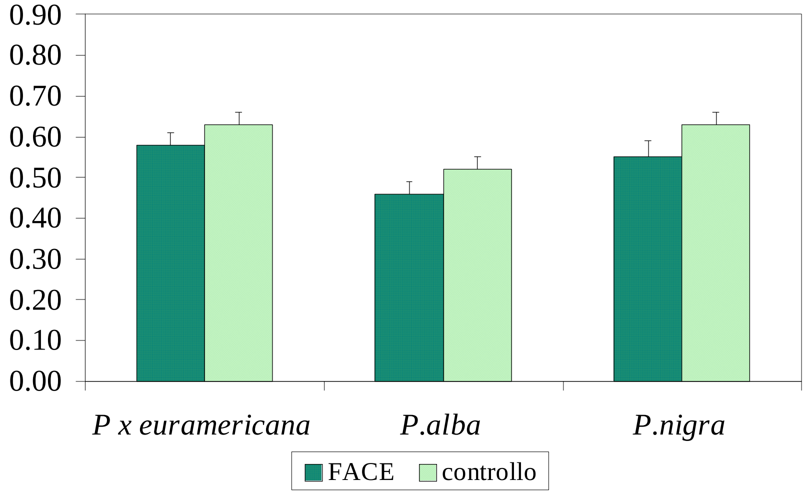
Table MAN-6. *Carbohydrate content of stem wood at the POPFACE site. Values are means (SE).*

	glucose µmol g^{-1} DW^{-1}	fructose µmol g^{-1} DW^{-1}	sucrose µmol g^{-1} DW^{-1}	starch µmol g^{-1} DW^{-1}
P.alba				
FACE	19.3 (3.2)	14.1 (2.7)	75.2 (9.8)	14.5 (1.8)
control	12.8 (2.2)	10.1 (2.0)	70.2 (12.1)	15.9 (2.6)
P. nigra				
FACE	59.5 (6.0)	45.0 (4.5)	93.8 (10.9)	27.1 (3.6)
control	47.0 (5.4)	37.9 (4.8)	119.3 (5.9)	43.3 (5.2)
P. x euramericana				
FACE	57.9 (9.2)	37.7 (5.5)	101.6 (7.4)	33.0 (4.9)
control	61.4 (9.6)	42.0 (6.3)	126.0 (15.8)	23.5 (3.3)

Table MAN-7. *Stem wood density (g cm^{-3}) at the POPFACE site. Values are means (SE). HGI: height growth increment*

	P. alba		*P. nigra*		*P.x euramericana*	
	control	FACE	control	FACE	control	FACE
whole stem	0.381 (0.013)	0.388 (0.008)	0.409 (0.011)	0.408 (0.009)	0.350 (0.017)	0.348 (0.014)
HGI 1	0.379 (0.005)	0.386 (0.005)	0.367 (0.004)	0.380 (0.003)	0.311 (0.005)	0.314 (0.003)
HGI 2	0.329 (0.004)	0.365 (0.010)	0.387 (0.007)	0.381 (0.004)	0.306 (0.004)	0.303 (0.004)
HGI 3	0.441 (0.018)	0.422 (0.006)	0.470 (0.011)	0.467 (0.011)	0.434 (0.024)	0.440 (0.015)

Figure MAN-11. *N concentration (% of DW) in stem wood at the POPFACE site. Columns are means with SE*



Research activities during the third reporting period

The phytotron equipment – used during the 2nd year – was functioning continuously over the third report period. It was provided with measuring and regulating systems for CO_2, temperature and air humidity. On the basis of means of monthly minima of air temperature for the night and maxima for the day in Berlin-Dahlem (1909-1969; Meteorological Institute of the FU-Berlin) 2 x 5 temperature levels were adjusted for each month separately with the following deviations from the means: -4, -2, 0=base, +2, +4 °C (deviation from this target value. ± 0.2 °C): Absolute air humidity was kept approximately constant by means of a humidifier. Each phytotron chamber contained 6 oaks and 2 beech saplings in 10- litre pots filled with homogenized medium fertile forest soil. Soil moisture was maintained constant by manual watering. This experiment was conducted in five chambers with ~390 and in five chambers with ~700 µmol mol^{-1} CO_2. A group of 6 pots with oaks and 2 pots with beech had been positioned outside and both tree species were also growing without restrictions by pot size in the field for comparisons. Classical growth parameters were measured throughout this 3rd report period. In addition, 3 model-ecosystems (mini-ecosystems) were used for studying only CO_2 effects on growth of oak. The mini-greenhouses stood in the field and covered a ground area of 0.8 x 0.8 m and were closed beneath containing a block of 0.4 m^3 medium rich soil. Two of the acrylic greenhouses were supplied with 698 ± 30 µmol mol^{-1} CO_2 and one glasshouse served as a control with ambient air (360 ±34 µmol mol^{-1} CO_2). All these mini-greenhouses were acclimatised according to the recorded outside micro-climate (temperature: ±0.5 °C, absolute air humidity: ± 15%, wind in the range of 0.5 – 2.5 m s^{-1}). In each of the mini-glasshouses 16 oaks were growing. The aerial parts of the mini-greenhouses were renewed in this second reporting period in order to follow the above-ground growth of saplings. The same parameters as in the ten mini-greenhouses were measured monthly and the final destructive harvest took place at the end of the 2nd experimental season (half-time of 3rd reporting period) and biomasses of leaves, twigs, branches, stems coarse roots (ø > ~2 mm) and fine roots (Ø < ~2 mm) were determined.

Stem dark respiration was measured in spring at 15 °C before bud break on oak saplings (*Quercus robur*) from the 10 phytotron chambers, in the middle of summer at a temperature gradient and in autumn after leaf fall at 15 °C again.

Results and conclusions

A. Gas exchange measurements

Figure MAN-12 shows the response of total respiration of juvenile oak stems to elevated CO_2 and temperature levels during the 2nd gas exchange measurement campaign in late summer 2003. Mean values are given on a surface area basis. Respiration rates of saplings grown at elevated CO_2 are greater than the rates of those trees from the chambers that were supplied with unchanged ambient air. This positive CO_2 effect can possibly be explained by greater mass concentration per volume unit at elevated CO_2. Expressed on volume basis one might expect no CO_2 effect. This recalculation has still to be done. CO_2 levels caused no significant differences between spring and autumn at 15 °C. If the difference between dark respiration rates in spring and autumn at 15 °C on the one hand, and those from the summer at the same temperature on the other hand can be considered as growth respiration, one can calculate maintenance respiration for the given temperature range 15-30°C. Figure MAN-13 represents maintenance and growth respiration under the assumption that the CO2 effect on dark respiration can be neglected.

Figure MAN-12. *Total dark respiration rates of juvenile oak stems in July at different temperature levels and elevated (~700) and ambient air CO_2 concentration (~390 µmol mol^{-1}); n = 15.*

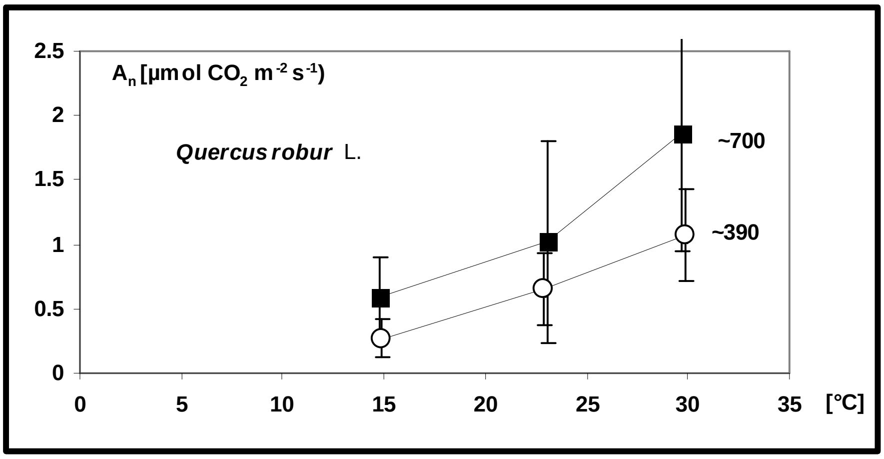
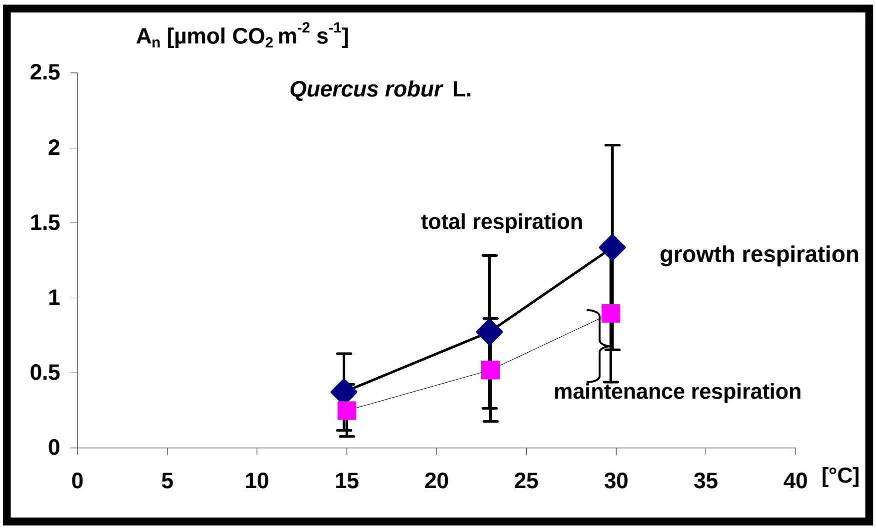


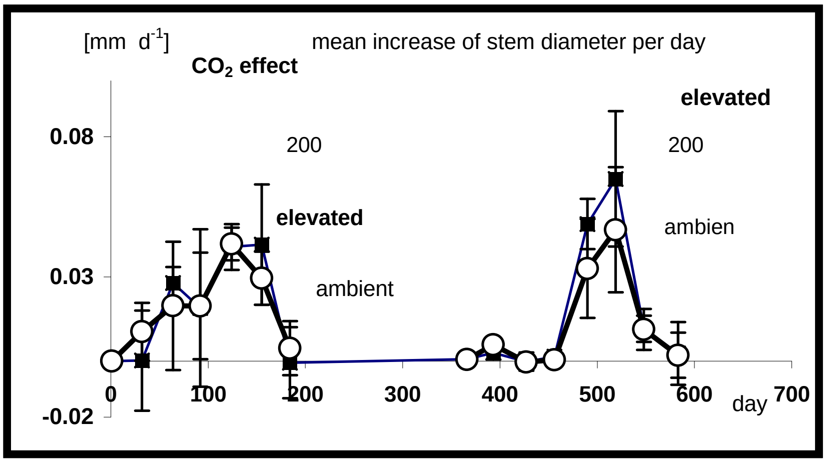
Figure MAN-13. *Total respiration and calculated maintenance respiration of juvenile oak stems normalized to 15 °C (before bad break and after leaf fall) in summer; n = 15*



B. Non-destructive monthly growth measurements

<u>Stem diameter</u>
Early growth of juvenile oaks was less evident than in the 1st year. The slightly higher values of the year 2003 indicate that trees were still growing very well despite the relatively limited soil volume, restricted by the pots (Figure MAN-14). All data were first pooled for the factor CO_2 only (regardless of temperature levels).

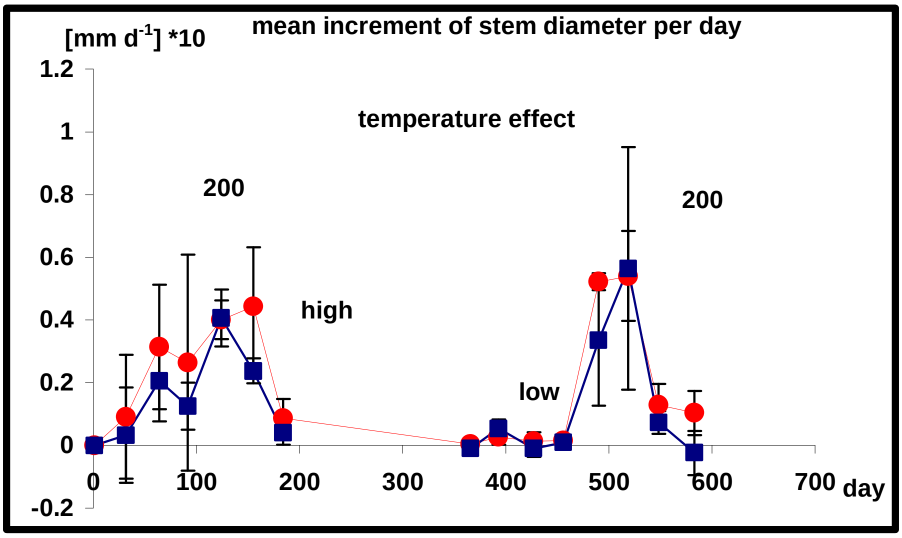
Figure MAN-14. *Absolute increase of the stem diameter of juvenile oak grown at ambient air and elevated CO_2 concentration (~700 µmol mol^{-1}); n = 30.*



The probability for a positive CO_2 effect in Aug.-Sept. 2003 is high whereas almost no CO2 effect could be detected in year 2002.

In a second evaluation step data were pooled for the factor temperature only (regardless of CO_2 levels). There is a certain positive signal at elevated temperature (Figure MAN-15) in comparison with decreased temperature levels in early summer and a possibly significant slightly positive temperature effect at the end of the seasons; n = 24. (Data have still to be tested statistically.)

Figure MAN-15. *Growth of stem diameter of juvenile oak at heightened (+ 2, + 4°C, •) and lowered (- 2, -4°C, •) temperature levels in phytotron chambers (n = 24).*



<u>Stem height</u>
In the year 2003 most saplings produced a first and a second flush (Figure MAN-16).

Figure MAN-16. *Effect of elevated CO_2 (~700 µmol mol^{-1}: •) on growth of stem height of juvenile oak in comparison with growth at unchanged ambient air (•); n = 30.*

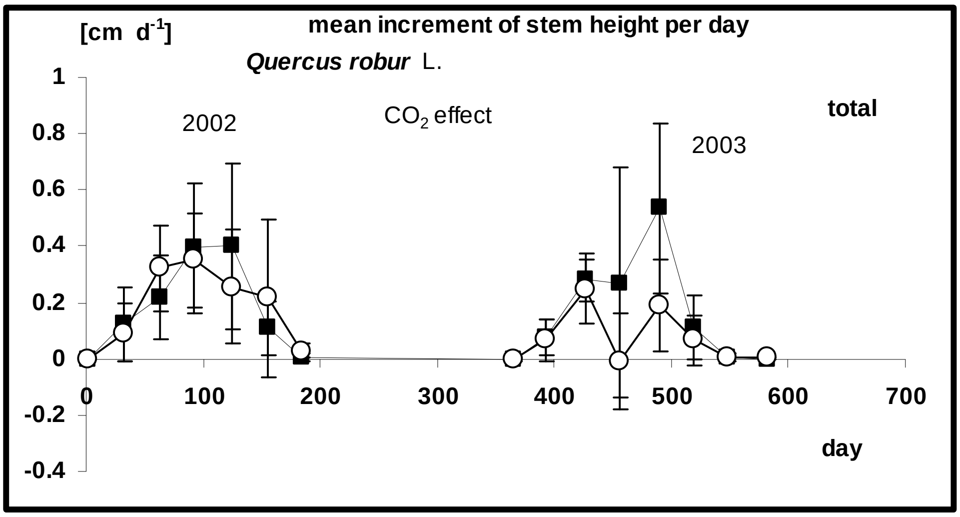
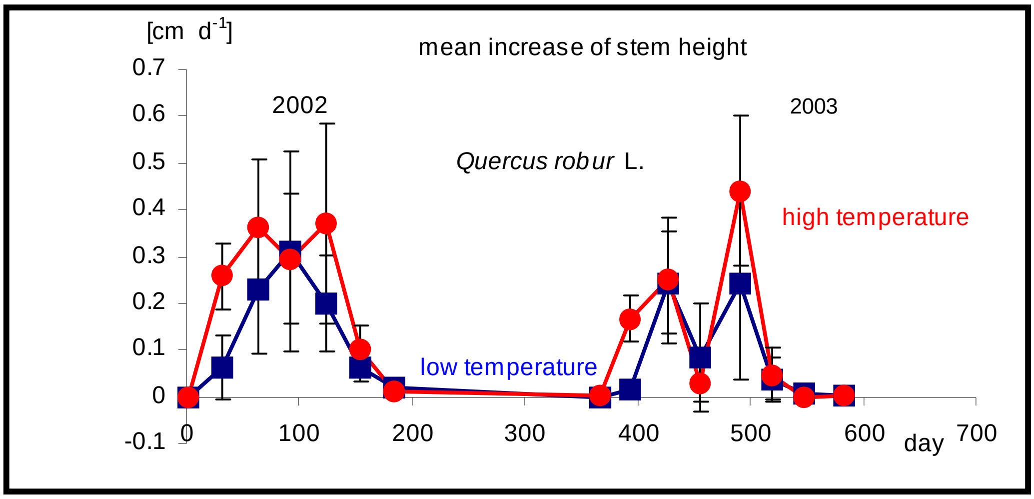


Figure MAN-16 also includes all data from the 3 mini-ecosystems and pots in the field and the field control of free rooting saplings. Overall a certain CO_2 enhancement is especially obvious between the 1st to the 2nd flush in year 2003 (without statistical tests yet).

We preliminary conclude that the temperature effect on growth of stems is more important than the CO_2 effect (Figure MAN-17).

Figure MAN-17. *Effect of lowered (- 2, - 4°C, •) and heightened temperatures (+ 2, + 4°C, •) on absolute growth of stem height of juvenile oak per day; n = 24.*

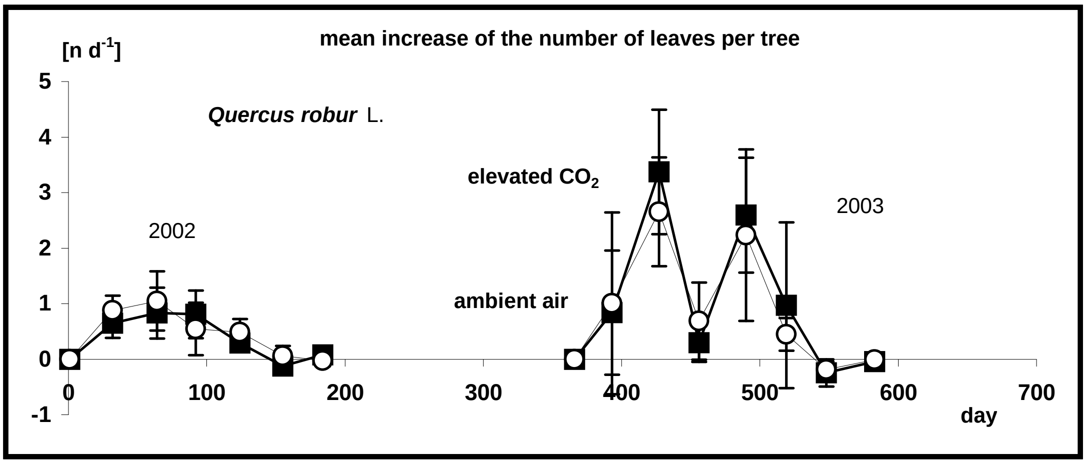


Of course, in both years increase was earlier in response to elevated temperature levels, but also higher growth peaks were reached in both the vegetation periods of our experiment on juvenile oaks.

<u>Number of leaves</u>

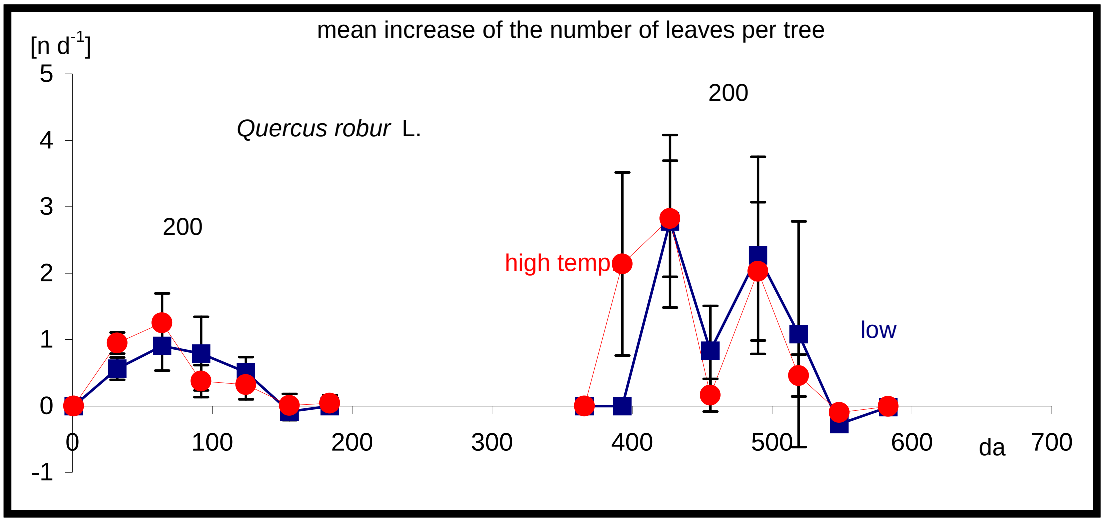
On the average, number of leaves per tree was rather similar at ambient air and at elevated CO_2 concentration. A certain positive CO_2 effect might have had occurred at the two growth peaks in 2003 (Figure MAN-18). Variability was especially high in the 2nd season.

Figure MAN-18. *Effect of elevated (~700 µmol mol^{-1} CO_2, •) and ambient air CO_2 (•) on the development of leaves on juvenile oak trees; n = 30).*



At the elevated temperature levels (+ 2°C, + 4°C), of course, bud break and lamina expansion started earlier than at decreased temperatures (- 2°C, - 4°C). Therefore, a positive effect on the number of leaves per tree is obvious in Figure MAN-19. These results show, too that this lead in spring and early summer is partly lost or even eliminated by the end of the season. Statistical tests have still to be conducted.

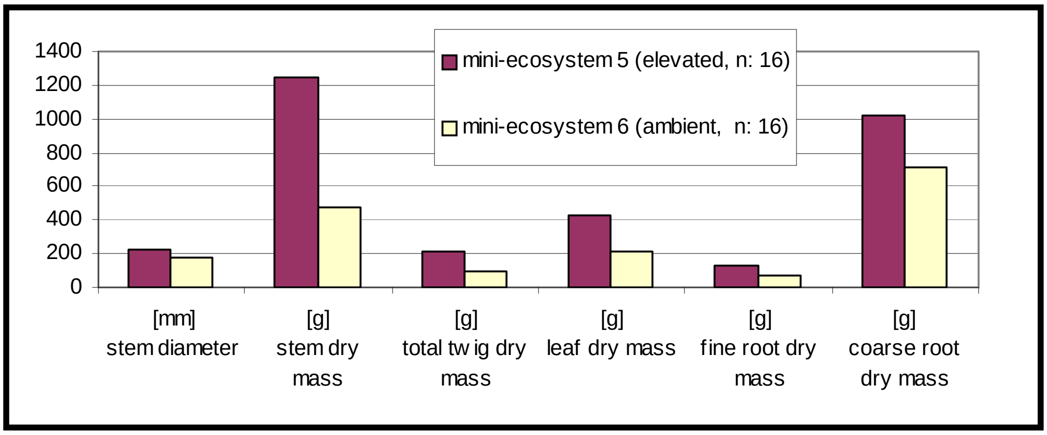
Figure MAN-19. *Effect of lowered (- 2, - 4°C, •) and heightened (+ 2, + 4°C, •) temperature levels on the number of leaves per juvenile oak tree; n = 24.*



Biomass

Results of the completed harvest of the trees in the mini-ecosystems are partly shown in Figure MAN-20 (only experimental factor: CO_2 concentration). After two years dry mass accumulation of up to 3 m tall juvenile oaks was clearly enhanced by the continuous additional CO_2 supply. Greatest relative difference occurred in stem biomasses.

Figure MAN-20. *Total mass accumulation of juvenile oak trees in mini-ecosystems (climatically adjusted to outside conditions) after growth for 2 years at elevated and ambient air CO_2 concentration (16 trees/0.16 m^2).*



MAIN RESULTS – Extension

The manipulative component was completed in period 3. Results have been presented in previous annual reports, and in the Final Report.

2.5.2.1 WP3: Analyses Of Qualitative Properties In Manipulative Experiments

Work-package number:	3						
Start Date:	Planned Jul 01			Status: No change			
Completion Date:	Planned Nov 03			Dec 03			
Current status	Completed						
Partners Responsible:	P2, P1, P4, P5			Status: No change			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	9	11(-10)		4	9		
Year 1 – person-months employed	3	1		1	2		
Year 2 – cumulative person-months employed	7			3	7		
Year 3 – cumulative person-months employed	9	1		4	9		
Total – including extension	9	1		4	9		

Key change: remaining P2 person-months have been re-allocated to activities of WP7.

OBJECTIVES
This work package will produce material for an assessment of the specific way in which allocation may be influenced by elevated CO_2 treatment and the biochemical, anatomical and bio-mechanical properties to be used in successive WPs. The main objective will be to analyse the qualitative properties of timber from manipulative experiments. This will be achieved by:
3.1 Non-destructive seasonal measurements of physiological growth parameters: bud burst, photosynthesis, stomatal conductance, transpiration, photosynthesis, leaf chlorophyll content, leaf and needle loss to inform model parameterisation, calibration and validation. Use will also be made of existing information;
3.2 Non-destructive annual measurements of mensurational parameters: etc. to inform model parameterisation, calibration and validation;
3.3 At final harvest, destructive sampling biomass of tree compartments (leaves, buds, twigs, branches, stems, fine roots (< 2 mm) and coarse roots (> 2 mm)) will be made to develop allometric mass distribution ratios to inform model parameterisation, calibration and validation.

METHODOLOGY AND STUDY MATERIALS
FACE, OTC growth chambers and mini-ecosystems will be employed to raise the temperature and CO_2 levels and modify water and N availability of experimental plots at each experimental manipulation site. Saplings and juvenile individuals of selected species will be grown and the performance of each established seedling will be recorded over a period of three years. The impact of manipulated growth conditions upon the growth components will be assessed using non-destructive estimates of aboveground biomass and destructively at final harvest to also provide estimates of below ground biomass. Partner 2 will develop appropriate protocols to achieve consistent and standardised results between Partners in this Work Package.

The following monitoring measurements are being carried out at tertiary sites, with each Partner responsible for his national sites.

•

		UK		Belgium		Germany		Italy		
		1/0	Timestep	1/0	Timestep	1/0	Timestep	1/0	Timestep	Remarks
Meteo	Air temperature	•	30 mins		-	•	30 mins	•	30 mins	
	Soil Temperature	•	30 mins		-	•	30 mins	•	30 mins	
	Wind speed	•	once		-	•	once	•	1 min	
	Solar radiation	•	30 mins	•	1 hr	•	30 mins	•	30 mins	
	Vapour pressure	•	32 mins	•	1 hr	•	32 mins	•	30 mins	
	CO_2	•	32 mins	•	30 mins	•	32 mins	•	1 min	
	O_3	•	32 mins		-	•	32 mins			
	CO_2 exchange					•	30 mins			
	H_2O exchange					•	30 mins			
Soil Water	20 cms	•	30 mins		-	•	30 mins			
Physiology	Photosynthesis	•	g.s.	•	g.s.	•	g.s.	•	g.s.	Growing season
	Transpiration	•	g.s.	•	g.s.	•	g.s.	•	g.s.	Growing season
	Stomatal conductance	•	g.s.	•	g.s.	•	g.s.	•	g.s.	Growing season
	Sapflow		g.s.				g.s.	•	g.s.	

The following growth parameters will be measured annually from 10 juvenile trees harvested at the end of the growing season over the 3 year period:

Parameter	UK (n=10)	Germany (n=10)	Italy (n=10)	Belgium (n=10)
stem length	•	•	•	•
stem diameter (2x)	•	•	•	•
number of branches	•	•	•	•
number of buds		•		
number of leaves		•		
leaf area	•	•	•	•
dry mass of stem	•	•	•	•
dry mass of fine roots	•	•	•	•
dry mass of coarse roots	•	•	•	•

DELIVERABLES

7. Standardised methodology and protocol for assessing growth patterns and allocation of juvenile plants grown in manipulative experimental conditions.
8. Database on growth patterns and allocation from individuals for a range of species, environmental conditions, management options and atmospheric change.
9. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.

MILESTONES – Year 1

New data on the quantification of carbon allocation from trees across a range of species grown in plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Tertiary site protocol. Completed Oct 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 2

New data on the quantification of carbon allocation from trees across a range of species grown in plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Tertiary site protocol. Completed Oct 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Scheduled for completion in Dec 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 3

New data on the quantification of carbon allocation from trees across a range of species grown in plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Tertiary site protocol. Completed Oct 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completion in Dec 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 Dec 03 Final Version Feb 05	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extended Period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Tertiary site protocol. Completed Oct 01.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Completion in Dec 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 Dec 03 Final Version completed Feb 05	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP3 – Year 1

Two of the 5 tertiary sites originally proposed for use in this project (Montalto di Castro, Italy and Antwerpen, Belgium), were no longer available for research purposes, due to the delays in the contract start date. However plant material collected from trees grown in the OTCs has been collected and will be used by MEFYQUE.

Key Changes to WP3 – Year 2

There are no changes to WP3 for the current year, with the exception for reallocation of P2's person-months for this WP to WP7.

Key Changes to WP3 – Year 3

None

Key Changes to WP3 – Year 3

None

2.5.3 The Laboratory Component

The **LABORATORY COMPONENT** uses established laboratory infrastructure and procedures to assess whether the anatomy, biochemical composition and mechanical properties of wood vary as a result of growth conditions (climate and CO_2 concentration). Laboratory procedures are being used to assess these characteristics for:

(a) new plant material from the monitoring and manipulative experiments;

(b) existing plant material produced in previous manipulative experiments;

(c) over-mature standing timber, to contrast properties for timber grown at ambient (≅350-370 µmol mol^{-1}) and elevated CO_2 concentrations (≅700 µmol mol^{-1}).

The main results achieved in the first year of MEFYQUE for the laboratory component are separated into wood anatomy, biochemical and physico-mechanical studies, respectively.

2.5.3.1 Wood Anatomy Studies

Aim. The aim of the anatomical studies is to correlate anatomical modifications with changes identified through biochemical and bio-mechanical analyses. In addition to new plant material, existing material from completed manipulative experiments will also be investigated. The main objective will be to analyse the anatomical properties of wood from the monitoring and manipulative experiments in laboratory conditions. This will be achieved by:

Qualitative determination of the different portions of cell types, cell *lumina* and cell wall thickness of plant material grown will be carried out:

in ambient CO_2 from different sites and for a representative range of forest management conditions;

on new plant material after one, two and three years Of CO_2 enrichment and/or manipulation of climatic and management factors;

on existing plant material after up to five years of CO_2 enrichment and/or manipulation of climatic and management factors.

Qualitative determination of cell wall growth and lignification at elevated CO_2 concentration will be carried out.

Changes in tension and compression wood proportion as these are considered to be important criteria for quality evaluation will be assessed. The transition zone between juvenile and mature wood will be evaluated from anatomical analysis and the amount of juvenile wood will be compared for plant material grown under ambient and elevated CO_2 conditions.

MAIN RESULTS - YEAR 1

The main results of studies carried out to assess wood anatomy are as follows:

- Field sampling and laboratory protocol for collection and analysis of wood material respectively. The protocol is provided at Appendix 1-F.
- Preliminary anatomical analysis of wood anatomy samples.

Samples have currently been provided from 4 primary sites in the UK; wood material is being stored under cool conditions (4-10 degrees Celsius) until processing begins.

To date measurements have been carried out on *Pinus sylvestris* samples from the Berlin tertiary site. Tree ring and bark widths have been measured on four radii of all *Pinus* samples (n=76) (Figure ANA-1). An attempt has been made to distinguish between early wood and latewood (Figure ANA-2) using visual assessment that have proved complex due to the lack of a net transition and intra-annual growth fluctuations. The area of cell lumina of early wood and latewood tracheids and cell lumina:cell wall area ratios have been measured on 20-40 lumina in 18 areas along three radii on 10% of the 3-year old *Pinus* samples (approximately 540 lumina measured per sample). Cross sectional digital photographs have been taken in 8-bit greyscale (0-255 grey levels) and analysed using a Leica Qwin image analysing system (Figure ANA-3). Initially images were masked manually, then the picture was transformed into a binary image and objects were then measured automatically (Figure ANA-4).

Figure ANA-1. *Pinus sylvestris samples from the Berlin tertiary site. Position of measured radii.*

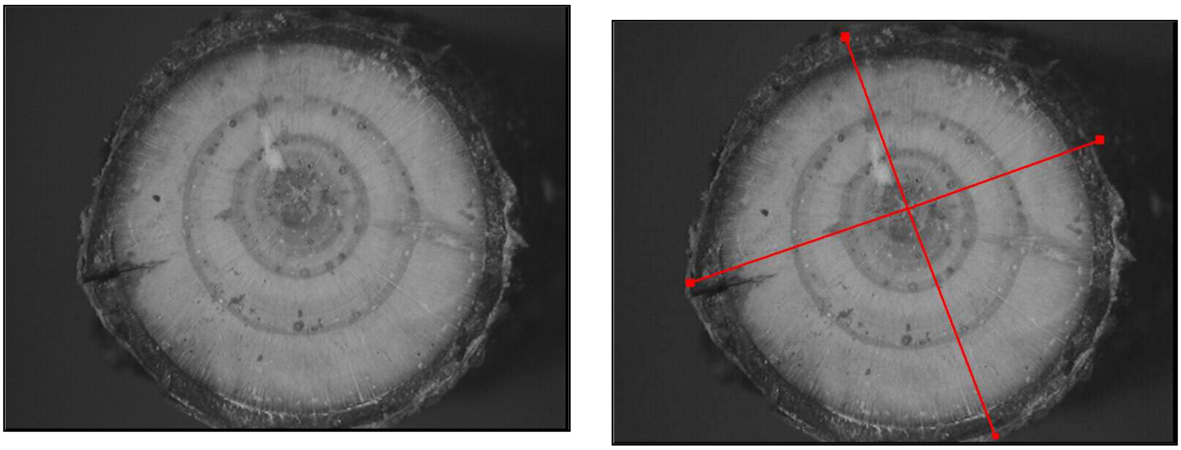


Figure ANA-2. *Pinus sylvestris samples from the Berlin tertiary site. Visual assessment of early wood and latewood positions.*

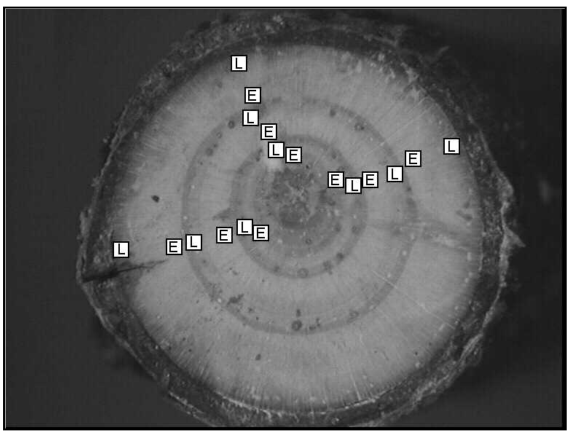
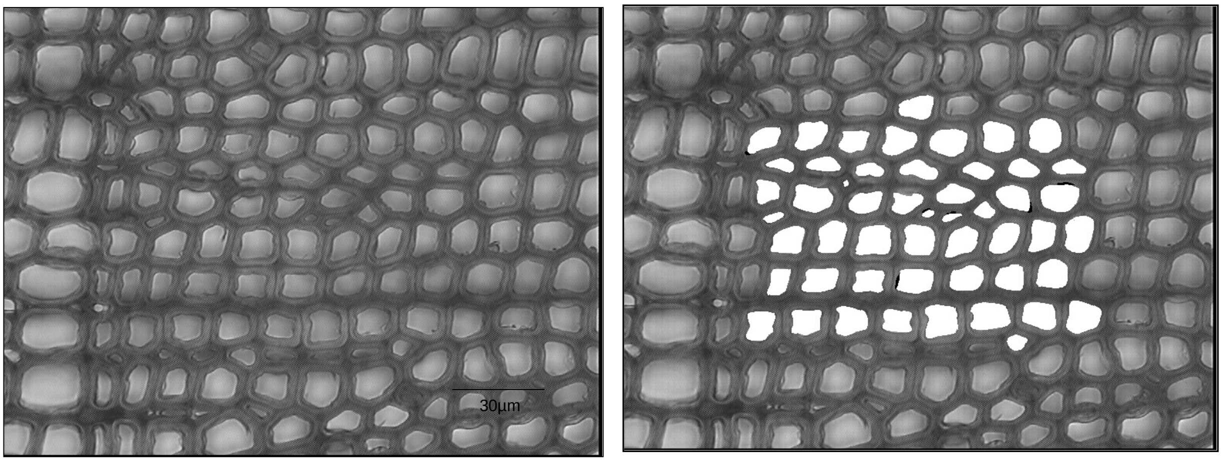


Figure ANA-3. *Leica Qwin image analysing system*

Figure ANA-4. *Pinus sylvestris sample No. 139 from the Berlin tertiary site (treatment: 700ppm CO2, -4°C). Manual masking of tracheid lumina.*



Preliminary results indicate that there is no clear relationship between diameter growth rate and cell cross-sectional area (Figure ANA-5). Data indicate an increase in both the mean and the variability of mean cell lumina area with plant age. There is significant variation in cell lumina area between different positions within the same plant and the same year of plant growth than between plants and treatments. Figures ANA-6,7 outline the frequency of lumina diameter over 3 years of growth in early- and latewood. The high variability of the measured parameters makes it necessary to measure a greater number of sub-samples per sample.

Figure ANA-5. *Pinus sylvestris sample No.139 from the Berlin tertiary site (treatment 700p pm CO2, -4°C). Relationship between diameter growth rate and cell cross-sectional area.*

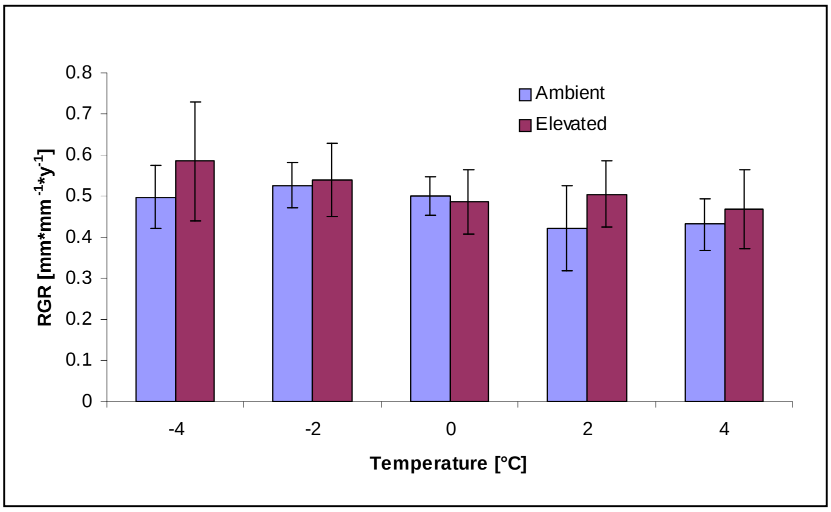


Figure ANA-6. *Pinus sylvestris sample No.139 from the Berlin tertiary site (treatment 700p pm CO2, -4°C). Lumina area frequency count in earlywood.*

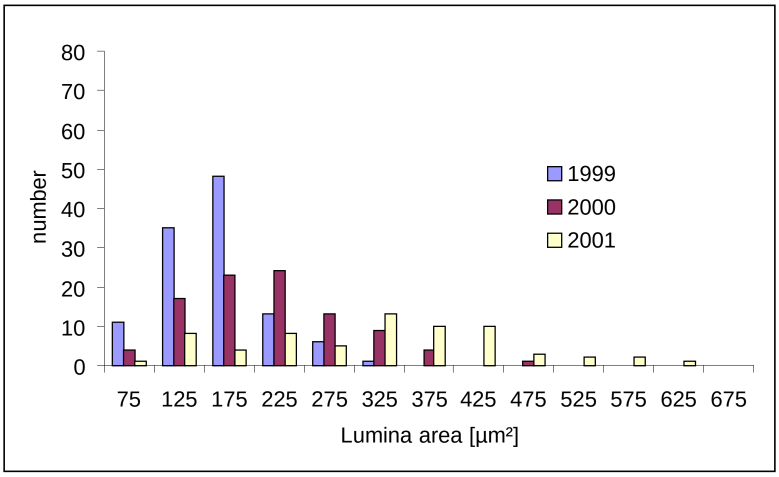
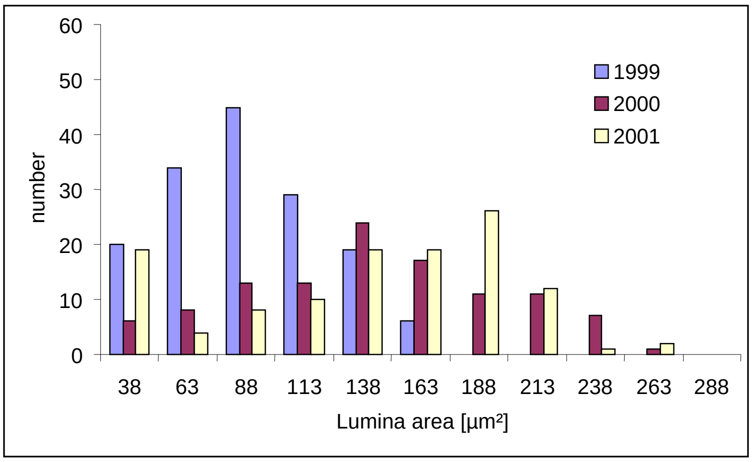


Figure ANA-7. *Pinus sylvestris sample No.139 from the Berlin tertiary site (treatment 700p pm CO2, -4°C). Lumina area frequency count in latewood.*



To date progress has been relatively slow as masking cell lumina on digital photographs are being carried out manually. A study is now under way to compare results of lumina masked manually with those identified automatically by the image analysing system in order to accelerate sample processing.

MAIN RESULTS – YEAR 2

To date the focus of activity has been on the Brasschaat site in Belgium (primary site) and the Tertiary site in Italy. Few analyses have been carried out. On the tertiary site material to the small dimensions of pine, beech and oak of plant material grown for only 3 years in elevated CO_2 growth.

<u>Materials and Methods</u>

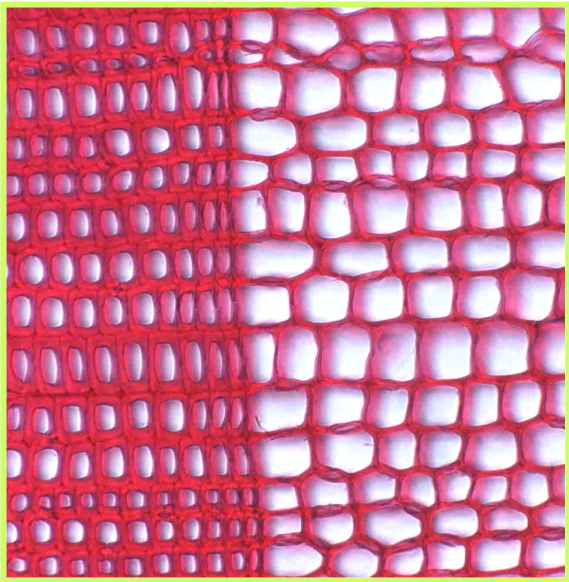
Quantitative anatomy and density profiles. In outline, the sample preparation procedure is as follows:
Cut samples from logs or bore using Pressler corer.

Preparation of samples -- this is slow and must be completed with care – cutting, polishing and staining each sample can take up to 1 hour.

Microscopic measurements and assessments.
Data preparation and manipulation.
Following staining stem anatomy has been assessed under a microscope in the transversal, tangential and radial sections with the following measurements taken -Lumina area and diameter of conductive tissue
Lumina area and diameter of conductive tissue
Cell wall thickness of early and late wood
Ring width
Vessel/fibre length
Density profile and early/latewood ratio
Ratio between tissue types

Quantitative anatomy and cell structure analysis. The objective of this sub-task is to obtain detailed data on cell structure. Up to now, quantitative wood anatomical measurements have always been done manually, on thin microtomed sections using a microscope. In recent years, digital image processing has offered faster means for performing such analyses but methods are still lacking for automating and speeding up the data collection. New sample preparation methods and automated image analysis procedures are required, customised for every species, since the preparation of microtomed sections is very time-consuming, the sections and the images can be of poor quality in spite of careful preparations, and because manual computer-aided measurements are also time-consuming and labour-intensive. Initial literature-based data will be provided to UIA (P2) for six species of interest. The actual measurements will focus on the last three growth-rings of the dominant trees for these six species, and for the softwoods, only the suppressed trees will be studied (last three rings). More rings will be analysed in the material from Brasschaat (UIA-site), for which the prepared samples are already available for manual computer-aided analysis.

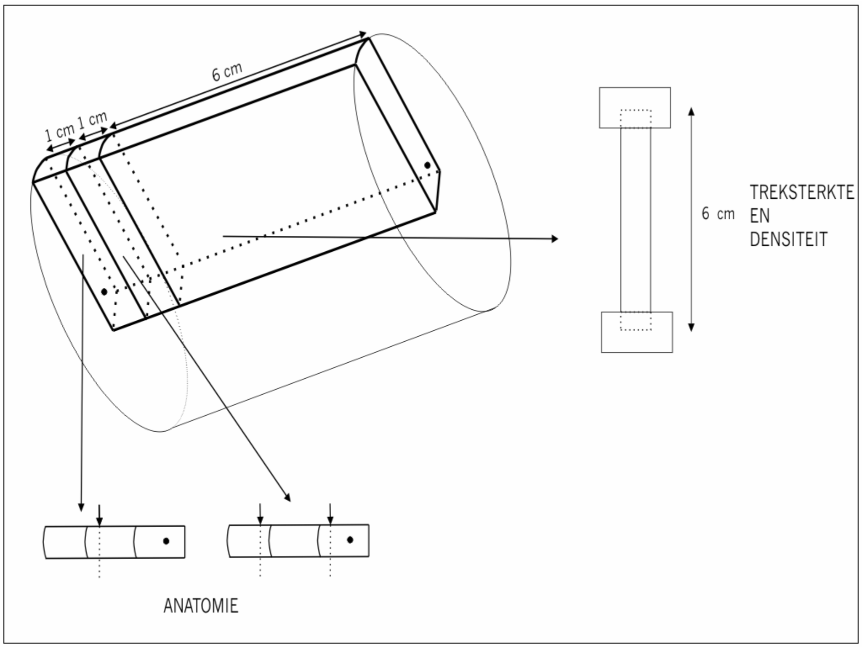
Figure ANA-8. *Digitised Pinus sylvestris thin section (stained) taken near the growth ring border showing latewood (left) and earlywood (right) cells.*



Primary site. Stem-discs were sawn at three different height-levels from nine Scots Pines sampled at the Brasschaat site (UIA). In each stem-disc, small cubes including the 15 outermost growth-rings were cut out along the N-radius, which were subjected to microtome sectioning. The 20-35 µm transverse sections were stained with safranin (stains lignin red) prior to permanent embedding. Two to five *replica* sections were made for each sequence of 15 rings. An example of a Scots Pine section is shown in figure ANA-8 above. A total of 290 sections are available at this point, which will allow us to study 405 rings (9 trees x 3 heights x 15 rings).
The microtomed cuts are analysed by means of an interactive image analysis system (TimWin). At relatively low magnification, the radial evolution of porosity will be estimated as a measure of lumen to cell-wall proportion (semi-automatic), for each of the 405 rings. At higher magnifications, wall thickness will be recorded manually (but computer-assisted), on a reduced number of frames (*i.e.* for selected ring-types), to obtain typical earlywood and latewood values.

Tertiary site. Material from this site consists of wood sampled from 3 different poplar clones the diameter of which reached 4-8 cm after 3 years of elevated conditions. The influence of genetic differences was minimal due to fact that clones were used. Not only anatomical features were determined; analysis of physical-mechanical and chemical components were added to the research protocol to be able to understand and explain possible differences in anatomical structure. Due to technical reasons (deviating properties of the pith growth ring) only the last two growth years were useful in this protocol.
The anatomical part was subdivided into two main research topics. At first attention was given to testing of different staining methods. Literature provides overall standard colouring techniques. The evaluation of a staining technique specific for this juvenile poplar material was the first step to build up the further anatomical protocol. Together with a literature overview of possible preparation methods, the findings are being prepared for a technical note to be published in *Holzforschung*.
After the determination of the most value-adding staining method, slides were made per growth ring. These slides were used to produce images of the whole growth ring giving a radial gradient. In the first stage of this research attention was given to vessel characteristics. The measurements were still done manually. With the TIMWIN-system (4.2) it will be possible to assess more features in a shorter period of time.
To determine physical properties, density was measured on small samples of 5x0.8x0.1 cm that were sliced according to a radial gradient. The same specimens were also used for the determination of tension strength (mechanical property), making it possible to compare differences in anatomical features to altering physical-mechanical properties. Figure ANA-9 gives an overview of how the samples were taken for anatomical features and strength measurements. Samples were ground for chemical analysis, to be carried out in due course.

Figure ANA-9. *Sampling of the poplar stems for anatomical features (anatomy) and physical-mechanical features (treksterkte-densiteit)*



Quantitative anatomy and density profiles. A large number of samples have been received from monitoring and manipulative sites for anatomical studies (Tables ANA-1and ANA-2).

Table ANA-1. *Number of samples for anatomical studies from primary sites.*

Site	Number of discs	Condition	Species
FR01	6	Green	Oak
FR02	9	Green	Sitka spruce
FR03	9	Green	Sitka spruce
FR04	9	Green	Scots pine
FR05	6	Green	Oak
FR06	9	Green	Scots pine
FR07	9	Green	Sitka spruce
FR08	13	Green	Sitka spruce
FR09	9	Green	Norway spruce
FR10	9	Green	Scots pine
UIA01	9	Green	Scots pine

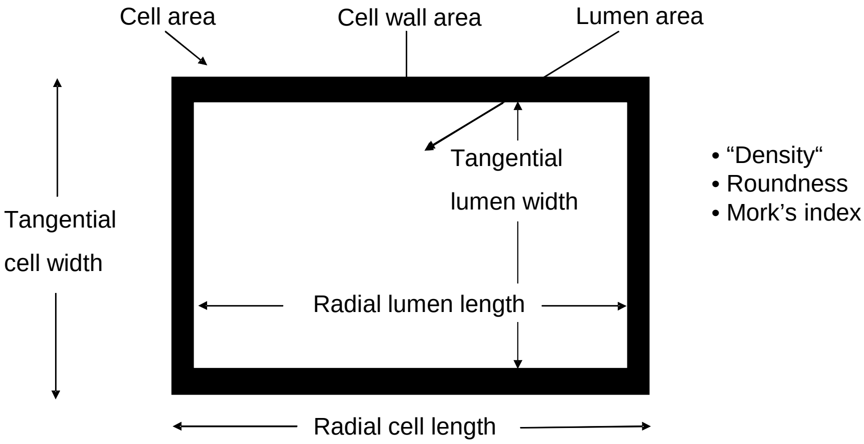
Table ANA-2. Number of samples for anatomical studies from tertiary sites.

Site	Number of discs	Species
FR09	47	Black pine
FR09	47	Douglas fir
FR09	36	Beech
FR04	46	Oak
FR05	6	Oak
UNITUS	26	Poplar
UNITUS	26	Poplar
UNITUS	26	Poplar
TUB	60	Scots pine
TUB	50	Beech

Developing and establishing an automatic method for measuring anatomical properties on cross sections by transmitted light microscopy. The work is carried out initially with an image analyse system (Leica Qwin on a Leica Quantimet500IW workstation), which also provides a macro-programming facility. Digital imaging can be divided in three steps: Image acquisition – image procession – measurement. While the first step has to be done manually, the others are driven by macros. For this it is necessary that the thresholding (the selection of a grey level, which separates all pixels in black or white in the following step of binarisation) be done automatically. Measuring features in the same images automatically and manually checked the accuracy of the applied method of thresholding, carried out by means of a grey-level histogram. The error was 5%, an acceptable balance given the benefits of speed of automatic measurements. Automatisation provides the opportunity to measure more variables on single cell level (Figure ANA-10).

The second step in the automisation of the method is done by macros programmed for SAS. Macros were used to sort and fit the data and to carry out further statistical evaluation.

Figure ANA-10. *Variables measured for single cells*



Width of tangential cell wall * 2	=	radial cell length – radial lumen length
Width of radial cell wall * 2	=	tang. cell width – tang. lumen width
Cell wall area portion	=	cell wall area / cell area

__Measuring intra-annual profiles of wood anatomical properties of samples from monitoring and manipulative sites.__ Cell dimensions reflect the cambial activity throughout the vegetative period. In order to ascertain the environmental triggers of growth responses there is a need for measuring intra-annual profiles of the cell dimensions. Intra-annual profiles of the 13 variables (Figure ANA-10 above) were measured for 50 Scots pine samples from the tertiary site in Berlin and on 6 Scots pine trees from the Brasschaat (Belgium) and Rannoch (UK) primary sites. From the tertiary site material measurements were carried out on the 2 last growth rings, while on the primary site material measurements were taken on the last 10 growth rings. Samples from the primary sites were taken at 35-cm tree height. This height was chosen because at the stem base the supply of the cambium with carbohydrates as a function of tree height is minimal so that the greatest sensitivity to environmental conditions can be expected at this height. Results are shown in Figures ANA-11,12 below.

Figure ANA-11. *Intra-annual profiles of cell wall area portion in the years 1992-2001 of six Scots pine trees from the Rannoch (UK) primary site. The upper left graph (sample 1801) also shows the standard deviation.*

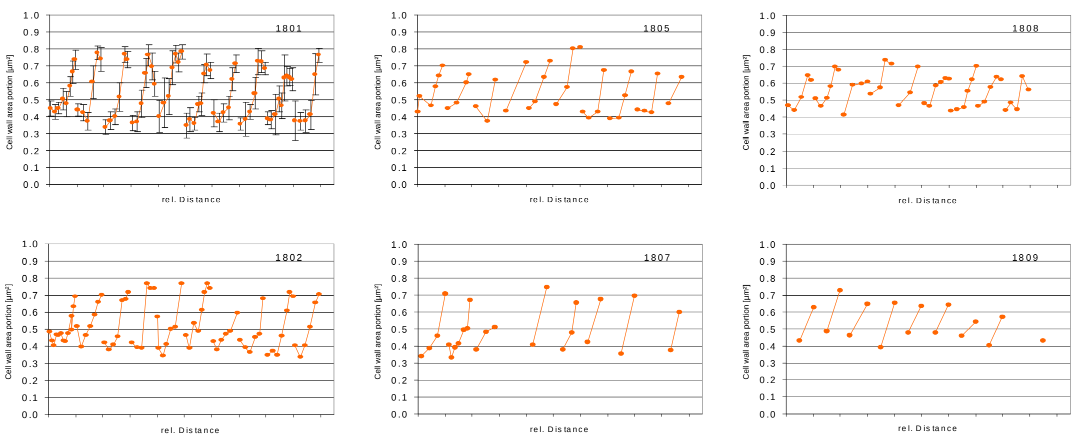
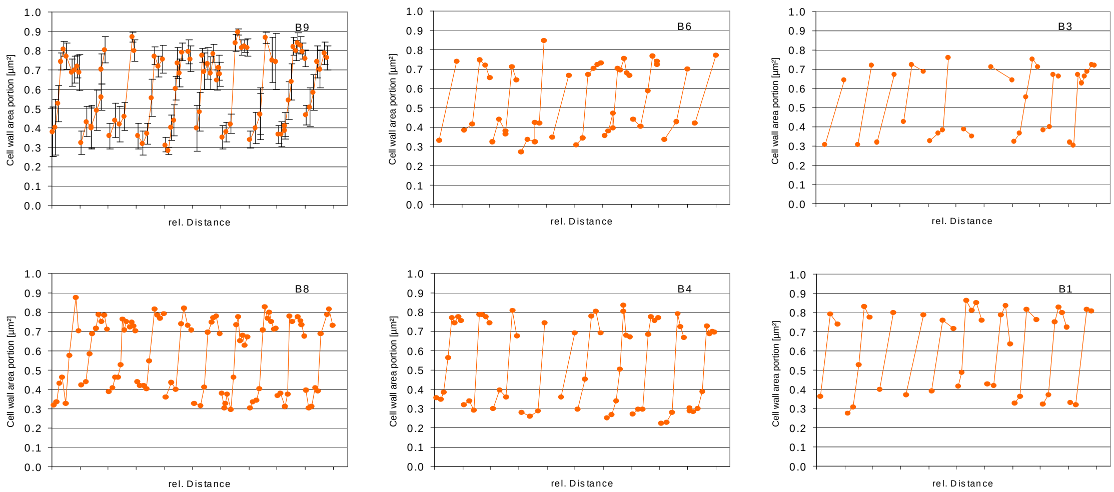


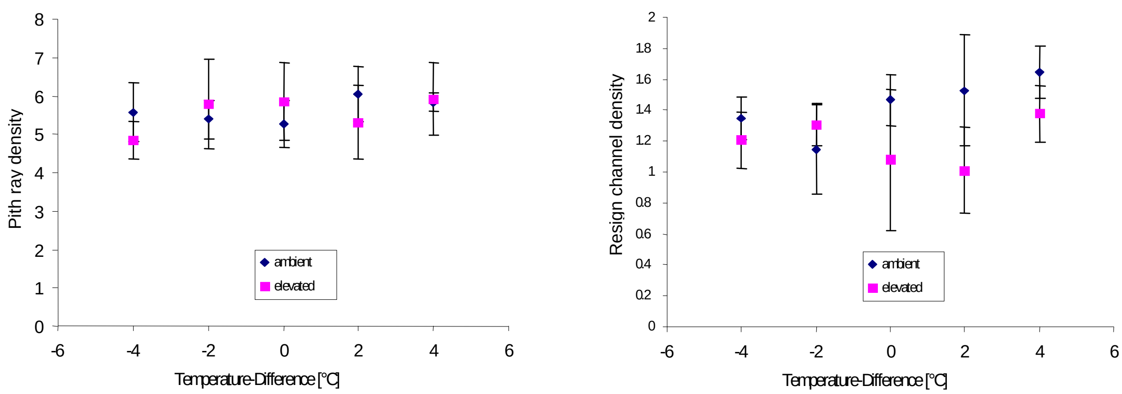
Figure ANA-12. *Intra-annual profiles of cell wall area portion in the years 1992-2001of six Scots pine trees from the monitoring site in Brasschaat (Belgium). In the upper left graph (sample 1801) the standard deviation was included.*



Results show greater intra-annual differences between the earlywood and latewood of older trees than in younger trees, by comparing the older Brasschaat trees to the younger Rannoch trees. The same trend exists between dominant trees (fig.ANA-11: 1801 &1802; fig ANA-12: B9 & B8) and suppressed trees (fig.ANA-11: 1809 &1808; fig ANA-12: B3 & B1).

Trying to measure the parenchyma content automatically failed. In order to obtain a value for parenchyma, the number of pith rays and resin channels per unit area was counted, as shown in Figure ANA-13 below. The results show no clear differences between the treatments.

Figure ANA-13. *Pith ray and resin channel density of Scots pine trees in the 10 experimental groups of the tertiary site in Berlin.*

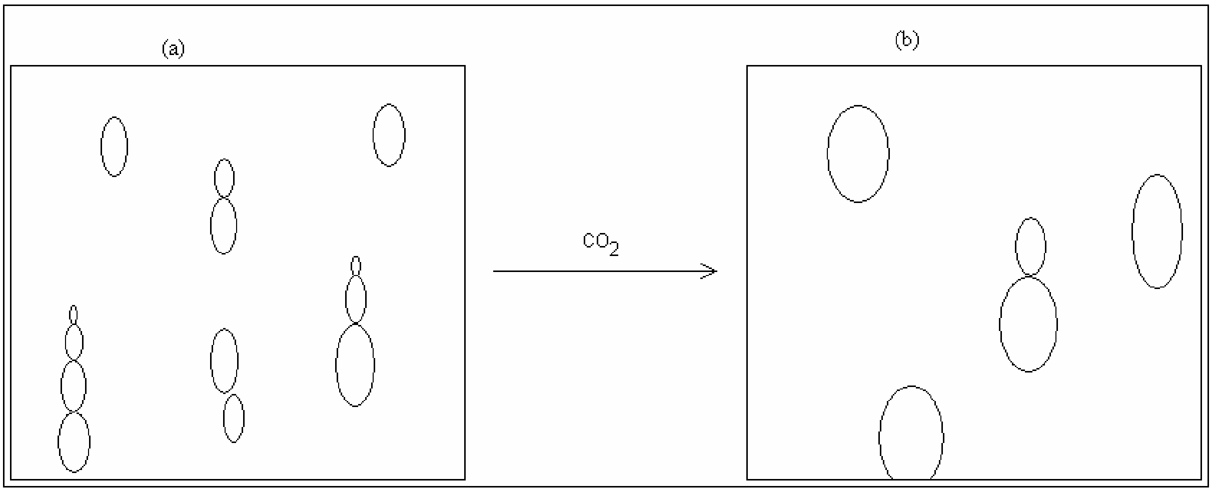


Further sub samples from the last growth ring of 78 poplar-samples of the site in Viterbo have been macerated and the fibre length has been measured. This work has been completed, but has not been elaborated for presentation in the report.

Quantitative anatomy and cell structure analysis. Measurements using the TIMWIN-system will be performed in year 3 on the six species of interest. However, new sample preparation methods and image analysis procedures are currently being developed at RUG (AP6) to automate and speed up the estimation of tissue partitioning and cell dimensions. Development efforts are also focusing on getting access to micro-densitometric data (*e.g.* using radiographical techniques). New, better performing image analysis software (Visilog 6 Xpert) will be used for this purpose and alternative sample preparation methods (other than microtome sectioning) are being explored.

CO_2-*elevated material.* A large staining experiment was carried out on poplar material from the tertiary UNITUS site to identify the best staining technique suitable for anatomical studies. Of the 52 staining combinations, the staining consisting of 1 minute astrablue followed by 5 minutes safranine met most of the requirements with regard to further distinguishing and measuring cell types. Results from the staining experiment are described below.
To date one tree in all (treated and non-treated) clones have been investigated, while for the *P. nigra* clone, 3 replicates have been analysed. In a first exploratory phase, attention was given to vessel characteristics. Although working with very homogenous material, not all results for the different clones pointed in the same direction. A general conclusion of the effects CO_2 treatment on the anatomical features is summarised in Figure ANA-14.

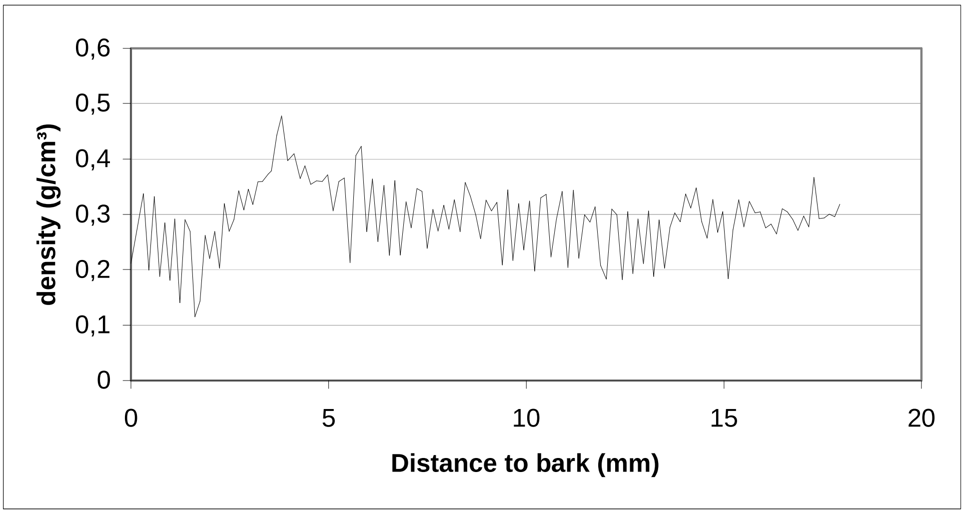
Figure ANA-14. *Differences in wood anatomy between ambient (a) conditions and CO_2- elevated (b) conditions for juvenile poplar.*



The figure shows that the number of vessels is decreasing, while the surface of the individual vessel lumen is increasing. Also the number of vessels per vessel group is decreasing. The density (Figure ANA-15 below) shows a clear trend with a peak near the end of the growing season and a minimum halfway the season. The density decreases with growing season, but always increases within the growth ring from early- to latewood. The effect is not always consistent for all replicates of the clone *P. nigra*. As could be foreseen the tension strength follows the same trend as the density. This is confirmed by a linear regression with high correlation coefficient. This correlation differs for the clone *P. alba* in comparison with the clones *P nigra* and *P. euramericana*.

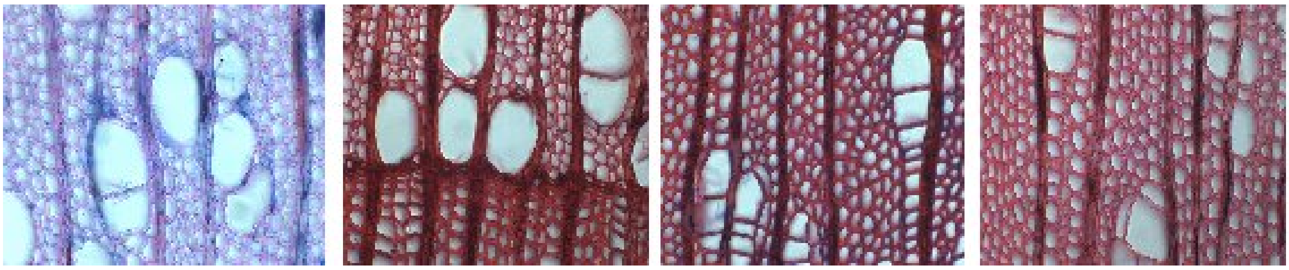
For the last two clones a similar density will lead, under elevated CO_2 conditions, to a lower strength. For *P. alba* an opposite conclusion could be made. Possible explanations could be linked to axial anatomical features (fibre length, vessel length, etc), presence of tension wood or chemical differences. Such a hypothesis deserves to be studied in more detail.

Figure ANA-15. *Detailed radial profile of the density for P. euramericana 'I214' under elevated conditions*



Staining experiment on elevated CO_2 poplar wood material. The aim of this study was to determine the most suitable wood staining combination that would highlight the different cell types observed in the wood of poplar grown under conditions of elevated CO_2. Table ANA-3 below outlines evaluation criteria used in this study, taking into account the main cell types being vessels, fibres and parenchyma. Parenchyma was further subdivided into ray parenchyma and terminal parenchyma. With vessels and fibres a distinction made between early- and latewood. An evaluation was carried out separately for cell lumen and cell wall. Examples of staining are shown in Figure ANA-16 below.

Figure ANA-16. *Examples of poplar wood (transversal section) grown under elevated CO_2 conditions and stained with different staining agents for different durations*.



For the 10 criteria used, a discrete score was given going from 1 (very well stained and excellent for further automatic processing) decreasing through 0.8, 0.5, 0.3 to 0 (not stained or very irregularly stained). Five repetitions were carried out for every criterion. The median value was then calculated for every criterion and compared to the overall median for those criteria across all staining methods. If the score was higher for a given staining method this means that at least 50% of all staining methods are worse concerning these criteria. In this case the staining method received score 1 for that criteria. If the median value is smaller than the overall mean, at least 50% of the staining methods score better for that criteria and a score of 0 was given. If the median values were equal a score of 0.5 was given. The sum of all individual criteria scores gave an objective parameter to rank the different colouring techniques according to the set standards of further automatic image processing. Table ANA-3 below summarises the colouring combination used for each experiment as well as their final score.

Table ANA-3. *Scores for the different staining methods with different staining duration.*
A = astrablue; F = Fast green; R = Rhodamine B; M = malachite green; O = Acridine orange; T = toluidine blue; G = no second staining

			First Staining																			
			S			A			F				R			M			O			T
		Time	2'	5'	30'	15''	1'	2'	15''	1'	4'	10'	5'	10'	30'	1'	2'	5'	4'	7'	10'	5'
Second staining	S	5'				7,0	9,5	8,5	5,0	8,5	9,0	5,0										
		15''																				2,0
	A	15''	3,5	5,5	6,0								1,0	5,0	1,5							
		1'	3,5	6,0	4,5								4,5	3,0	2,0							
		2'	5,5	5,5	5,5								2,5	5,0	1,5							
	F	15''		3,0																		
		1'		3,5																		
		4'		1,5																		
	R	10'				3,5	3,5	2,0														
	M	1'																	8,0	5,0	6,5	
		2'																	7,0	7,5	7,5	
		5'																	7,5	4,5	8,0	
	O	4'														5,5	4,5	2,5				
		7'														6,0	2,5	0,5				
		10'														6,5	5,0	1,0				
	G					2,0																2,0

Of all 52 staining combinations the staining consisting of 1 minute astrablue, followed by 5 minutes safranine met most of the requirements with regard to further distinguishing and measuring cell types.

MAIN RESULTS – YEAR 3

Analyses Of Wood Anatomical Properties In Laboratory Conditions

Quantitative wood anatomy, cell porosity and microdensity profiles

From nine Scots Pines from Brasschaat (Belgium), stem-discs were sawn out at five different height-levels. From each stem-disc, small cubes including the outermost growth-rings were sampled (along the N-radius), which were subjected to microtome sectioning. The 20-35 µm thick transverse sections were stained with safranin (stains lignin red) prior to permanent embedding. Partner 4 performed detailed image analysis on these cuts, in order to determine cross-sectional tracheid dimensions, such as lumen diameter and cell wall thickness at 200 µm intervals, within a select number of growth rings. Partner 6 analysed the same rings at lower magnification, using an interactive image analysis system (TimWin), and extracted radial profiles describing the intra-ring evolution of cell porosity at 5 µm steps (Figure ANA-17).

Figure ANA-17. *Example of a radial porosity profile with a radial stepsize of approximately 5 µm*

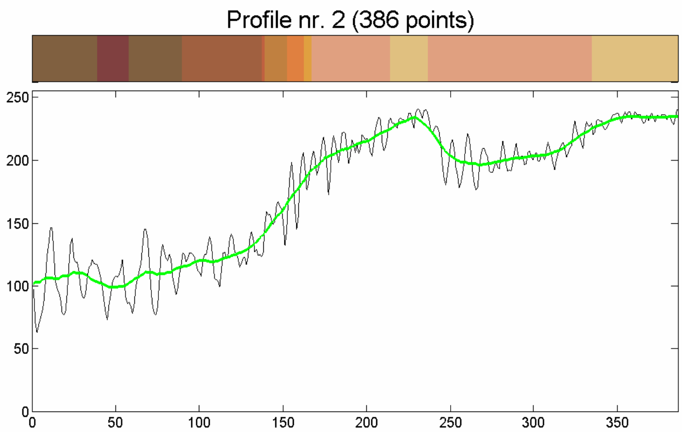
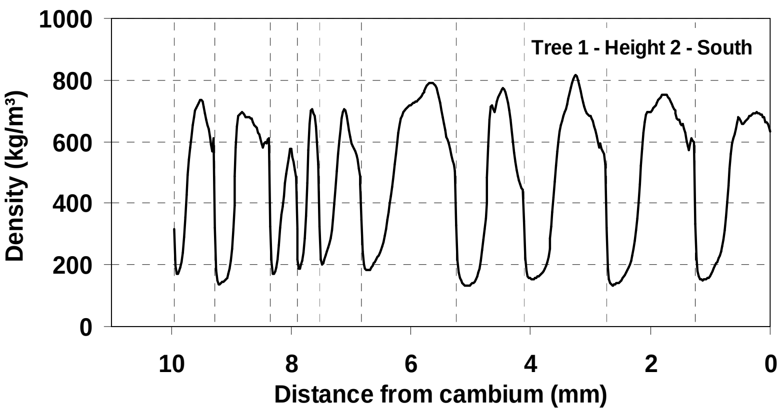
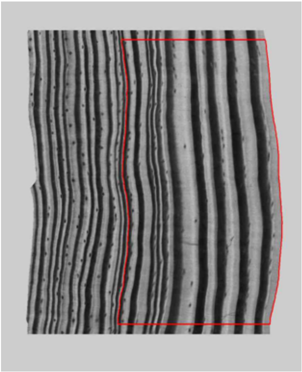


Figure ANA-18. *Example of a radial microdensity profile with a stepsize of 21.2 µm - corresponding X-ray image shown on right.*





These two types of data (anatomical and porosity profiles) will be correlated with each other to allow interpolation of the anatomical profiles for which one data point is available every 200 µm. A next step will be to link the interpolated anatomical data to real density profiles obtained through classical X-ray analysis. The radiographical procedure has been performed at INRA Nancy (free of charge) and provided digital X-ray images that will be analysed using image analysis scripts written by Partner 6. The output of this analysis will be microdensity profiles with a radial stepsize of 21.2 µm (Figure ANA-18).

The two types of profiles are available in common for the following sets of rings:
* dataset 1 (height 1 only): 10 outer rings in trees 1, 3 and 6 - this should yield two times 30 profiles (3 x 10 x 1);
* dataset 2 (heights 3, 4 and 5): 3 outer rings in all nine trees - this should yield 2 times 81 profiles (9 x 3 x 3);

In addition to the anatomical and porosity profiles, the calibrated microdensity profiles make up another dataset:
* dataset 3 (heights 3, 4 and 5): 3 outer rings in all nine trees, so another 81 profiles (9 x 3 x 3);
This joint work between Partners 4 and 6 is still ongoing and will lead to a joint paper on the link between intra-ring cell porosity profiles and cell anatomical features. Furthermore, the detailed anatomical and microdensity profiles will be used to validate the model output generated for Scots Pine in Brasschaat by Partner 2.

Vessel characteristics and element length of CO_2-elevated material from POPFACE
The technical annex specifies research on wood under CO_2-elevated conditions. Because the dimensions of pine, beech or oak are still small after 3 years of CO_2 elevated growth, assessment of wood quality is difficult. To be able to point out differences in structure between non-elevated and CO_2-elevated grown wood, partner 6 focused on the Popface material. The diameter after 3 years under CO_2-elevated conditions had already reached 4-8 cm (*cf.* second year progress report).

In total, 22 plants of the clone *Populus nigra 'Jean Pourtet'* were sampled from the ambient plots 2, 3 and 6 and from the elevated CO_2 plots 1, 4 and 5 (clone codes: 1HB03, 1HB04, 1HB06, 1HB07, 2HB00, 2HB03, 2HB04, 2HB07, 3HB04, 3HB05, 3HB11, 3HB12, 4HB05, 4HB12, 5HB03, 5HB04, 5HB09, 5HB10, 6HB04, 6HB09, 6HB10). Clear internode samples of these 22 plants were microtome cross-sectioned and stained with safranin for quantitative wood anatomical analysis of vessel characteristics at high resolution (pixels of 1.2 µm x 1.8 µm - interactive TimWin scripts). The analysis yielded detailed 2-D maps of all vessels inside a 1 mm-wide tangential strip (ring 2), including data on vessel diameter and frequency (Figure ANA-19). From these data, conductivity measures were calculated (Figure ANA-20).

Figure ANA-19. *Example of 2-D blobmaps of vessel characteristics of clone 5HB03: vessel conductivity (on top) and vessel frequency (bottom) - Y-axis gives tangential distance in microns. Blob size is proportional to highest value of selected variable.*

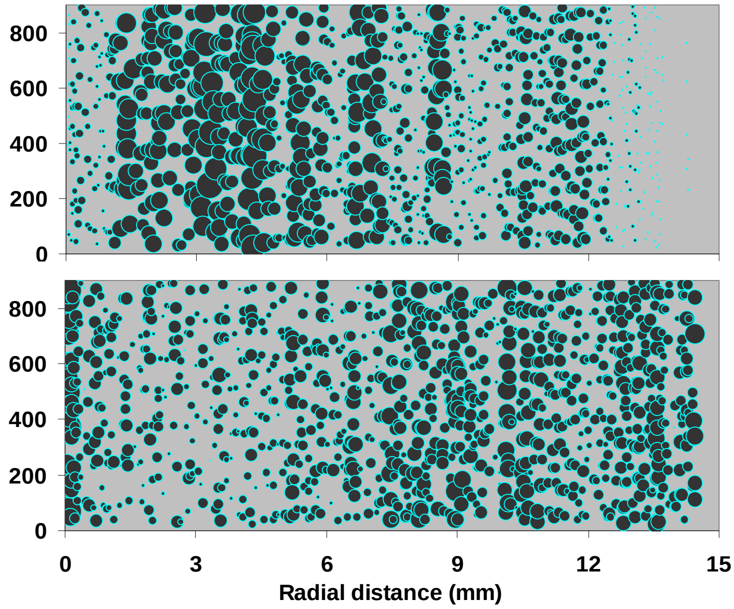
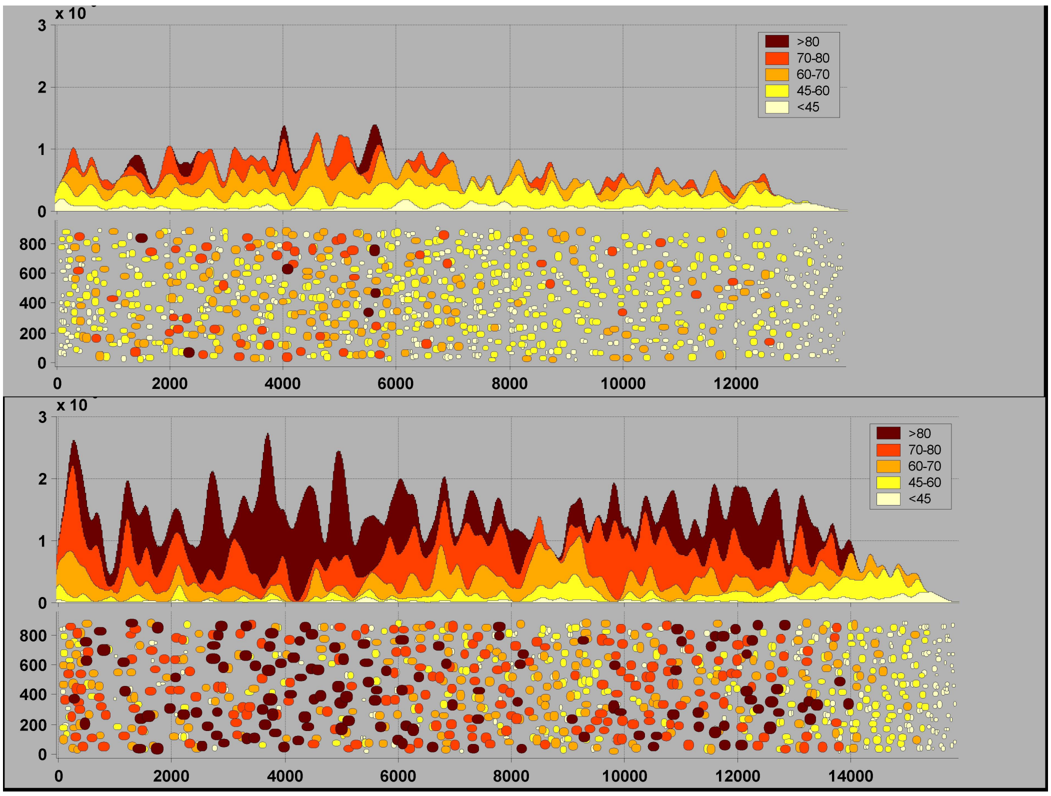
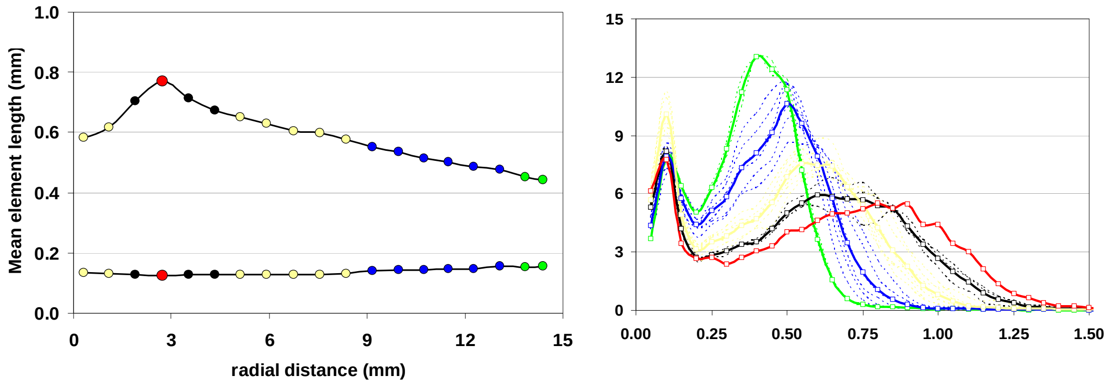


Figure ANA-20. *Two examples of radial distributions of vessel conductivity (filled area graphs) and of 2D distribution of vessel diameters (blobgraphs): vessel conductivity (on top) and vessel diameter (bottom) - X axis gives radial distance in microns and Y-axis gives respectively conductivity (mm^4) and tangential distance in microns. Vessel size is scaled proportional to highest value and colours correspond to five vessel diameter classes.*



Moreover, in the same internodial clear specimens, ring number 2 was sub-sampled radially, extracting 120 µm thick strips of about 6 cm length and 8 mm wide tangentially. These thin strips were subjected to testing of physical and mechanical properties (see WP 6). After this testing the remains of the strips were grouped (1 cluster consisting of 5 subsequent strips) and macerated. The macerates were analysed with a Kajaani Fibre Analyser at the BioComposites Centre in Bangor, Wales, UK. Fibre and vessel element length distributions were provided for at least 15.000 elements out of each macerated strip (Figure ANA-21).

Figure ANA-21. *Example of element length measurements (clone 5HB03). Left graph: mean fibre length (top curve) and vessel element length (bottom curve) in mm. Right graph: element length distributions for each of 19 clustered macerates - X axis gives element length class in mm and Y-axis gives frequency in % - five groups of distributions could be distinguished.*



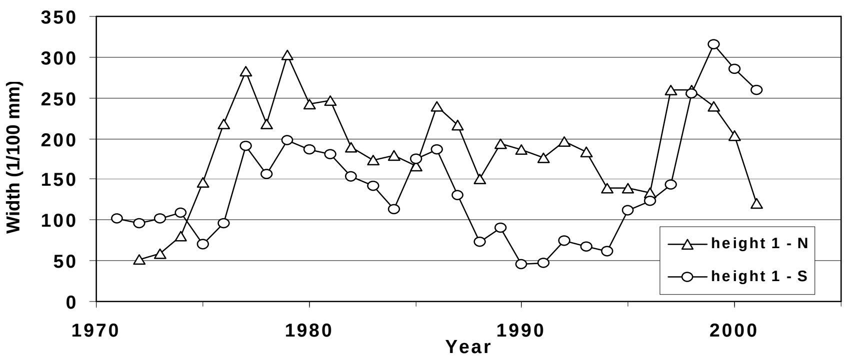
Dendrochronological analysis of trees from Italian sites
In addition to the ring-width measurements previously recorded on the material from FR-sites (78 trees, *cf.* year 2 progress report), dendrochronological analyses have been performed on 27 trees from three Italian sites, sampled at 4 heights:

9 Beech trees from Collelongo;
9 Beech trees from M. Amiata ;
9 Silver fir trees from Cinte T.;

This yielded a nominal total of 108 disks (216 radii) to be measured. The Italian disks were nearly air-dry, in contrast with the earlier evaluated FR-material which had been stored in freezers and measured in wet condition.

The N-S radial strips sawn from each disk were surfaced with a high-speed circular saw prior to measurement with the Lintab equipment at 10 µm resolution. The individual chronologies were crossdated per tree and per site, then converted from Heidelberg format (*.fh) to ascii-file format (space delimited *.txt). The txt-files were subsequently sent to Ms. T. Houston (Partner 1) for incorporation in the Mefyque database (species parameter files). An example of two cross-dated ring-width sequences is given in Figure ANA-22.

Figure ANA-22. *Example of two crossdated ring-width chronologies of Silver Fir (height 1, N and S-radii, tree 1 of Italian site 3, Cinte T)*

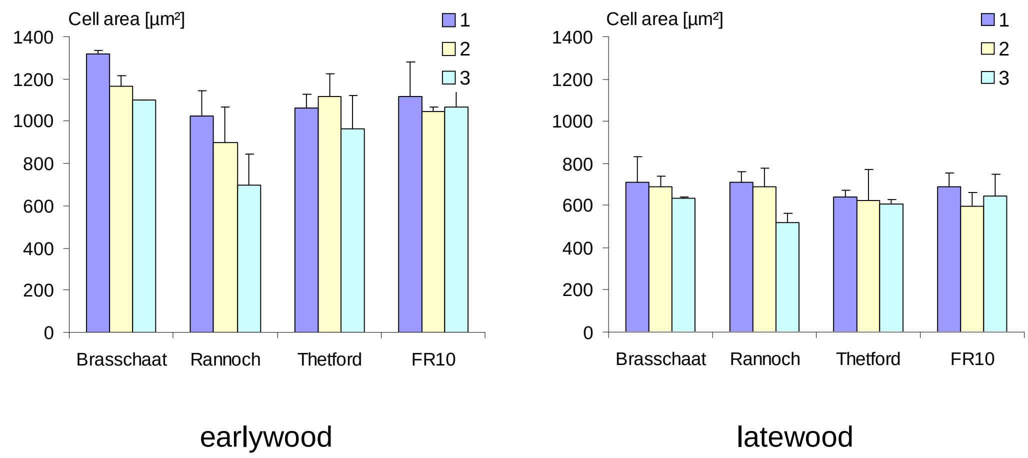


Intra-annual profiles of wood anatomical properties of Softwoods from monitoring and manipulative sites

Cell dimensions reflect the cambial activity throughout the vegetation period. There is a need for measuring intra-annual profiles of the cell dimensions for ascertaining environmental triggers of growth responses. Intra-annual profiles of 13 variables (see annual report 2003) were measured for 70 samples from the experimental site in Berlin and respective 6 trees from the monitoring sites Brasschaart (Belgium), Rannoch (UK), Thetford (UK) and Sherwood (UK). All the samples were Scots pine samples. Measurements were done on the 2 last growth rings from the experimental site and measurements were done on the 10 last growth rings from the monitoring sites. Statistical analyses routines were programmed to manage the data with the software package SAS 8.0 (SAS Institute). In a first step of data evaluation earlywood and latewood was separated with Mork's index.

The practical work on Scots pine trees from monitoring sites has been completed.

Figure ANA-23. *Cell area of earlywood and latewood cells of Scots pine trees of four primary sites (n = 24). The trees are divided in dominant (1), co-dominant (2) and suppressed (3). The three dominance levels are according to the MEFYQUE sample plot protocol.*



Cell area did not differ significantly between the dominance classes (Figure ANA-23). A significant effect of tree dominance on cell wall width was found in latewood cells (Figure ANA-24). Also the ratio of cell wall area to total cell area was significant higher in latewood cells of dominant trees (Figure ANA-25). The resin canal density, which was correlated to tree ring width (Figure ANA-26), was significantly higher in suppressed trees. In latewood a significant time effect was found for cell wall width and ratio of cell wall area to total cell area. Significant differences between the sites were evident for all cell features. The parenchyma content, which was measured in terms of cross sectional wood ray area, did not differ significantly between sites and dominance classes.

Figure ANA-24. *Cell wall width x 2 of earlywood and latewood cells of Scots pine trees of four primary sites (n = 24). The trees are divided in dominant (1), co-dominant (2) and suppressed (3) trees.*

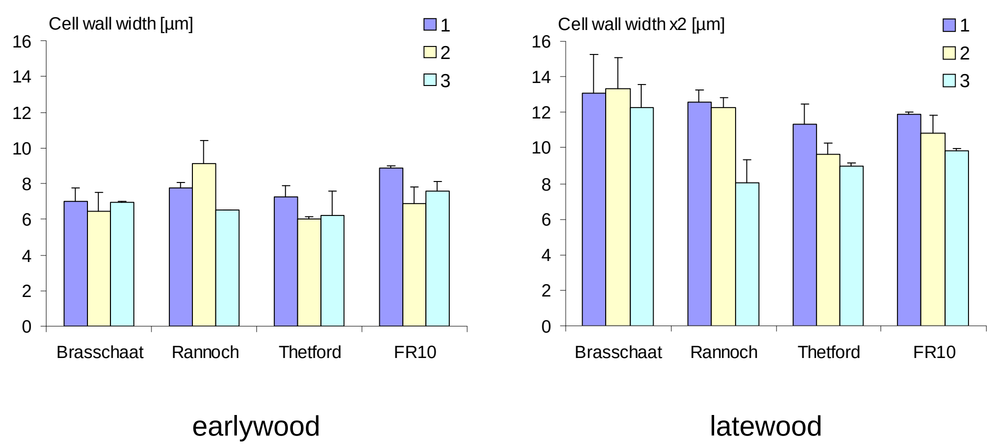


Figure ANA-25. *Ratio of cell wall area to total cell area of earlywood and latewood cells of Scots pine trees of four primary sites (n = 24). The trees are divided in dominant (1), co-dominant (2) and suppressed (3) trees.*

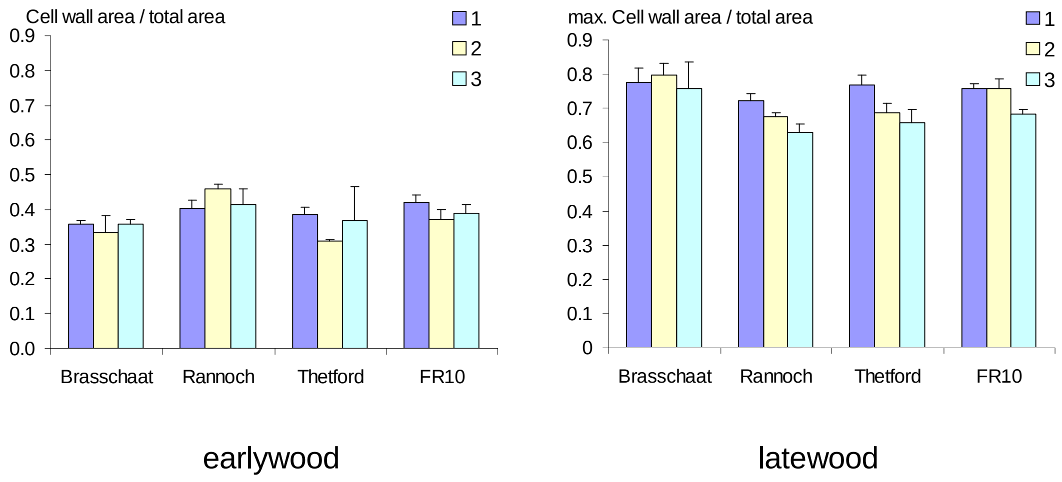
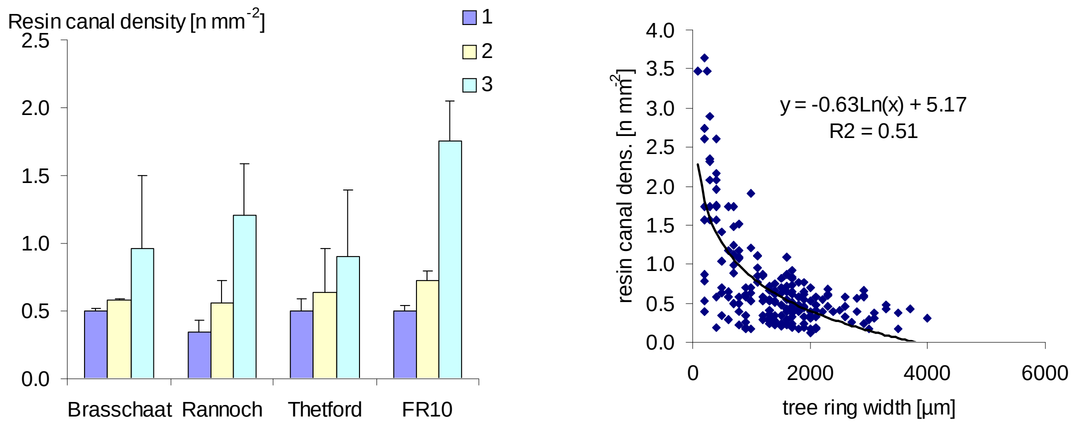
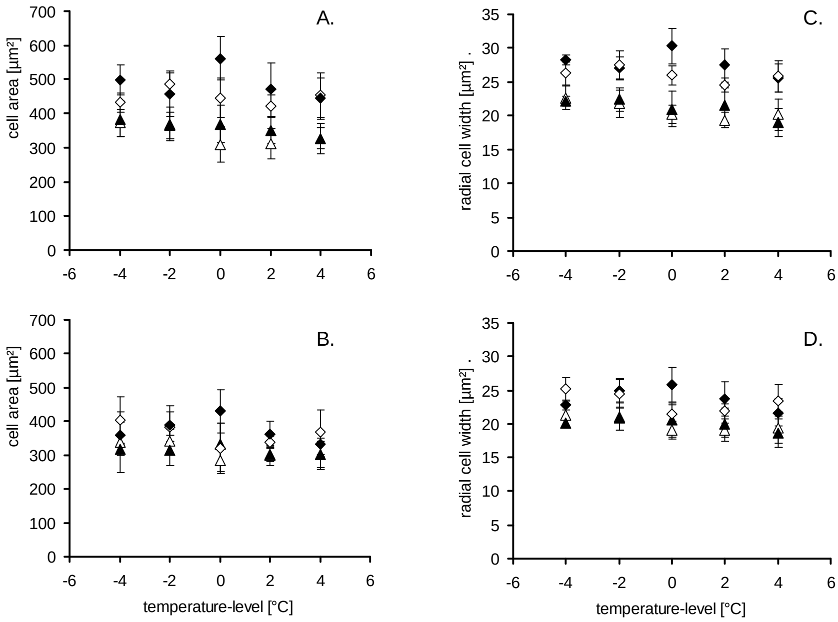


Figure ANA-26. *Resin canal density of earlywood and latewood cells of Scots pine trees of four primary sites (n = 24). The trees are divided in dominant (1), co-dominant (2) and suppressed (3) trees.*



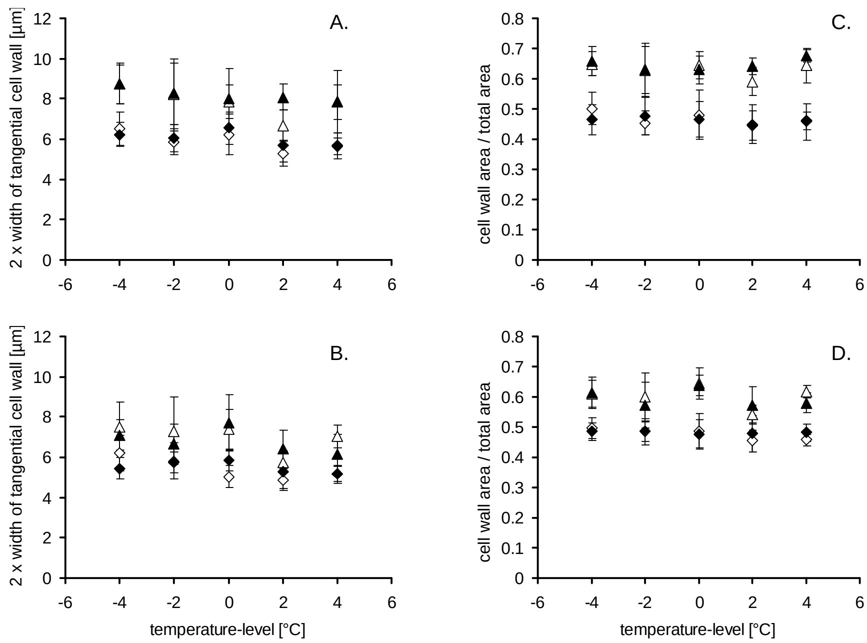
The work on the juvenile Scots pine tress from the tertiary site in Berlin was completed. Cell area, cell wall width and the ratio of cell wall area to total cell area were chosen to represent the wood anatomical properties on single cell level (Figures ANA-27 & ANA-28). Trying to measure the parenchyma content automatically failed. The number of pith rays and resign channels per unit area was counted in order to obtain a value for parenchyma content (Figure ANA-29).

Figure ANA-27. *Cell area (A. and B.) and radial cell width (C. and D.) of earlywood and latewood cells in relation to the temperature-levels of the treatments. A. and C. show the results of the 3rd year and B. and D. of the 2nd year; with •: earlywood/ambient, •: earlywood/elevated, • : latewood/ambient, • : latewood/elevated.*



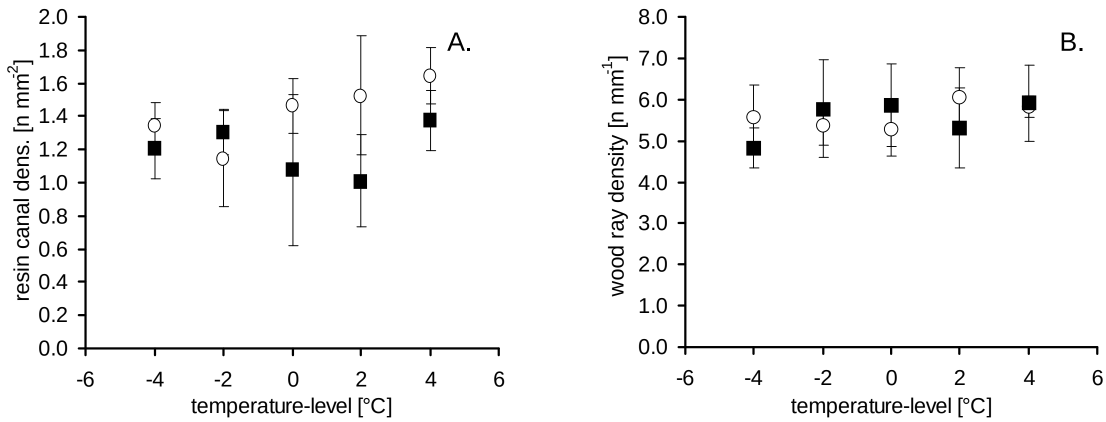
The results of the measurements for the juvenile Scots pine trees from the tertiary site in Berlin indicate that cell features were very slightly affected by elevated CO_2: Only the cell area in earlywood (Figure ANA-27) tended to become larger at elevated CO_2 (8%). Resin canal density was 43% higher at ambient than at elevated CO_2, but wood ray density was not significantly changed by CO_2 (Figure ANA-29).

Figure ANA-28. *Width of tangential cell wall x 2 (A. and B.) and ratio of cell wall area to total cell area (C. and D.) of earlywood and latewood cells in relation to the temperature-levels of the treatments. A. and C. show the results of the 3rd year and B. and D. of the 2nd year; with •: earlywood/ambient, •: earlywood/elevated, • : latewood/ambient, • : latewood/elevated.*



A temperature effect on wood anatomy was more evident. In the last two years of the experiment widths of latewood cell walls declined by 11% and of earlywood cell walls by 13% with temperature increasing to +4 °C above the long-term local mean (Figure ANA-28). Cell area in latewood was 16% greater in the 3rd year at the lowest temperature level (-4 °C). The ratio of cell wall area/total cell area in early- and latewood and the cell area of earlywood showed no statistically significant differences between the temperature levels (Figure ANA-28). Comparing all data from the lowest (-4 °C) and the highest (+4 °C) level, resin canal density was ~29% higher in the 2nd and ~16% in the 3rd year. Wood ray density was not significantly affected by temperature (Figure ANA-29).

Figure ANA-29. *Resin canal density (A.) and wood ray density (B.) in relation to the temperature-levels of the treatments in the 3rd year of the experiment; with •: ambient CO_2 concentration, •: elevated CO_2 concentration*



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Wood anatomical properties of Heartwood

Samples from the last growth ring of 72 poplar-samples (*Populus x euramericana*, *P. nigra* and *P. alba)* of the POPFACE-site in Viterbo were macerated and the fibre length was measured. 3-year old stems deriving from the first rotation cycle were used for the analyses. At two opposite radii two pieces of wood were cut at each radius (together four pieces per sample) from the latest tree ring of 70 trees. One piece per radius was cut from the beginning of the tree ring; the other one was cut from the ending of the tree ring (Figure ANA-30). The four sub-samples were separately macerated, stained and mounted on glass-slides with conventional methods. The length of 50 fibres, which were straight, fully macerated and non-damaged, was measured in each sub-sample (together 200 fibres per tree) using a digital imaging system. Differences between species and CO_2-concentrations were tested with a two-factorial ANOVA for significance.

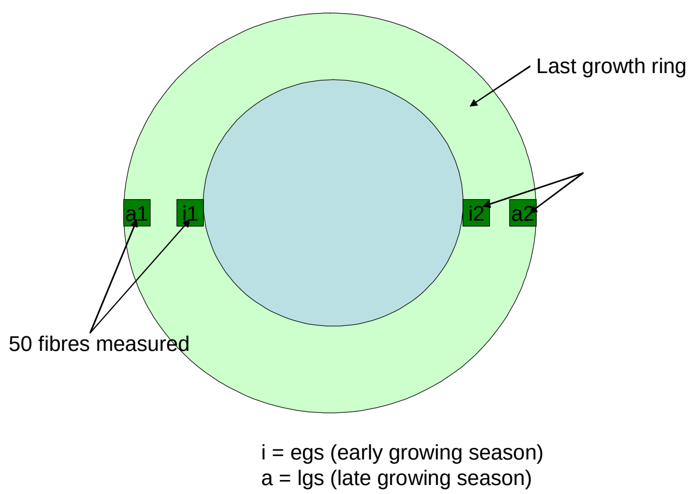


Figure ANA-30. *Sampling for maceration*

The fibres were significantly longer at elevated CO_2; also differences between species were statistically significant (Figure ANA-31). The ratio between fibre lengths from beginning and ending of the tree ring show no significant differences between species and treatments.

Figure ANA-31. *Fibre length from beginning of the growth ring (egs) and from ending of the growth ring (lgs) for three poplar species grown in short rotation culture under ambient and elevated (~550µmol mol^{-1}) CO_2 concentrations.*

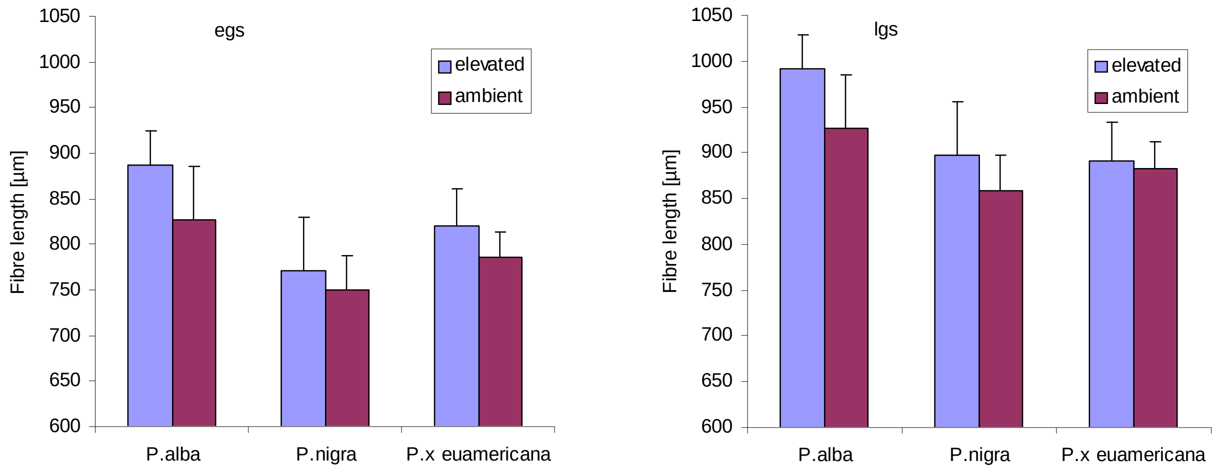
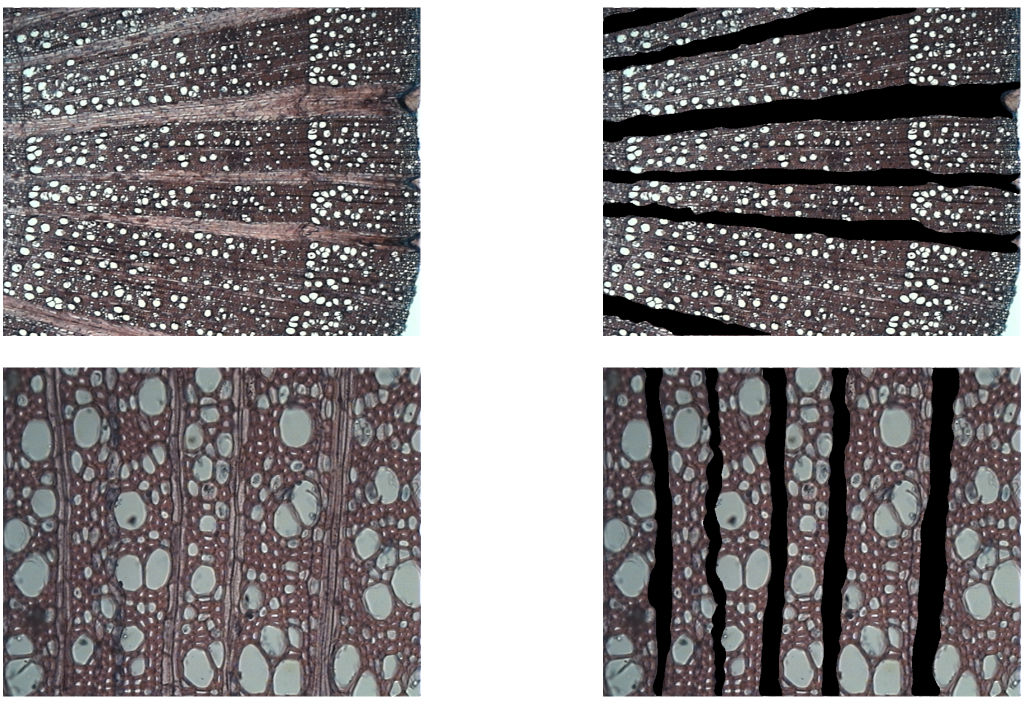


Figure ANA-32. 20µm thick cross section of beech from tertiary site in Berlin. Wood ray tissue was detected manually (fig. on the right).



Cross sections of 50 juvenile beech trees from the tertiary site in Berlin were cut, stained and mounted on glass-slides with conventional methods (Figure ANA-32). Parenchyma was segmented manually from other tissue because automatic measurement of the parenchyma content failed.

Preliminary results show that on cross sections cut 2 cm above ground the relative lumen area of the vessels and the parenchyma content were poorly affected by CO_2. The parenchyma content, which was divided in wood rays wider than six cell rows, wood rays up to six cell rows wide and axial parenchyma outlines an optimum curve in dependency on temperature.

MAIN RESULTS – Extended Period

Most of the anatomical analysis was completed during years 1-3.

Cell features (cell area, cell wall width, ratio of cell wall area /total area) were not significantly affected by CO_2 (Table 3.2). Cell growth was only slightly enhanced by elevated CO_2 (Figure 3.6). In the 2nd year of the experiment differences between the CO_2 treatments were < 5% in all variables. In the 3rd year cells tended to become larger; on average, latewood cell area increased by 6% and 8% in earlywood at elevated CO_2 concentration (statistically not significant). At ambient CO_2, resin canal density had been 29 % higher in the 2nd year and 43% higher in the 3rd experimental year than at elevated CO_2. Wood ray density was not significantly affected.

Table ANA-4 Probability classes of statistics for anatomical characteristics and wood properties. Results of the two-factorial repeated ANOVA are shown, with the sum the effects of the last two experimental years. Columns headlined with COV show the results for the inclusion of RGRCSA as covariate. n.s.: not significant; * : $p < 0.05$; ** : $p < 0.01$; *** : $p < 0.001$; X : effect was not estimated.

	Repeated 2-factor ANOVA										Regression
	CO2		temperature		CO2 x temperature		time		control (Dunnett's - test)		Slope > 0
		COV		COV		COV		COV	2ndyr.	3rdyr.	
EW. Cell area	n.s.	n.s.	n.s.	n.s.	*	*	***	n.s.	n.s.	*	n.s.
EW. Cell width	0.06	*	n.s.	*	**	**	***	n.s.	n.s.	*	*
EW. Cell wall width	n.s.	n.s.	*	*	n.s.	n.s.	***	n.s.	*	*	***
EW. Cell/total area	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
LW. Cell area	n.s.	n.s.	0.08	n.s.	n.s.	n.s.	***	*	*	n.s.	**
LW. Cell width	n.s.	n.s.	***	**	n.s.	n.s.	***	*	*	n.s.	***
LW. Cell wall width	n.s.	n.s.	0.05	*	n.s.	n.s.	***	n.s.	*	n.s.	**
LW. Cell/total area	n.s.	n.s.	0.08	0.08	n.s.	n.s.	***	n.s.	n.s.	n.s.	n.s.
Wood ray density	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***	n.s.	*	n.s.	*
Resin can. density	*	**	**	***	n.s.	n.s.	***	n.s.	*	n.s.	**
Tree ring width	*	X	0.07	X	n.s.	X	***	X	n.s.	n.s.	n.s.
RGRCSA	n.s.	X	0.07	X	n.s.	X	***	X	n.s.	n.s.	*
Latewood content	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
Wood density	n.s.	X	n.s.	X	n.s.	X	X	X	*		***

2.5.3.1.1 WP4: Analyses Of Wood Anatomical Properties In Laboratory Conditions

Work-package number:	4						
Start Date:	Planned Jul 01			Status: No change			
Completion Date:	Planned Feb 04			May 04			
Current status	Completed						
Partners Responsible:	P4, AP6, P7			Status: No change			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex				15(+2)		6(+4)	3(+7)
Year 1 – person-months employed				5		1	1
Year 2 – cumulative person-months employed				10		4	1
Year 3 – cumulative person-months employed				16		9	9
Total including extension				20		12	11

Key Changes:
P4: 2 person-months reassigned from WP7 to WP4
AP6: 4 person-months reassigned from WP2 to WP4
AP6: 7 person-months reassigned from WP7 to WP4

OBJECTIVES
The aim is to correlate anatomical modifications with changes identified through biochemical and bio-mechanical analyses. In addition to new plant material, existing material from completed manipulative experiments will also be investigated. The main objective will be to analyse the anatomical properties of wood from the monitoring and manipulative experiments in laboratory conditions. This will be achieved by:
4.1 Qualitative determination of the different portions of cell types, cell *lumina* and cell wall thickness of plant material grown: (a) in ambient CO_2 from different sites and for a representative range of forest management conditions; (b) new plant material after one, two and three years Of CO_2 enrichment and/or manipulation of climatic and management factors; (c) existing plant material after up to five years of CO_2 enrichment and/or manipulation of climatic and management factors.
4.2 Qualitative determination of cell wall growth and lignification at elevated CO_2 concentration.
4.3 Assess changes in tension and compression wood proportion as these are considered to be important criteria for quality evaluation. The transition zone between juvenile and mature wood will be evaluated from anatomical analysis and the amount of juvenile wood will be compared for plant material grown under ambient and elevated CO_2 conditions.

METHODOLOGY AND STUDY MATERIALS
Wood biochemical studies will be carried out for all experimental sites on both juvenile and adult material on a representative number of samples (approx. 10 trees per site/experiment, where appropriate), with a total of approx. 4000 samples analysed. Additionally, existing material from the German sites will also be investigated, up to a total of 120 samples.

<u>Morphological and biochemical assessment</u>. Cross-sectional examination of thin sections (30 • m) of wood will be employed to assess changes in the proportion of cell types (conductive [vessel/tracheid] tissue, storage (parenchymatic and structural [fibre] tissues) tension, compression and juvenile wood from plant material from the monitoring and manipulative sites. Instrumentation used will include optical microscopy, microtome and standard staining procedures (phloroglucine + HCl). Partner 4 will develop appropriate protocols to achieve consistent and standardised results.

<u>Sample preparation procedure</u>. In outline, the sample preparation procedure will be as follows:
- Cut samples from logs or bore using Pressler corer.
- Preparation of samples -- this is slow and must be completed with care – cutting, polishing and staining each sample can take up to 1 hour.
- Microscopic measurements and assessments.
- Data preparation and manipulation.

Step 3. Following staining stem anatomy will be assessed under a microscope in the cross, tangential and radial sections with the following measurements taken per section:

Anatomical
1. Cell wall thickness (longitudinal + tangential sections)
2. Cell lumina (cross section)
3. Tree ring width (whole sections)
4. Grade of lignification – half quantitative (whole sections)

Total sample. In total, it is foreseen approximately 19,000 data points will result from the anatomical studies carried out on the plant material sampled at the primary, secondary and tertiary sites.

DELIVERABLES

10. Standardised methodology for determining selected anatomical wood properties.
11. Data incorporated into a database on the anatomical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change
12. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.

MILESTONES – Year 1

New data on the quantification of wood anatomical characteristics from trees across a range of species, environmental and management perturbations in participating Member States, and across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Wood anatomy protocol. First version Jul 01, final version May 02.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and completed	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and completed	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 2

New data on the quantification of wood anatomical characteristics from trees across a range of species, environmental and management perturbations in participating Member States, and across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Wood anatomy protocol. First version Jul 01, final version May 02.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Ongoing, with completion scheduled in Jun 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Wood anatomy protocol. First version Jul 01, final version May 02.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Ongoing, with completion scheduled in Jun 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extended period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
II. (Partial)	Sampling and analytical protocols	Dec 01	Wood anatomy protocol. First version Jul 01, final version May 02.	P5	P1, P2
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Ongoing, with completion scheduled in Jun 03	All	
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03 Final database Feb 05	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP4 – Year 1

None.

Key Changes to WP4 – Year 2

A significant delay occurred during this period given the time consuming sample preparation for transmitted light microscopy. The following numbers demonstrate the magnitude of the problem:

Samples received in Berlin:	monitoring sites 97
	manipulative sites 374
Samples prepared and measured:	monitoring sites 13 (last ten years, cross sections)
	manipulative sites 50 (cross sections) & 78 (macerated).

Although only a small portion of the total sample size has been assessed to date, about 25,000 single cells were measured; this has now in part been solved by developing and establishing an automatic measurement method, but some delays are being carried through into the 3rd reporting period. A further problem has been caused by the failure to measure the parenchyma content automatically on cross sections. In the 3rd period new efforts will be made to measure the parenchyma content manually.
At the plenary meeting held in May 03 and given the large volume of samples collected to date, the consortium decided to focus the activities for developing species parameters for 6 major species only (Pinus sylvestris, Picea excelsa, Picea sitchensis, Quercus spp, Fagus sylvatica and Populus euramericana) as the priority for the next project phase. Sampling was to be focussed on the last 3 growth rings on dominant trees for all species and the 3 last growth rings of suppressed trees from softwood species. Where possible, new data are to be integrated with knowledge in existing literature.

Key Changes to WP4 – Year 3

None – Activities nearing completion

Key Changes to WP4 – Extension

None – Activities now completed

2.5.3.2 Biochemical Studies.

OBJECTIVES

The main objective of the biochemical studies is to analyse the biochemical properties of wood from the monitoring and manipulative experiments in laboratory conditions. This will be achieved by:
Enzymatic determination of stem wood and coarse root metabolism (*d*-glucose, *d*-fructose, sucrose and starch);
Quantitative analytical determination of sucrose, starch and cell wall components.

MAIN RESULTS - YEAR 1

The main result of biochemical studies carried out on wood samples is as follows:

- Field sampling protocol for the collection of wood required for biochemical analyses.
- Field sampling methodology for wood to be used for biochemical studies has already been provided at Annex 1-F.
- Initial evaluation of analytical methods for non-structural and structural carbohydrates and their modification for the determination of glucose, fructose, and sucrose are concerned
- New information concerning the determination of lignin determination was collected from other institutions; lignin methods remain to be tested.
- Powdering of bulk samples prior to analytical determination of constituents.
- Determination of C/N content of selected wood samples.

To date *Fagus sylvatica* saplings dating from 1999, 2000 and 2001 sampled form the Berlin tertiary site have been powdered, with the exception of 40% of branches and portions of the stem, retained for future measurements of mechanical wood properties. Total C- and N- contents of this material [as a % of dry mass] were determined thermo-conductometrically (Leco-Instruments). To date 992 data have been determined and data have been stored, evaluated and documented.

The C/N-content of powdered fine roots, coarse roots and the oldest – 4-year-old – portion of the stem from juvenile *Pinus sylvestris* plants from the Berlin tertiary site have been determined. The three needle classes have been analysed separately. Thus 1020 data have been determined and data have been were stored, evaluated and documented. Branches remain to be milled and analysed, and portions of the stem, retained for future measurements of mechanical wood properties.

Results indicate that at elevated CO_2 concentration N-content [as a % of dry mass] is smaller in the leaves of juvenile *Fagus sylvatica* only, but not in fine roots, coarse roots and the older (4 years) portion of the stem. Resource limitation (in this case of N) on the always positive CO_2 effect on photosynthesis and growth is not only possible in pots but also in the field under the canopy of adult beech trees. Over the 3-year experimental period N-content decreases in all plant compartments, most evidently in stems and coarse roots and to a lesser extent in leaves. In general there was no clear temperature effects of N-uptake of fine roots, coarse roots and stems within the temperature range of 8 degrees Celsius of the experimental set-up [that ranges from (local mean *minus* 4 degrees Celsius) to (local mean plus 4 degrees Celsius)]. A possible slightly negative effect of lower temperature regimes on N-uptake of leaves can be diminished by the additional CO_2 supply has been detected.

Samples of sapwood and heartwood have been taken using a corer from discs of *Pinus sylvestris* and *Picea sitchensis* felled at a UK primary site (site 6; n=9). The material was milled to fine powder and C/N contents [% of dry mass] of 84 samples were determined. Data are currently stored in the project database and awaiting evaluation. Preliminary results indicate a significant increase of carbon from the youngest sapwood to heartwood of 11% and a decrease of nitrogen by 33% (see Figure BIO-1).

Figure BIO-1. *Nitrogen concentration of stem dry mass of beech saplings grown at elevated CO_2 (~700 µmol mol^{-1}, filled squares) and ambient air CO_2 concentration (open circles, control) in comparison with pots and saplings growing externally in the field at ambient CO_2.*

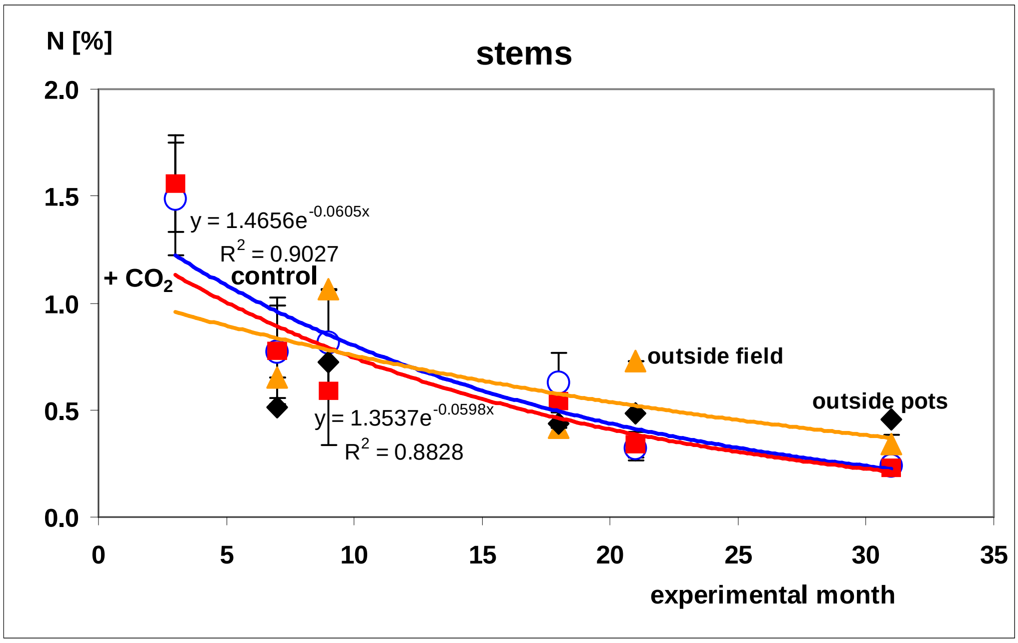
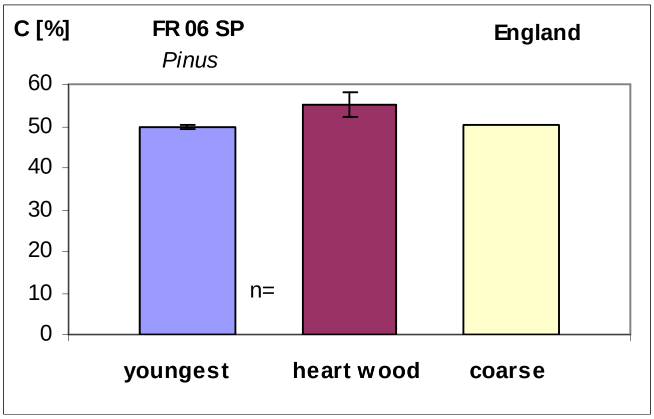
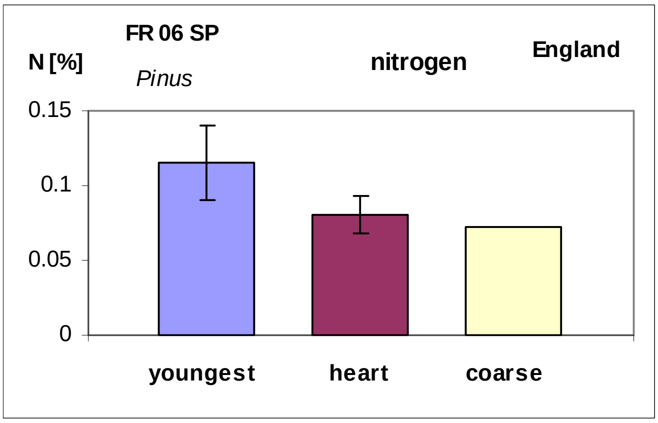


Figure BIO-2. *Pinus sylvestris sapwood and heartwood carbon and nitrogen content (as % of dry mass) from trees sampled at MEFYQUE primary site 6.*





MAIN RESULTS – YEAR 2

Materials and Methods. Analytical methods of non-structural and structural carbohydrates were tested and modified as glucose, fructose, and sucrose are concerned. New information about methods for lignin determination had to be collected from other institutions. Methods for determination of total lignin had to be tested.

Dry mass from harvests of *Fagus sylvatica* saplings at the Berlin tertiary site (final harvest) was powdered completely. Total C- and N- contents of this material [% of dry mass] were determined thermo- conductometrically (Leco-Instruments). All juvenile *Pinus sylvestris* of the tertiary site in Berlin was powdered and the C/N content of powdered fine roots, coarse roots and all stem parts from the juvenile Scots pines was determined. The three needle groups (1-3- year-old) were analysed separately.

Samples of sapwood and heartwood and (where possible) of the transient zone between sapwood and heartwood were taken with a corer from discs sent from Belgium (Brasschaat, Scots pine), England (pedunculate oak, Sitka spruce, Norway spruce, Scots pine), and all material was milled in the laboratory of partner 4. In addition, samples from all main organs of the Scots pine from Grünewald were milled and prepared for chemical analyses. In this last case the stem was cut into 7 sections which were analysed separately as far as C/N was concerned.

During the last six months of the 2nd reporting period most efforts were concentrated on determination of carbohydrates of the solid material (wood from stems) in co-operation with the Institute of Wood Chemistry of University of Hamburg (BFH) and the Institute of Food Chemistry of the TU-Berlin (ring analyses). The following substances were determined:

(cellobiose), traces not in all samples
rhamnose,mannose,
arabinose,galactose,
xylose,cellulose (as glucose units) and total lignin.

Determination of non-structural carbohydrates (glucose, fructose, sucrose and glucose from starch) is delayed but was started in the last months of this reporting period and is since then running in the laboratory of the TU-Berlin group intensively.

Deliverables
C/N analyses of juvenile beech from the tertiary site in Berlin are finished (1584 analyses). Data were sent to the database manager at FR together with the dry mass values of all samples. In total 1584 analyses have been conducted. Also the C/N analyses of juvenile Scots pine in the Berlin-experiment (foreseen in this programme) are accomplished. Total number of determinations was 1458. Data were all sent to the database in England (FR). C/N analyses of disks from the primary sites in Belgium (Scots pine), England (pedunculate oak, Sitka spruce, Norway spruce, Scots pine) and Germany (Scots pine) were completed with a total of 906 analyses. All data were sent to the database at FR

The carbohydrates, listed above, were determined in Scots pine disks from Belgium, England and Germany (532 data points by the end of the reporting period). The same substances were also determined in powdered wood material from the Berlin experiment: 848 data points to date. In total 5,328 data points have been achieved by the end of the 2nd year, made possible by the fact that preliminary tests on methods and C/N analyses were done 2 months before the official beginning of the project. It is estimated that, to date the TU-Berlin group already invests about 20 person-months into this work-package alone. Chemical work is still required to be continued in the 3rd year of this project.

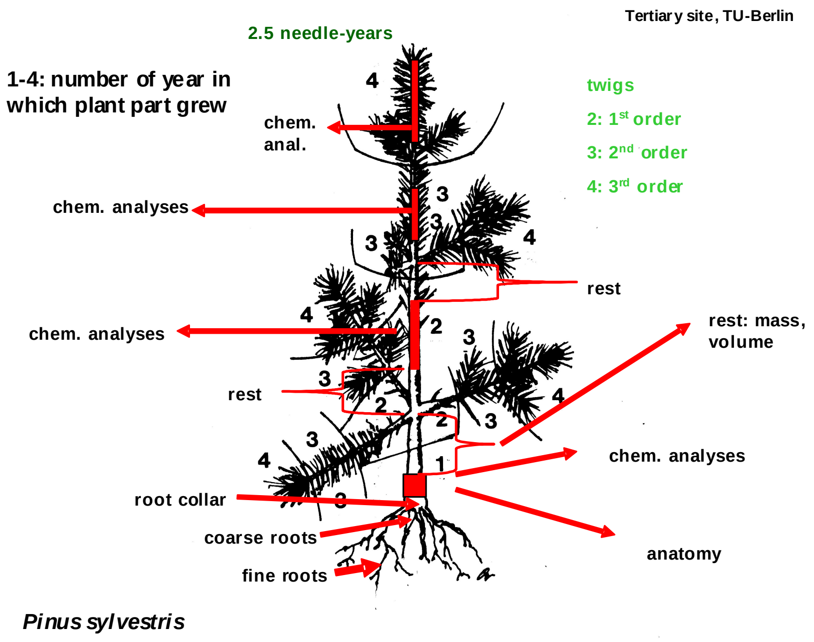
Carbon and Nitrogen. Samples for C-N analysis from different tree compartments have been taken from both primary and tertiary sites. Table BIO-2 outlines the number of C-N analyses so far carried out on plant material from the primary sites.

Table BIO-2. *Number of C-N analyses carried out on primary sites to date.*

Position	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08	FR10	IT01	IT02	IT03	IT04	TUB01	TUB02	UIA01	Grand Total
Branches	4	6	6	6	4	6		10	10						18		70
Cones															18		18
Leaves	4				4												8
Needles (year 1)		6	8	6		6	6	12	6						12		62
Needles (year 2)		6	6	6		6	6	10	6								46
Needles (year 2+3)															12		12
Roots	8		6	6					4							12	36
Roots (centre)	4		10	12				14	14								54
Roots (coarse)		14				2									6		22
Roots (peripheric)	4		10	12				14	14								54
Stem (bark)	14		18	19	10		18	18	20						12	10	139
Stem (centre)	12	16	18	18	12	18	20	16	20						14	18	182
Stem (transient zone)	12				12			16	18								58
Stem (youngest sapwood)	12	16	18	22	12	18	18	16	18						14	18	182
Grand Total	74	64	100	107	54	56	68	126	130						106	58	943

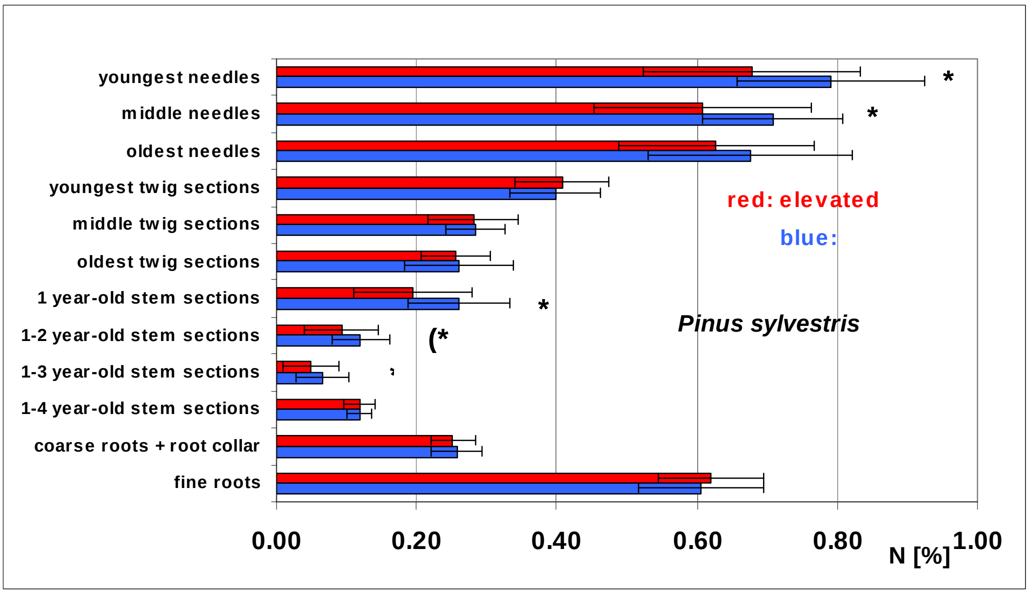
Results from the tertiary site. Berlin. At the Berlin tertiary site, the juvenile pines from the manipulative experiments at the tertiary site in Berlin were separated into fine roots, coarse roots, 4 stem sections, 3 branch sections, and three needle groups, as shown in figure BIO-3.

Figure BIO-3. *Sampling design on four-year-old Scots pines grown for three years at two different CO_2 concentration and five different temperature levels in phytotron chambers at the TU-Berlin.*



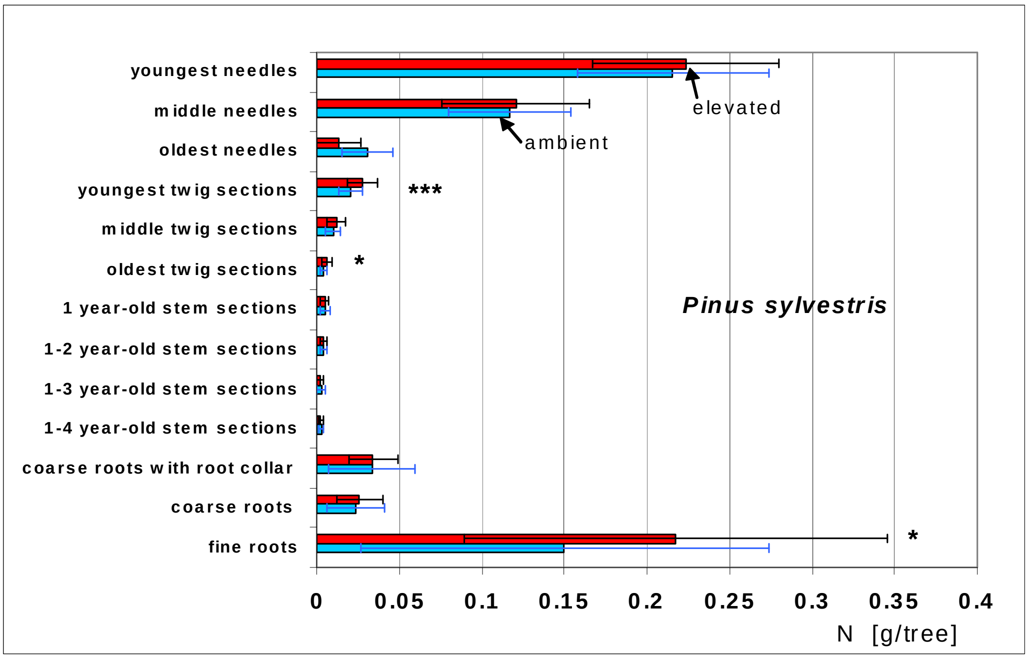
Juvenile beech from the first experiment was dissected into fine roots, coarse roots, 4 stem sections, 3 twig sections and leaves. Nitrogen concentrations [%] of all needles are decreased at elevated CO_2 on the average. This is statistically significant in the needles of the last year and those from the year before the last one. In twigs no CO_2 influence on N concentrations could be detected (Figure BIO-4). Whereas, with the exception of the oldest stem part, concentration was lower also in the stems.

Figure BIO-4. *N concentration in different organs of juvenile Pinus sylvestris at ambient air and at elevated (700 µmol mol^{-1}) CO_2; *: $p < 0.05$, (*: p: 0.05 – 0.1).*



If one calculates the total amounts of nitrogen within the plant organs it can be shown that relative differences in percent are equalised in most cases because of positive CO_2 effect. Figure BIO-5 gives an example for the total amounts of nitrogen accumulated in the different plant organs. Even significantly more nitrogen is stored in the twigs at elevated CO_2.

Figure BIO-5. *Absolute amounts of nitrogen in different organs of Pinus sylvestris at ambient air and at air with elevated (700 µmol mol^{-1}) CO_2 concentration; ***: p<0.001; **: p<0.01, *: p<0.05.*

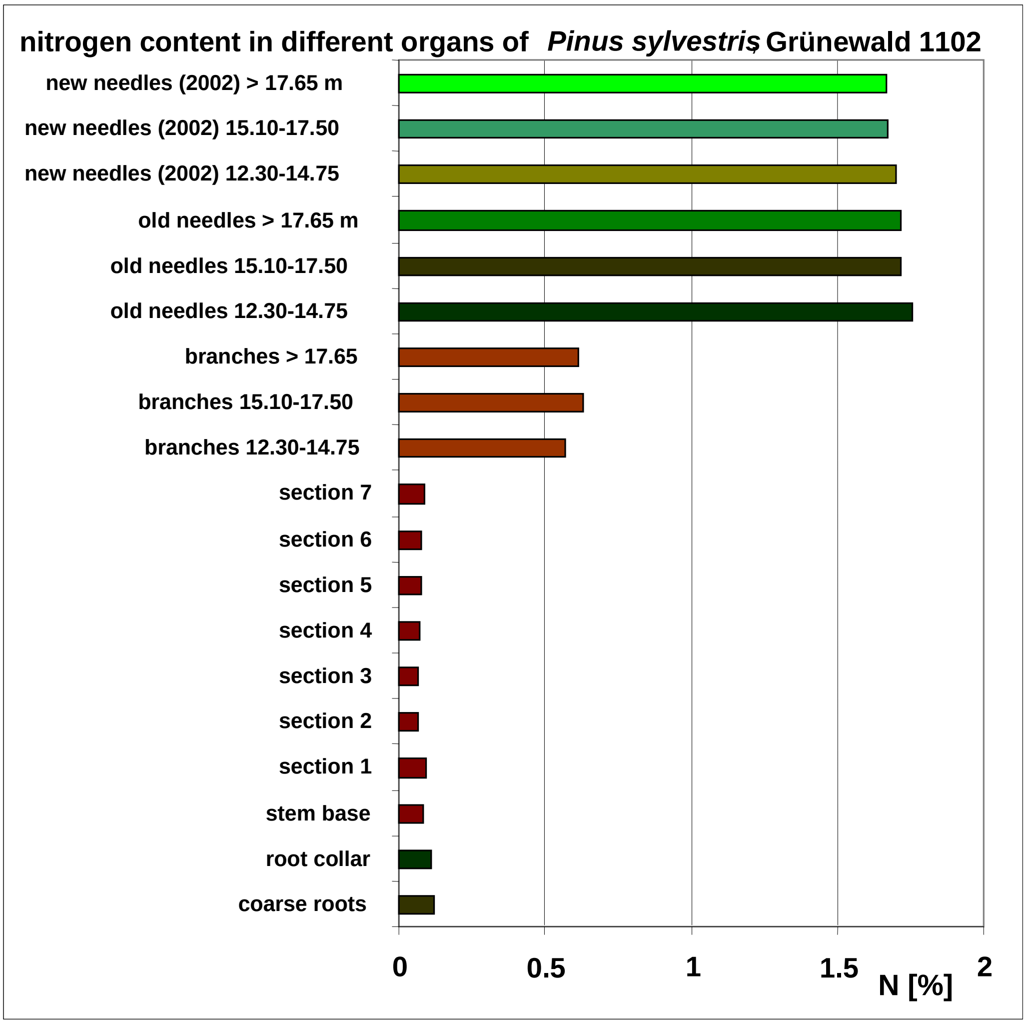


Total nitrogen amounts, which were accumulated in dependence of temperature elevation, were also tested statistically. In youngest and oldest needle, in coarse roots with root collar and coarse roots alone significantly less nitrogen was found. The only organ the highest absolute nitrogen value at higher temperatures was the fine root.

Results from the juvenile beech at the tertiary site are available but have yet to be presented in similar graphs.

<u>Results from primary sites</u>. The pattern of nitrogen distribution in the 50-year-pold *Pinus sylvestris* from the primary site in Grünewald is quite different from that of the juvenile trees as expected (Figure BIO-6). Most striking are the high percentages of nitrogen in the branches and the decrease in concentration in the needles from the bottom to the top of the crown.

Figure BIO-6. *Nitrogen distribution in one representative 50-year-old Pinus sylvestris from the primary site in Berlin /Grünewald.*



In disks from England, Belgium and Germany nitrogen contents decreased from the periphery of the stem towards the centre, as shown in Figures BIO-7,8 below.

Figure BIO-7. *Decrease of nitrogen [%] in base disks from bark (1), to youngest sapwood (2), to transition zone (3), to heart wood (centre wood, 4) of Pinus sitchensis and Pinus sylvestris from primary sites in England.*

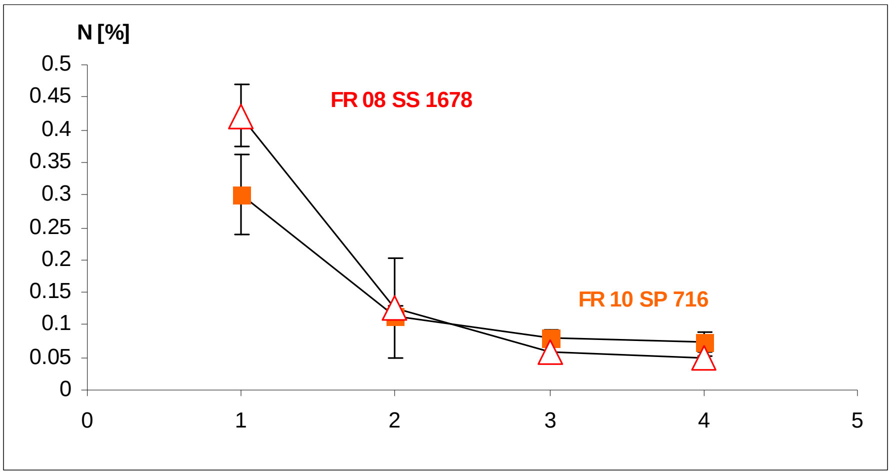
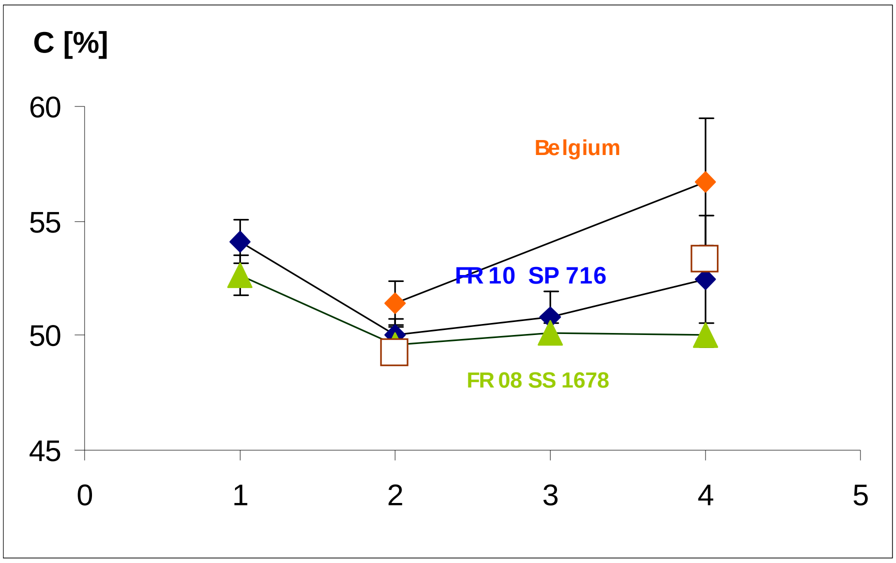


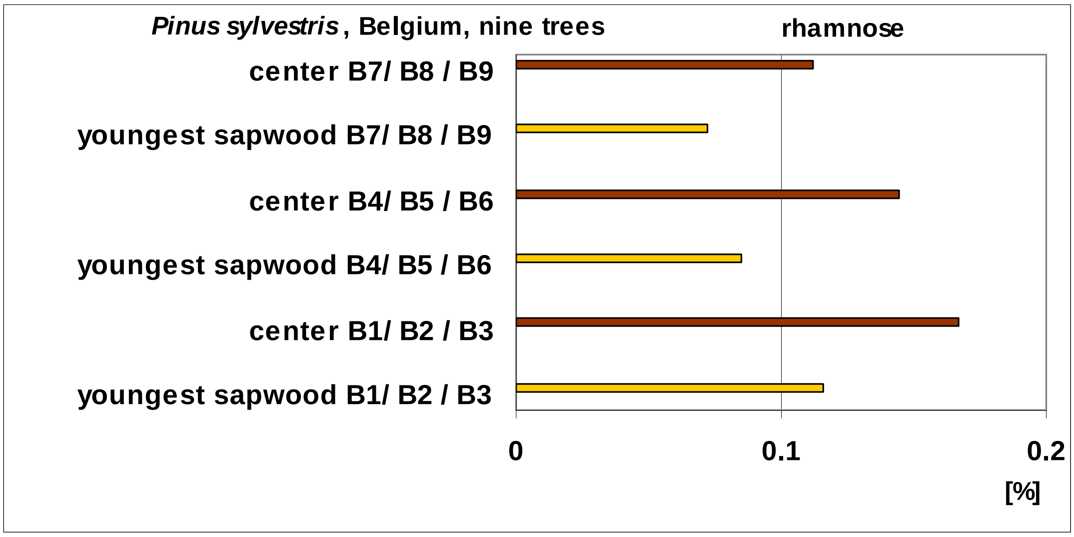
Figure BIO-8. *Total carbon concentrations [%] in base disks from bark (1), to youngest sapwood (2), to transition zone (3), to heart wood (centre wood, 4) of Scots pine (SP), Sitka Spruce (SS) in England and Scots pine from Belgium (on top) and Germany, • : Scots pine from Grünewald/Berlin.*



Carbon concentrations remain almost unchanged from the periphery towards the central wood of Sitka spruce whereas carbon concentrations increase slightly but significantly from outside to inside. Carbon concentrations of the oldest pines of this study from Belgium are the highest and their horizontal increase is the most obvious.

Carbohydrate analyses
During the second half of this reporting period all efforts were concentrated on the analyses of non-structural and structural carbohydrates. In order to get enough material for the analyses, wood powder left over from the C/N-analyses and separately for suppressed, subdominant dominant trees to obtain enough material for the analyses. Preliminary results, illustrating examples for 3 out of 8 chemical species analysed, are shown below.

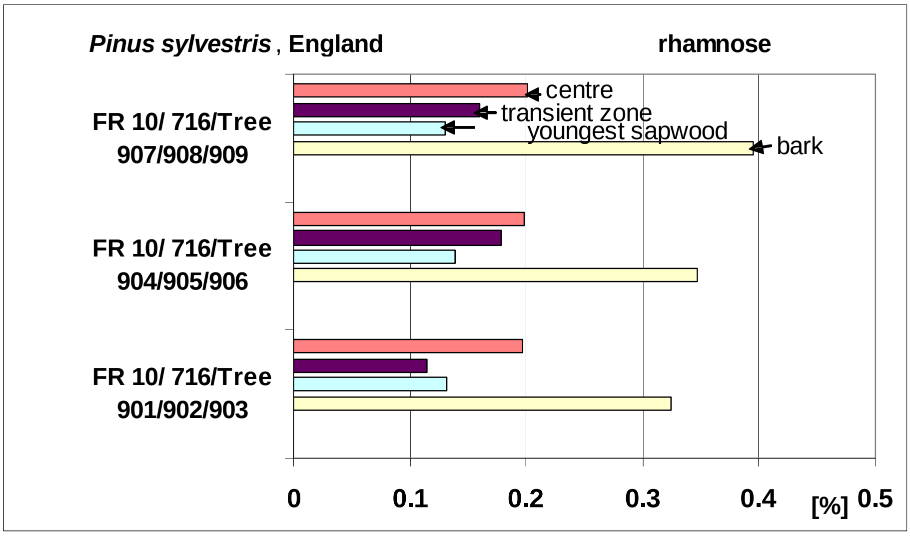
Figure BIO-9. *Rhamnose concentrations in the stem base of dominant (B1, B2, B3), subdominant (B4, B5, B6) and suppressed (B7, B8, B9) Pinus sylvestris in Brasschaat /Belgium.*



Rhamnose concentration decreases from dominant to the suppressed trees in the youngest sapwood as well as in the heartwood of *Pinus sylvestris* at the Belgian primary site. Heartwood concentration is by approximately 30% higher in the centre of the stems than in the periphery.

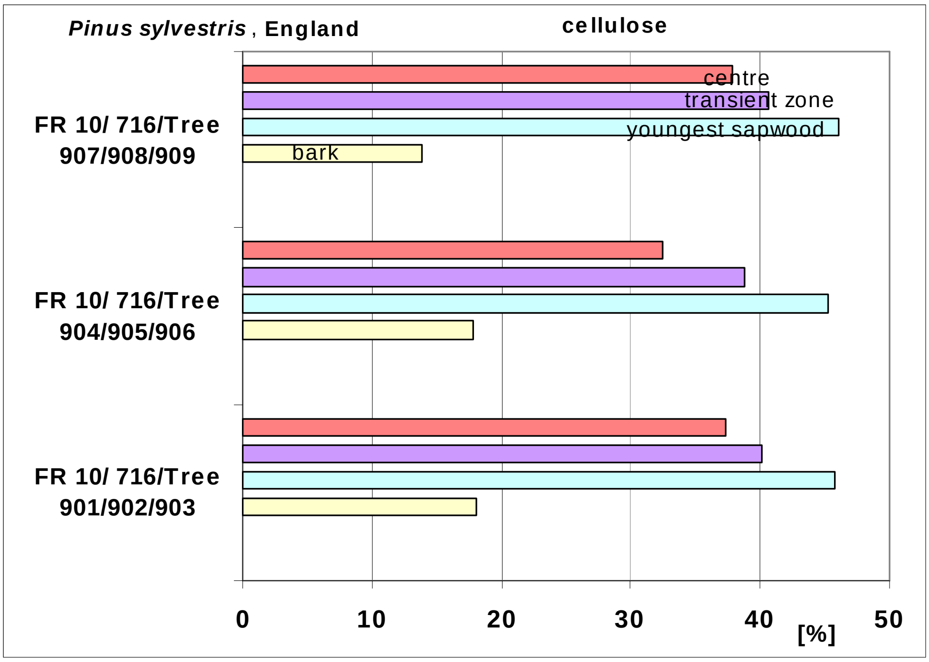
The example from one UK site is shown in Figure BIO-10 below. It indicates no clear trend in rhamnose concentration or less content of this carbohydrate in the dominant trees in contrast with the trees from the Belgian site. Again the increase from the youngest sapwood towards the centre of the stem is obvious.

Figure BIO-10. *Rhamnose concentration in Pinus sylvestris stems from a stand in England (FR).*



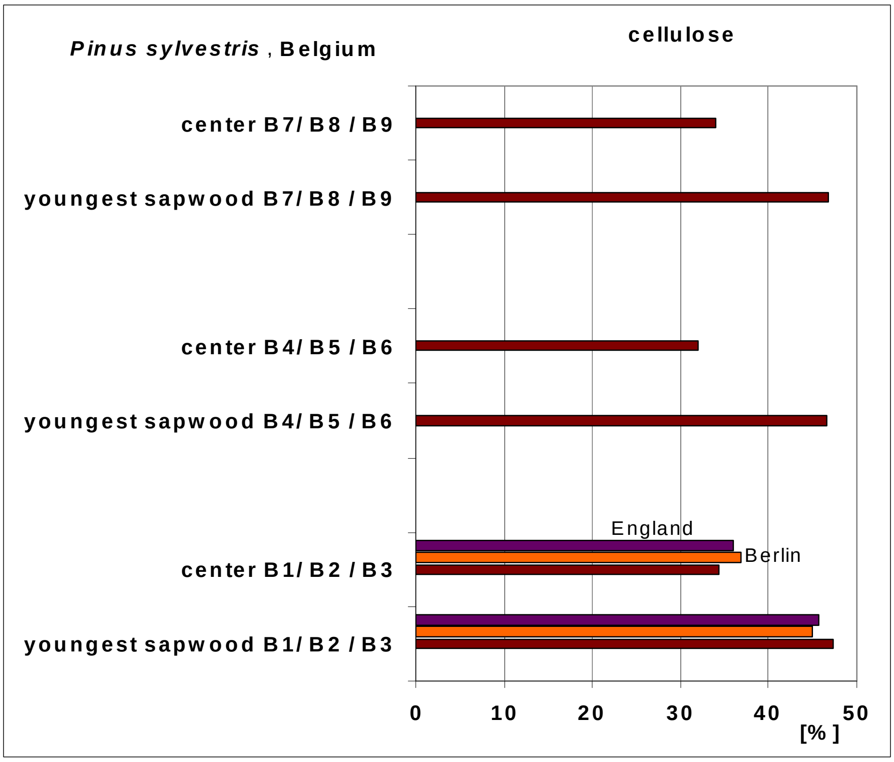
The main component cellulose decreased from the *Pinus sylvestris* stem periphery towards the centre as is shown in Figure BIO-11 below. Again, there was no clear difference between groups of trees belonging to the different dominance classes.

Figure BIO-11. *Cellulose concentration at the base of a Pinus sylvestris stem at a stand in England (FR).*



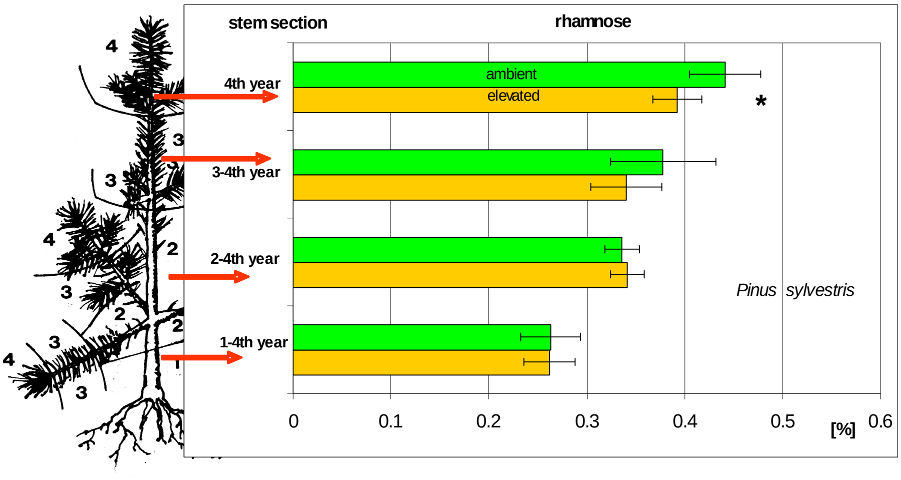
Pinus sylvestris wood from the English stand (mean) and from the German stand (Berlin/Grünewald) have lower cellulose contents in the youngest sapwood at the stem base than wood from the Belgian site. Cellulose contents of the heartwood are slightly lower in the Belgian sample than in the samples from England and Germany (Figure BIO-12).

Figure BIO-12. *Comparison of the cellulose concentrations [%] in wood at the base of Pinus sylvestris stems from the Belgian sites with samples from England and Germany (Grünewald/Berlin).*



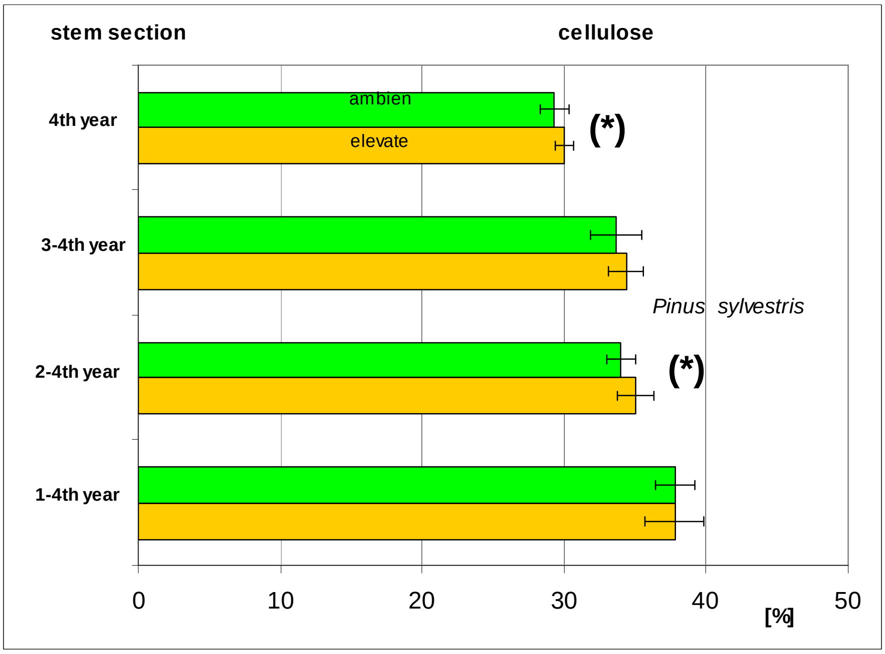
At the Berlin tertiary site, rhamnose concentration (Figure BIO-13) decreases evidently from the youngest down to the oldest stem part. On the average, contents are higher in the younger parts of the stems grown at ambient air than at air with CO_2 enrichment (700 µmol mol^{-1}).

Figure BIO-13. *Rhamnose contents [%] from bottom to the top of juvenile Pinus sylvestris stems grown at ambient air and at air with elevated CO_2 concentration at the tertiary site in Berlin; *: $p<0.05$.*



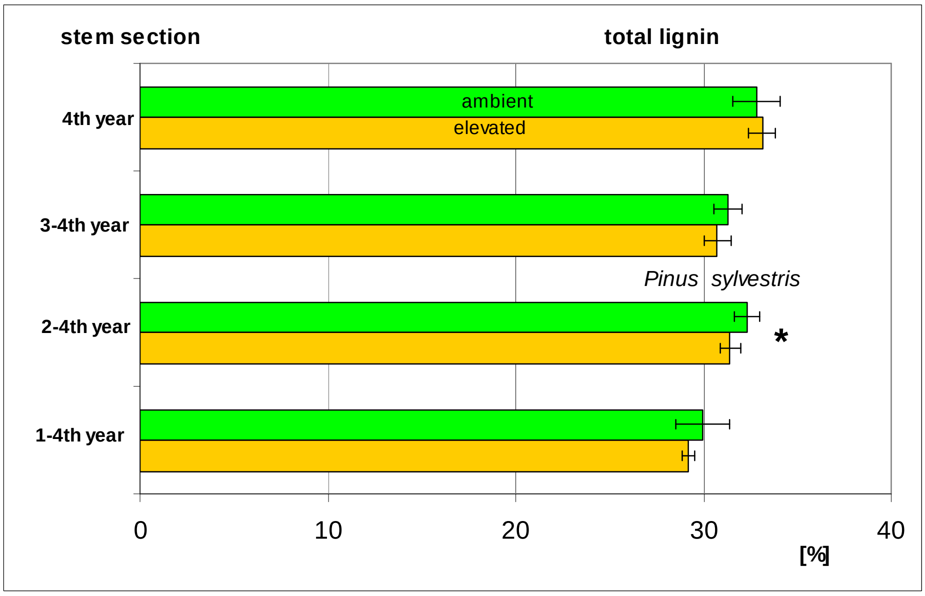
Cellulose contents decrease from the oldest towards the youngest stem sections of the four-year-old Scots pine in the experiment at the tertiary site in Berlin. In tendency cellulose contents are slightly higher at elevated CO_2 concentration, at least in the younger stem parts (Figure BIO-14).

Figure BIO-14. *Cellulose content from bottom to the top of juvenile Pinus sylvestris stems grown for three years at ambient air and air with elevated CO_2 concentration; (*): p: 0.05-0.1.*



Results from analyses of total lignin (Figure BIO-15) show no distinct tendency either from bottom to the top of stems or in comparison of stems from the two different CO_2 treatments.

Figure BIO-15. *Total lignin content from bottom to the top of juvenile Pinus sylvestris stems grown for three years at ambient air and air with elevated CO_2 concentration; *: p<0.05.*



MAIN RESULTS – YEAR 3
Samples sent to the laboratory of participant 4
for the analysis of non-structural carbohydrates:

FR 04	9 discs	Scots pine	England
B 1-9	9 discs	Scots pine	England
FR 06	9 discs	Scots pine	England
FR 10	9 discs	Scots pine	England;

for the analysis of structural carbohydrates:

FR 02	9 discs	Sitka spruce	England
FR 03	9 discs	Sitka spruce	England
FR 08	9 discs	Sitka spruce	England;

for C/N-analysis:

Collelongo 9 discs beech Italy.

Research activities during the third reporting period

Results and conclusions
A lot of effort was concentrated on testing the limitation of the analytical methods for determining non-structural carbohydrates with enzymes. In general, only traces of these substances could be found in stems and were often values were close or beyond the limits of the chemical method. Therefore, all data below 0.1 % in Figure BIO-16 can be considered as traces which could not be analysed exactly enough.

Monitoring sites
Figure BIO-16 stands as one example of the results that were obtained for the primary sites in the UK. Really measurable amounts could only be detected in the barks reaching the highest values in suppressed individuals. Contents of those substances in the Scots pines in Brasschaat (Belgium) were the lowest in comparison with all other sites. There, only in the bark traces, slightly below the sensitivity limit of the method, were found.

Figure BIO-16. *Glucose, sucrose and fructose contents in wood and bark from the basal stem log of dominant (1801, 1802, 1803), co-dominant (1804, 1805, 1806) and suppressed Scots pine (FR 04, Rannoch-UK).*

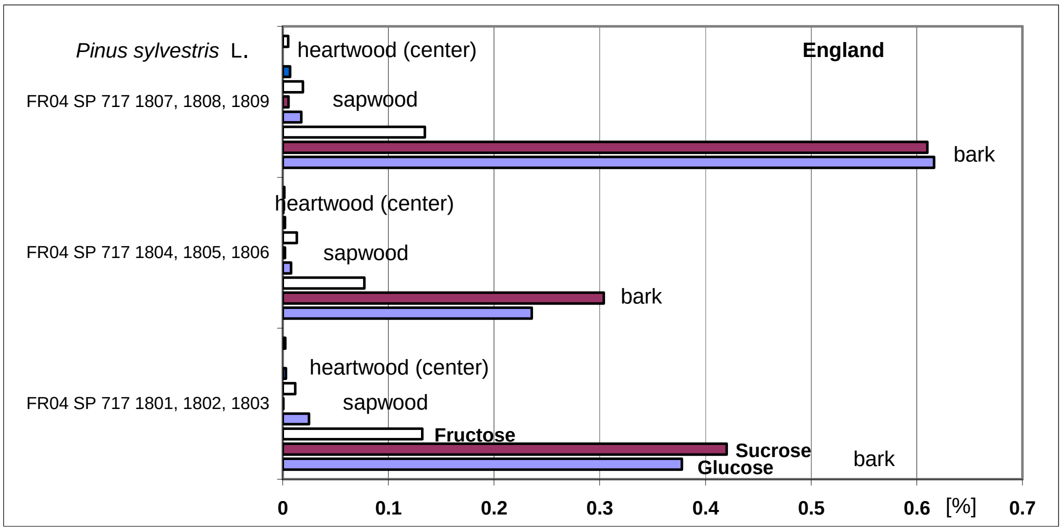


Figure BIO-17. *Starch contents in wood and bark from the basal stem log of dominant (1801, 1802, 1803), co-dominant (1804, 1805, 1806) and suppressed Scots pine (FR 04, Rannoch-UK).*

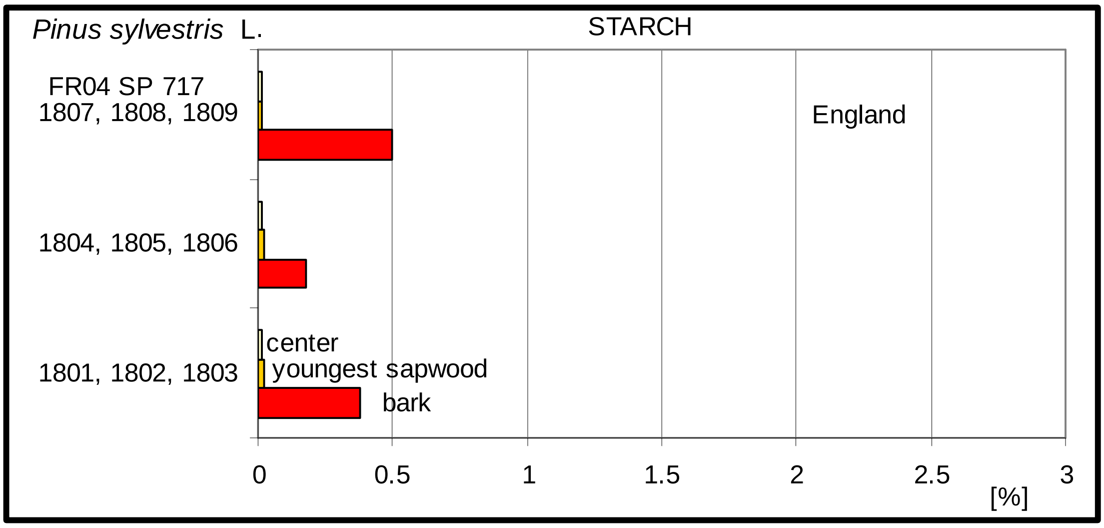
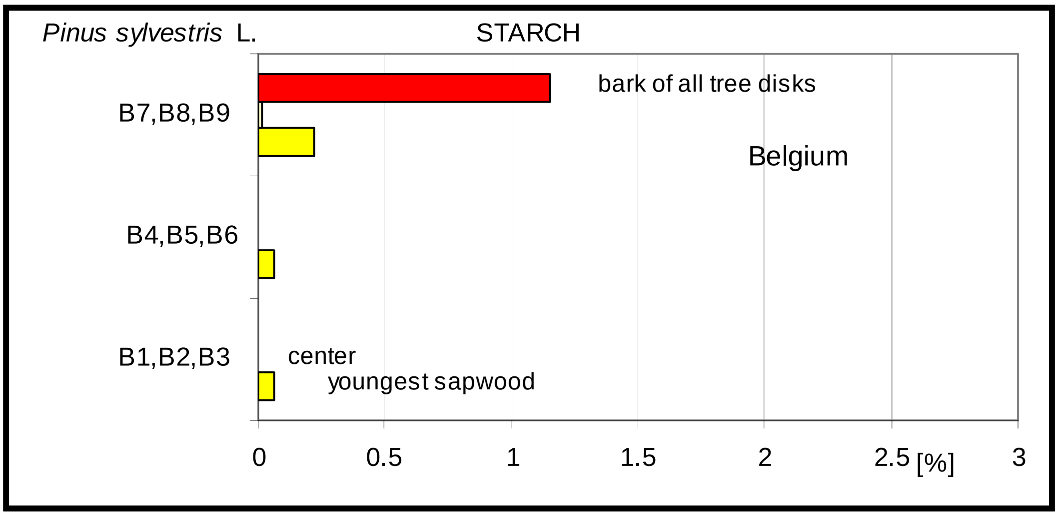


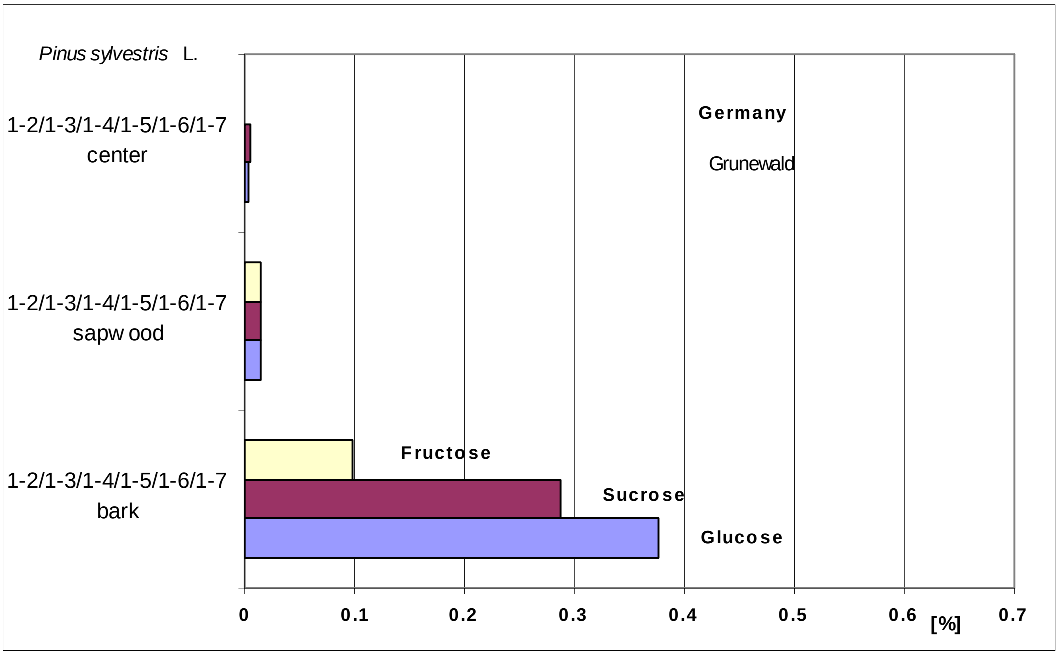
Figure BIO-1 shows the starch content of the FR 04 (Rannock, UK)-samples. Differences between the trees from the 3 different dominance classes could only be shown for the bark material again. In the most dominant trees also in the periphery of the stem disk (youngest sapwood) a little more starch was accumulated than in the two other classes.

Figure BIO-18. *Starch contents in wood and bark from the basal stem log of dominant (B1,B2,B3), co-dominant (B4,B5,B6) and suppressed Scots pine (B7,B8,B9) in Brasschaat (Belgium).*



Exceptionally high contents of starch were found in the bark and the youngest sapwood of Scots pine disks from the Belgian primary site. The powdered samples from Grunewald (Berlin, Germany), taken at different stem heights (2-7), had to be mixed up together in order to get enough material for the analyses. (C/N- and non-structural carbohydrate contents were already determined from the same material before; compare 2nd report.)

Figure BIO-19. *Glucose, sucrose and fructose contents in wood and bark taken at 5 different tree heights of Scots pine in Grunewald-forest, Berlin (Germany).*

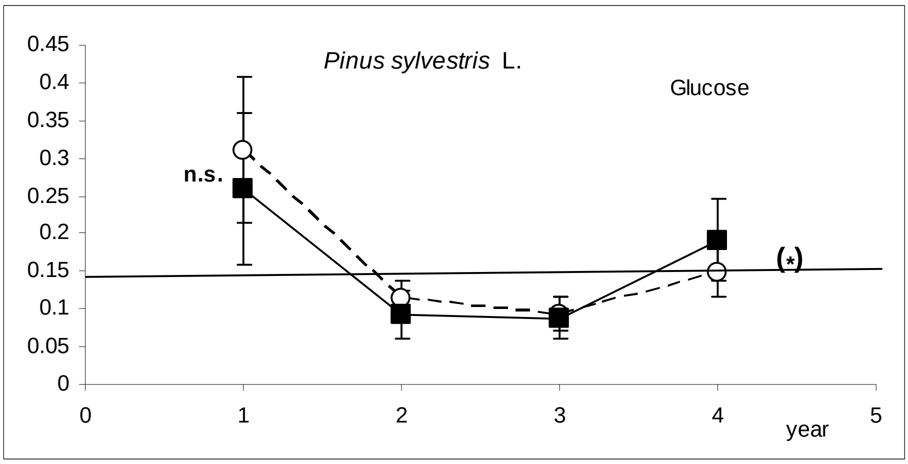


The magnitude of bark contents was rather similar to that of the English samples. But less sucrose was found. (Especially sucrose contents vary over the season.). The clear difference between sapwood and heartwood (centre) was obvious again. Only sucrose was found in the central wood. Starch contents of the Grunewald pine was the lowest of all MEYFYQUE samples from *Pinus sylvestris* L.

Tertiary site
Stems

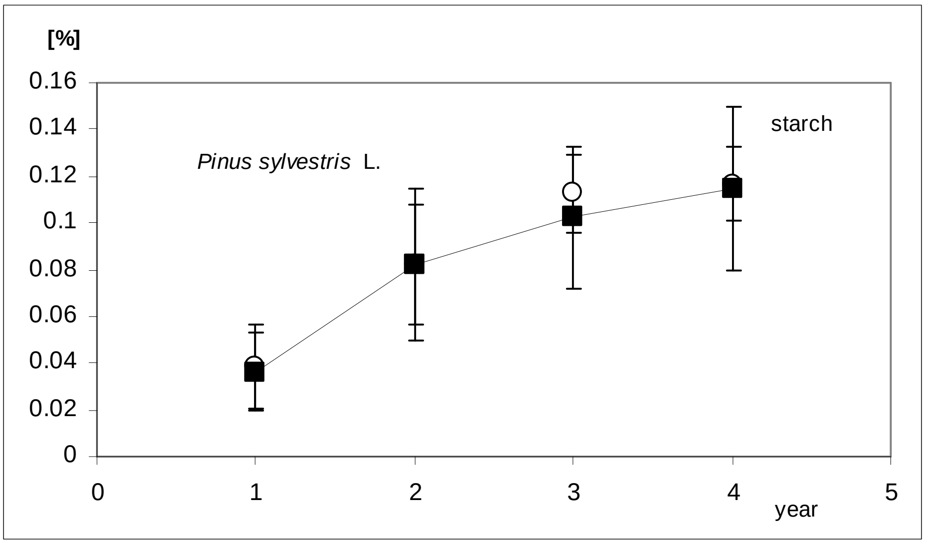
Glucose-, sucrose- and fructose-contents of woody plant parts of juvenile Scots pine (phytotron, TU-Berlin) were very similar to those of the analysed adult trees. Therefore, only the glucose contents are shown here (Figure BIO-20). First, all data were pooled for the CO_2 factor only (regardless of the temperature level of the CO_2 x temperature experiment). The line in figure BIO-20 marks the sensitivity limit of the biochemical method.

Figure BIO-20. *Glucose contents in 4- year-old Scots pine grown at elevated (~700 µmol mol^{-1}, •) and ambient air CO_2 concentration (~390 µmol mol^{-1}, •); number 1-4: year in which the stem section was developed; n = 16; 1: oldest section; n.s.: not significant, (*): p < 0.1.*



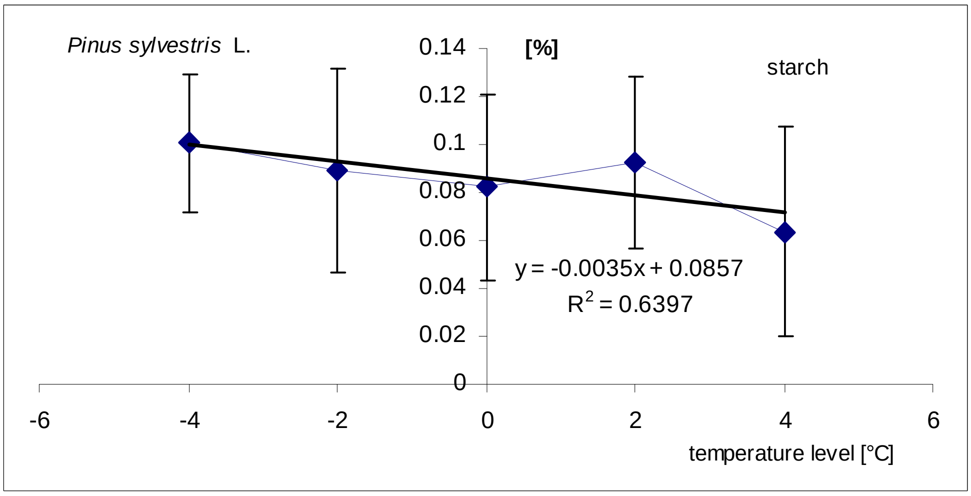
No statistically significant differences could be found in response to the two different CO_2 concentration levels of the experiment. At the top of the stems (year 4) there was a certain tendency ($p < 0.1$) for a positive CO_2 effect on glucose contents (Figure BIO-20). Fructose and sucrose showed a similar accumulation in the stem section at the bottom of the sapling but no tendency of being increased by the elevated CO_2 supply. All relative contents of those three soluble non-structural carbohydrates were not altered by temperature.

Figure BIO-21. *Starch contents in 4- year-old Scots pine grown far 3 years at elevated (~700 µmol mol l^{-1}, •) and ambient air CO_2 concentration (~390 µmol mol^{-1}, •); number 1-4: year in which the stem section was developed; n = 16 (1: oldest section).*



The traces of starch of stem wood material showed an opposite trend along the stem. It increased from the bottom to the top. Means – calculated for the two different CO_2 concentration levels – were almost identical. These results indicate that there is a small starch accumulation in the top shoot in September which could be retrenched in autumn and winter or used for the new flush in the coming spring. In contrast to the soluble no-structural carbohydrates starch also showed a certain tendency to decrease slightly with increasing temperature (Figure BIO-22, all data pooled for the 5 different temperature levels, regardless of the CO_2 concentration).

Figure BIO-22. *Starch content of stem wood of juvenile Scots pine grown for 3 years at five different temperature levels(- 4, -2, 0 = base, +2, +4 °C); base: long-term local annual monthly mean temperature (day and night) in Berlin-Dahlem (Germany).*

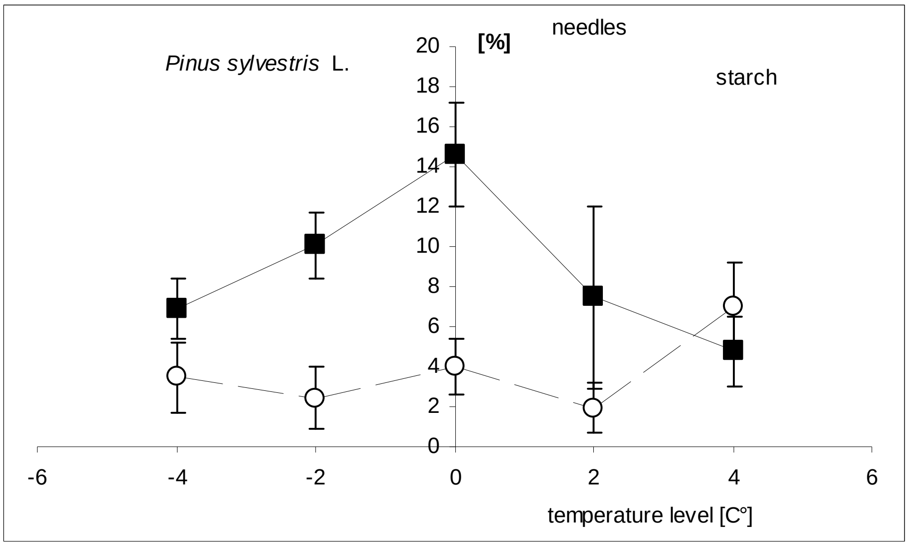


Needles

All values of glucose, sucrose, fructose and starch of the needle samples were clearly above the lower sensitivity limit of the analytical method.

Scots pine in the CO_2 x temperature experiment (phytotron). Also the contents of these soluble non-structural carbohydrates were not affected by (needle) age.

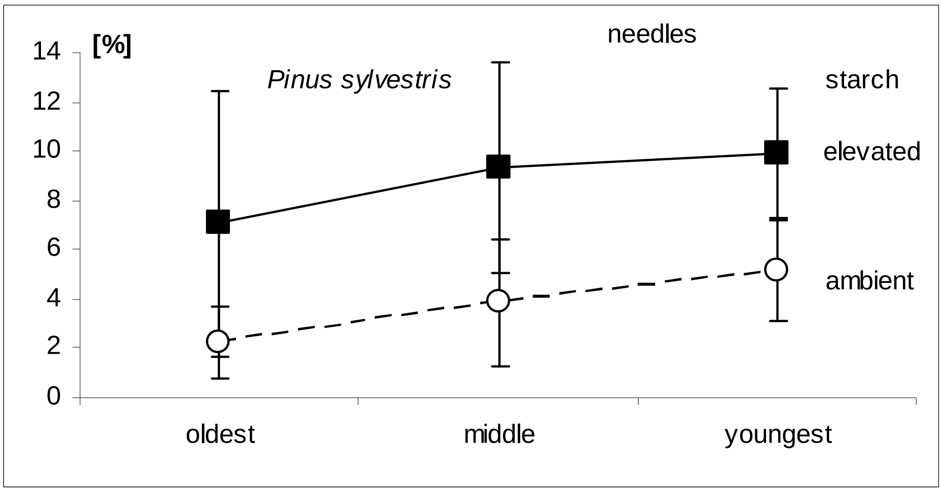
Figure BIO-23. *Starch content of Scots pine needles grown for 3 years at five different temperature levels(- 4, -2, 0 = base, +2, +4 °C; base: long-term local annual monthly mean temperature (day and night) in Berlin-Dahlem) and at elevated (~700 µmol mol-1, •) and at ambient CO_2 concentration (~390 µmol mol^{-1}, •)*



But there was neither a clear CO_2 nor any evident temperature effect on glucose-, sucrose- and fructose-content of the three annual needle sets of the juvenile Scots pine in the CO_2 x temperature experiment (phytotron). Also the contents of these soluble non-structural carbohydrates were not affected by (needle) age.

In contrast to the three soluble sugars, starch showed a clear response to CO_2 and the combination of elevated CO_2 and temperature (Figure BIO-23). Temperatures around the long-term annual mean seem to be optimal for the CO_2 enhancement of starch accumulation of the used German provenance of Scots pine. In addition, there was a clear effect of the age (Figure BIO-24, independent from temperature and CO_2).

Figure BIO-24. *Starch content of the three annual needles sets (oldest, middle and youngest) on juvenile Scots pine grown for three years at elevated (~700 µmol mol-1, •) and at ambient CO_2 concentration (~390 µmol mol^{-1}, •).*

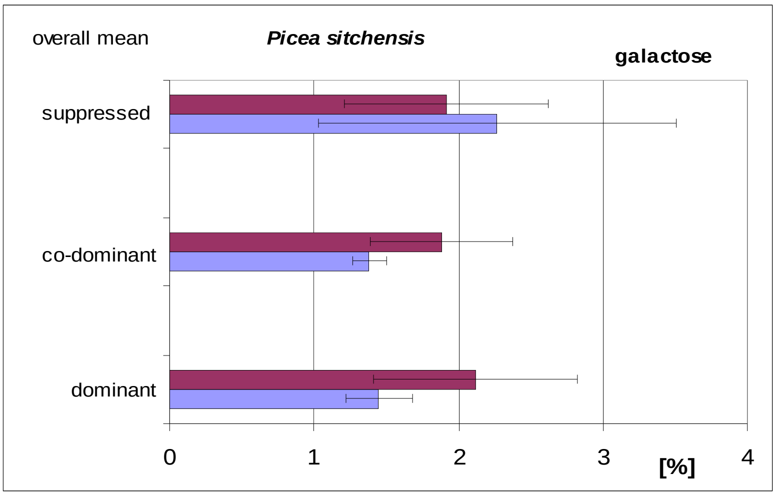


Structural carbohydrates

The component of pectin, and thus important substance in the middle lamella, galactose had the lowest concentration in the dominant trees and the highest in the suppressed Sitka spruces, on the average of all trees and samples (central and peripheral wood) from FR 02 (Coalburn - UK), FR 03 (Tummel - UK) and FR 08 (Sawley - UK). Figure BIO-25 shows the mean differences between the dominant classes at the bottom and the difference between peripheral (blue columns) and central wood (violet columns) on the top. Dominant and co-dominant had higher contents in the centre of the stems and in the suppressed trees mean contents were almost equal. The great standard deviations are mainly due to differences between the 3 stands. Data have still to be submitted to statistical tests.

Figure BIO-25. *Galactose contents in wood from the basal stem log of dominant, co-dominant and suppressed Sitka spruce (FR 02, 03, 08 - UK); overall means at the bottom and differences between peripheral (blue)and central wood (violet) at the top.*

Sitka spruce



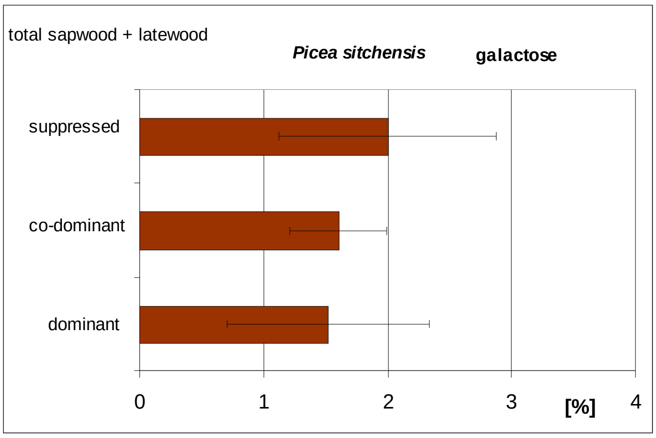
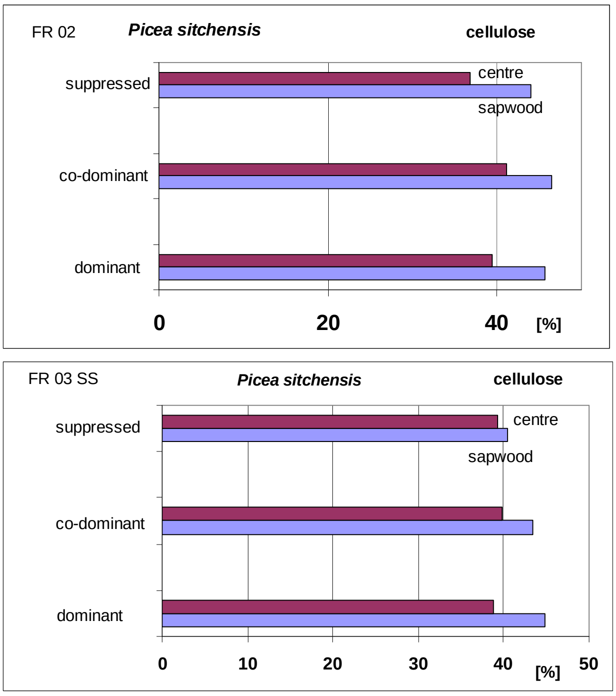


Figure BIO-26. *Cellulose contents in wood from the basal stem log of dominant, co-dominant and suppressed Sitka spruce (FR 02, 03 - UK); peripheral wood (blue) and central wood (violet).*

Sitka spruce

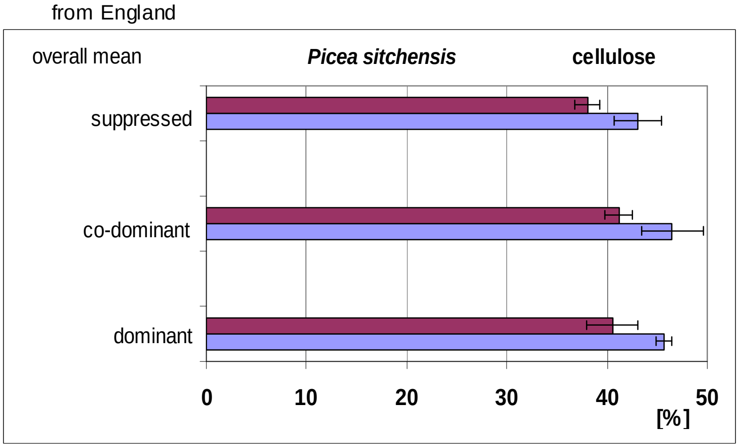


Rhamnose-, mannose-, arabinose-, and xylose-contents were also determined quantitatively. Cellobiose occurred in traces only. All data were sent to FR (UK) for further interpretation. Cellulose contents are shown for the stands FR 02 and FR 03 in figure BIO-26. In both cases less cellulose could be found in the central wood (3-4% less). This decrease from the peripheral to the central wood was also obvious in the discs from the site 08 (FR). Figure BIO-27 presents the total means of cellulose contents and shows that the cellulose concentrations were almost identical in the dominant and in the co-dominant tree classes, on the average. Suppressed trees had less cellulose in the peripheral as well as in the central wood.

Figure BIO-27. *Means of cellulose contents in wood from the basal stem log of dominant, co-dominant and suppressed Sitka spruce (all sites, UK); peripheral wood (blue) and central wood (violet).*

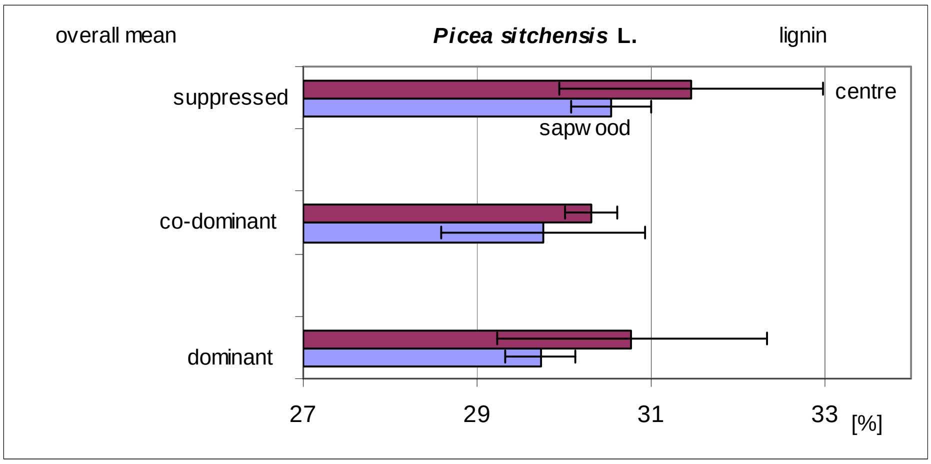
Sitka spruce WP 5

from England



Lignin behaved the opposite way to cellulose. In general, contents were slightly higher in the centre of the stem disks than in samples from the periphery (BIO-28).

Figure BIO-28. *Means of lignin contents in wood from the basal stem log of dominant, co-dominant and suppressed Sitka spruce (all sites, UK); peripheral wood (blue) and central wood (violet).*



And in contrast to cellulose, on the average, lignin reached the slightly highest values in suppressed trees and approximately the same mean contents in co-dominant and dominant trees. In all tree classes maximum of lignin concentration occurred in between the central and the peripheral wood (Figure BIO-29).

Figure BIO-29. *Lignin contents in wood from the basal stem log of dominant, co-dominant and suppressed Sitka spruce (site FR 08 - UK); peripheral wood (blue), transition between sapwood and heartwood (orange), and central (heartwood) wood (violet).*

Sitka spruce

WP 5

from England

MAIN RESULTS – Extended Period

Nitrogen

Significantly lower nitrogen concentrations in the needles of the juvenile Scots pines at elevated CO_2 correspond with the results of many older studies, indicating a negative effect of elevated CO_2 on the N-concentrations of the main photosynthetic active organs.

A new aspect is that a decrease in nitrogen concentration could not only be found for needles but also in the youngest stem sections of juvenile pines. This shows that this CO_2 effect is of greater importance than expected because it has far-reaching consequences for the nitrogen supply of other plant organs than needles (or leaves). This effect could not be revealed in the oldest basal stem section of the pines in our experiment. After comparing the nitrogen concentrations of the 50-year-old pine from Grunewald with those from the juvenile trees we can postulate a rather similar distribution pattern starting from the stem base upwards to the branches and needles for both developmental stages. On the other hand, the juvenile trees had relatively higher nitrogen concentrations in the below ground parts as far as the upper root parts and the coarse roots are concerned. Unfortunately, in the forest, fine roots could not be harvested as precisely as with the pot experiment. Therefore, N-concentrations of fine roots are not presented in this report.

Juvenile trees had approximately the same concentrations of nitrogen as the adult forest tree from Grunewald (Berlin) in the stem, whereas the concentrations in branches and needles of the adult tree were twice as high as in the same organs of the juvenile trees. Although only one tree from a homogeneous forest stand was completely analyzed one can conclude that N-limitation of a positive CO_2 effect on photosynthesis and growth would more likely occur in a pot experiment than in Grunewald. In other words, limitation of the CO_2-effect by a lack of nitrogen in pine forests around Berlin – and certainly in most regions of Central Europe – is not probable because the positive CO_2 effect was still evident at much lower N-concentrations in the plant tissues (as was shown by our experiment).

Elevation of temperature had negative effects on absolute nitrogen concentrations of most organs with the exception of fine roots, the middle twig sections and two-year-old needles. This negative effect was statistically highly significant in some cases. One clear effect of increasing temperature was the comparatively low N-concentration in the oldest annual needle set. This can be taken as a sign for earlier aging at higher temperature levels. (Considerable amounts of nitrogen must have been already exported from the old needles.)

Non-structural carbohydrates

The very low concentrations of 'soluble carbohydrates'(glucose, fructose, sucrose and starch in the basal stem wood of the juvenile Scots pine clearly show that at the harvest time in September these substances were not activated and transported to any considerable extent. Although many of the values scattered around the sensitivity limit of the analytical method it could clearly be shown that the largest amount of glucose and fructose occurred in the basal stem part and also that a certain probability of a positive CO_2 effect on glucose accumulation in the top shoot of the young pines can be assumed. In consequence, one could argue that some of the additional net carbon uptake by photosynthesis at elevated CO_2 concentration is going to the glucose pool in the youngest shoot, whereas starch concentrations behaved oppositely to the 'soluble carbohydrates'. Its concentration increased from the bottom to the top of the stems, and CO_2 concentration had no influence. Therefore, it can be concluded that in stems of juvenile pines starch is not the pool for the additional amount of carbon which is taken up at elevated atmospheric CO_2 concentration.

On the other hand, increasing temperature had a clear negative effect on starch concentration (decrease with increasing temperature). This finding also clearly indicates that starch accumulation in the lowest stem part is a function of temperature within a realistic temperature range around the local means in Central Europe.

In the needles starch seems to be the only pool which takes additional amounts of carbon at elevated CO_2 concentration. This enlargement of the starch pool in the needles without clear effects on other pools further down in the plant body might point to a potential difficulty in the transport of carbohydrates downwards. It is also possible that greater amounts glucose are activated from the starch pool with a delay and then transported basipetally. Significantly more starch was accumulated at the lower temperature levels and some interaction between temperature and CO_2 can be presumed because temperature effect was only evident with trees grown at elevated CO_2 concentration. An aging effect on starch concentrations could also be shown: In the older the needles were the less starch was found.

As expected, in general, concentrations of the soluble carbohydrates were the highest in the bark of the adult Scots pines (England) and the suppressed trees had the most glucose and sucrose in their bark in comparison with the two other dominance classes. In the co-dominant tree class the lowest concentrations of all substances were found in the periphery of the basal stems as well as in the central wood. The horizontal decrease of 'soluble carbohydrates' from the bark towards the central wood was also obvious in the Grunewald individual.

No sucrose was found in the wood of dominant and co-dominant trees and very small amounts of this substance in the suppressed ones. Therefore, one can conclude that at harvest time of the disks the most prominent transport carbohydrate of plants, namely sucrose, was not available in considerable amounts in the basal stem wood. All these results support the general conclusion that dominant trees in a pine stand differ evidently from suppressed trees in the carbohydrate composition of wood.

Structural carbohydrates

Because rhamnose, mannose, arabinose, galactose and xylose are components of the woody material and were determined as mono-saccharides by means of the HPLC-technique as substances of the so-called solid material, they are considered under the head-line 'structural carbohydrates' together with cellulose and lignin in this report.

These substances occurred in much greater amounts in the stem wood material than starch and 'soluble carbohydrates' and therefore, could have had a much greater potential to offer pools for the via photosynthesis additionally up-taken carbon amounts at elevated atmospheric CO_2 concentration.

Data of the rhamnose, mannose, galactose, cellulose and favone-lignin determinations were evaluated in detail within the time-frame of the MEFYQUE project. Therefore, only these results are discussed here.

Temperature effects on the concentrations of all the substances analyzed in this study could not be detected with the exception of galactose. Nevertheless, the possibility that temperature effect could have had occurred in our experiment cannot be fully excluded and therefore, this aspect warrants further investigations.

Cellulose and flavone-lignin of course were qualitatively and quantitatively the most important components of the juvenile Scots pine wood. It can also be concluded from cellulose determinations that elevated CO_2 concentration causes an increasing size of the cellulose pool at least in the younger stem parts, whereas lignin concentrations were not clearly altered by elevated CO_2. There was a certain opposite trend in the concentrations of these two components: Cellulose amounts increased towards the bottom parts, lignin decreased slightly or remained unchanged.

Galactose – as mentioned above – seems to be a temperature dependent wood component. Interpretation of this phenomenon is not yet possible on the basis of our results.

Rhamnose concentrations in the disks from the adult Scots pine trees show the exceptional performance of the adult Scots pines from Belgium. In contrast to the pines from England, the decrease of rhamnose concentration from dominant over co-dominant to suppressed trees is quite obvious. On the other hand, results from all pine stands show that concentration of this component increases from the periphery of stem wood of Scots pine towards the centre.

Cellulose concentrations decreased towards the centre of the stem disks of pines from England and we hypothesise that they are possibly replaced by other substances such as lignin. However, lignin data have still to be evaluated (outwith the MEFYQUE project).

Sitka spruce stem wood was very different from that of Scots pine, also as far as the components of the 'solid material' are concerned. Mannose concentrations were evidently higher in the juvenile pines and surprisingly reached the highest level in the co-dominant trees, on the average. The reason for this phenomenon is still unknown.

Galactose is a component of pectin and therefore, takes essentially part in the formation of the middle lamellae. If one considers the suppressed trees as individuals being in a 'younger' stage of ripening, these higher amounts of galactose seem to be plausible. This assumption corresponds with the finding, that - in contrast to the dominant and co-dominant trees - galactose concentrations were higher in the periphery of stem disks (younger wood) than in the central wood (older wood).

Cellulose and lignin also behaved conversely if one compares peripheral and central wood: Cellulose concentrations were lower in the centre of the stem and there lignin concentrations were higher and vice-versa. This again is a clear hint to a distinct antagonism of cellulose and lignin in Sitka spruce. In one case. An additional wood sample was taken for analyses at equal distance between the centre and the periphery of the disk; here the highest lignin concentrations were reached. Therefore, one could argue that the increase of lignin concentrations [%] towards the central wood is not linear in Sitka spruce stems but is better described by an optimum curve and optimum is located somewhere in the middle between central and peripheral wood.

2.5.3.2.1 WP5: Analyses Of Wood Bio-Chemical Properties In Laboratory Conditions

Work-package number:	5						
Start Date:	Planned Jul 01			Status: No change			
Completion Date:	Planned Feb 04			Status: No change			
Current status	Completed						
Partners Responsible:	P4, P7			Status: Addition of AP6 (sample preparation only)			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex				12	+2		2
Year 1 – person-months employed				5		1	0
Year 2 – cumulative person-months employed				10	2	1	
Year 3 – cumulative person-months employed				11	2		0
Total including extension				13	2	1	

Key changes:
P5: 2 person-months reassigned from WP7 to WP5
P7: 2 person -months reassigned to WP7 to WP5

OBJECTIVES
The main objective will be to analyse the biochemical properties of wood from the monitoring and manipulative experiments in laboratory conditions. This will be achieved by:
5.1 Enzymatic determination of stem wood and coarse root metabolism (*d*-glucose, *d*-fructose, sucrose and starch);
5.2 Quantitative analytical determination of sucrose, starch and cell wall components.

METHODOLOGY AND STUDY MATERIALS
Wood biochemical studies will be carried out for all experimental sites on both juvenile and adult material on a representative number of samples (approx. 10 trees per site/experiment, where appropriate). Additionally, existing material from the German sites will also be investigated, up to a total of 120 samples.

Samples from stems and coarse roots of juvenile individuals of selected species grown in manipulative experimental facilities and probe samples extracted from adult trees at the monitoring sites, will be taken at the end of three subsequent vegetation periods. Special below-ground containers in the experimental facilities, which enclose soil blocks of 0.4 m^3**,** will enable the extraction of root samples with only minimal impact on the individual tree. In addition to new plant material, existing plant material from completed manipulative experiments is available for selected investigations of biochemical wood properties. Established laboratory techniques will be employed to determine modifications in the metabolism of secondary products through the comparison between analysed plant material from the monitoring and experimental manipulation sites. Destructive samples of above- and below-ground compartments will be taken from the manipulative experiments over a period of 3 years and any changes to biochemical properties assessed. Standard laboratory methods in Good Laboratory Practice (GLP) conditions for total quality control will be used to analyse:
(a) Sucrose , glucose, fructose (spectrophotometrically, microtitre plate reader);
(b) Starch (spectrophotometrically, microtitre plate reader);
(c) Cell wall components (GC-MS).

Partner 4 will develop appropriate protocols to achieve consistent and standardised results between Partners in this Work Package.

Sample preparation procedure. In outline the sample preparation procedure will be:

Cut samples from logs.
Sample preparation.
Analysis.
Data preparation and manipulation.

Step 3. The following parameters will be estimated:

Biochemical
Non-structural and structural carbohydrate content
Total lignin, cellulose and hemicelluose content
Total N content (also for other compartments e.g. leaf, branch, stem, fine and coarse roots)

In detail, the following elements will be determined quantitatively: D- Glucose, D-Fructose, Sucrose, Starch, Lignin, Residuals, Cellulose, Ash (mineral).

Total sample. In total, it is foreseen approximately 5,500 data points will result from the biochemical studies carried out on the plant material sampled at the primary, secondary and tertiary sites.

DELIVERABLES

13. Standardised methodology for determining selected biochemical wood properties.

14. Database of biochemical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change.
15. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.

MILESTONES – Year 1

New data on the quantification of wood biochemical characteristics for trees for a range of species, environmental and management conditions in participating Member States, and across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood chemistry protocol. First version Jul 01, final version May 02.	P4	AP6, P7
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Ongoing	P4	AP6, P7
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 2

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood chemistry protocol. First version Jul 01, final version May 02.	P4	AP6, P7

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Ongoing, with completion scheduled in Jun 03	P4	AP6, P7
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood chemistry protocol. First version Jul 01, final version May 02.	P4	AP6, P7
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Ongoing, with completion scheduled in Jun 03	P4	AP6, P7
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extended period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood chemistry protocol. First version Jul 01, final version May 02.	P4	AP6, P7
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Completed Jun 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Started Jul 02 and ongoing	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Completed Dec 04	P4	AP6, P7
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03 Final Version Feb 05	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP5 – Year 1

As a number of Partners do not have grinding equipment required to powder wood samples, the time required to mill samples has unexpectedly had to be extended by approximately 2 months to date. The University of Gent (AP 6) has provided additional grinding facilities to significantly reduce sample preparation time.

Following the imposition of restrictions on the felling of trees at the Grünewald primary sites and currently under review with the forest owners, wood samples for biochemical analyses on *Pinus, Quercus*, and *Fagus* were taken using a special micro-corer at monthly intervals starting in April 2002. These samples are in addition to the original working plan as outlined in the Technical Annex.

Key Changes to WP5 – Year 2

None

Key Changes to WP5 – Year 3

None – nearing completion

Key Changes to WP5 – Extension
None

2.4.3.2 Physico-mechanical studies.

OBJECTIVES
The main objective will be to analyse the physico-mechanical (biomechanical) properties of wood from the monitoring and manipulative experiments in laboratory conditions.
The main aim of this work package is to quantify changes in a range of wood physico-mechanical properties (static bending, compression parallel to grain, density and moisture content) to correlate with results of chemical and anatomical modifications. This will be achieved by:
WP6.1 Measurement and comparison of growth ring width of trees grown under ambient and elevated conditions and width of early- and latewood increment, at breast height of the test trees
WP6.2 Quality assessment of structural timber grown in manipulative experiments.
WP6.3 Assessment of drying distortions of timber grown in manipulative experiments.
WP6.4 Quality assessment of samples of timber grown in manipulative experiments to determine key mechanical and physical properties.

MAIN RESULTS - YEAR 1
The delay in 3-D scanning activities has resulted in a slow-down of measurement and data collection activities in WP6 and including:

production of battens;
drying sawn battens;
measurement of drying distortion;
assessment of battens strength and stiffness;
measurement of growth characteristics for modelling.

In the absence of any wood material, activities have focused on developing a wood technology protocol (Annex 1-G) and semiautomatic devices for assessing kiln drying distortion of sawn battens and their growth characteristics. Draft protocols have been completed for (a) measurement and recording of growth features on the battens; (b) small material from tertiary sites. A measuring jig/device has been designed and constructed that will be used to assess a batten for spring, twist and bow and feeds the measurement directly into a computer. Financial support for this equipment is being provided jointly by MEFYQUE, another EU project (COMPRESSION WOOD) and a UK national programme.

Measuring and recording growth features is very time consuming when done by hand and there is therefore an urgent need for a semiautomatic or an automatic device that will measure and record growth characteristics. Trials have taken place to assess a low cost option using a laser spot or line on the sawn surface and assessing the elliptical hallow by using a 2-D camera. Initial results are proving to be most encouraging.

MAIN RESULTS – YEAR 2
Mechanical and physical properties of battens. Two packs of battens are being characterised for growth features for the MEFYQUE programme.

One pack is of Sitka Spruce from Lockerbie. This pack was sawn from 59 logs, to give 118 battens 100 mm wide (2 from each log) and 24 battens 75 mm wide, with two 75 mm battens cut from each of certain logs. We have FR Laboratory ID numbers for almost all of these battens.

The other pack is also of Sitka Spruce, from Adam Wilson, Troon. There are 107 battens in this pack, of various widths from 100 mm to 250 mm wide, with between 2 and 5 battens sawn from each log, although the majority of logs produced only 2 battens. We do not have FR Lab ID numbers for these battens, although the base ends of the logs had colour codes and numbers, most of which were reasonably clearly identifiable on the battens. Battens wider than 100 mm were sawn down at BRE to leave a central portion 100 mm wide.

The 75 mm battens from Lockerbie and the offcuts from reducing the width of the Troon battens have been sent to Dr. Joris van Acker at Gent University (AP6), for small clear strength testing.

From each batten, about 250 or 300 mm was sawn from the end with the orientation quadrant marks (the base end for almost all of the Lockerbie logs, but the upper end for the Troon logs). The ends of the 100 mm battens were used to determine the original position of the battens in the log. The angle and distance of the centre of the battens from the pith, the spacing of the growth rings, proportion of juvenile wood, and angle of north from the broad axis of the battens was determined from these ends, together with their density. The main lengths of the 100 mm battens have been measured to determine distortion on drying, stress graded, their grain angle measured, and the number and size of substantial knots in the central 800 mm portion of each batten recorded.

The sawn surfaces of the battens were too rough and stained to be evaluated visually for compression wood. Also, the battens had been sawn to rather variable thickness. Hence, the faces of the main lengths of the battens have been planed down (equally from both sides) to 41 mm. They will be stress graded again, to produce more consistent results from the more regular thickness. The extent of compression wood on the surface is currently being assessed visually.

Mechanical and physical properties of small clears. Sample preparation, mechanical and physical properties assessment will based on industry-standard tests to European Standard EN 408 on 20x20x10 and 50x50x5 mm cross-section samples cut from l m long logs. Samples will be cut from the North and/or East direction of each log radiating out from the pith. One sample from juvenile wood, one from the interface between juvenile and adult wood and one from adult wood will be tested. The small clears will be sawn according in august 2003. The testing is foreseen for the period October-December 2003. The tests include a 4-point bending test and determination of compression strength.

Growth ring analysis. Growth ring measurements have been performed on:

78 trees from nine UK sites: see Table below for species and number of trees per site;
four disks per tree;
Two radii per disk (N and S).

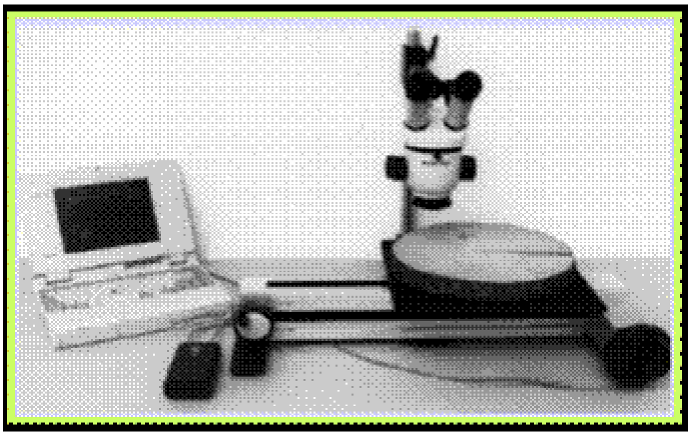
This analysis yielded a total of 312 disks (624 radii) for measurement. The N-S radial strips sawn from each disk were stored in freezers and surfaced with a high-speed circular saw prior to measurements.

Number of trees sampled and tree species studied per FR site

Site	Site name	Number of trees	Species
FR1	Straits	6	Oak
FR2	Coalburn	8	Sitka spruce
FR3	Tummel	9	Sitka spruce
FR4	Rannoch	9	Scots pine
FR5	Grizedale	6	Oak
FR6	Thetford	9	Scots pine
FR7	Clunes	9	Norway spruce
FR8	Sawley	13	Sitka spruce
FR10	Hope	9	Scots pine

Ring-width and earlywood-latewood widths were recorded with a LINTAB (TSAP software)

FIGURE PHY-1. *LINTAB equipment (Photo: F. Rinn).*



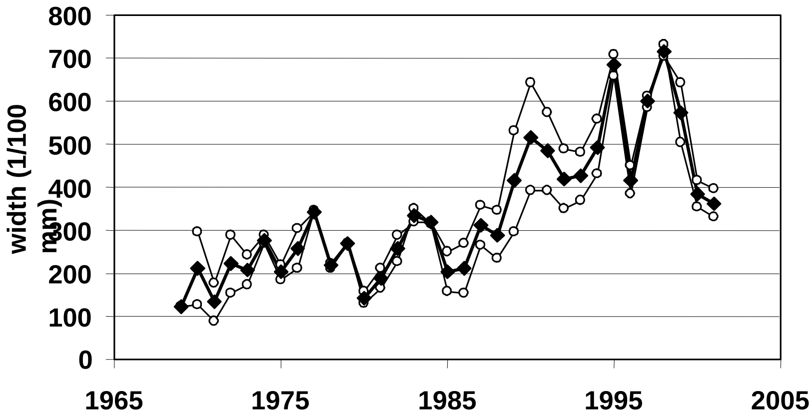
The following parameters and settings have been used:

30 outer growth-rings measured per radius ;
10 µm resolution (1/100 mm) ;
data stored in Heidelberg format (*.fh).

Subsequently, the rough ring-width sequences (624 chronologies) have been synchronized using PAST32 software. Cross-dating is based on visual and statistical criteria (Gleichlaufigkeit, Baillie-Pilcher or Holstein t-test, cross-correlation). Final cross-dated results are saved to Excel files.

Synchronization and calculation of the average curves was performed first at each height level (2 chronologies per disk), then between the four chronologies (*cf.* four height levels) respectively of N- and of S-radius, then at tree level (eight chronologies per tree) and finally between trees belonging to a site. An example of two cross-dated ring-width sequences and the corresponding average curve are given in figure PHY-2 below, for tree 1 from site FR01 (Oak).

FIGURE PHY-2. *Synchronised ring-width sequences (N & S) and mean chronology for Site FR01, tree 1 (oak).*



Measurements have been completed for 612 radii, with six disks left to analyse at the time of writing. The cross-dating work is still ongoing. The delivered input for the database will be Excel- or ASCII-formatted files containing synchronized data of annual ring-widths and earlywood-latewood widths of 78 trees (4 species, *cf.* Table I), *i.e.* eight series per tree, as well as the average curves for the levels 'height', 'radius', 'tree' and 'site'. Over 56000 basic data points were produced. These data will be forwarded for inclusion to the database and used for the development of the species parameter files.

When using the dendro-chronological data, it should be noted that:

Curve-averaging causes signal smoothening, especially at higher level (between trees) - the use of individual curves is probably recommended;

LINTAB measurements are recorded along a single radius and do not account for intra-ring width variations which may be observed near knots, branches and at the stem base (onset of roots);

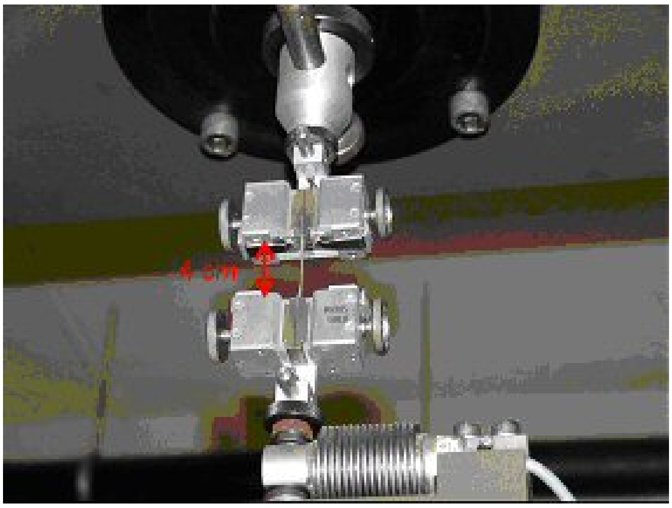
Observed tendencies should be compared to expected tendencies and interpreted accordingly: normally juvenile rings are wider, which results in decreasing trends from pith to bark and from top to bottom - the influence of reaction wood should also be taken into consideration;

Higher up the tree, stem-disks are smaller and may contain less than 30 rings. The transition between early wood and latewood is clearly visible in Oak. In softwoods, however, marking this border is subjective and therefore measurements are less reliable.

MAIN RESULTS – YEAR 3

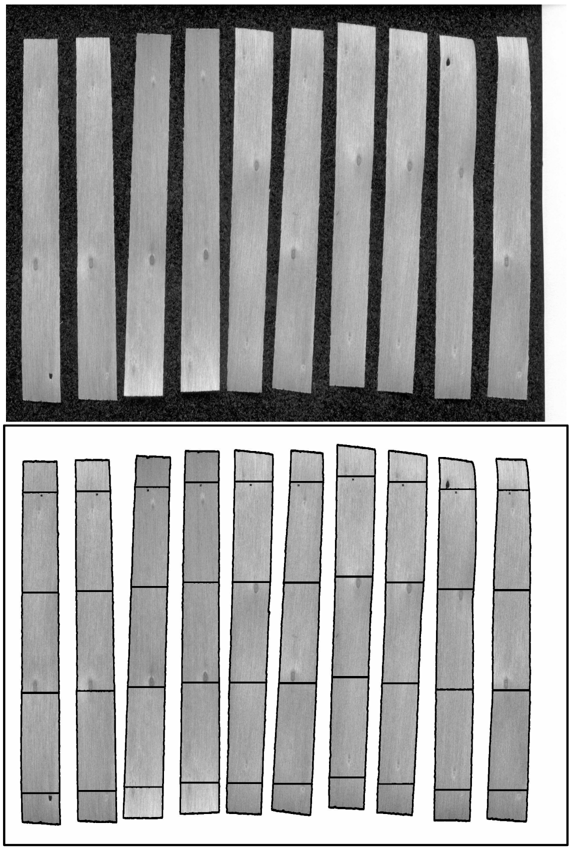
Partner 6 received FR material to cut out small clears. The small clears will be sawn according to European Standard EN 408 in august 2003. The testing has been executed in the period Oct.-Dec. 2003. The tests include a 4-point bending test and determination of compression strength. Test results have been forwarded to BRE (Partner 7).

Figure PHY-3. *Close-up of thin strip clamped for tensile testing (Zwick).*



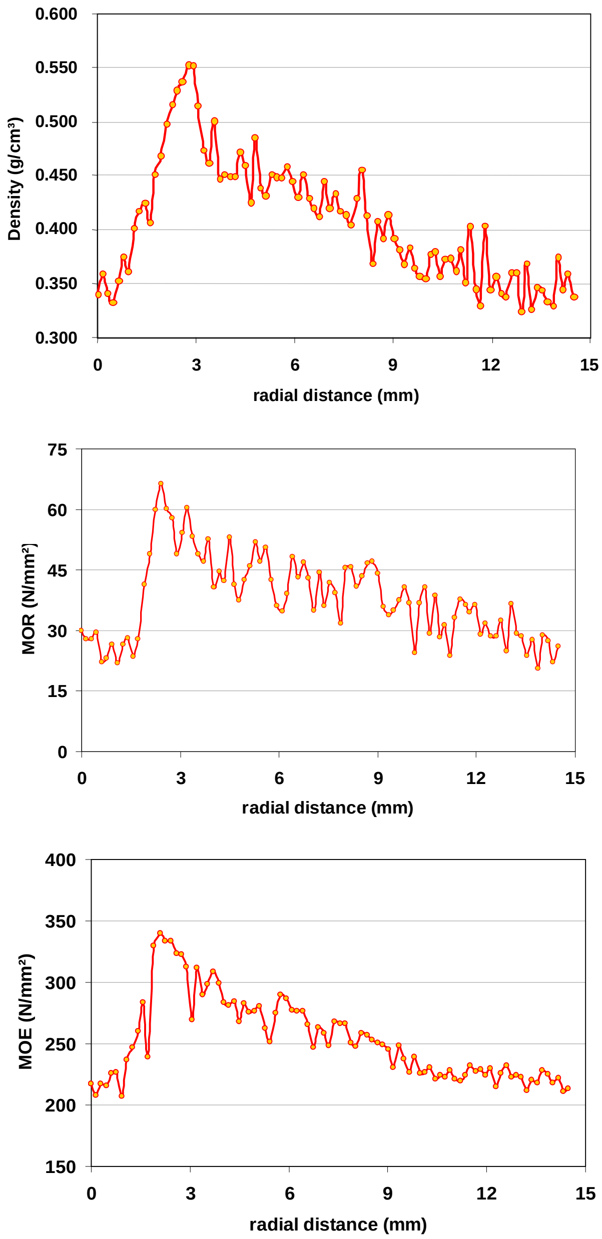
The thin strips of Poplar material described in WP4 were subjected to mechanical testing to estimate MOE and MOR, using a universal test bench specially equipped with a low tensile stress-strain probe (Zwick). All strips were conditioned at 12% emc and weighed prior to the tensile testing in order to determine their volumetric weight. The latter required also to know the exact volume of each strip. Therefore, strips were scanned on a flatbed scanner at 1200 dpi (Figure PHY-4, top). The tangential and longitudinal dimensions were determined using fully automatic image analysis scripts (Visilog 5.4) developed by Partner 6 (Figure PHY-4, bottom). Radial dimensions were estimated with a Mitutuyo micrometer.

Figure PHY-4. *Top: scanned image of 10 thin strips prior to testing - Bottom: output after image analysis showing different sections considered for dimensional characterisation of each strip.*



The first results indicate a clear relationship between the evolution of certain vessel characteristics (Figure ANA-19), fibre length (Figure ANA-21) and physical and mechanical properties (Figure PHY-5). The curves describing intra-ring density, MOE, MOR, mean fibre length and vessel conductivity clearly follow similar or correlated trends.

Figure PHY-5. *The evolutions of density (top graph), MOR (middle) and MOE (bottom)in ring 2 of clone 5HB03 show similar trends.*



MAIN RESULTS – Extended period

The analysis of samples has now been completed, and entered into the database

2.5.3.3.1 WP6: Analyses Of Wood Physico-Mechanical Properties In Laboratory Conditions

Work-package number:	6						
Start Date:	Planned Sep 01			Status: Delayed			
Completion Date:	Planned Oct 03			Status: Jun 04			
Current status	Completed						
Partners Responsible:	AP6, P7			Status: Delayed			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex						10	8
Year 1 – person-months employed						1	1
Year 2 – cumulative person-months employed						3	3
Year 3 – cumulative person-months employed						9	7
Total including extension						11	8

OBJECTIVES

The main objective will be to analyse the physico-mechanical (biomechanical) properties of wood from the monitoring and manipulative experiments in laboratory conditions.

The main aim of this work package is to quantify changes in a range of wood physico-mechanical properties (static bending, compression parallel to grain, density and moisture content) to correlate with results of chemical and anatomical modifications. This will be achieved by:

6.1 Measurement and comparison of growth ring width of trees grown under ambient and elevated conditions and width of early- and latewood increment, at breast height of the test trees

6.2 Quality assessment of structural timber grown in manipulative experiments.

6.3 Assessment of drying distortions of timber grown in manipulative experiments.

6.4 Quality assessment of samples of timber grown in manipulative experiments to determine key mechanical and physical properties.

METHODOLOGY AND STUDY MATERIALS

Wood density, mechanical stress, juvenile and compression wood will be carried out on approx. 10 trees/site from at least 2 stem heights with as many replicates per height as possible (not more than 10).

Sampling. The following parameters will be assessed:

Mechanical
Wood density
Mechanical stress
Drying distortion
Knot area
Slope of grain
Juvenile and compression wood area

Sample preparation, mechanical and physical properties assessment will based on industry-standard tests carried out on 20x20x10 and 50x50x5 mm cross-section samples cut from l m long logs. Samples will be cut from the North and/or East direction of each log radiating out from the pith. One sample from juvenile wood, one from the interface between juvenile and adult wood and one from adult wood will be tested.

1. Growth rings. A LINTAB III positioned linetable connected with a computer and a microscope with an accuracy of 1/100 mm, will be used for the width measurements. To evaluate specific responses of wood characteristics to elevated CO_2, in order to reconstruct the impact of historical increases in CO_2, dendro-chronological techniques will be used.

2. Quality assessment of structural timber. Quality assessment according to standard industrial practice, as well as a more discriminating assessment *via* the strength and stiffness of the timber. Short logs will be converted in partner countries; cut samples will be delivered wet and wrapped for successive drying and testing and 2.4 m battens produced using standard milling practices to assess

axial compression strength tests using an electro-mechanical Zwick testing machine; compression and tension wood will be microscopically measured by colour tests; mechanically stress grade using a machine to record modulus of elasticity at 100 mm intervals; classify according to C16 or C25 or reject structural classification; establish true modulus of elasticity [MOE] and modulus of rupture [MOR] under 4 point bending according to CEN Standards, at the weakest point.

3. Assessment of Drying Distortions. Straightness after initial drying and in service is the second important criteria for structural use. Battens for Objective 1 will be kiln dried to 15% moisture content (MC) and assessed to measure: nominal density of wood samples (the question of the applicability of these analyses to commercial timber should be born in mind, as the young trees used here consist largely of juvenile wood, although the results can be extrapolated by resistograph drilling); percentage of shrinkage, together with the influence of juvenile wood, tension and compression wood on dimensional stability; drying distortion (twist spring and bow) on a flat slate; MC at centre of each batten at two depths (5 and 15 mm) to produce the moisture gradient; knot area on the middle 30 cm of the 200 cm distortion measurement span; slope of grain in this position, area of juvenile wood and any compression wood.

4. Quality assessment by small clear samples to determine mechanical and physical properties**.** Where longer logs are not available, from example from the tertiary sites, small samples (60x20x20mm) will be examined to assess basic structural wood properties of knot free wood. Partner 7 will develop appropriate protocols to achieve consistent and standardised results between Partners.

Number of Samples. For machine stress grading / distortion assessment and 4 point bending approx. 30-50 samples will be used for each site.

Methodology

Structural sizes. For structural sizes the following procedure will be adopted:

Sample from logs 2-3 battens per log dry without constraint to 15-18% MC gives inherent distortion.
Machine grade - giving details of individual spans (every 100mm up batten - 900mm is the grading span).
Measure drying distortion - twist, spring and bow - link to moisture content.
Carry out 4 point bending to destruction giving MOR - Rupture strength and MOE stiffness- MOE takes considerable time because a cradle holding a transducer is attached to the batten before testing.
Analyse.

Small clears. For small clears the bending test will be used:

Cut samples from log.
Dry / condition at 20 degrees Celsius and 65% Rh.
Final machining of samples.
Test MOR and MOE (MOE again takes considerable time - but is an important factor).
Analyse.

Juvenile and compression wood. Juvenile and compression wood will be analysed on microtome slides:

Preparation of samples -- this is slow and must be completed with care – cutting and staining each sample can take up to 1 hour.
Microscopic measurements and assessments.
DATA preparation and manipulation.

Total sample. In total, it is foreseen approximately 35,000 data points will result from the physico-mechanical studies carried out on the plant material sampled at the primary, secondary and tertiary sites.

DELIVERABLES

16. Standardised methodology for determining selected wood physico-mechanical properties.
17. Database on the physico-mechanical properties of wood from trees for a range of species, environmental conditions, management options, atmospheric and climate change.
18. Calibration and validation data for coupled mensuration-mechanistic dynamic model of tree growth, yield and quality.

MILESTONES – Year 1
New data on the quantification of wood physico-mechanical properties from trees across a range of species, environmental and management perturbations in participating Member States, and across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood physico-mechanical protocol. Draft Jul 01	P7	AP6
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Planned Dec 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Dec 03	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Mar 04	P7	AP6
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	First version Mar 02 and ongoing	P1	AP6, P7

MILESTONES – Year 2
New data on the quantification of wood physico-mechanical properties from trees across a range of species, environmental and management perturbations in participating Member States, and across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood physico-mechanical protocol. Draft Jul 01	P7	AP6
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Planned Dec 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Dec 03	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Ongoing, with completion scheduled in Jun 03	P7	AP6
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	AP6, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood physico-mechanical protocol. Draft Jul 01	P7	AP6
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Planned Dec 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Dec 03	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Ongoing, with completion scheduled in Jun 03	P7	AP6
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03	P1	AP6, P7

MILESTONES – Extended Period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
III. (Partial)	Laboratory and analytical protocols	Dec 01	Wood physico-mechanical protocol. Draft Jul 01 Competed Dec 01	P7	AP6
VI. (Partial)	Completion of Phase 1 sampling programme	Jul 02	Planned Dec 02 Completed Dec 02	All	
XI. (Partial)	Completion of Phase 2 sampling programme	Dec 03	Dec 03	All	
XII. (Partial)	Completion of laboratory studies	Mar 04	Completed Sept 04	P7	AP6
XVII. (Partial)	Unified database of data from the monitoring, experimental, laboratory and manipulative components	Jun 04	Version 2 to be released in Dec 03 Final Version Feb 05	P1	AP6, P7

Key Changes to WP6 – Year 1
Following the delay in 3-D scanning activities Partner 8 (BRE) is requesting the carry-over of funds from Year 1 to Year 2 in order to complete outstanding tasks. Staff are already in place to support scheduled activities.

Key Changes to WP6 – Year 2
Significant delay remains in this WP, given the delay in 3-D log scanning and the processing of sawn timber. It is anticipated that significant headway will be made into the delay by Dec 03.

Key Changes to WP6 – Year 3
None

Key Changes to WP6 – Extension
None

2.5.4 The Modelling Component

The **MODELLING COMPONENT** builds upon existing state-of-the-art empirical and process-based models available in MEFYQUE, and developing new modules, to create a new model that will simulate timber yield at the forest stand scale under current and future scenarios of atmospheric composition. This new model will be integrated with:

- a coupled empirical-process sub-model of timber quality as affected by ambient and modified atmospheric composition, environmental change and management (WP7);
- a new sub-model for estimating the productivity of a range of wood products (WP7);
- a new energy budget sub-model for the energy costs of production and exploitation of wood products (WP8).

In turn, the forest growth-quality stand scale model will inform an existing and upgraded large-scale scenario model (EFISCEN) that up-scales stand features to the forest management scale.

2.5.4.1 The Stand Scale Model

OBJECTIVES
The objective of this work package is to produce a workable coupled mensuration - mechanistic dynamic model operating at the stand scale, encompassing C, N and H_20 responses, to provide predictions of wood quality, tree growth and form as a function of environmental and management conditions, for present and future climates. The main objective will be to model wood quality and tree growth at the stand scale for representative sites across Europe.

MAIN RESULTS - YEAR 1
The main results achieved in the first year of MEFYQUE for the modelling component are:
The initial design, development and validation of components of the process-based growth and quality model at the forest stand scale.
A new energy budget sub-model for the energy costs of production and exploitation of wood products.

a. Process model (WP7). The overall structure of the MEFYQUE stand-scale process model is outlined at figure STA-1 that also indicates progress on module and database development.

Figure STA-1. *Schematic overview of the stand-scale process model. The figure outlines development to date of specific model components*

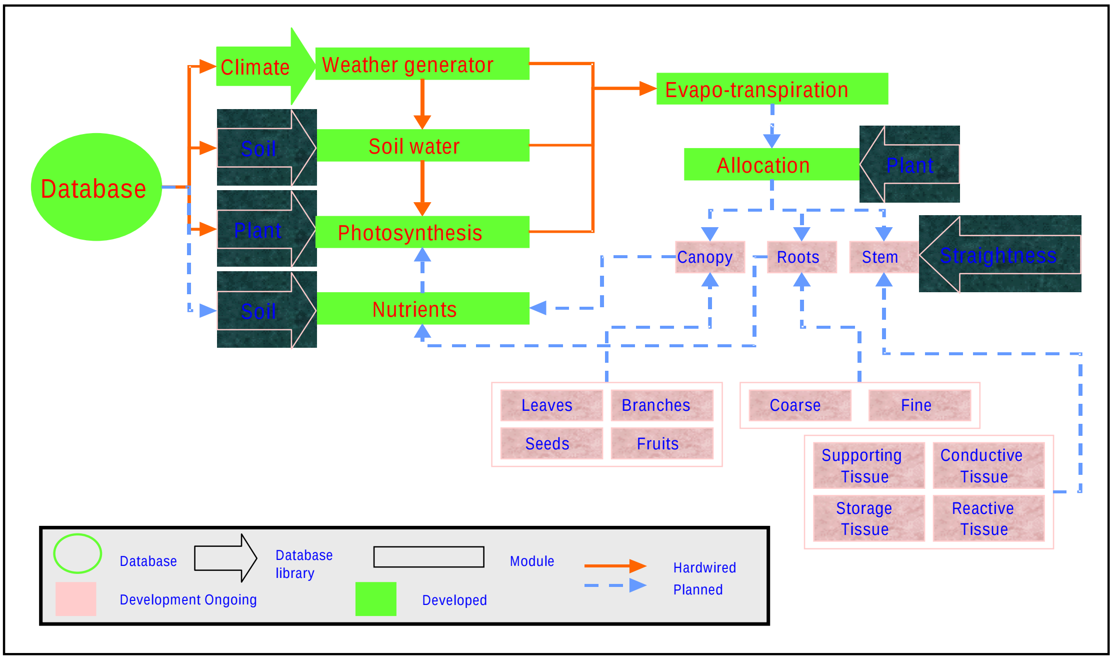


Figure STA-2. *Strategy for module integration.*

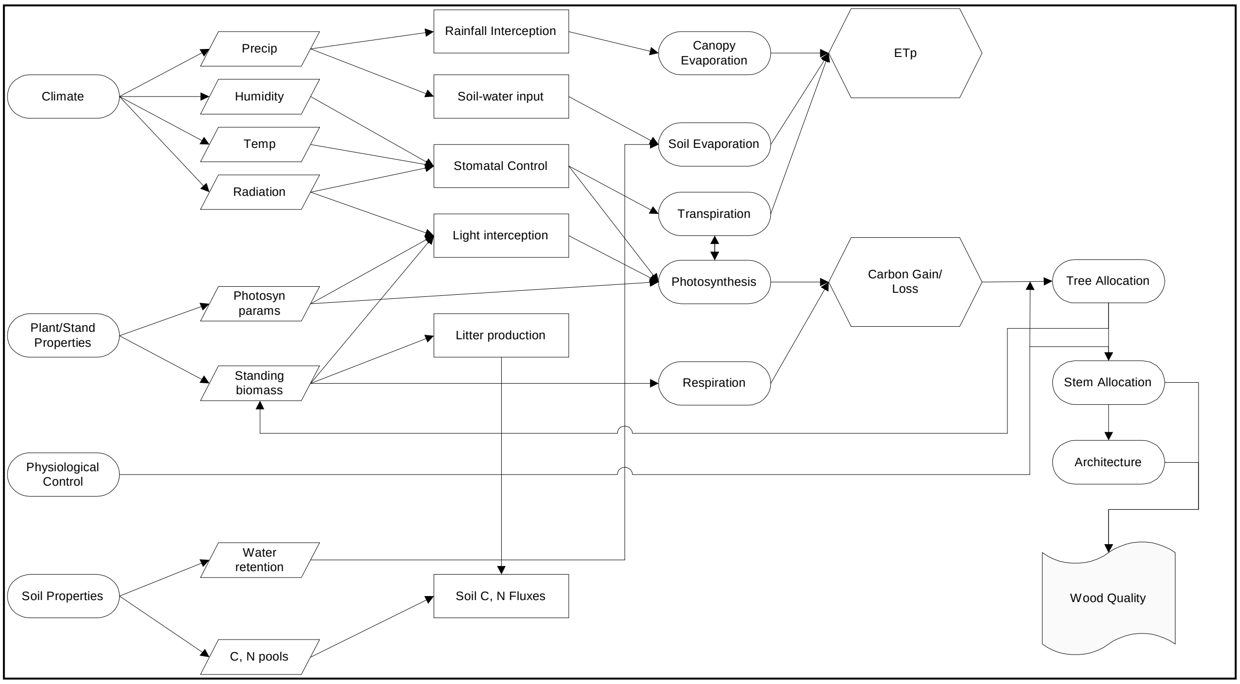


Figure STA-3. *Comparison of observed vs simulated H_20 fluxes above the canopy at the MEFYQUE secondary Straits site.*

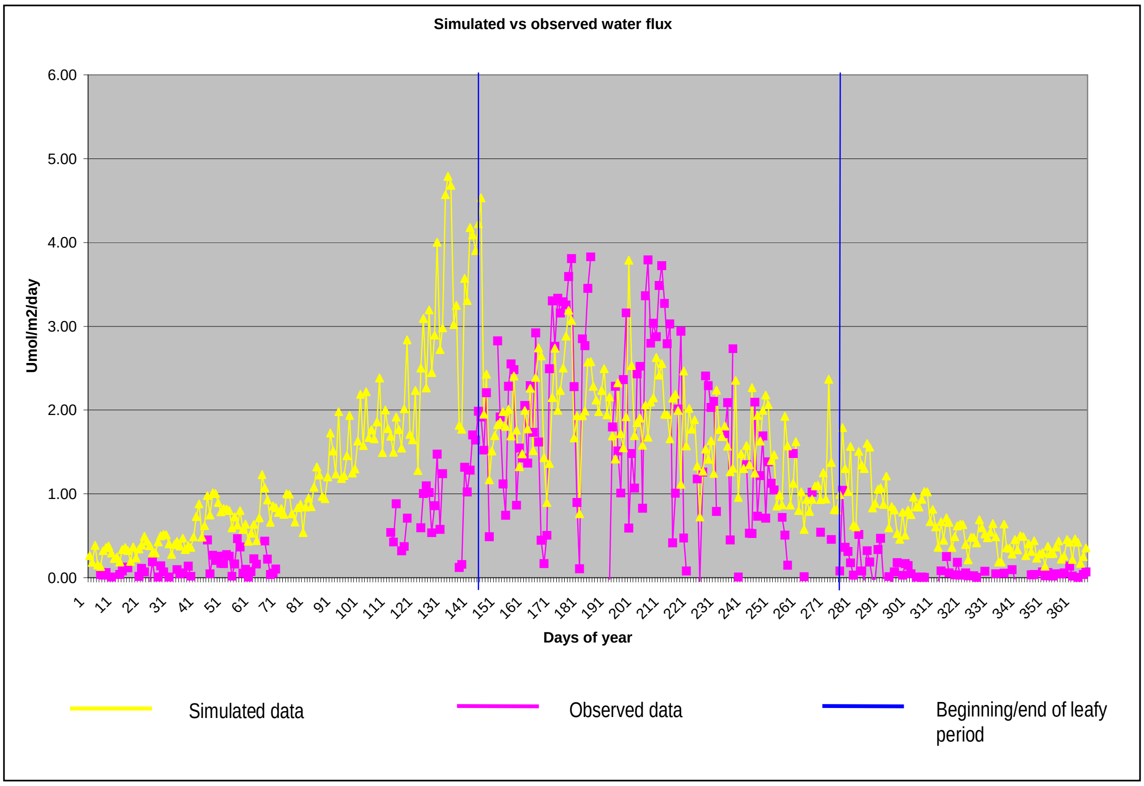
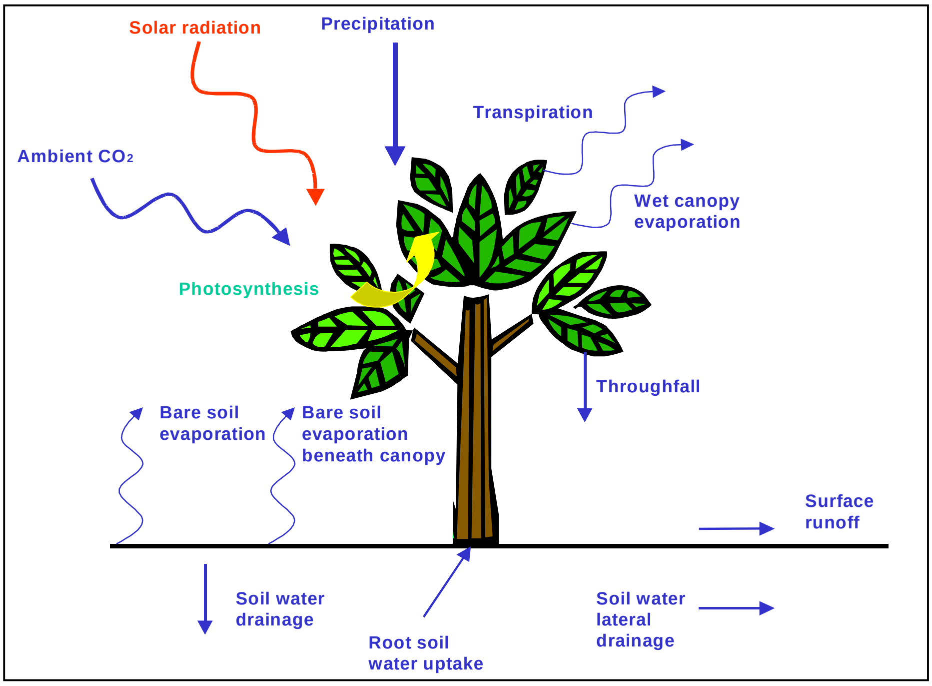


Figure STA-4. *Schematic representation of physical, biophysical and biological processes simulated by the ETp module.*



From first principles, the model simulates those forest ecosystem processes that determine the biomass productivity of a species, given specific edaphic and climatic conditions. The overall model is separated into modules, with each module simulating a specific and relevant (physical, biophysical or biological) process. A protocol for the integration of the existing sub-models was developed and a strategy agreed upon to separate the development of specific modules between the MEFYQUE modelling teams. This protocol is shown diagrammatically at figure STA-2.

To date attention has focussed on the development of a weather generator, and an integrated evapo-transpiration modules that, together with the existing soil C and N turnover (based on Thornley's soil model) and respiration module extracted from the SECRETS model[17] (held by University of Antwerpen) will form Version I due for release in December 2002. Version II of the model will include a first attempt at modelling wood quality, based on a general strategy and underlying hypothesis concerning the incorporation of a wood quality module.

Results of the validation exercise carried out in the UK for the weather generator are provided at Annex 1-H. In year 2 of MEFYQUE it is planned to extend the validation exercise to other selected EU countries.

For illustrative purposes, and as a first order validation of the outputs from the integrated ETp module, model simulations are compared with measured H_20 eddy-flux covariance data from the MEFYQUE secondary site at Headley, UK (site 1). Schematically, for a given tree species of known size, growing on a specified soil type, climate and CO_2 concentration, the ETp module (figure STA-4) approximates evapotranspiration separated into 4 components: wet canopy evaporation; transpiration; evaporation from bare soil shaded by the canopy and bare soil evaporation in direct sunlight. As can be seen from Figure STA-3, the present version the model over-estimates soil evaporation during the winter period. Research is currently under way to improve the description of soil temperature and evaporation. Once complete, ETp model outputs will be compared with H_20 flux data, GPP and NPP estimates from the other secondary sites of the MEFYQUE project to assess the model's overall predictive accuracy in European conditions.

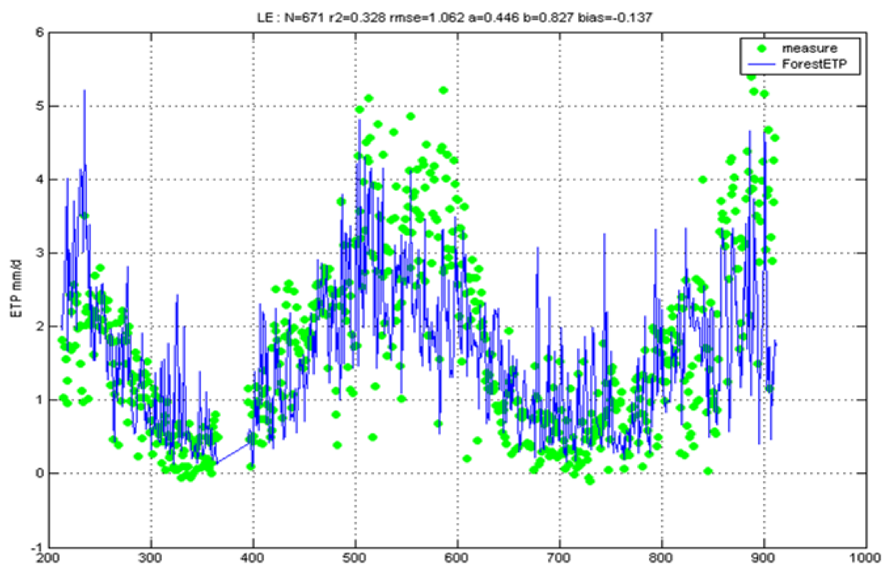
MAIN RESULTS – YEAR 2

The growth-quality stand scale model.

During the second year the plot scale model has been further developed and refined, resulting in a Version 1 (by Dec 2003) and Version 2 (May 2004). Validation against a range of secondary-type sites throughout Europe in ongoing;

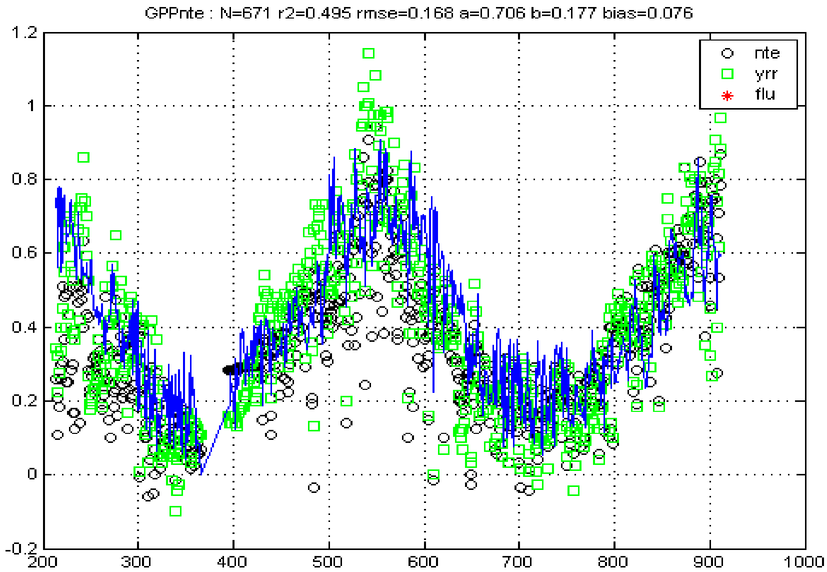
Example outputs against measured flux data are shown at Figures STA-5,6 below.

Figure STA-5. *Comparison between simulated and observed water vapour flux at a selected secondary site.*



[17] Sampson DA, Janssens JA and Ceulemans R (2001). Simulated soil CO_2 efflux and net ecosystem exchange in a 70-year-old Belgian Scots pine stand using the process model SECRETS. Annals of Forest Science 58: 31-46.

Figure STA-6. *Comparison between simulated and observed GPP at a selected secondary site.*



The changes to the plot-scale model were all related to allowing a realistic and dynamic simulation of wood quality in coniferous and deciduous species. The basic requirements driving model development were to develop explicit equations for:

Differentiating between supportive, conductive and storage tissues in a dynamic fashion linked to the evolution of the environmental drivers.

Differentiating between early- and late-wood development, in a dynamic fashion linked to the evolution of the environmental drivers.

Allowing environmental and competitive effects on macro allocation (e.g. crown shape, root/shoot ratio, and height growth).

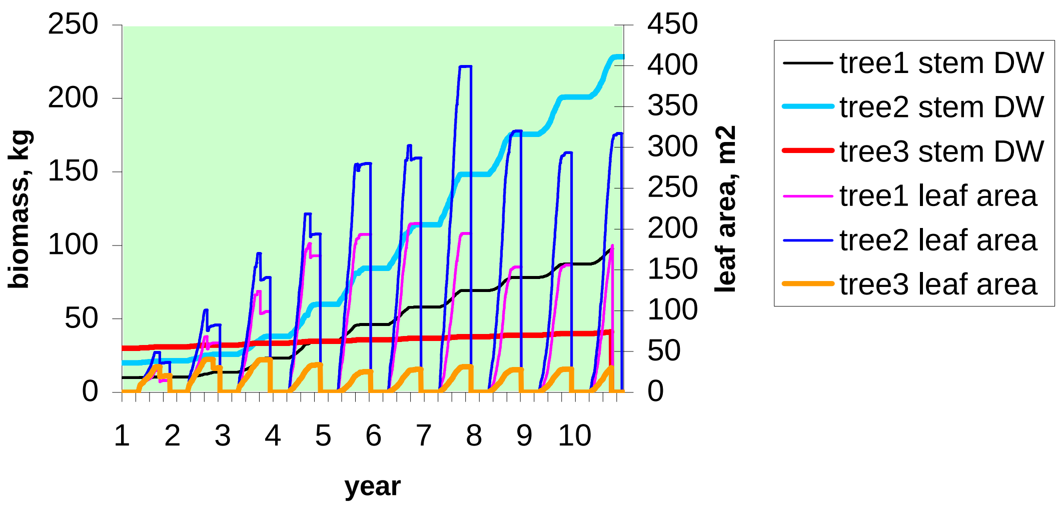
Developing output necessary for the wood quality calculations, to include sapwood area, wood density, knots, and vessel width, stem lean and taper.

Simulating log grading and batten production from stems depending on the 3D characteristics

Ensuring code documentation and compatibility between different compilers

Currently, the forest plot simulates up to 1000 different trees or categories of similar tree (dominant, sub-dominant and suppressed), which can individually differ in characteristics (Figure STA-7 below). Competition between the trees is simulated as the average competition between the tree categories. All carbon, H_2O and N fluxes and pools in the living biomass and the soil are simulated.

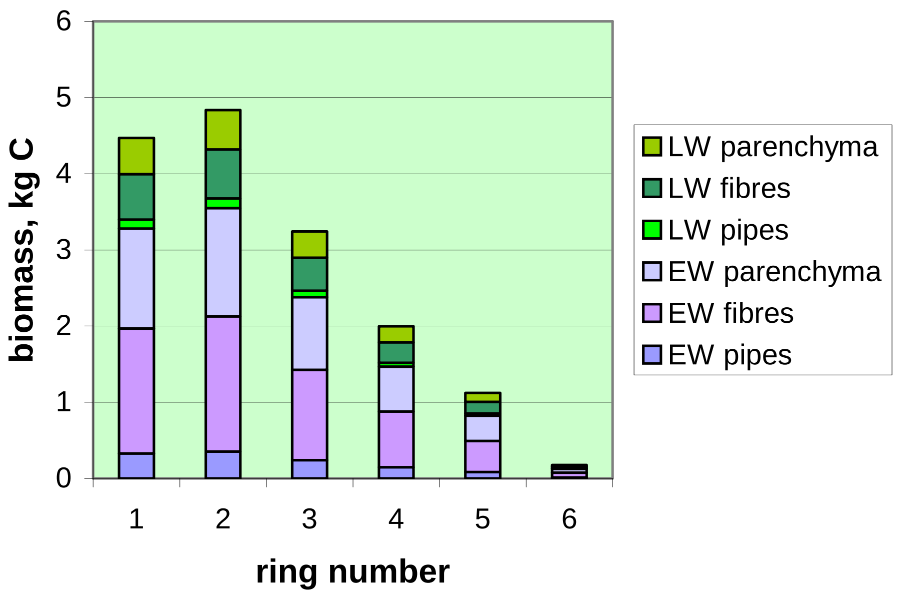
Figure STA-7. *Output of the allocation module of the stand scale model showing stem biomass and leaf area development of a dominant, a sub-dominant and a suppressed tree.*



New module development includes the following:

Macro and micro-allocation. The module is based on a newly developed refinement of the functional balance, which describes the pipe or vessel requirements for each unit leaf area depending on tree and environment characteristics. The distribution of carbon between leaves, roots, conductive, supportive and storage tissues is simulated on a daily basis. Allocation changes between growth phases. The branching pattern and branch development is also simulated depending on the light environment. The module is working realistically (Figure STA-8 below) and now requires site-specific calibration.

Figure STA-8. *Development of parenchyma, fibres and pipes in earlywood and latewood of a simulated dominant tree during 6 years*



Intra-annual Growth Phasing. Taking a broadleaf species, the year is divided into five phases of growth and dormancy. (Coniferous species will operate on a sub-set of the five phases). Either environmental or physiological events, or a combination of both, trigger the onset of each phase.

The first phase commences with bud-burst, determined largely from accrued chilling and warming, and sees the initiation of foliage development together with some earlywood production. The source of carbon, is from that stored previously. Development of this phase consists largely of re-filling the previously existing crown, using old and new pipes (maintaining the pipe-model hypothesis).

The second phase starts when either there is insufficient light within the crown for productive foliage, or the carbon reserves have been exhausted. This period of development sees the main growth phase, and consists of extension of the canopy (following light availability) and production of both foliage and earlywood, maintaining the pipe-model relationships. Carbon fuelling this development is from current photosynthesis.

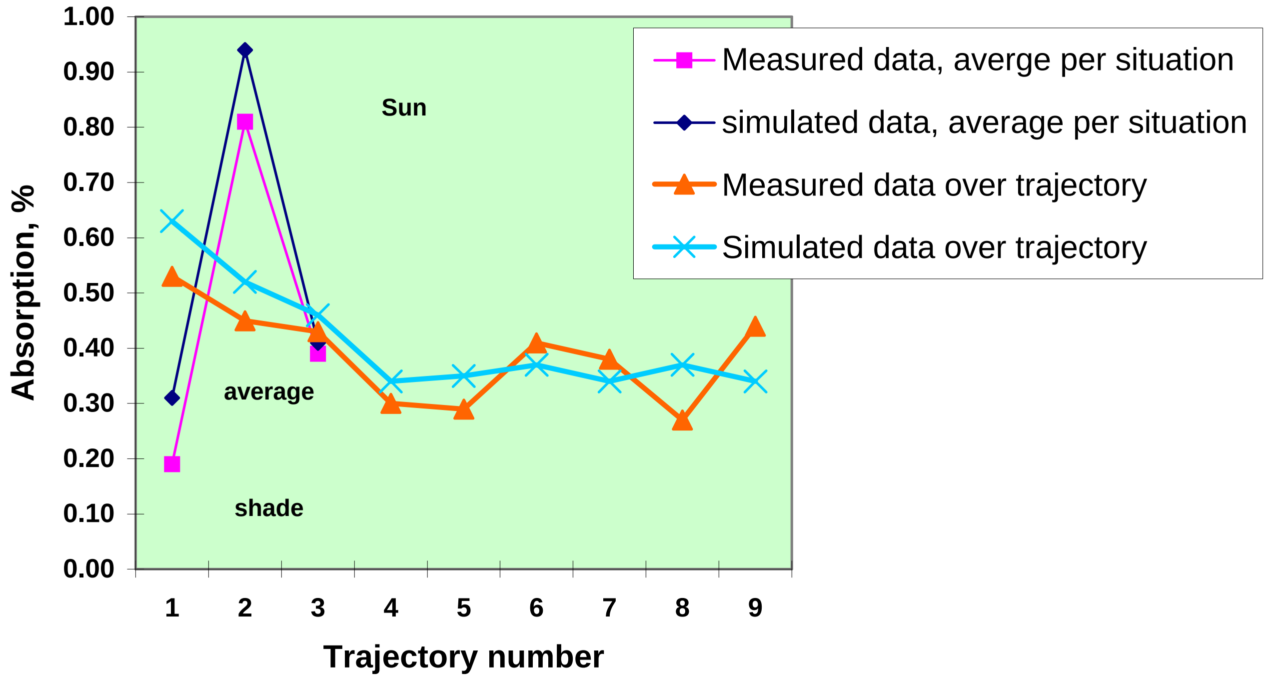
The third phase is the onset of latewood development; the initiation of this phase is mainly triggered by a reaction to soil-moisture deficit. During this phase, not only is latewood developed, but also carbon assimilate is stored in the parenchyma.

The fourth phase is the onset of translocation and leaf-fall. Often this is determined by daylength, but a method is used to combine this with other environmental factors affecting photosynthetic production; leaf-fall is assumed to commence when photosynthetic production regularly falls below a threshold, or when physical damage may have occurred (e.g. a frost).

The final phase commences with the completion of senescence (or the lack of productive photosynthesis), and is basically a phase of dormancy for the tree, where respiration costs are incurred, which are met out of stored carbon.

Light absorption module. The light absorbed by sunlit and shaded leaves within each tree section (both vertical and horizontal layers) is determined and is used to calculate photosynthesis. The light environment also steers allocation (increased height growth under light stress, allocation of new foliage to tree sections that are not yet completely filled), mortality (death of whorls that are no longer viable) and autumn leaf fall (as layers become light-limited). This module has been calibrated and validated for the Level 2 plot at Brasschaat (Figure STA-9 below).

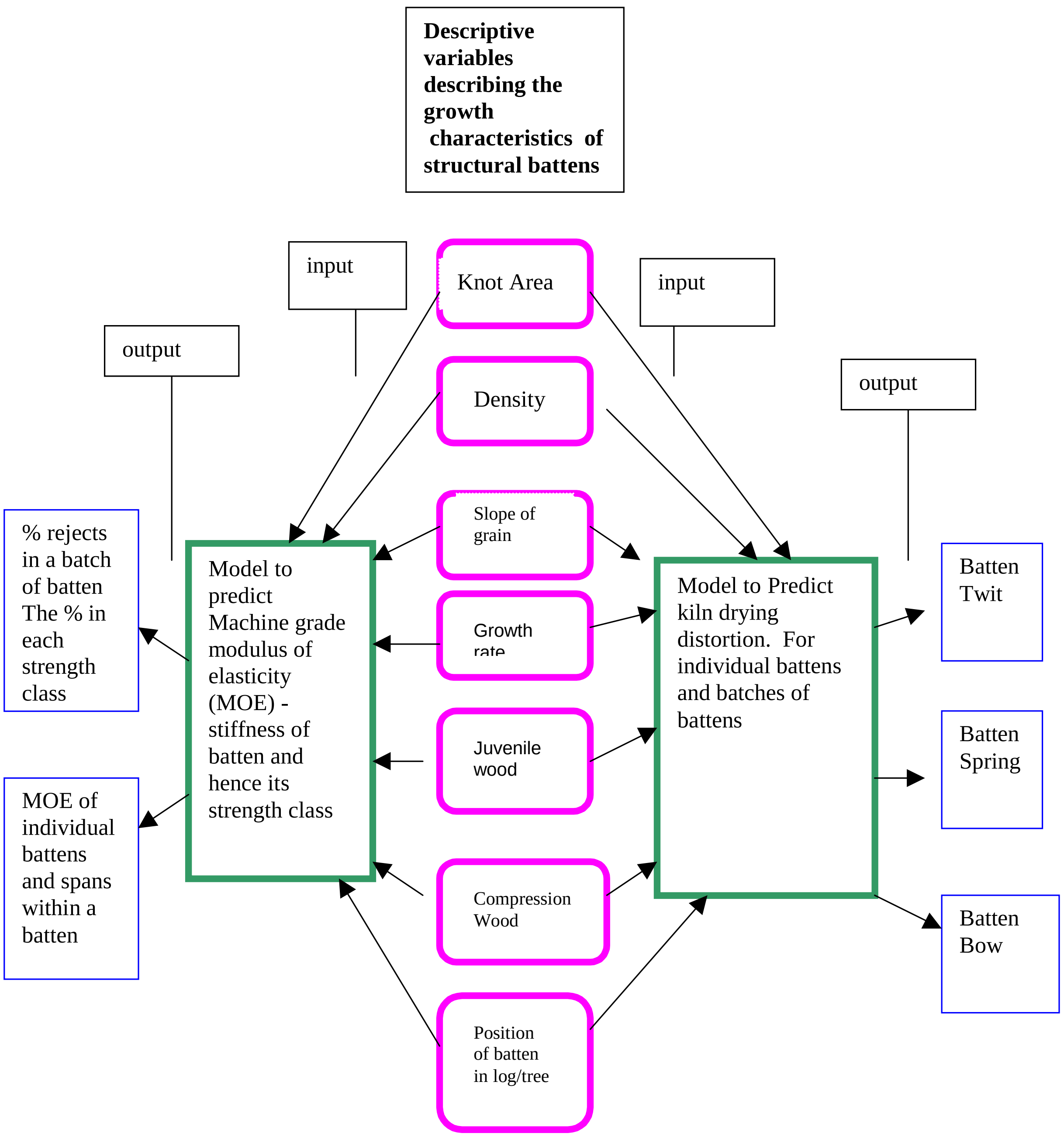
Figure STA-9. *Measured and simulated absorption of radiation on different trajectories through a Pinus sylvestris canopy*



Mortality. In this module, branch whorl death, leaf death and tree death are simulated based on the photosynthesis-respiration balance of the tree (section) and the current growth phase. The module is working but needs site-specific calibration

Wood products module. From the allocation to the different tissue types the density and knotting of every tree ring at every stem height is known. This information is used to calculate the logs from a harvested tree and the quality grading and batten production from these logs. Existing models (Figure STA-10 below) simulating log sawing and predicting values for Sitka spruce battens for machine grade stiffness and drying distortion of twist, spring and bow are being modified using parameters collected during the MEFYQUE project. Changes to the existing model are being carried out through new module development (labelled models BREM3 – BREM6). BREM3-5 are detailed below, while BREM6, which provides costing estimates of converting various shapes and grades of logs and the subsequent processing to obtain useable components, will be considered in Year 3 if time is available.

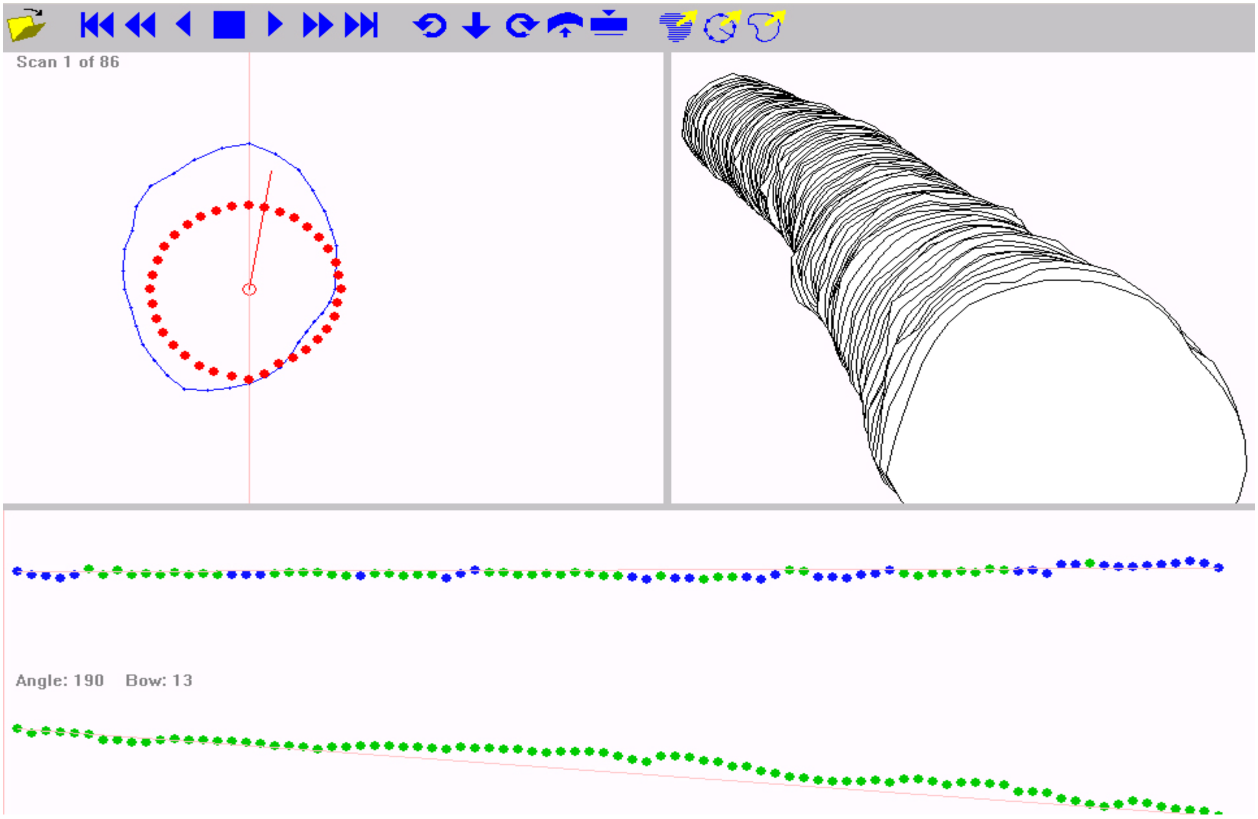
FIGURE STA-10. *Wood Quality Model*



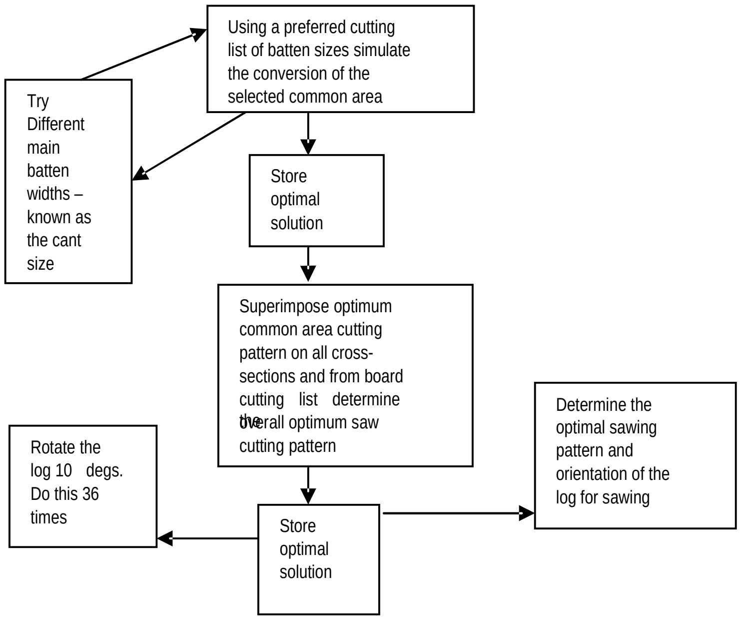
The modelling component being carried out by BRE in MEYFQUE can be divided into 3 parts. A 4th part on costing the process of converting various shapes and grades of logs and the subsequent processing in order to obtain useable components will be considered in year 3 if time is available.

BRE M3: log shape re-construction and simulation of sawing routines. BRE M3 is a simulation model that re-constructs logs cut from the dimensional output from the virtual tree growth model that models tree growth from first principles. The plot model produces a cross-sectional shape every 10-cm up the tree described by 36 polar co-ordinates. The data for each cross-section is linked by a common datum, thus tree bow and taper are described. BRE M3 is a modification of the BREM1 which was designed to handle 3D log data collected from industrial sawmill and at BRE where mefyque sample logs were scanned and sawn. This model was described in WP2. The modified version used in this WP actually reads polar co-ordinates and then outputs the cross-sectional data in rectangular mm strip co-ordinates for 2 common areas and every cross-section up the log for 36 rotations of the log. As described before the general common area is the cylindrical shape up a log from which full length square edged battens can be cut. In this model the 1st common area is that used in the simulation of normal sawing while the 2nd common area is used when simulating a sawing system which follows the log bow in one plane, as shown in Figure STA-11.

FIGURE STA-11. *Reconstructed 3D log showing common areas.*

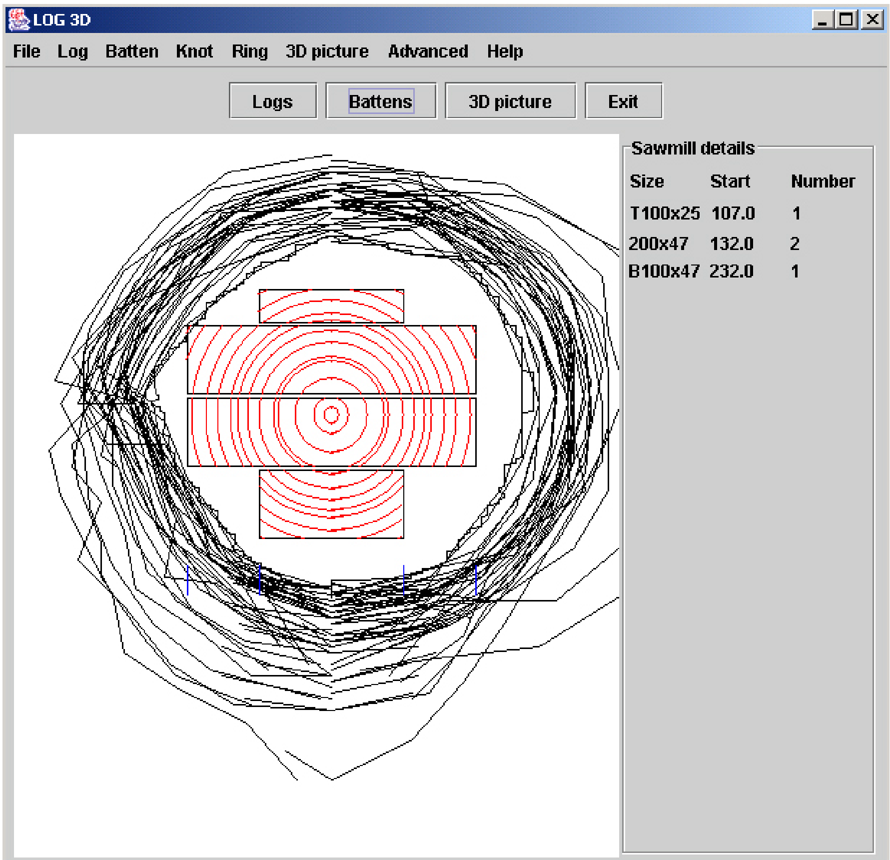


BRE M4: Sawing simulation model. The BREM3 Model can be seen as the engine that carries out the prediction of the optimal volumetric sawing conversion of the plot simulation model. This is an iterative process as follows:



BREM5: Modelling tree growth characteristics on battens. Model BREM5 has 2 stages. Stage 1 uses the reconstructed log of BREM3 with the optimal sawing solution and cutting orientation of BREM4 superimposed and models more tree growth characteristics on relevant 10-cm cross-sections. At present growth rate and the density of each annual ring is modelled on every cross-section an example is shown in Figure STA-12.

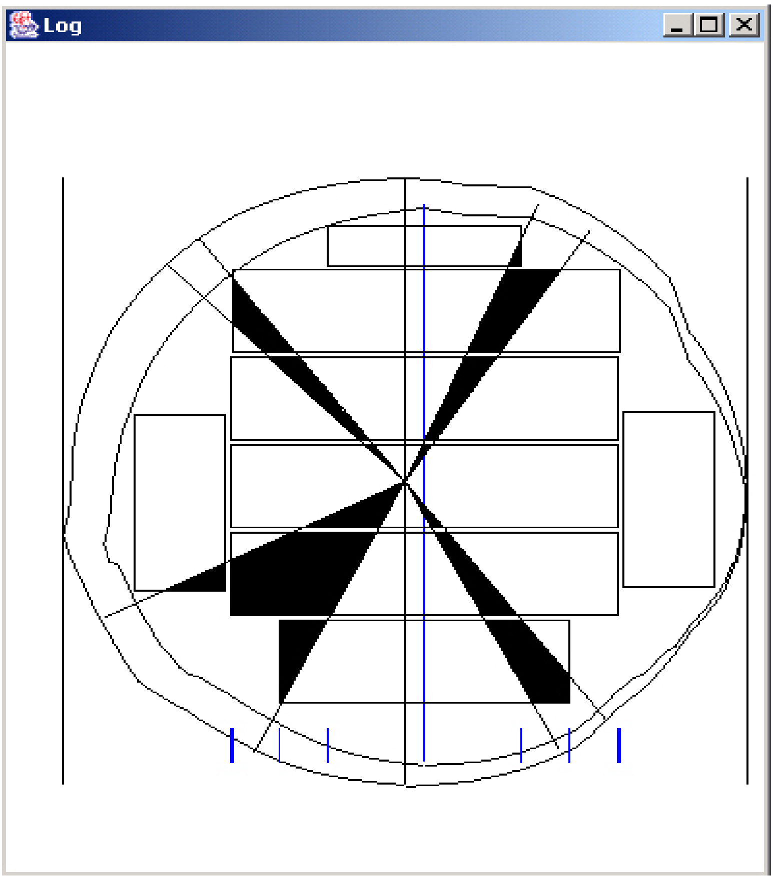
Figure STA-12. *Example output from model BREM5.*



The plot model grows simulated coniferous trees that develop a whorl of branches every year and produces some inter whorl branches. In the BREM5 whorls are determined on the nearest 10-cm cross-section (in future models the exact distance will be use between whorls). Figure STA-13 shows an example of a branch whorl on a cross-section with the optimal cutting pattern.

Routines have been developed with in BREM5 to deal with conical shaped branches in the first instance. In reality branches are conical to start with then turn into a frustum of a cone shape. In other words, the taper of the branch dramatically decreases at some point; taper will eventually be modelled in year 3.

Figure STA-13. *BREM5 example output: branch whorl on a cross-section with the optimal cutting pattern.*



Stage 2 modelling of BREM5 superimposes the annual density on the simulated battens every 10-cm up the batten. An average value is taken of all the tree annual growth rings that fall into a particular batten cross-section, remembering that a growth ring will occupy a particular % of the cross-section of a batten. Also, Stage 2 modelling of BREM5 superimposes tree branches as knots on the battens and calculates the knot surface area on all 4 surfaces of a batten and the position of knots up the batten. In the future stage 2 modelling of BREM5 will include spiral grin as slope of grain, % juvenile wood and compression wood on each batten. The output of BREM5 is a series of descriptive variables that accurately describe the simulated sawn battens cut from the virtual trees generated by the plot scale model.

BREM6: Predicting values for stiffness and distortion for modelled battens. Model BREM6 will use existing BRE prediction models and modify them with the data collected in WP6 to give accurate predictions for values of machine grade stiffness and drying distortion of twist, spring and bow for each batten. Future versions of BREM6, though probably not in the lifetime of MEYFQUE, will link the predictions and magnitude and position of degrading growth feature of all the material contained in a particular log and intelligently determine the most efficient use for the log.

MAIN RESULTS – YEAR 3

The main objective for the third year concerning the plot scale model was the calibration, validation and use of the model for different sites across Europe. As the first validations (for *Pinus sylvestris* in Brassschaat) brought to light some weaknesses in the model, important changes were made. Two modules were considerably improved during this year: the first is the woodquality module, where the wood tissue development of a growing tree is mechanistically simulated in function of the climate, growth-phase, competitional status and growth rate. New mathematical expressions were developed to predict cell wall thickening and tracheid lumen area decrease in function of the leaf development rate. Secondly, a new soil module was developed on a less phytocentric basis and including the simulation of the mycorrhizal carbon pool and the interaction between trees and mycorrhizae (since this appears to play a major role in explaining the total carbon balance of a forest).

The growth model outputs many variables, including the ring-widths at 25-cm heights. This allows reconstruction of the profile of the tree.

A stand is represented by quantities of individuals of a certain type. In the simplest non-homogeneous case this would be A type representing dominant, co-dominant and suppressed. During management treatments, different quantities of each type can be removed, representing top, neutral, low thins etc., which the proportion of individuals from various diameter classes removed. In the first instance the simulated trees are largely straight. A function has been developed which imposes deviation from straight following a set of rules.

The trajectory continues in the same direction for growth within a year. The default is for the trajectory to continue, though this is modified by

A need to seek light. i.e. to grow vertically

A random movement

Figure STA-14 shows a typical result of bend imposed on a tree. This is then used as input into the cross-cut model, which determines, where and how-long the logs are cut from the entire bole of the tree.

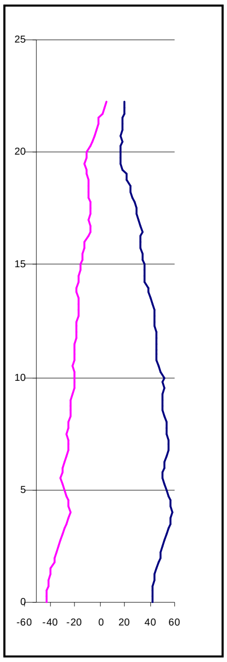


Figure STA-14. *Profile of a simulated tree with bend characteristics imposed*

The information from the growth model is retained and carried with the log-length description, thus a log can be described in terms of rings and length. The bole of the tree has therefore been divided into various log-lengths and a proportion of unutilisable material.

Reading sawmill binary data files

A programme was designed during second year to interpret the binary files (.3dl and .wsd) produced from the 3D log scanner used to measure the log shapes from both Adam Wilson and Sons, Troon and BSW, Lockerbie. The collected data was converted into polar co-ordinates and Cartesian strip co-ordinates, depending on the users' preference and programmed interface, in order to calculate the common area (max area for batten production) and to assess the maximum log bow. These two variables are important in calculating the end use of the logs/trees from each of the forest areas and whether they are used for either construction material or for a lower value markets.

The programme is not a simple file transformation programme, in that, it also has a visual interface and is able to calculate the bow in accordance with every 10 degrees spin around the log. This aids in the determination of the best cutting angle, in order to optimise the logs sawn material out-put.

This programme was fully developed by the middle of the third year and since its completion all 256 scanned logs have been analysed and re-constructed into whole trees.

During the remaining project period, the log/tree shape data will be added to the main data-base. However, at this point in time, discussions are on-going on how best this can be achieved. The data will eventually be used to determine the quality of each tree from a given area. It will also be used to compare tree quality with batten performance.

Cross-Cut Model

The development of this model began shortly after the completion of the file transformation programme was completed. It was decided that the best production method was to incorporate it directly into the file transformation programme. The cross-cut programme is currently running for three different lengths which produce different quality products (4.8m length logs for high value construction material, 2.8m length logs for lower value construction material and 1.8m log length for fencing and packaging material).

This model uses three inputted variables to produce the different log lengths from the tree data. These variables are maximum deviation from the neutral axis (max bow), and maximum number and size of branches. The model requires further development for ease of use.

Optimiser Model

This model was produced at the beginning of the third year. Polar co-ordinates produced from the cross-cut model are used to develop virtual battens and boards. The objective of the model is to optimise the sawn products from the common area identified within the log. Running this model in conjunction with the growth and allocation model developed by The Forestry Commission (FC) and Antwerp University, it will be possible to maximise the sawn out-put from the log and re-orientate the cutting position of the log in relation to the presence of knots. The virtual battens produced by this model, portray the position and orientation of knots along each of the four surfaces. As previously mentioned, the model is able to re-position the log (by a change of cutting angle) if the knots fall in an in-correct pattern on the batten. When volume optimisation is completed the average density of each 10 cm cross-section is calculated. The model also determines the position of knots from the FC yearly density and branch data. This in turn, will assist in the batten data required by the stress grading model.

This model will not only optimise the common area to produce structural material but will also optimise the remaining material, in terms of producing side boards of different length. The programme will out put the volume of structural battens, volume of boards, volume of chips and also the volume of saw dust. These volume out-puts will then be included into the EFISCAN model to produce the carbon allocation.

Stress Grading Model

A version of this model is running, but more data is required to increase its precision. The parameters that are currently used are density, rate of growth, distance from pith, grain angle and knot distribution.

This model is due for completion by the end of 2004. The data received from the laboratory component of the project is currently being analysed for addition to the overall model. Currently, the FC growth model is not able to generate the grain angle of the trees being produced and the optimiser is therefore unable to produce the grain angle required for these battens.

At this point, it is not clear whether another model will be developed to incorporate the grain angle so that the model can be applied to the virtual battens. However, due to the variability of the data, the accuracy of this type of model may be reduced.

Due to the problems in producing predictive models for compression wood, it is not possible to include this component into the stress-grading model. Other parameters that could be included at a later stage are slope of grain and micro-fibril. At present it is not possible to include these characteristics, as the growth model does not produce them.

Deliverables

The deliverables for this WP during the third year were the predictions of wood quality and yield across a representative range of sites and silvicultural regimes in participating countries, under current and future climate scenarios (deliverable 22) and predictions of the environmental impact of these same scenario's (deliverable 23). Although some runs with the model have been completed (see above), a considerable part of this deliverable will be met only during the extension of the project (within the next 3 months)

Milestones

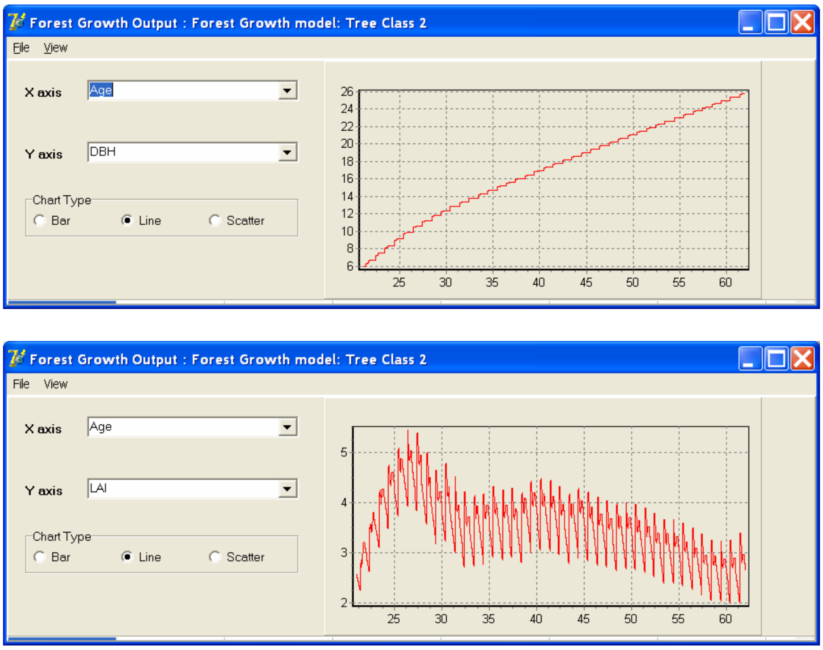
There were no milestones for this WP during the third year.

MAIN RESULTS – Extension

The work carried out during this phase of the project was in bringing together the novel allocation mechanisms developed in the simpler, Mefyque-Lite model, with the more detailed Forest-growth model.

Figure STA-15 shows example outputs for a stand simulation, using the front-end developed.

Figure STA-15: Example Simulations of the forest growth stand model



The growth model links to the cross-cut optimiser and grading sub-models developed, though each model is run sequentially. The Simulation for a stand produces output files amounting to some 15 GB, with the optimiser model talking the longest to run (approx 24 hours) in cutting the logs into timber battens.

2.5.4.1.1 WP7: Modelling Of Wood Quality And Tree Growth At Stand Scale For Representative Sites Across Europe

Work-package number:	7						
Start Date:	Planned Jun 01			Status: Delayed			
Completion Date:	Planned Dec 03			Dec 04			
Current status	Completed - Partial						
Partners Responsible:	P1, P2, P3, P4, P5, AP6, P7			Status: P1 responsible for WP			
Start Date:	Jul 01						
Completion Date:	May 04						
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	12(+2)	12(+3)	3	4(-4)	5(+2)	10(-10)	4(+1)
Year 1 – person-months employed	4	1	1	0	0	0	1
Year 2 – cumulative person-months employed	10	8	1		1		3
Year 3 – cumulative person-months employed	13	13	3		6		4
Total – including extension	20	17	3		7		5

Key changes
P1: 2 person-months reassigned from WP8 to WP7
P2: 3 person-months reassigned from WP10 to WP7
P4: 4 person-months reassigned from WP7 to WP4
P5: 2 person-months reassigned from WP9 to WP7
AP6: 10 person-months reassigned from WP7 to WP4
P7: 1 person-month reassigned from WP8 to WP7

OBJECTIVES
The objective of this work package is to produce a workable coupled mensuration - mechanistic dynamic model operating at the stand scale, encompassing C, N and H_20 responses, to provide predictions of wood quality, tree growth and form as a function of environmental and management conditions, for present and future climates. The main objective will be to model wood quality and tree growth at the stand scale for representative sites across Europe. This will be achieved by:
7.1 Integrating empirical mensuration models with process-based dynamic models of relevant physical, biophysical and biological processes at an appropriate spatial and temporal scale to improve predictions of tree growth at stand level.
7.2 Coupling growth with tree form to predict quality of standing timber.
7.3 Coupling growth with biochemical and mechanical properties of wood to predict quality.
7.4 Developing the coupled mensuration - mechanistic dynamic model operating at the stand scale, encompassing relevant C, N and H_2O responses, to provide predictions of wood quality, tree growth and form as a function of environmental and management conditions, for present and future climates.

METHODOLOGY AND STUDY MATERIALS
Existing soil-plant-atmosphere models operating at the stand scale, which couple growth responses in the xylem and in the canopy to C, N and H_20, will be integrated with existing mensuration models of stand structure and architecture. Data developed under Work Packages 3 – 7 will be used to develop and refine modules of timber quality. The coupled model will be calibrated using existing mensuration models and data-sets, and new data collected from the monitoring sites collected for this purpose. The model will simulate, sequentially, single species stands or combinations of single and multiple-species forests, and the quality of the timber produced. A major by-product of the model will be estimates of carbon sequestration from forest stands across a range of sites, as a function of representative management conditions and in relation to timber and wood quality. State-of-the-art scenarios of future atmospheric compositions developed by the most recent General Circulation Models (GCMs) and placed in the public domain through the EU-ECLAT 2 (ENV4-CT98-0734) project will be used to inform the climate input to the coupled model. The integrated model will thus comprise several process modules that are either written from published literature, modified from previously published models or constructed for this purpose. All models will be developed in Object Orientated code using C- or object oriented Fortran 90, and the Delphi programming language to provide the user interface. This approach allows the characteristics and behaviour of an object to be coupled and allows for a modular programming approach, with all outputs available for use by any other model. Partners 1 and 2 will be

responsible for developing appropriate modelling protocols to integrate existing modelling procedures into the unified framework.

DELIVERABLES

19. Protocol for integration of sub-modules.
20. A prototype coupled mensuration mechanistic dynamic model of tree growth, timber production and wood quality operational at the stand scale.
21. A user-friendly version of the model available as a prototype decision support system.
22. Predictions of timber production accounting for tree quality across a representative range of sites and silvicultural regimes in participating, countries, also accounting for scenarios of future environmental change.
23. Predictions of environmental impact in terms of current and future forest stand composition and structure, its nutrient status and dynamics, and ecosystem carbon balance across a representative range of sites and silvicultural regimes in participating countries, also accounting for scenarios of future environmental change.

MILESTONES – Year 1

New integrated (empirical and process-based) model on tree growth, yield and wood quality at forest stand scale for a range of species, environmental conditions, management options, and also across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
VII.	Prototype mechanistic dynamic model at plot scale	Dec 03	Version 1. Dec 02 Version 2. May 03 Final version. Dec 03	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 2

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
VII.	Prototype mechanistic dynamic model at plot scale	Dec 03	Version 1. Dec 02 Version 2. May 03 Final version. Jan 04	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
VII.	Prototype mechanistic dynamic model at plot scale	Dec 03	Version 1. Dec 02 Version 2. May 03 Final version. Dec 04	P1	P2, P3, P4, P5, AP6, P7

MILESTONES – Extension period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
VII.	Prototype mechanistic dynamic model at plot scale	Dec 03	Version 1. Dec 02 Version 2. May 03 Final version. Feb 05	P1	P2, P3, P4, P5, AP6, P7

Key Changes to WP7 – Year 1

None

Key Changes to WP7 – Year 2

The major change to activities has been the re-focussing of personnel effort from other WP to developing the stand-scale quality model. This has had little or no impact on the achievement of deliverables from which staff effort has been diverted.

Key Changes to WP7 – Year 3

The final version is delayed due to problems with some late delivery of data, and that the model was initially developed in parallel with data collection, and so needs iterative data/improvements cycle to continue.

Key Changes to WP7 – Extended Period

none

The final model has reached the prototype stage, with initial validation carried out.

2.4.4.2. Energy Sub-Model

Objective. A carbon book-keeping model will be developed and will be integrated with the stand scale model (WP7) through the C outputs inherent to this model. Data on timber processing fossil fuel inputs will be collated and incorporated into the model, in the form of a database which informs the model. A series of forest management and wood processing scenarios will be developed and expressed in terms of activities and operations, using protocols defined for the energy budget sub-model. The integration of the sub-model into the prototype integrated model (WP9) will permit a cost:benefit analysis of forest management options to be evaluated in terms of fossil fuel energy inputs *versus* product out-turn, and GHG emissions *versus* carbon sequestration potential for the scenarios of interest.

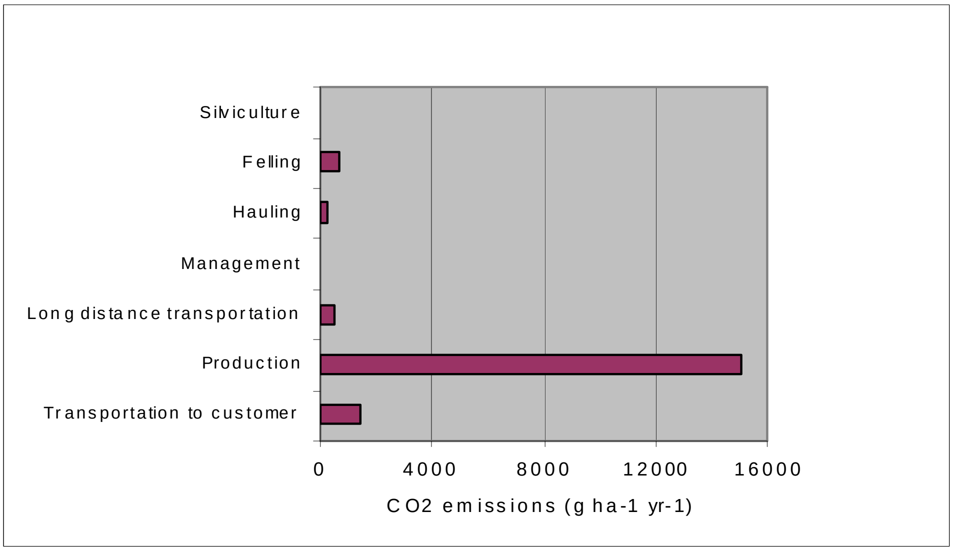
MAIN RESULTS – YEAR 1

Energy sub-model (WP8). As part of the development of the energy sub-model, a review of forestry working practises, wood processing methods and implicit fossil energy inputs was carried out. The review is provided at Appendix 1-I, and forms the basis for the development of the MEFYQUE energy budget sub-model. Currently an Excel version of the model is available and was used to test the modelling approach and the parameter values prior to its inclusion in the upscaling model later in the project. For the purpose of illustrating the energy budget sub-model, Figure ENE-1 outlines the results from a simulation of a case study of fossil carbon emissions from a Finnish Scots pine wood production and wood use chain, which assumes the following conditions:

General assumptions (“input data” sheet)	Chosen activities (“control” sheet)
Scots pine stand are located in Finland 200 m^3 of timber is harvested from 1 ha 68% of production comprises saw logs (of which 44 % pulp wood), 32% is pulp wood fresh weight of timber is 0.8 Mg m^{-3}, dry weight is 0.4 Mg m^{-3}, carbon content 50 % 10 forest management trips to the site, 20 km each transport distance of harvested timber to a mill is 100 km transport distance of wood products to customers is 1000 km	silviculture: scarification, tending of seedling stands (sheet “silvic”) manual felling using chainsaw (sheet “felling”) hauling using a forwarder (sheet “hauling”) transport of harvested timber to a mill using trucks (sheet “long dst transport”) production lines of harvested timber: sawmill and chemical pulp and paper (sheet “production”) transportation of wood products to customers using trucks (sheet “trans to cust”)

Simulations for this case study indicated that more than 80% of the total fossil carbon emissions resulted from the manufacturing processes associated with wood products.

Figure ENE-1. *Fossil CO_2 emissions from a typical Finnish wood production and wood use chain by activity as calculated using the prototype MEFYQUE energy budget sub-model.*



MAIN RESULTS – YEAR 2

The EFI energy sub-model. The EFI energy sub-model that was developed according to the review of forestry working practices and made available as a computer-based model in year 1 of the project has been incorporated into EFISCEN model and will be used for the upscaling work in this project (WP9). The sub-model is also ready for use in the stand-level integrated model developed in WP7.

A second energy sub-model (not originally foreseen by the Technical Annex) has been developed by BRE that simulates fossil fuel energy inputs and greenhouse gas (GHG) emissions versus carbon sequestration for forestry activities and timber processing. The model has been developed specifically for UK conditions.

The BRE Energy Sub-Model. The data presented here were gathered by studying the resource consumption and emission generation accruing to the first two stages (raw material extraction; forestry, and primary product manufacture; saw-milling) of a full life cycle for timber products. Two forest types (Sitka spruce and Corsican pine) were assessed over relevant harvesting periods in the UK. Timber processing was investigated by determining the inputs and outputs over 1 year for 15 sawmills (representing 70% of UK-grown sawn softwood timber production). The studies were performed using the methodology of Life Cycle Assessment (LCA) to generate impacts in kg of CO_2 equivalents and MJ of energy. The technique and the results obtained are set out in the following sections.

Methodology

An outline of the LCA process is given in box 1.

Box 1. Outline of LCA

Stage 1
Goal & Scope
Defines:
- purpose of study
- intended use
- product(s) defined
- functional basis for comparison chosen
- level of detail and quality

Stage 2
Inventory Analysis
Involves:
- Mapping processes that produce functional unit
- Gathering data on amounts of energy and raw materials used, plus emissions to air, land and water for each of the processes
- Converting data into environmental effects in an inventory table summed over the whole life cycle.

Stage 3
Impact Assessment
3 steps:
- *classification* - effects of resource use and emission generation are allocated to the relevant impact categories
- *characterisation* - contributions of different substances to each impact category are referenced to that of a specific substance (' *normalisation*' is an extension of this step and relates the level of impact recorded for the product in each category, for example, to the total amount of each problem occurring in the UK in one year)
- *valuation* - results for each impact category are weighted to indicate their relative importance

Many processes produce more than one output; consequently there is a need to decide how the environmental impacts generated by the process should be shared (allocated) between them. Both forestry and saw-milling produce more than one output, so allocation must be considered. The BRE approach is to avoid allocation wherever possible (by breaking down a process into sub-processes). However, allocation is often unavoidable and BRE has decided that the solution is to relate the amount of each product to its economic importance to the process:

product value / total process value

where product value = amount of product x unit price of product and total process value = sum of all process' product values.

So, for the forestry assessments, the total impacts were shared between saw logs and any thinnings, and for saw-milling between the sawn timber and the derivatives of bark, chips and dust. However, sequestered carbon was calculated solely by mass.

The Process Flow Diagrams below show the processes included in the assessment of forestry and saw-milling, as shown in Figures ENE-2, 3 below.

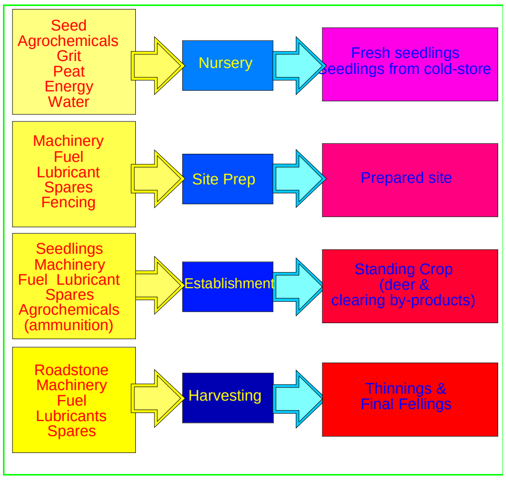


Figure ENE-2. *Forestry Process Flow Diagram*

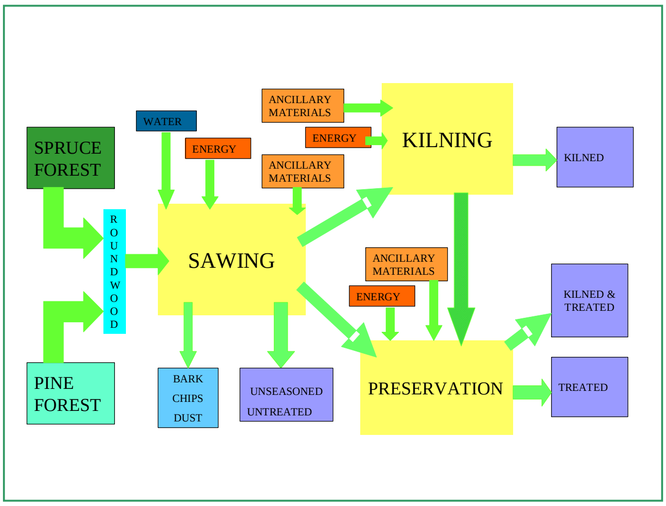


Figure ENE-3. *Sawmilling Process Flow Diagram*

Results

CO_2. The results presented below convert any GHG emissions to the equivalent amount of CO_2 needed to cause the same effect over a period of 100 years. Results are given for:

Forestry: for 1 green tonne of spruce or pine log at the forest roadside. The results show the CO_2 sequestered in the log (as a negative figure, since CO_2 has been removed from the atmosphere) and caused by forestry activities.

Saw-milling: for processing 1 m^3 of timber, separated into sawing, kilning and preservative treating (including transport from the forest to the mill and on-site processing).

For producing 1 m^3 of: sawn timber, kilned timber (including sawing), treated timber (including sawing), and kilned and treated timber (including sawing). These results take forward the amounts of CO_2 accrued in the forestry stage and represent the average species mix and log conversion rates used by the 15 mills studied.

The results presented in Table ENE-1 (for forestry) and Table ENE-2 (for timber processing) incorporate any GHG emissions (as CO_2 equivalents) caused by the extraction, processing and transport of any resource consumed during forestry and timber processing activities (e.g. any plastic banding used in the forest or in the mill will have caused the emission of GHGs during the extraction of the oil and its conversion into plastics and its transport to the forest or mill).

Table ENE-1. *CO_2 equivalents for forestry.*

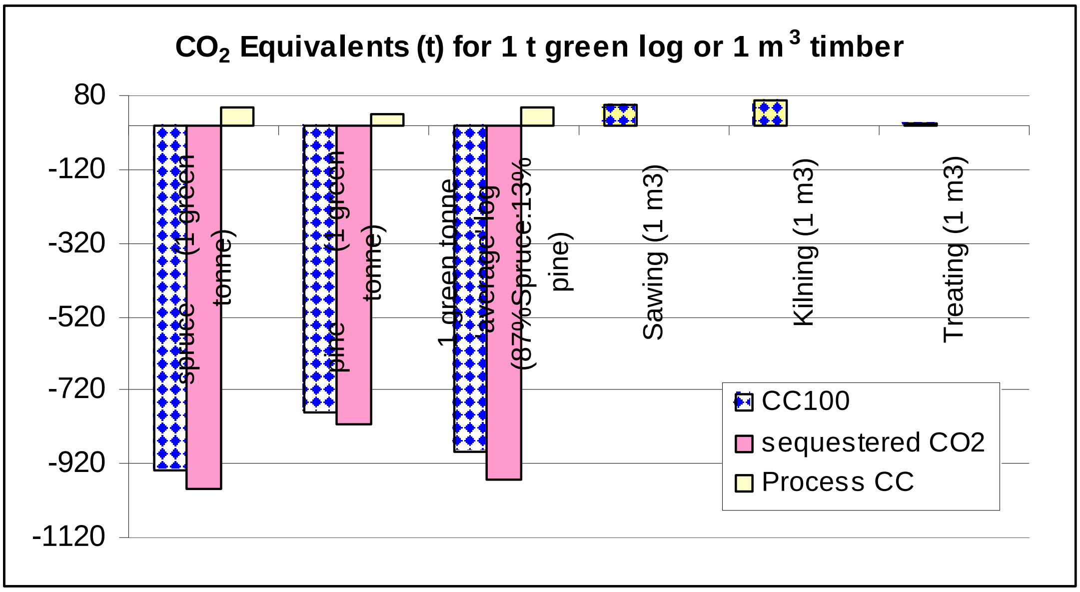
	Spruce(1 green tonne)	Pine (1 green tonne)
sequestered CO_2	-986.15	-812.84
Process CC	49.61	30.94
CC100	-936.5	-781.9

Table ENE-2. *CO_2 equivalents for timber processing.*

	1 green tonne 'average' log (87%Spruce:13%pine)	Sawing (1 m³) average	Sawing (1 m³) sd	1 m³ Sawn timber (414 kg m⁻³ @ 20%mc)	Kilning (1 m³) average	Kilning (1 m³) sd	1 m³ Sawn & Kilned	Treating (1 m³) average	Treating (1 m³) sd	1 m³ Sawn & Treated	1 m³ Sawn, Kilned & Treated
sequestered CO_2	-963.62										
Process CC	47.18										
CC100	-887.91	51.78	16.0	-836.1	65.64	52.8	-770.5	1.654269	0.88	-834.5	-768.8

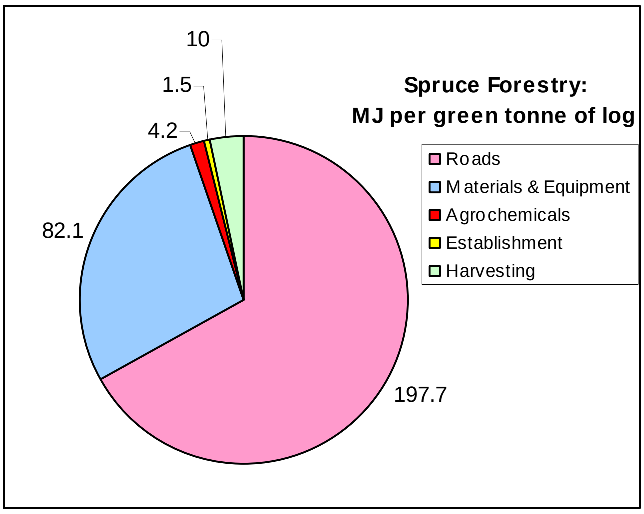
Figure ENE-4 presents the processing CO_2 equivalents for forestry and saw-milling.

Figure ENE-4. *CO_2 equivalents for forestry and saw-milling – blue & yellow diamonds for saw-milling indicates that for these values the CC100 and process CC are the same (where CC = Climate Change).*



Energy use. The energy used in the forestry activities needed to produce 1 green tonne of log and the energy used to saw, kiln or treat 1 m^3 of sawn softwood are presented in Figures ENE-5 and ENE-6 below.

Figure ENE-5. *MJ of energy required to carry out different forestry activities.*



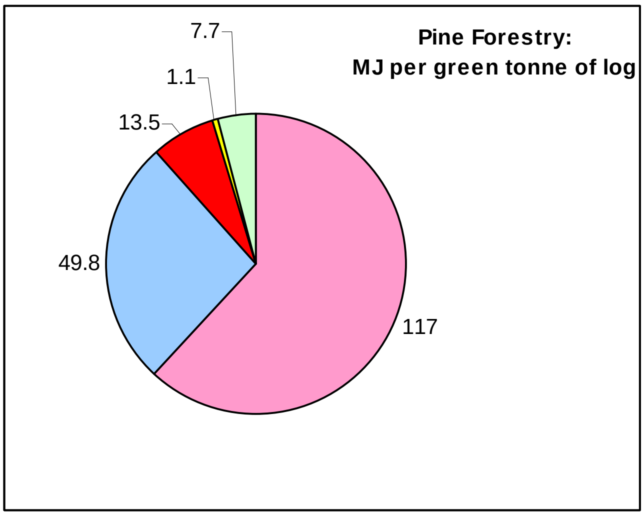
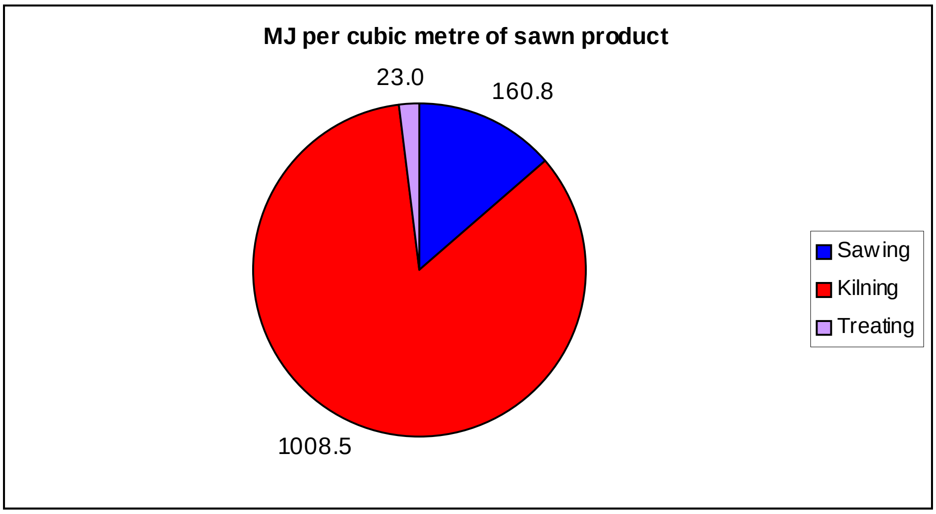


Figure ENE-6. *MJ of energy required to carry out different timber processing activities.*



These figures indicate that the construction and maintenance of forest roads are the largest source of energy consumption for forestry, and that kilning is the most energy demanding part of sawn timber production.

Wider environmental considerations. Whilst it is important to consider the amounts of both GHGs and energy use needed to achieve a product or purpose, it is also very important to look at the environmental impacts these emissions contribute to and to consider as wide a range of issues as possible. LCA has been developed to achieve exactly this.

The LCA approach has been developed to show how a product performs in 13 environmental impact categories relative to the impacts that each UK citizen causes in one year (this 'normalising' puts all impacts on the same scale and allows direct comparisons between the categories) – see box 2. The resulting environmental profile carries a lot of information about the impacts of a product and can be used to determine which parts of the process or life cycle contributed the greatest impacts and where improvements can be made. The profile can also be used to objectively compare different materials assessed using the method.

Box 2. BRE Environmental Profiles Methodology

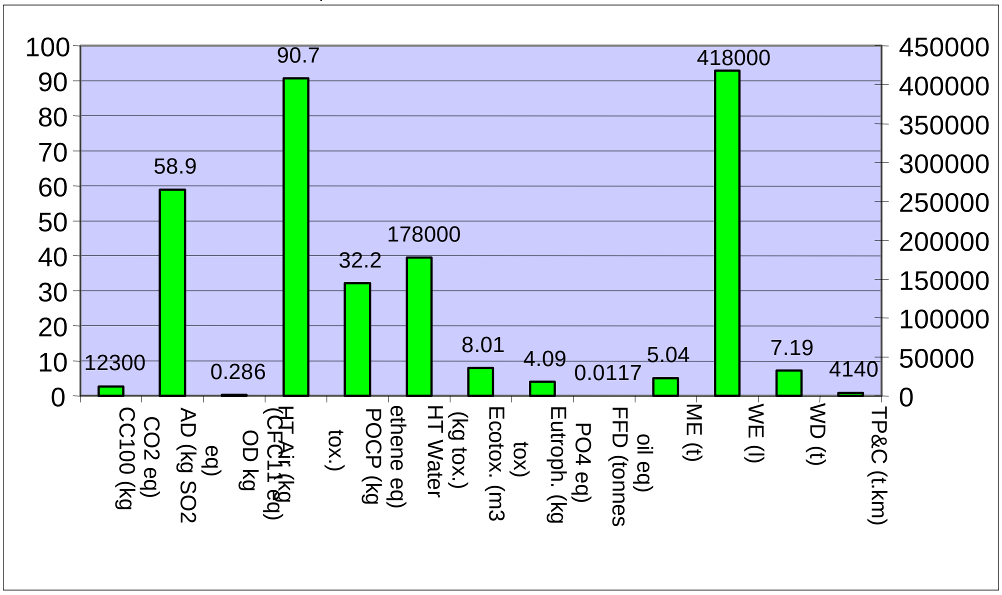
BRE developed a set of 13 impact categories to reflect the environmental burdens accruing to construction.

- Climate Change (100 years)
- Acid Deposition
- Ozone Depletion
- Human Toxicity to Air
- Low Level Ozone Creation
- Human Toxicity to Water
- Ecotoxicity
- Eutrophication
- Fossil Fuel Depletion
- Minerals Extraction
- Water Extraction
- Waste Disposal
- Transport Pollution & Congestion

Fuller details are given in the BRE Environmental Profiles Methodology document (Howard, Edwards & Anderson 1999).

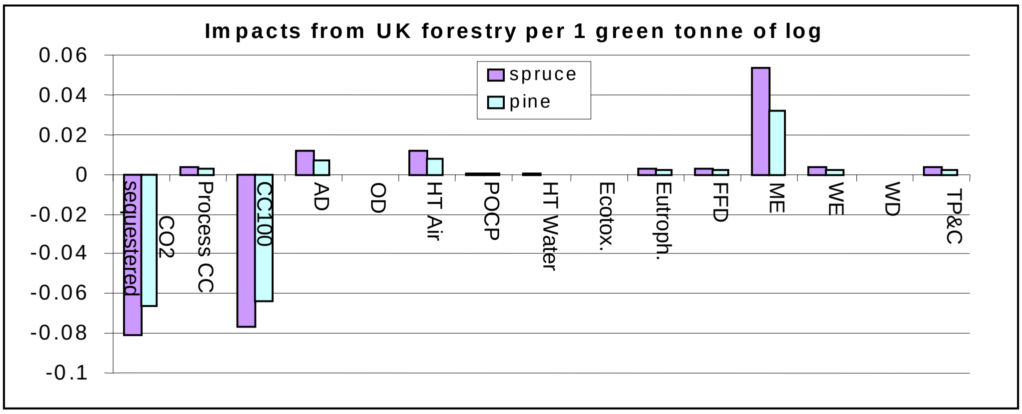
The chart below shows the annual impacts of 1 UK citizen in each of the 13 impact categories. These numbers are used to produce the normalised profiles.

Environmental Profile for the Annual Impacts of 1 UK Citizen



The normalised environmental profiles for 1 green tonne of spruce log and 1 green tonne of pine log are shown in Figure ENE-7.

Figure ENE-7. *Normalised environmental profiles for 1 green tonne of spruce and pine log.*

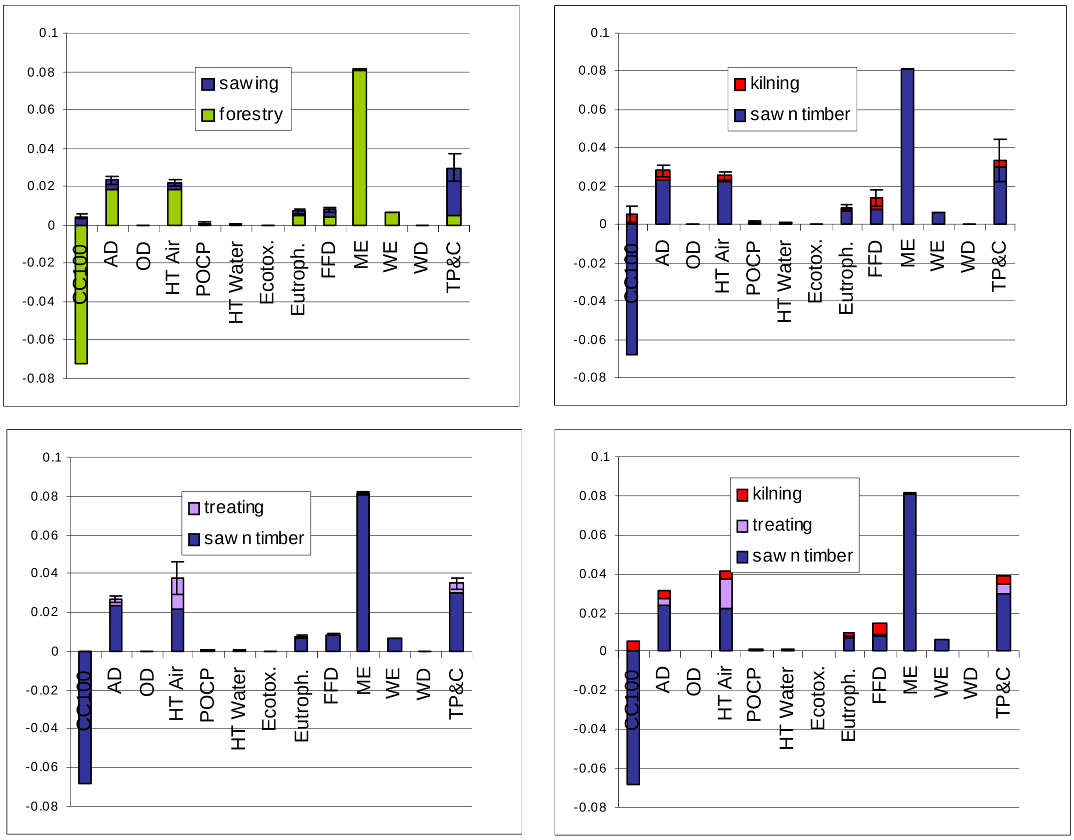


These results indicate that::

- Forestry actually caused negative (beneficial) climate change burdens because it takes up and fixes carbon dioxide (in 1998, the harvest from UK public estate forests locked up just over 2.1 million tonnes of carbon dioxide).
- Most forestry activities needed to produce 1 m^3 of log gave impacts that were less than 1% of those caused annually by 1 UK citizen.
- The construction and maintenance of forest roads proved to be the largest source of the impacts in most categories. This was as a result of energy and fuel consumption necessary to operate the heavy equipment involved and the mineral extraction required to obtain the roadstone.

Figure ENE-8. gives the profiles for 1 m^3 of the following timber products: sawn timber (showing the contribution of the forestry stage); kilned timber (including forestry and sawing); treated timber (including forestry and sawing), and kilned and treated timber (including forestry and sawing).

Figure ENE-8. *Normalised environmental profiles for 1 m^3 of sawn product (including forestry contribution via log input).*



The sawn timber profiles indicate that:

- The production of sawn timber requires little energy and fuel consumption. This resulted in the climate change impact remaining negative.
- The impacts of transportation were dominated by the delivery of roundwood to the mill.
- Kilning timber consumed energy and fuel, contributing to climate change but the net impact remained negative. Fuel and energy consumption also increased impacts in other areas such as human toxicity to air.
- Preservative treating timber did not consume much energy, so climate change remained negative. However, the production of the preservative resulted in mineral extraction and human toxicity to air dominating the treatment profile.

MAIN RESULTS – YEAR 3

All deliverables have been developed and made available during the 2nd project year. The sub-model is ready for use in the stand-level integrated model development in WP 7 and integrated to the EFISCEN model that will be used for the upscaling work in the project (WP 9).

MAIN RESULTS – Extended period

The deliverables of this work package have been previously completed

2.5.4.2.1 WP8: Development Of The Energy Budget Sub-Model

Work-package number:	8						
Start Date:	Planned Oct 01			Status: No change			
Completion Date:	Planned Feb 02			Completed Nov 03			
Current status	Completed						
Partners Responsible:	P3, P1, P7						
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	3(-2)		7				4(-1)
Year 1 – person-months employed	1		5				1
Year 2 – cumulative person-months employed	1		7				3
Year 3 – cumulative person-months employed	1		7				3
Total – including extension	1		7				3

Key changes
P1: 2 person-months reassigned from WP8 to WP7
P7: 1 person-month reassigned from WP8 to WP7

OBJECTIVES

A carbon book-keeping model will be developed and will be integrated with the stand scale model (WP7) through the C outputs inherent to this model. Data on timber processing fossil fuel inputs will be collated and incorporated into the model, in the form of a database that informs the model. A series of forest management and wood processing scenarios will be developed and expressed in terms of activities and operations, using protocols defined for the energy budget sub-model. The integration of the sub-model into the prototype integrated model (Work Package 9) will permit a cost:benefit analysis of forest management options to be evaluated in terms of fossil fuel energy inputs *versus* product out-turn, and GHG emissions *versus* carbon sequestration potential for the scenarios of interest.
The main objective will be to develop an energy budget sub-model. This will be achieved by:
8.1 Developing an energy and carbon book-keeping sub-model.
8.2 Integrating the sub-model with the prototype integrated model
8.3 Applying the prototype integrated model to scenarios of multi-objective and forest production management and timber pricing.

METHODOLOGY AND STUDY MATERIALS

Available and process-derived data on forestry working practices, timber and wood processing methods and fossil fuel energy inputs will be integrated with new data and plausible (hypothetical) descriptions of a representative range of silvicultural prescriptions including potential future scenarios accounting (for example) for constraints on harvesting and chemical use. These data will be incorporated into databases for use as input variables to the carbon and energy book-keeping models. Existing computer based models that account for energy inputs and outputs and GHG balances of bio-energy production systems will be extended to represent general timber and wood production processes. The models will be reprogrammed in object oriented languages (C++ or object oriented Fortran 90), and integrated with the stand and regional scale models described under Work Packages 7 and 9. The Delphi programming language will be used to provide a stand-alone interface to the sub-model.

DELIVERABLES

24. A review of forestry working practices, wood processing methods and implicit fossil energy inputs,
25. A computer-based model of fossil energy and carbon-based balances available as source code, or executable user-friendly interface.

26. Sub-model within the integrated model to evaluate impacts of environmental and silvicultural changes on fossil energy requirements and greenhouse gas balances of wood production processes.

MILESTONES – Year 1

Upgraded energy budget sub-model for integration with the forest patch scale model for cost:benefit analysis of forest management options to be evaluated in terms of fossil fuel energy inputs *versus* product out-turn, and GHG emissions *versus* carbon sequestration potential for the scenarios of interest for a range of species, environmental conditions, management options, and also across a range of plausible future scenarios of atmospheric composition change.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
IV.	Energy budget model	Feb 02	Feb 02	P3	P1, P7

MILESTONES – Year 2

A second energy sub-model has been developed that was not originally foreseen by the Technical Annex. The model has been developed to deal specifically with UK conditions. The new model will not be integrated into the EFI regional-scale model as part of the present project.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
IV.	Energy budget model	Feb 02	Nov 02	P3	P1, P7

MILESTONES – Year 3

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
IV.	Energy budget model	Feb 02	Nov 02	P3	P1, P7

MILESTONES – Extended Period

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
IV.	Energy budget model	Feb 02	Nov 02	P3	P1, P7

Key Changes to WP8 – Year 1

None.

Key Changes to WP8 – Year 2

None.

Key Changes to WP8 – Year 3

None

Key Changes to WP8 – Extended period

None

2.4.4.3 Upscaling

The objective is (a) to integrate the wood quality and tree growth model, developed under WP7 and (b) the energy budget model, developed under WP8, to inform, through model integration, an upscaling model operating at regional and national level. In turn, this model will forecast implications of environmental change and forest management on timber yield and quality, on economic return and productivity of wood products and carbon sequestration. State-of-the-art and future socio-economic scenarios placed in the public domain through EU-ECLAT 2 (ENV4-CT98-0734) project will be used to inform the input to the coupled model. For the sake of clarity, the integrated model in this project is understood to be the stand level model combined with energy and wood products models, developed in earlier WPs. The main objective will be to improve the existing upscaling model to apply it to the needs of this project.

MAIN RESULTS - YEAR 1

Upscaling: The year 1 schedule foresaw little activity in this work-package. Together with the growth and quality stand-scale model, the energy budget sub-energy model and the wood products module, forms the essential integrative additions to the improved version of the EFISCEN model. In turn, the upscaling EFISCEN model will be used later in the project to forecast implications of environmental change and forest management on timber yield and quality, on economic return and productivity of wood products and carbon sequestration. Details of the economic module to be developed by the project have yet to be decided.

MAIN RESULTS - YEAR 2

Model integration and upscaling: The stand scale model and a regional scale upscaling model are being compiled to develop a unified modelling tool that describes the forestry wood chain (Figure UPS-1 below) that will be applied to study effects of various factors (scenarios) on various forest variables (Figure UPS-2 below). These integrated models will be suitable for studying the effects of environmental change, forest management and socio-economics on timber quantity, timber quality, carbon sequestration, fossil carbon emissions and economic return.

Figure UPS-1. *Schematic view of forestry wood chain (green arrows = forest originating carbon, dashed black arrows = fossil carbon) and modelled using the age-volume matrices and the wood product module in EFISCEN. The age-volume matrices will be replaced by the outputs from the stand-scale simulation model.*

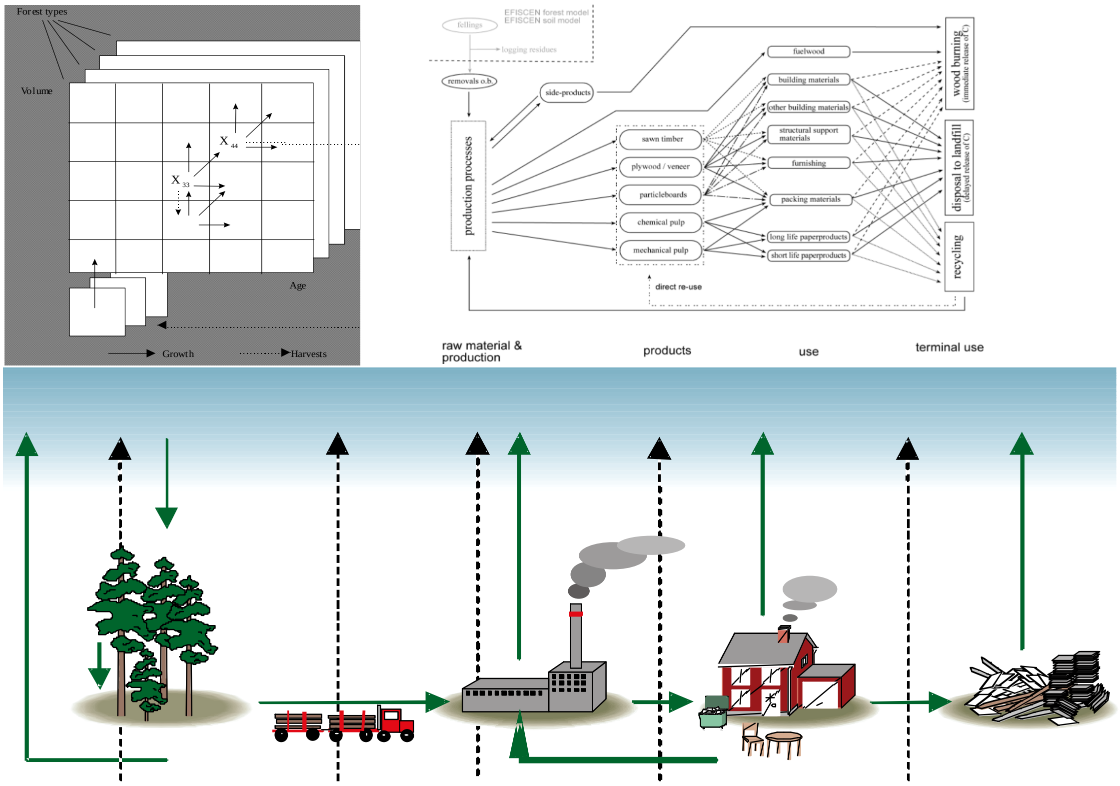
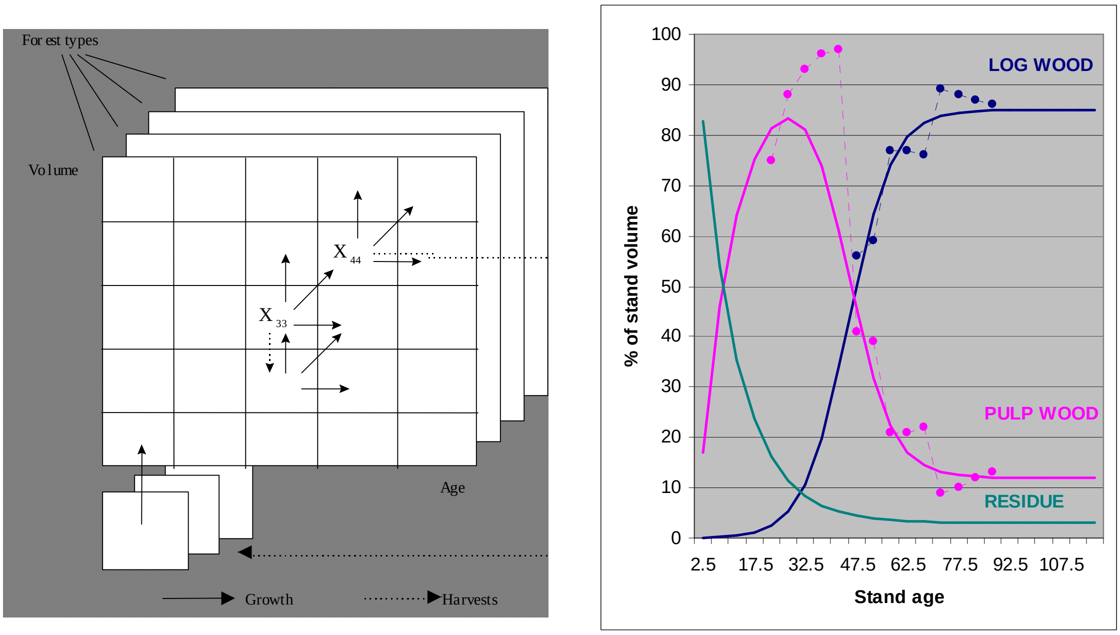


Figure UPS-2. *Preliminary example of using stand scale information on wood quality in EFISCEN upscaling model. The stand scale model will be used to calculate proportions of different quality classes as a function of stand age (graph on right) and volume (not shown the figure). These functions will be used to fill in these proportions in the cells of the age-volume matrixes of the upscaling model. Depending on what kind of stands in terms of age and volume are harvested, the harvested timber is distributed differently among the quality classes and thus divided differently into the production lines of the wood product module. This will affect the pools of products, fossil carbon emissions and economic return.*



Stand scale integration. In year 3 the tree growth and wood quality model (developed in WP7) will be combined with the energy budget sub-model (developed in WP8). In addition, the wood products module of the upscaling model will be made available and incorporated into the stand-scale model. This is possible, as the wood products module can be also applied at the stand scale.

Upscaling: The development of the upscaling model will consist of adding the energy budget submodel of WP8 to the upscaling model, accounting for the stand scale effects on wood quality and quantity, which are studied using the stand scale model of WP7, in the upscaling model.

The energy budget submodel developed in WP8 has already been added to the upscaling model EFISCEN. The upscaling model classifies forest according to stand age and volume (Fig. UPS-1). It keeps track of the development of forest area in these classes. Timber harvested and removed from forest is put into a wood product module. In this module, it is first divided into different production lines according to its quality. These production lines are different in terms of products manufactured, production efficiencies and the life cycles of the products including terminal use.

Timber quality will be accounted for in upscaling by using the stand scale forest model to calculate the proportions of different quality classes of the growing stock as a function of stand age and volume: % quality class of growing stock = f(stand age, volume) (Fig. UPS-2). In other words, the stand scale model is used to calculate the proportions of different quality classes in the cells of the matrixes of the upscaling model. Depending on what kind of stands in terms of age and volume are harvested, the harvested timber is distributed differently among the quality classes and thus divided differently into the production lines of the wood product module. This will affect the pools of products, fossil carbon emissions and economic return.

<u>Scenarios</u>. The environmental scenarios to be used will be the same as used and thoroughly analysed in another EU funded project ATEAM (www.pik-potsdam.de/ateam). The forest management scenarios will be developed based on the results of another EU funded project SilviStrat (www.efi.fi/projects/silvistrat).

MAIN RESULTS - YEAR 3

The general protocol for model integration and upscaling was done in year 2 of the project. Within this year the protocol was transferred into a modelling framework, which will enable the tasks given by. For this purpose a modelling workshop was organised at EFI headquarters in December 2003. During this workshop and in the following months the data exchange between the single modelling components was rendered more precisely. Figure 1 shows this framework set-up with the single modelling components and the flows of data from the stand-scale models to the upscaling model EFISCEN.
In context with the implementation of the upscaling modelling framework the EFISCEN European Forest Resource Database (EEFR) had been analysed on suitable tree species and regions for the stand-scale and upscaling modelling as well management comparability between the stand-scale and upscaling model.

The tasks for WP10 are ongoing and could not been completed as the integrated model for the stand scale (D 20) is not yet fully functioning with all its components. So far the work in WP 10 consisted of preparations for the model integration and upscaling (WP 9) including the evaluation and selection of environmental, socio-economic and management scenarios for the EU forestry and wood products sector (D 31, D 34). The environmental and socio-economic scenarios are combined in IPCC climate change scenarios. This data is based on the climatic scenarios derived for the ATEAM project (http://www.pik-potsdam.de/ateam). From the set of scenarios the two most extreme IPCC storylines (A1, B1) were selected for the HadCM3 and the PCM models. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

Data provided for the modelling of forest growth cover information on cloud cover [%], diurnal temperature range [°C], precipitation [mm], mean temperature [°C] and vapour pressure [hPa] for each of the points on a 10' x 10' grid resolution.

The information flow from the integrated stand-scale model to WP 9 and 10 consists of three main components:
information on growth alterations due to climate change,
log-grading data, and
parameters for the sawmilling industry section of the wood products model.

EFI will calculate a range of scenario simulations that cover a plausible range of potential implications of climate change on timber quality for the forestry-wood industry-chain; these scenarios will only be applicable to Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) for Southern Finland.
In respect of
i):

The vulnerability of European forestry to climate change has been assessed in the EU-funded project ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling). Findings from this project will be applied to assess impacts of climate change on tree growth for the selected species. The ATEAM project had used the Lund-Potsdam-Jena Dynamic Global Vegetation Model which is also a process-based model type working on the landscape level.

ii):

For the mentioned species detailed information is available of the common log-grading system for Finland. In Finland harvested trees are graded into two categories: logs for pulping purposes and logs for sawmilling. These statistics give information on percentages of pulp logs and saw logs for trees at a certain diameter at breast height (DBH) and total tree height. This data can be transformed into an age-dependent look-up table for the forest resource model EFISCEN and used to derive log grading for the harvested timber. Potential changes of timber quality due to climate change impact will be analysed with changes to the standard distribution of pulp and saw logs at a given stand age. An alteration of ± 10 and 20% compared to the original values should give an adequate coverage of potential future changes.

iii):

The integrated stand-scale model should provide also information on efficiency in the sawmilling sector as well as assortments produced from the processed logs. For the back-up solution the current practices of the Finnish sawmilling industry will be analysed and used to compile a parameter set, which represents the most important production lines. For the scenarios this parameter set will be changed within a plausible range to simulate timber property induced changes in the processing and further usage of the produced commodities.

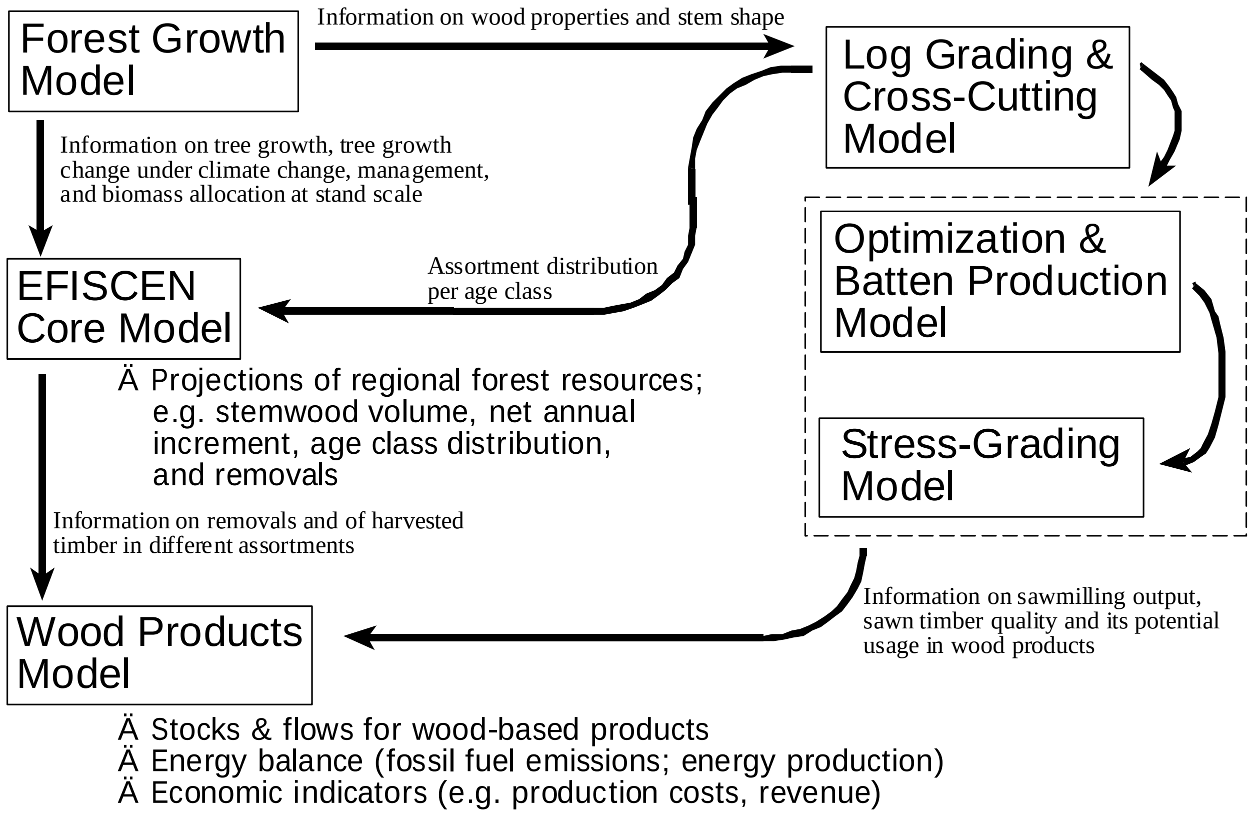


Figure UPS-3. *Modelling framework for the upscaling approach. Boxes represent stand-alone models or modelling components. The integrated stand-scale model consists of the forest growth model and the three sawmilling models (log grading & cross cutting, optimisation & batten production, and stress grading). The upscaling model has two components: the forest resource model EFISCEN and a wood products model coupled with it. The arrows indicate data flow from one modelling component to the other. Where applicable additional information was given on the data flows.*

MAIN RESULTS – Extended period

Climate change and management scenarios, were applied to the EFISCEN model. The table below shows an overview of the three emission scenarios applied in the study (Image Team 2001; Nakicenovic and Swart 2000).

Emission scenario	Keywords	Main assumptions
a1fi	Global economic	Fossil-fuel intensive; very rapid economic growth; fast increase in productivity and GDP; high consumption, very little environmental concern
a2	Regional economic	Focus on regional identity; emphasis on self-reliance in terms of resources; high energy and carbon intensity; high population growth; little environmental concern
b1	Global environmental	High economic growth; large preference for clean fuels; fast increase in productivity; high level of environmental consciousness; emphasis on global solutions to environmental and social sustainability

Wood demand scenarios

The current (2000) wood demand was scaled with demand projections from Image 2.2 (Image Team 2001) for each of the three emission scenarios. In the a1 scenario, wood demand increases strongly. Wood demand also increases in the a2 scenario, but to a smaller extent and more steadily than in a1. In b1, wood demand decreases. The table below shows the % deviation of removals when the EFISCEN model is applied to Finland for the various scenarios described above.

Scenario	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Current climate	98.6	98.2	97.9	97.7	97.5	97.3	97.1	96.8	96.5	96.6	97.1	97.6
Had-a1	98.6	98.2	97.9	97.5	97.1	96.7	96.1	95.4	94.6	94.5	95.2	95.9
Had-a2	98.6	98.2	97.9	97.7	97.5	97.4	97.3	97.3	97.2	97.5	98.1	98.6
Had-b1	98.6	98.2	97.9	97.6	97.2	96.9	96.5	96.0	95.4	95.3	95.9	96.6
PCM-a2	98.6	98.2	97.9	97.6	97.2	96.8	96.5	95.9	95.3	95.2	95.8	96.5

2.4.4.3.1 WP9: Protocol For Model Integration And Upscaling

Workpackage number:	9						
Start Date:	Planned Dec 02			Status: Delayed			
Completion Date:	Planned Jun 03			Dec 04			
Current status	Completed						
Partners Responsible:	P3, P1, P2, P5						
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	4	3	20		7(-2)		
Year 1 – person-months employed	0	0	0		0		
Year 2 – cumulative person-months employed	1	1	4		0		
Year 3 – cumulative person-months employed	2	2	15		3		
Total including extended period	4	3	20		5		

Key Changes to WP9 – Year 1
None.
Key Changes to WP9 – Year 2
None.
Key Changes to WP9 – Year 3
P5: 2 person-months reassigned from WP9 to WP7
Key Changes to WP9 – Extension
None

OBJECTIVES
The objective of this work package is (a) to integrate the wood quality and tree growth model, developed under work-package 7 and (b) the energy budget model, developed under work-package 8, to inform, through model integration, an upscaling model operating at regional and national level. In turn, the upscaling model will forecast implications of environmental change and forest management on timber yield and quality, on economic return and productivity of wood products and carbon sequestration. State-of-the-art and future socio-economic scenarios placed in the public domain through EU-ECLAT 2 (ENV4-CT98-0734) project will be used to inform the input to the coupled model. For the sake of clarity, the integrated model is understood in this project as the stand level model combined with energy and wood products models, developed in earlier WPs. The main objective will be to improve the existing upscaling model to apply it to the needs of this project. This will be achieved by:

9.1 To incorporate growth effects on timber quality as a function of environmental and management conditions into an existing up-scaling model based on empirical and simulation data developed by earlier work-packages.

9.2 To develop future scenarios of timber quality at regional level accounting for a range of forest management practices under changing climatic conditions.

METHODOLOGY AND STUDY MATERIALS

a. Overview.

This work package will allow further refining of the upscaling model and incorporation of a new quality sub-module for standing timber and basic structural and physico-chemical properties of processed wood products. Timber quality and changes in timber quality as a consequence of environmental and management change identified in WP7 will be scaled up to country level in this work package. The existence of the upscaling model and of broad, detailed and individually validated sub-modules, making up the forest stand model makes the realisation of the prototype integrated system an achievable task. The regional and national scale model of forest resources in Europe describes scenarios of forest state in terms of area distribution over age and volume classes. Dynamics of volume increment are expressed as transitions between volume and age classes within an area-based forest. Management practices such as thinning and final felling (harvesting), and regeneration can also be simulated in the model. Harvested timber is processed into wood products. Timber pricing is developed through integration between production costs and socio-economic and trade scenarios. This model can be run for a range of regions included in the forest inventory database. More recently, additional modules have been incorporated to account for whole tree biomass, thus allowing stemwood volumes to be converted to whole tree biomass by region, age class and tree species. Biomass can also be converted into equivalent carbon units. Carbon book-keeping allows calculation of forest and wood product carbon budgets. Plausible socio-economic scenarios will inform timber pricing under different management scenarios. The model is predisposed for further integration with the types of model outlined at WP8 to allow net annual increment, biomass allocation and litter production to be adjusted to changing atmospheric conditions. Different forest management scenarios can be applied to current and changing climatic conditions to: (a) provide predictions of future developments of forest stand structures, forest and wood products; (b) at work package 9 to allow carbon book-keeping to allow calculation of forest and wood products carbon budgets and follow harvested timber processed into products until such products are removed from use and oxidised; (c) translate changes in timber quality to stumpage prices paid at regional and national levels. The integrated model will allow a range of forest management to be applied to current and changing climatic conditions to provide predictions of the future development of forest structures, forest and wood product carbon stocks and fluxes, separately and concurrently for different regions of Europe.

b. Model integration.

Model integration between the stand model and EFISCEN will occur using a response surface of selected outputs developed by the integrated stand-scale model, provided from WP7. The energy budget sub-model developed in WP8 will be integrated into the large-scale scenario model as part of WP9. Details of the integration will be sorted out in collaboration with the leading partner of the relevant WPs. Modifications and new features to the existing large scale scenario model EFISCEN will be needed and these will be carried out as part of WP9.

c. Scenarios.

c1. Climate change scenarios. Results from a selection of climate change simulations performed by a number of climate modelling centres will be used, as made available through the public IPCC Data Distribution Centres network. These data extract results from transient, warm-start simulations which include both greenhouse gases only and greenhouse gas and sulphate aerosol forcings. Fields will be mean monthly changes on the 1961-1990 mean baseline climatology and also full monthly time series; daily data will be available in some cases from the respective modelling centres. The appropriate grid squares will be selected and temporally downscaled using the weather generator to be developed as part of WP5.

c2. Socio-economic and management scenarios. Socio-economic and management scenarios will take into account the extent of possible implications of changes in: stumpage prices (based on tree species, wood quality); forest management (felling levels, if for example certain tree species will be favoured etc.); products manufacturing (based on the wood quality and species, production of certain products may change). Implications are investigated in terms of future forest resources, carbon pools in trees, soil and wood products, emissions of fossil carbon from harvesting and manufacturing wood products and the use of other primary energy. Socio-economic aspects are considered in terms of mean net revenues of a land-owner (difference between annual stumpage returns and regeneration costs) and value of products sequestration in the forest sector, emissions from use of fossil energy, income for forest owner and value of products based on average (export) prices.

d. Modelling Effort.
Overall, the modelling effort is therefore significant, with work under this heading summarised as follows:

<u>Stand scale growth model</u>. The following steps are foreseen:
- Development of a single model from existing procedures available to the relevant consortium partners.
- Calibration and validation of the new stand scale for project sites using data from WP1 – WP3.

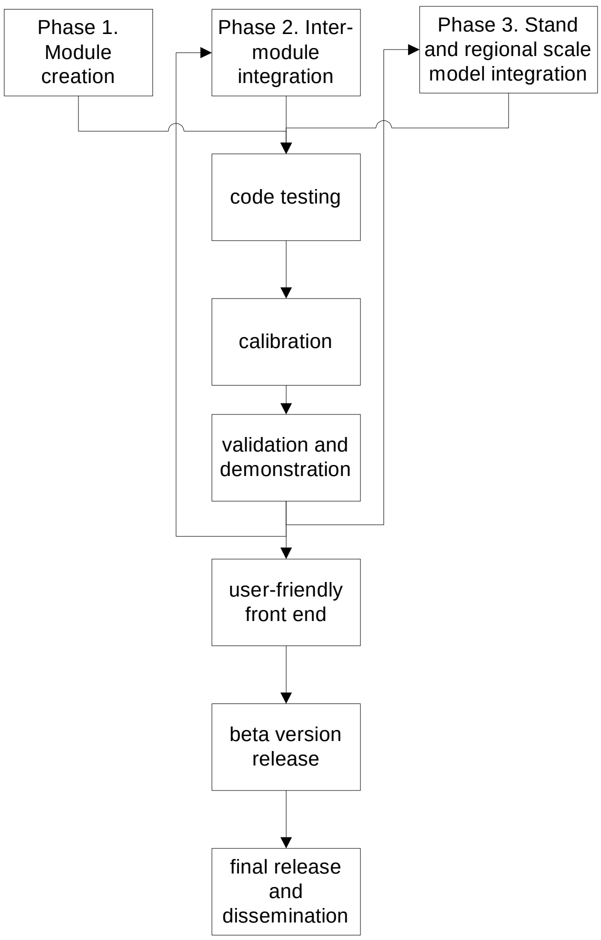
<u>Empirical-process based model of timber quality</u>. The following steps are foreseen:
- Adaptation of existing and appropriate models of cambial growth
- Incorporation into the stand scale model.
- Testing and validation of the model based on results of WP4 and WP5

<u>Wood products model</u>. The following steps are foreseen:
- Development of wood products model.
- Incorporation into the stand scale model.
- Testing against available literature data.

<u>Energy sub-model.</u>
- Development of energy sub-model.
- Incorporation into the stand scale model.
- Testing against available literature data.

<u>Model integration between the stand scale and regional scale models.</u>
- See section 2.3.4.2 and appendix 1-I for a description of EFICEN.

The proposed modelling procedure can be summarised as follows:



DELIVERABLES

27. Protocol for model integration and upscaling.
28. An integrated model and model output accounting for tree growth and production, wood quality, carbon sequestration, fossil energy and GHG balances and timber pricing operational at the scale of EU Member States.
29. Database integrated with the model of plausible future environmental socio-economic and management scenarios applicable to the EU forestry and wood products sector.
30. Validation of model outputs against empirical databases of processes observed in the monitoring and manipulative components.
31. A portfolio of plausible future environmental, socio-economic and management scenarios for the EU forestry and wood products sector.
32. A portfolio of model predictions for all variables listed in deliverable 28, produced by running the improved upscaling model using empirical data from earlier work-packages and simulation data from the stand-scale model as input.

MILESTONES – Year 1

Improved upscaling model modified to account for wood quality.
Agreed scenarios of environmental, socio-economic and management practice.
Integration and upscaling analyses at regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XIII.	Regional scale model	Apr 04	Apr 04	P3	P1, P2, P4, P7
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Year 2

Improved upscaling model modified to account for wood quality.
Agreed scenarios of environmental, socio-economic and management practice.
Integration and upscaling analyses at regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XIII.	Regional scale model	Apr 04	Apr 04	P3	P1, P2, P4, P7
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Year 3

Improved upscaling model modified to account for wood quality.
Agreed scenarios of environmental, socio-economic and management practice.
Integration and upscaling analyses at regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XIII.	Regional scale model	Apr 04	Apr 04	P3	P1, P2, P4, P7
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Extended Period
Improved upscaling model modified to account for wood quality.
Agreed scenarios of environmental, socio-economic and management practice.
Integration and upscaling analyses at regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XIII.	Regional scale model	Apr 04	Apr 04	P3	P1, P2, P4, P7
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

Key Changes to WP9 – Year 1
None.

Key Changes to WP9 – Year 2
None.

Key Changes to WP9 – Year 3
Prototype has been developed, awaiting completion of other models and simulations for integration.

Key Changes to WP9 – Extended Period
The delayed developement and validation of the stand and Optimiser programs means that the full pathway linking all models couldn't be achieved. Simulations were carried out using the EFISCEN model. Final outputs of the wood-chain model were made to closely match the requirements of the upscaling model in order to demonstrate the pathway.

2.5.4.3.2 WP10: Validation And Application Of Model Integration And Upscaling

Work-package number:	10						
Start Date:	Planned Jan 02			Status: Delayed			
Completion Date:	Planned Nov 03			Dec 04			
Current status	Completed. - Partial						
Partners Responsible:	P3, P1, P2, P5, P7			Status: No change			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	4	5(-3)	10		6		2
Year 1 – person-months employed	0	0	1		0		0
Year 2 – person-months employed	1	1	4		0		0
Year 3 – person-months employed	3	2	8		5		1
Total – including extended period	5	3	10		6		2

Key changes
P2: 3 person-months reassigned from WP10 to WP7

OBJECTIVES
The main objective will be to validate and apply the integrated and upscaling model. This will be achieved by:
10.1 Carrying out validation, sensitivity, uncertainty and robustness analyses to assess the predictive capability of models at a range of spatial and temporal scales.
In this project, the link between experimentation and the validation and application scales occurs at a range of scales, and is developed through nesting combinations of models and databases collected at a range of spatial and temporal resolution. This will be explored using demonstration areas at the regional scale within studied countries.
10.2 At the site scale, modelling components developed under WP8, will be assessed for current and future scenarios of atmospheric composition by simulating climate and management combinations at sites for which existing experimental data are available.
10.3 At the regional scale, assessing the predictive accuracy of the integrated model against available data for selected regions.

10.4 Application Scale. Quantifying the effects of changes in the scale of temporal and spatial inputs in order to assess the reliability of outputs for the region under study.

METHODOLOGY AND STUDY MATERIALS

Standardised graphical and quantitative indices and statistics will be used to describe and quantify model predictive ability.

A model tool will be incorporated into the integrated system to allow user-defined assessments where suitable empirical data are available.

Site scale. Data from the primary sites will be used in the model development and calibration, whilst flux data from the secondary sites will be used for short-term validation of the growth component of the model. New wood quality data collected through the monitoring and laboratory components will be adopted for model validation.

Regional scale. Available data such as forestry statistics, life cycle analysis, wood product inventories, will be used to validate the regional scale model. Whilst it is not possible to assess the predictive accuracy of projections under future scenarios, the adopted nested approach allows process-level changes observed at the manipulative sites to be encompassed at the coarser level of spatial resolution. In order to develop a range of future scenarios, outputs from a number of General Circulation Models will be used for model runs.

Application Scale. Assessing the quality of the integration process at a range of scales will be achieved through the validation process outlined above. Upscaling requires a quantification of the effects of changes in the scale of temporal and spatial inputs in order to assess the reliability of outputs for the region under study. There have been few rigorous studies of this scaling problem, in which simulated output data - obtained at different scales of resolution of the inputs - have been compared with measured data. There has been even less formalised research into the sensitivity of models and how this may change at scale changes. This will be achieved through a sensitivity analysis where the outputs of the upscaling model will be assessed across a range of outputs provided by the stand scale model. The working hypothesis is that appropriate outputs of site scale can reliably inform simulations at regional scale under current climate, as compared with geo-referenced inventory data.

DELIVERABLES

33. Standardised model assessment tools incorporated into the integrated model software to assess uncertainty in model predictions associated with output sensitivity to input parameters and scaling effects.
34. Portfolio of plausible future environmental socio-economic and management scenarios applicable to the forestry and wood products sectors in a selection of EU countries, with an associated uncertainty interval.
35. Portfolio of model predictions produced by running the above model using empirical data from earlier WPs and simulation data from the stand-scale model as input, with an associated uncertainty interval.

MILESTONES – Year 1

Predictive uncertainty associated with the improved upscaling model.
Uncertainty associated with scenarios of environmental and management practice.
Uncertainty associated with upscaling to the regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Year 2

Predictive uncertainty associated with the improved upscaling model.
Uncertainty associated with scenarios of environmental and management practice.
Uncertainty associated with upscaling to the regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Year 3
Predictive uncertainty associated with the improved upscaling model.
Uncertainty associated with scenarios of environmental and management practice.
Uncertainty associated with upscaling to the regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

MILESTONES – Extended Period
Predictive uncertainty associated with the improved upscaling model.
Uncertainty associated with scenarios of environmental and management practice.
Uncertainty associated with upscaling to the regional scale.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVIII.	Database of modelling scenarios	Jun 04	Jun 04	P3	P1, P2, P5

Key changes to WP10 – Year 1
None.

Key changes to WP10 – Year 2
None.

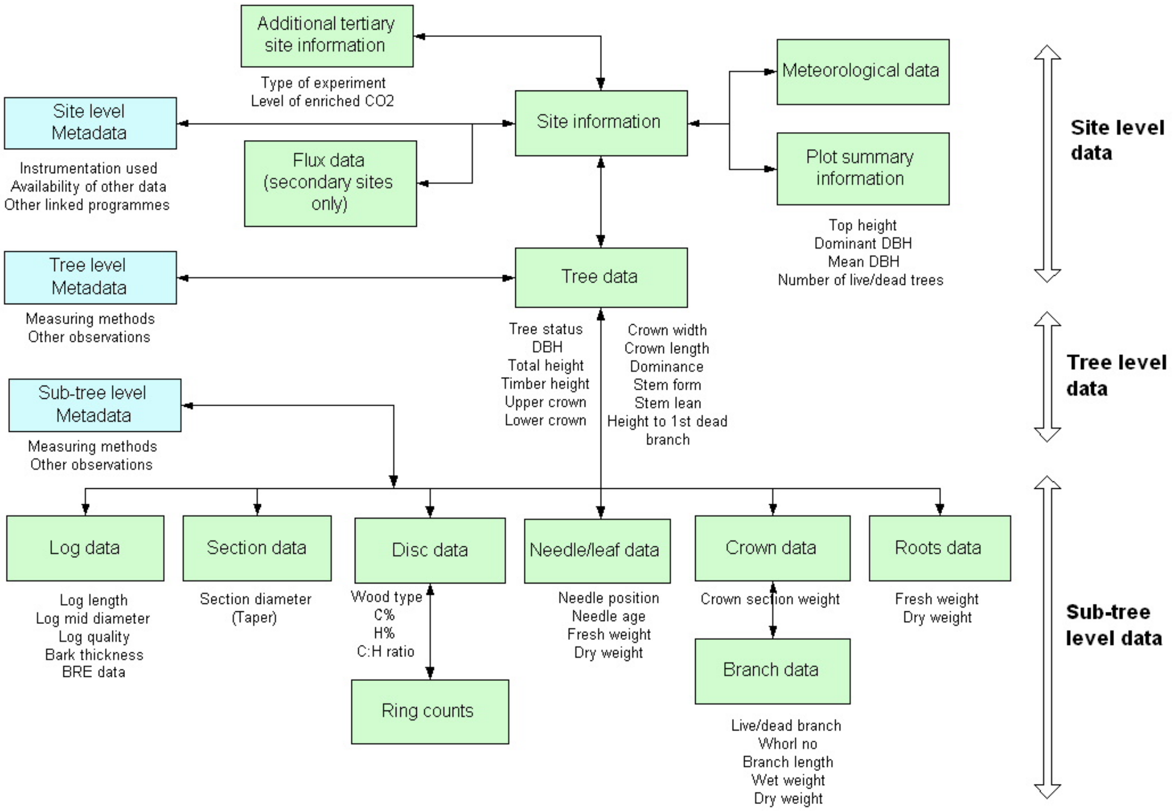
Key changes to WP10 – Year 3
As with WP9, completion of this deliverable has been delayed by the delay in stand and timber grading models. Preparation for this work has been done, with scenarios agreed and described.

Key changes to WP10 – Extended period
As with WP9, it was not possible to fully link and follow through impact scenarios from the growth model to the upscaling model, though common input/output formats were achieved.

2.5.4.4 Data Management

MAIN RESULTS – YEAR 1
The project database. Data gathered for the MEFYQUE project will be stored in a Microsoft™ ACCESS™ database; the structure of the database is provided at Figure DAT-1. The database design is broadly based around three levels of measurement: site, tree and sub-tree levels. At the site level, the SITE table contains information about the location, species and type of site (primary, secondary or tertiary). Linked to this and at the same level of resolution is specific information about tertiary sites (experiment design etc), meteorological information, secondary site flux data and plot level summary data.
The next level contains the TREE table, and stores information about individual trees selected for detailed measurement within each site. The table contains all those parameters relevant to a whole tree (e.g. DBH, height, stem quality), and is linked to all the sub-tree level measurements.
Each of the sub-tree components is stored in a separate table because of the different parameters and identifiers that are required for each part, and also because it is envisaged that much of the modelling and analysis effort will be organised by tissue type. However, sub-tree parameters data will be stored according to the tree from which they are derived, so a composite picture of all parts of any individual tree can easily be built.
Several meta-data tables explain all the codes and measurement types used in the project. These tables will occur at every level of the database, and will additionally be backed up by more detailed documents describing the methods used to extract the data and other relevant factors (e.g. history of the plot).

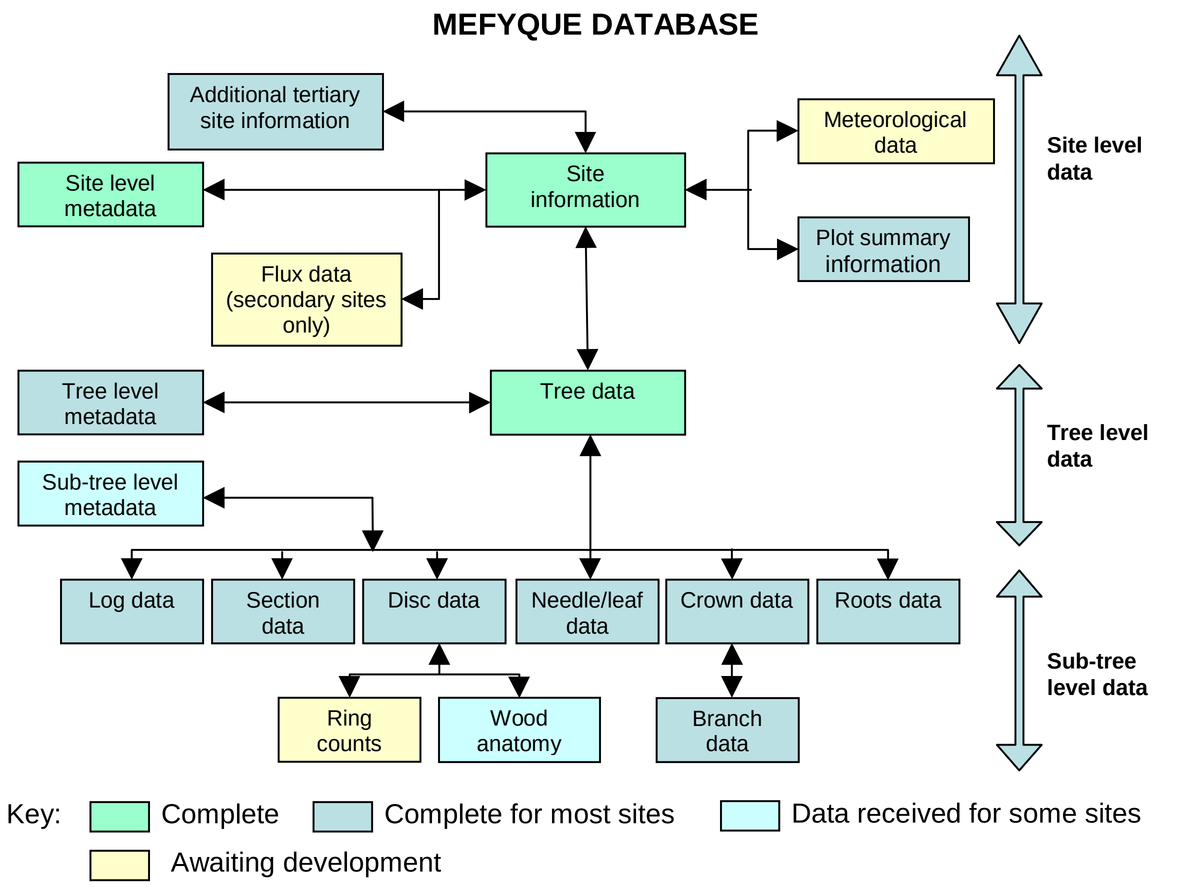
Figure DAT-1. *Proposed structure pf MEFYQUE database.*



MAIN RESULTS – YEAR 2

The project database (WP11). As an integral component of the modelling component, development of the project database has significantly progressed during year 2 of the project. Data are stored in a Microsoft™ ACCESS™ database. The database design is broadly based around three levels of measurement: site, tree and sub-tree levels. At the site level, the SITE table contains information about the location, species and type of site (primary, secondary or tertiary). Linked to this and at the same level of resolution is specific information about tertiary sites (experiment design etc), meteorological information, secondary site flux data and plot level summary data. The next level contains the TREE table, and stores information about individual trees selected for detailed measurement within each site. The table contains all those parameters relevant to a whole tree (e.g. DBH, height, stem quality), and is linked to all the SUB-TREE level measurements. Several meta-data tables explain all the codes and measurement types used in the project. These tables occur at every level of the database, and are backed up by more detailed documents describing the methods used to extract the data and other relevant factors (e.g. history of the plot).A significant portion of data from the project are now stored in the database, having been checked and formatted prior to loading. Site details and plot base measurements are now largely complete. Sub-tree measurements for those sites that have submitted data have also been loaded. Figure DAT-2 provides an overview of the project database and an indication of progress with data input.

Figure DAT-2. *Project database: data holdings and progress in data loading.*



MAIN RESULTS – YEAR 3

Data gathered for the MEFYQUE project is stored in a Microsoft™ ACCESS™ database, having been checked and formatted prior to loading. The main addition of data this year was from the Italian sites whose assessment had been previously delayed. In addition, tree ring data has been processed and added, and the C/N analyses were completed. The structure of the database has evolved to as the data is collected and analysed. Meteorological data is mostly already stored in organised databases so it was decided that only the metadata should be stored in the MEFYQUE database to save duplication of data and effort. Figure DAT-3 shows the updated state of data collection and entry into the database.

Figure DAT-3. *Project database: data holdings and progress in data loading.*

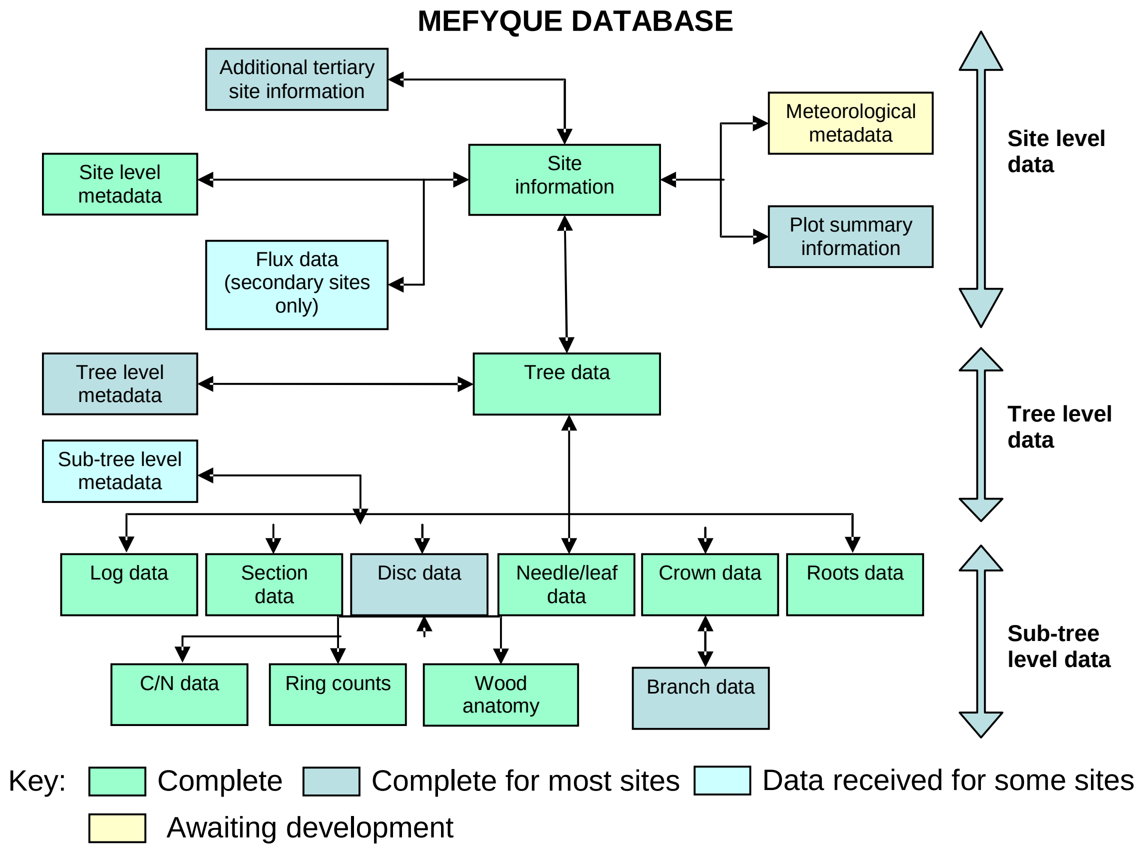


Table DAT-1 shows a summary of the number of trees measured at each primary site gathering mensurational data. Table DAT-2 indicates the progress in collecting and entering verified data into the database for the biomass and bio-chemical analysis samples.

Table DAT-1. *Primary sites. Number of trees measured for each mensuration parameter at the project sites*

Site	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08.1	FR08.2	FR10	IT01	IT02	IT03	IT04	TUB01	TUB02	UIA01
Stem form	6	7	0	0	6	9	2	6	4	9	72	70	75	85	102	175	88
Stem lean (scores)	6	8	0	0	6	9	3	6	4	9	0	0	0	0	102	175	0
Stem lean (measurements)	54	187	195	213	23	117	102	91	25	119	61	61	71	76	0	0	70
Dominance class	55	227	208	274	23	145	114	95	31	122	72	70	79	85	102	179	18
Dbh	72	242	213	283	29	154	117	103	35	150	72	70	78	85	102	176	88
Total height	17	18	19	19	16	39	19	18	18	39	27	43	44	51	62	41	88
Timber height	18	27	19	35	14	39	31	20	18	40	19	38	38	19	62	0	18
Height of 1st dead branch	4	8	7	9	3	9	9	8	4	9	8	11	32	16	0	0	0
Height of lower crown	6	18	19	19	15	10	19	18	14	19	19	38	39	19	62	41	8
Height of upper crown	1	18	19	19	12	19	19	18	14	19	19	38	39	19	62	41	8
Crown width	0	10	10	10	10	10	10	10	10	10	10	30	0	0	62	40	0

Table DAT-2. *Progress in the data collection of destructive biomass and biochemical samples*

Measurement type	FR01	FR02	FR03	FR04	FR05	FR06	FR07	FR08	FR10	IT01	IT02	IT03	IT04	UIA01	TUB01	TUB02
C/N data (bark)	ü		ü	ü	ü		ü	ü	ü					ü		ü
C/N data (branches)	ü	ü	ü	ü	ü	ü		ü	ü							ü
C/N data (cones)																ü
C/N data (heartwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (leaves)	ü				ü											
C/N data (needles)		ü	ü	ü		ü	ü	ü	ü							ü
C/N data (roots)	ü	ü	ü	ü		ü		ü	ü					ü		ü
C/N data (sapwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (transient zone)	ü				ü			ü	ü							
Green/dry weights (Branch)	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Green/dry weights (Disk)	ü	ü			ü	ü	ü	ü	ü							
Green/dry weights (Leaves)	ü				ü											
Green/dry weights (Needles)		ü	ü	ü		ü	ü	ü	ü							
Green/dry weights (Root)	ü	ü			ü		ü	ü	ü							
Tree bow												ü	ü			
Tree branch lengths	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Tree branch weights	ü		ü	ü	ü		ü		ü							
Tree crown width										ü	ü				ü	ü
Tree DBH	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree diameters (sections)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree dominance						ü	ü	ü		ü	ü	ü	ü	ü	ü	ü
Tree ht to 1st dead branch										ü	ü	ü	ü			
Tree logs	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree lower crown	ü	ü	ü	ü	ü		ü		ü	ü	ü	ü	ü	ü		
Tree ring data	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü				
Tree stem form	ü	ü			ü	ü		ü	ü	ü	ü	ü	ü		ü	ü
Tree stem lean measurements	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree stem lean scores	ü	ü			ü	ü	ü	ü	ü						ü	ü
Tree timber height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree total height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree upper crown	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		

MAIN RESULTS – Extended Period

Data has been collated and checked for errors before final entry to the database. The database contains 3 main types of data:

- Site parameters
  This includes location, plot size, species, ground vegetation, elevation, precipitation and soil type.
- Standing crop data
  These are basic mensurational parameters (height, diameter, upper/lower crown, crown width, tree lean) of the selected plot, plus more detailed measurements for the trees at each site that were felled. This includes taper and branch length/weights.
- Destructive data
  Logs were sawn into battens and these were subjected to a variety of stress tests including spring, twist, bow, MOE and MOR. Moisture content was logged. Green/dry weights were recorded for various tissue types. Discs were sent to Berlin for C/N analysis. Tree rings and wood anatomy were also measured.

The table below summarises the Measurement types stored in the database from the different sites.

Measurement type	**FR01**	**FR02**	**FR03**	**FR04**	**FR05**	**FR06**	**FR07**	**FR08**	**FR10**	**IT01**	**IT02**	**IT03**	**IT04**	**UIA01**	**TUB01**	**TUB02**
C/N data (bark)	ü		ü	ü	ü		ü	ü	ü					ü		ü
C/N data (branches)	ü	ü	ü	ü	ü	ü		ü	ü							ü
C/N data (cones)																ü
C/N data (heartwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (leaves)	ü				ü											
C/N data (needles)		ü	ü	ü		ü	ü	ü	ü							ü
C/N data (roots)	ü	ü	ü	ü		ü		ü	ü			ü		ü		ü
C/N data (sapwood)	ü	ü	ü	ü	ü	ü	ü	ü	ü					ü		ü
C/N data (transient zone)	ü				ü			ü	ü							
Green/dry weights (Branch)	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Green/dry weights (Disk)	ü	ü			ü	ü	ü	ü	ü							
Green/dry weights (Leaves)	ü				ü											
Green/dry weights (Needles)		ü	ü	ü		ü	ü	ü	ü							
Green/dry weights (Root)	ü	ü			ü		ü	ü	ü							
Log data - bark thickness	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü				
Log data - mid diameter	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü			
Log data - quality score	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Stress test - Bow		ü	ü			ü	ü	ü	ü			ü				
Stress test - MOE		ü	ü			ü	ü	ü	ü			ü				
Stress test - Moisture content		ü	ü			ü	ü	ü	ü			ü				
Stress test - MOR		ü	ü			ü	ü	ü	ü			ü				
Stress test - reaction load		ü	ü			ü	ü	ü	ü			ü				
Stress test - Spring		ü	ü			ü	ü	ü	ü			ü				
Stress test - Twist		ü	ü			ü	ü	ü	ü			ü				
Tree bow												ü	ü			
Tree branch lengths	ü	ü	ü	ü	ü	ü	ü	ü	ü							
Tree branch weights	ü		ü	ü	ü		ü		ü							
Tree crown width										ü	ü				ü	ü
Tree DBH	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree diameters (sections)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree dominance						ü	ü	ü		ü	ü	ü	ü	ü	ü	ü
Tree ht to 1st dead branch										ü	ü	ü	ü			
Tree lower crown	ü	ü	ü	ü	ü		ü		ü	ü	ü	ü	ü	ü		
Tree ring data	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü				
Tree stem form	ü	ü			ü	ü		ü	ü	ü	ü	ü	ü		ü	ü
Tree stem lean (measured)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree stem lean (scores)	ü	ü			ü	ü	ü	ü	ü						ü	ü
Tree timber height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Tree total height	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü
Tree upper crown	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü		
Wood anatomy parameters				ü										ü		

The database was designed in and created using Microsoft™ Access™. This was selected because of its simple, visual user interface and the fact that the program is readily available in most scientific and government organisations.

The database design is broadly based around three levels of measurement: site, tree and sub-tree levels. At the site level, the SITE INFORMATION table contains information about the location, species and type of site (primary/secondary). Linked to this and at the same level of resolution is specific information about tertiary sites (experiment design etc), and vegetation details.

The next level contains the TREE table, and stores information about individual trees selected for detailed measurement within each site. The table contains all those parameters relevant to a whole tree (e.g. DBH, height, stem quality).

The figures DAT-4 to DAT-7 summarise the relationships between measured variables in the database.

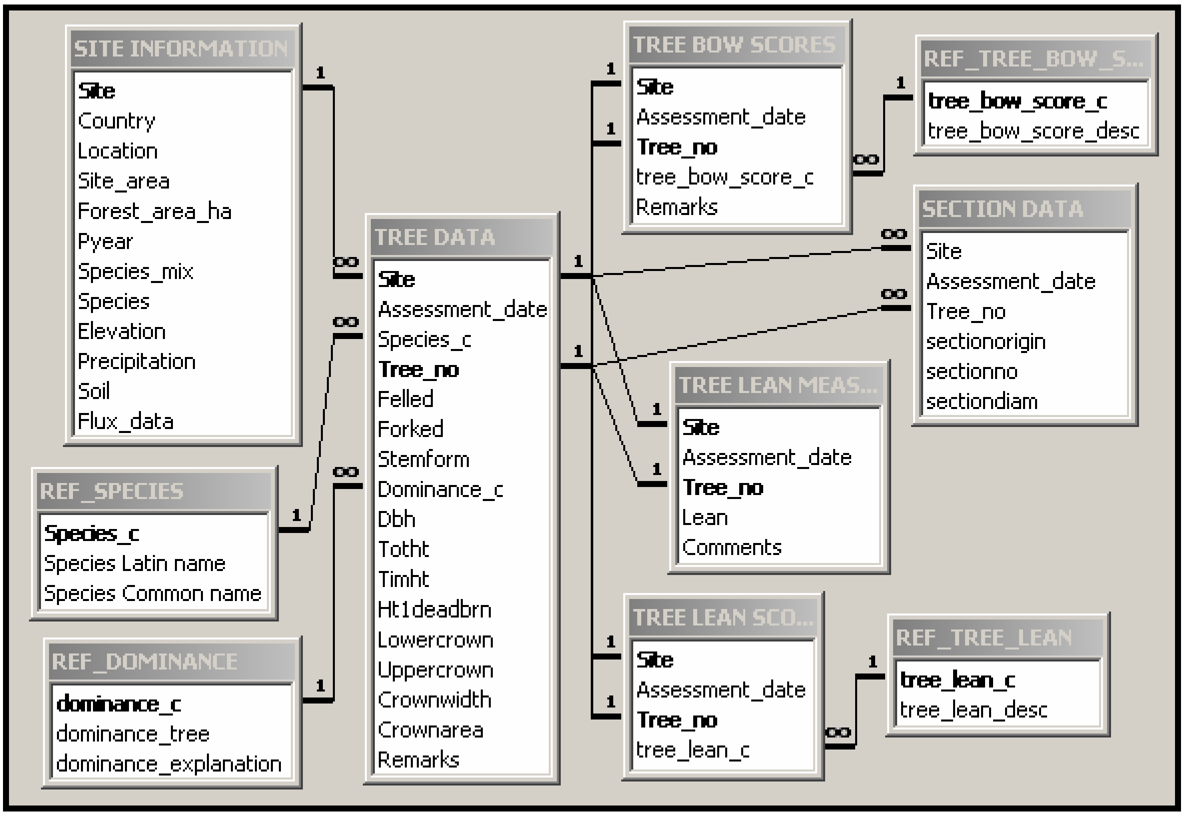


Figure DAT-4 SITE and TREE data and relationships

The sub-tree components are stored in separate tables because of the different parameters and identifiers that are required for each part. However, sub-tree parameters data are stored according to the tree from which they are derived, so a composite picture of all parts of any individual tree can easily be built.

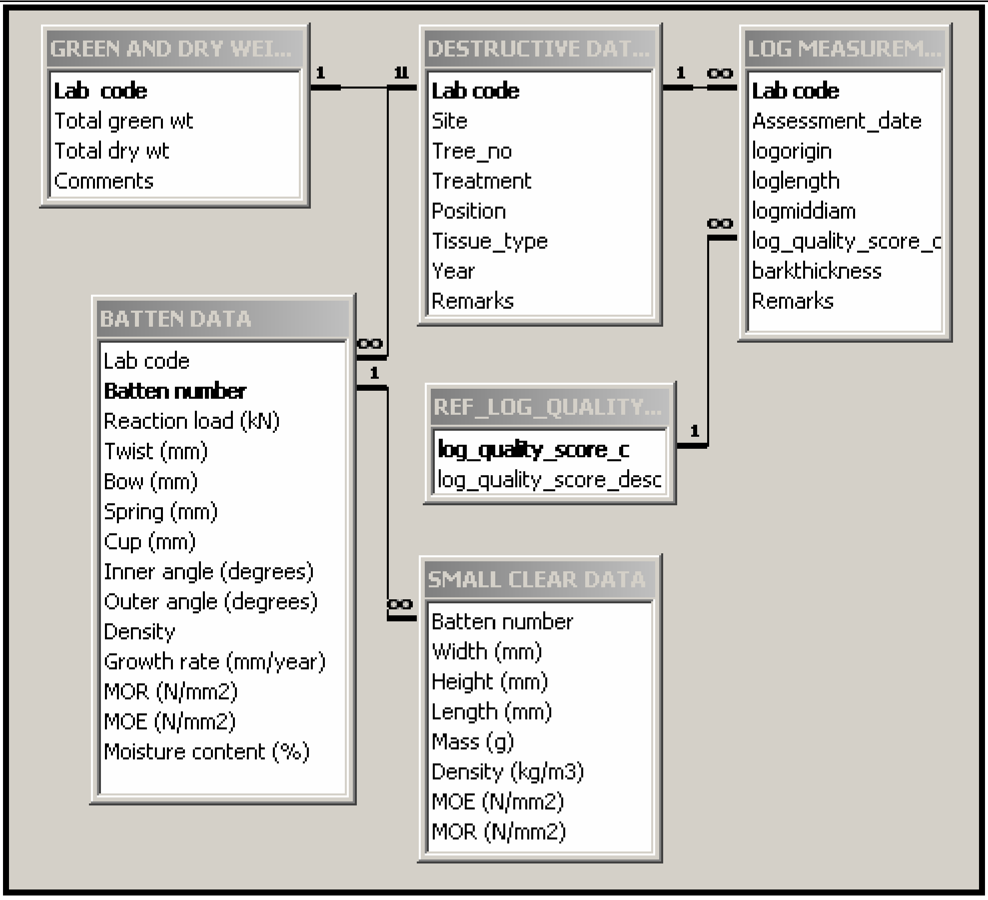


Figure DAT-5 Green/dry weights and log measurements

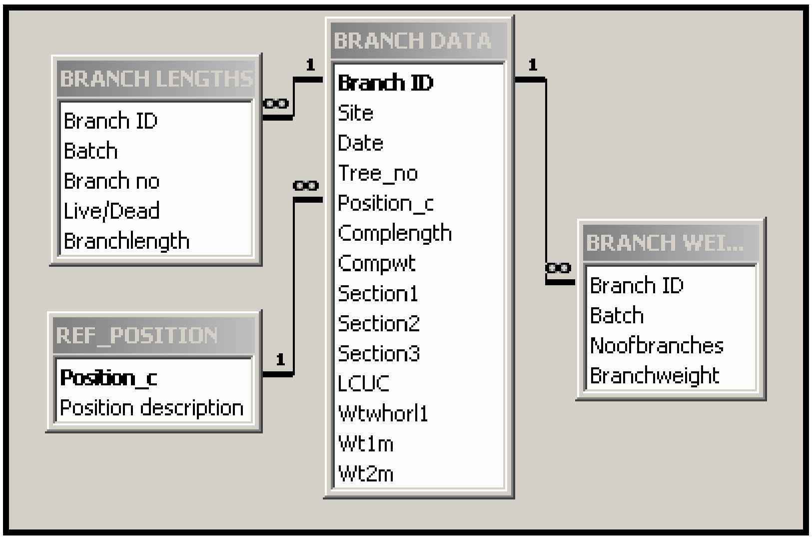


Figure DAT-6 Branch weights and lengths

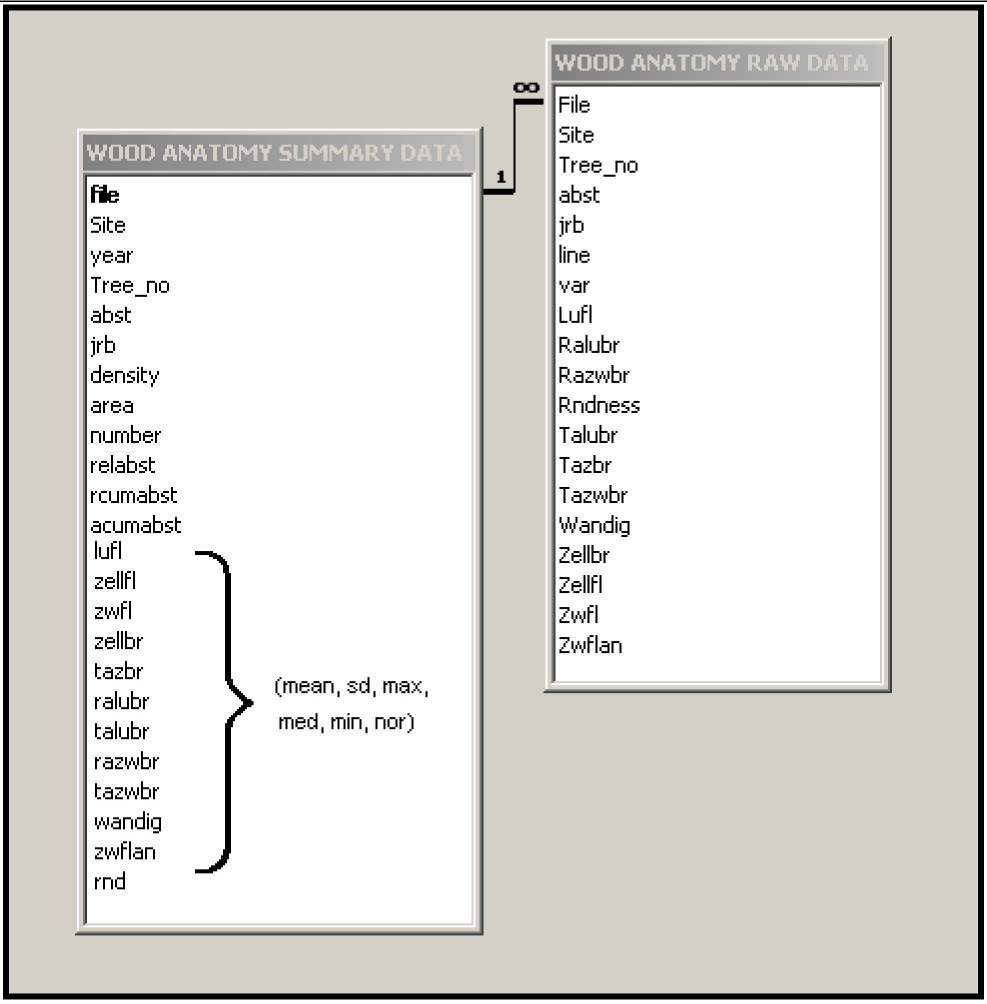


Figure DAT-7 Wood anatomy data

2.5.4.4.1 WP12: Management Tools

Work-package number:	12						
Start Date:	Planned Jun 01			Status: New WP			
Completion Date:	Planned Jun 03			Status: New WP			
Current status	Completed						
Partners Responsible:	P1			Status: No change			
Person-months per Partner	P1	P2	P3	P4	P5	AP6	P7
Technical Annex	3						
Year 1 – person-months employed	1						
Year 2 cumulative person-months employed	2						
Year 3 cumulative person-months employed	3						
Total – including extension period	7						

OBJECTIVES
Provision of project management systems required for successfully completing the MEFYQUE project.

DELIVERABLES

Project database design.
Project database.

MILESTONES
Project database version 1.
Project database version 2.
Project database final version.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVII	Project database	Jun 04	Jun 04	P1	

MILESTONES - Year 2
Project database version 2.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVII	Project database	Jun 04	Jun 04	P1	

MILESTONES - Year 3
Project database final version.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVII	Project database	Jun 04	Jun 04	P1	

MILESTONES - Extended period
Project database final version.

Milestone No	Title	Planned Delivery Date	Actual Delivery Date	Participants	
				Lead	Assoc.
XVII	Project database	Jun 04	Feb 05	P1	

Key Changes to WP11 – year 1
None.

Key Changes to WP11 – year 2
None

Key Changes to WP11 – year 3
None

Key Changes to WP11 - extended period
The database development and population was continuous throughout the project, though could only be finalised one all data had been received and checked.

2.6 DISCUSSION

Year 1

In this first year of the project he project has met its expected milestones and results. Only one project phase has been delayed due to external influences, unforeseen at the outset of this project.
Considerable progress has been achieved in the following areas:

- Development of harmonised protocols for field data collection at primary, secondary and tertiary sites.
- Establishment of 15 out of 17 primary sites.
- Continued data collection at secondary and tertiary sites.
- Wood anatomy and biochemistry data collection and analysis in laboratory conditions.
- Major developmental progress of the timber growth – wood quality model at the stand scale.
- Completion of the wood energy sub-model.
- Development of MEFYQUE database.
- Protocol for module integration with the upscaling EFISCEN model.
- Protocol for assessment of wood physico-mechanical properties.
- Two consortium meetings and a number of satellite meetings.
- Publications in peer reviewed journals.
- Project web site and brochure.

The unforeseen delay in progress for WP 6 (wood physico-mechanical properties) is expected to be rapidly resolved in the first 3 months of the project's second year.

Year 2

The project has largely met its expected milestones and results during its second year.

Two phases of the project continue to be delayed by external influences unforeseen at the outset of this project. The management action undertaken to rectify this issue has been considerable and headway has been made towards resolving outstanding deadlines. Partners whose progress is delayed are aware of the scale of effort required to rectify ongoing concerns over delivery, in line with the schedule of activities.

Considerable progress has been achieved in the following areas:

- Harmonised field data collection at primary, secondary and tertiary sites. At primary sites, data collection is largely completed at 15 out of 17 project sites. Data collection at the balance of sites was severely delayed by adverse weather conditions, and it is foreseen the programme will be complete by Oct 03.
- Continued data collection at secondary and tertiary sites.
- Wood anatomy and biochemistry data collection and analysis in laboratory conditions.
- Major developmental progress of the timber growth – wood quality model at the stand scale with release of version 2.
- Major developmental progress in the creation of a model reconstruction 3D log scanning images, including a module for optimised cutting of logs into battens as a function of shape.
- Completion of an additional wood energy sub-model, not originally foreseen by the Technical Annex.
- Continued development of MEFYQUE database.
- Initial module integration of the energy sub-model with the upscaling EFISCEN model.
- Two consortium meetings and a number of satellite meetings.
- Publications in peer reviewed journals.
- Updates to the project web site (scheduled for Sep 03 on completion of the 2nd Annual Report).

Year 3

Year 3 of the project has seen successes and difficulties. Progress has been made in the following areas:

- Near completion of the monitoring of primary, secondary and tertiary sites.

- Substantial analysis of both biochemical and anatomical properties of the wood samples taken.
- Development of preliminary scenarios
- Development of the various models along the chain
- Considerable development and population of the database.
- Publications in peer reviewed journals
- Participation at international conference (IUFRO, Vienna, may 2004)
- Preparation for the Wood chain conference, (Edinburgh 2004)
- Full consortium meetings and satellite meetings.

Difficulties have also arisen, largely with the validation and integration of the stand-scale and log models. Two primary factors have led to this phase of the modelling causing Delays

- Expert staff loss and long-term illness.
- Difficulties in combining programs written in different software.

The extension given by the commission will allow for the completion of the project, with

- All monitoring and analysis expected to be completed.
- A prototype growth-quality model
- A log-cutting model
- An energy carbon-budget model
- The scenarios and species and sites simulated will be limited.

Extended Period

The extension allowed the project to be completed in accordance with difficulties and limitations outlined in the sections above.

An international conference has held, in order to assist dissemination of the results (The Foresty Woodchain Conference, Edinburgh, September 2004).

Further papers have been submitted to scientific journals, and more will follow as researchers continue to work and publish from the basis developed during this project.

2.7 ACTION REQUESTED FROM THE COMMISSION

Year 1
Due to the delays imposed on progress in WP 6, Partner 8 is requesting that funds uncommitted in year 1 are carried over to year 2 in order to allow completion of activities foreseen in achieving targets for the physico-mechanical analysis of wood sampled at primary-tertiary sites.

This is a very important project component, as these data are of significant value to the wood processing industry, and provide the coupling between the research activities and those of major interest to the timber conversion industry.

Year 2
Following the plenary meeting held in June 03, the Consortium is requesting **extension of the project deadline of 6 months to December 2004 at nil additional cost.**

The request finds motivation given the following considerations:

- Due to unforeseen circumstances (adverse and severe weather conditions in the Alps and the Apennines) there has been a delay in the completion of data collection from 3 Italian primary sites. The delay in data availability affects the calibration and validation of the process-based stand growth and quality module that constitutes one of the principal deliverables of the project
- Due to unforeseen circumstances (collaboration with external organisations not in receipt of funding from the project), there has been delay in the execution of the physico-mechanical analyses of the project's Laboratory Component. The delay in data availability affects the calibration and validation of the process-based stand growth and quality module that constitutes one of the principal deliverables of the project.
- Under-estimation in forecasting the time required preparing samples for anatomical analyses of the project's Laboratory Component. The delay in data availability affects the calibration and validation of the process-based stand growth and quality module that constitutes one of the principal deliverables of the project.
- Development, calibration and validation of the stand scale process-based have taken longer than originally foreseen. While only a marginal delay has been incurred, the timetable of activities leading to model integration at the regional scale has been delayed. In turn, this affects the development and validation of the regional scale model describing the impacts on timber quality on the forestry wood chain that constitutes one of the principal deliverables of the project.
- Major efforts have been undertaken to maximise the overlap between 3 FP5 projects in the Forestry Wood Chain area, with the objective of achieving data and model sharing, and projecting major technology transfer to the stakeholder communities through a joint international conference to be held in autumn 2004. This process has been undertaken with full visibility and co-operation from the DG Research, specifically with the collaboration of the Scientific Officers managing the relevant FP5 projects. The planning process for the conference is now underway, and active discussions are taking place between the consortia to maximise data and mode sharing, in full respect of IPR requirements.
- The EU has delayed payment of Year 1 funds, not yet received at the time of drafting this report (Jul 03). Recent communications with the relevant EU Finance office (Jun 03) identified problems with the Year 1 cost statements. The relevant Partners have now addressed these concerns, although the outcome is not known at the time of drafting this report. This major delay on the availability of funds has had an increasingly negative impact on the ability of individual institutions (particularly Universities) to retain contract personnel employed on this project. This has exacerbated and compounded some of the delays already incurred through unforeseen circumstances.

It is the opinion of the Consortium that the above motivations constitute valid grounds for requesting prorogation of the project deadline, at nil cost to the European Commission. In particular the ability to complete the project deliverables by drawing on the new data and knowledge generated by 3 FP5 projects dealing with aspects of the forestry wood chain is seen as a major additional benefit resulting from a deferred deadline.
The planned international conference scheduled for Autumn 2003, co-organised by 3 FP5 projects dealing with aspects of the forestry wood chain offers the unique opportunity for projecting the results of a major European research effort in this arena of science to a number of stakeholder communities. Achieving this deliverable in the lifetime of the consortium is seen as constituting a major achievement of this project.

Year 3
None – Extension granted by the commission.

Extended Period
None – though final report delayed, due to staff involved with the project leaving on its conclusion, and long-term illness.

3 PROJECT MANAGEMENT AND PARTICIPANTS

The **MANAGEMENT COMPONENT** includes all those activities required to ensure the smooth progression of the project and include the following considerations.

Year 1

1. **Project staff**. The list of MEFYQUE principal scientists is provided at Appendix-A. A comprehensive list of project participants can be found on the project web site www.efi.fi/projects/mefyque. A number of undergraduates, post-graduates and post-doctoral fellows (not listed on the web pages) are also involved in MEFYQUE as follows:

- Dr. Xiao Chun-Wang. Visiting post-doctoral research fellow at the University of Antwerpen (B) involved NPP characterization, carbon allocation and allometric relationships in Scots pine at the experimental forest site.
- Begonia Yuste Sanchez (during the academic year 2001/02). Erasmus-Socrates exchange student at the University of Antwerpen (B) involved in collecting field data on the experimental forest site.
- Wendy Hendrickx. Graduate student at the at the University of Antwerpen (B) involved in collecting field data on the experimental site.
- Katrien Geudens. Thesis student (academic year 2002/03) at the University of Ghent (B).

2. **Consortium meetings**. Two full consortium meetings were held during the first year of MEFYQUE:

23-25 July 2001 at Forest Research, Alice Holt UK. The principal outputs from the meeting were as follows:

- Initial meeting of the consortium team and presentation of respective research activities.
- Agreement on the sampling strategies to be carried out at all MEFYQUE sites. This resulted in the production of the site sampling, wood anatomy, biochemical and wood technology protocols.
- Initial discussion concerning the modelling and data management strategies.

This meeting was also in part attended by Professor Barry Gardiner (Forest Research, UK) co-ordinator of the EU-COMPRESSION WOOD project. The aim was to extend the collaboration between the two projects through harmonisation of the respective sampling protocols and database management.

13-16 May 2002 at the Technical University of Berlin, Germany. The principal outputs from the meeting were as follows:

- Introduction of research assistants to the project consortium.
- Progress report on activities by each group in the consortium.
- Clarification on the sampling strategies and implementation of protocols to be carried out at all MEFYQUE sites.
- Structure of Annual Report.
- Scheduling of year 2 activities.
- The visit included field excursions to the Grünewald primary sites and the Berlin tertiary site.

3. **Satellite meetings**. A number of satellite meetings have also been held between individual partners to discuss particular aspects of the work schedule, as follows:

- July and December 2001. I.A. Janssens [University of Antwerpen (B)] visited the tertiary POPFACE site in Italy to collect experimental data on root respiration.
- 25 January, 21 February and 11 March 2002. Meetings at the Wood Technology Laboratory, University of Ghent (B) to agree on necessary input (from wood quality measurements) and output of the wood quality module (Reinhart Ceulemans, Gaby Deckmyn, Sam Evans, Tim Randle, Joris Van Acker and Lieven de Boever).
- 25 February –1 March 2002. Meeting at Forest Research, Alice Holt (UK) to agree model structure, modelling protocol and allocate module development between partners (Reinhart Ceulemans, Gaby Deckmyn, Sam Evans and Tim Randle).
- 2-15 March 2002. Visit by Carlo Calfapietra (University of Viterbo, Italy; POPFACE group) to UIA.

- 28 April 2002. Visit by Sam Evans (co-ordinator) to BRE (UK), to discuss with Keith Maun progress of activities in the 3D scanning and activities to measure the physico-mechanical properties of wood from primary – tertiary sites.
- 29 April 2002. Visit by Sam Evans (co-ordinator) to DG-Research in Brussels (B) with former EU Scientific Officer Dr Angelos Arabatzis to discuss project progress.
- 30 April 2002. Visit by Sam Evans (co-ordinator) to the Technical Univerisity of Berlin (D) to discuss with D. Overdieck progress of activities at German primary and tertiary sites as well as activities in the anatomy and biochemistry WPs.
- 17-19 July 2002. Meeting at University of Antwerpen (B) to review progress in the stand-scale model development and calibration (Reinhart Ceulemans, Gaby Deckmyn, Sam Evans and Tim Randle).
- 29 July – 2 August 2002. Visit by Luca Berichillo (PhD student, University of Viterbo) to Forest Research, Alice Holt (UK) in order to discuss phenology and flower/seed production modules of the stand-scale process model.

Year 2

1. **Project staff**. The list project participants is at Annex 1-A. And an updated list of project participants can be on the project web site www.efi.fi/projects/mefyque. A number of undergraduates, post-graduates and post-doctoral fellows (not listed on the web pages) continue to be involved in the project.

2. **Consortium meetings**. Two full consortium meetings were held during the second year of MEFYQUE:

25-28 November 2002 at University of Ghent, Belgium. The principal outputs from the meeting were:

- Presentation progress of respective research activities.
- Discussion of results and initial integration of project data into process-model development
- Management activity to resolve delays in WP 6.
- Planning of future activities and satellite meetings.

2-4 June 2003 at the University of Tuscia, Viterbo, Germany. The principal outputs from the meeting were as follows:

- Presentation progress of respective research activities.
- Discussion of results and initial integration of project data into process-model development
- Management activity to resolve delays in WPs 1 and 6.
- Planning of future activities and satellite meetings.

3. **Satellite meetings**. A number of satellite meetings have also been held between individual partners to discuss particular aspects of the work schedule, as follows:

- 17-19 July 2002. Meeting at University of Antwerpen (B) to review progress in the stand-scale model development and calibration (Reinhart Ceulemans, Gaby Deckmyn, Sam Evans and Tim Randle).
- 29 July – 2 August 2002. Visit by Luca Berichillo (PhD student, University of Viterbo) to Forest Research, Alice Holt (UK) order to discuss phenology and flower/seed production modules of the stand-scale process model.
- September 2002. One-week visit by Daniel Ziche (TUB) at BFH, Institute of Wood Biology, Hamburg (Germany).
- 4-7 October 2002. G Deckmyn (UIA) visit to FR.
- November 2002. One-week visit by Mrs. Karin Fenselau (TUB) at BFH, Institute of Wood Chemistry, Hamburg (Germany).
- November 2002. One-day visit by Dieter Overdieck (TUB) at BFH, Institute of Wood Chemistry, Hamburg (Germany).
- November-December 2002. Three-week visit by Daniel Ziche (TUB) visit to RUG.
- February 2003. One week visit by Lieven de Boever (RUG) to BRE.
- 24 February 2003. Sam Evans (FR) visit to BRE.
- 5 March 2003. Sam Evans liaison meeting with co-ordinators of FP5 project STRAIGHT (K Maun – BRE, UK).
- 30 April 2003. Sam Evans liaison meeting with co-ordinators of FP5 project STRAIGHT (K Maun – BRE, UK).

- 6-9 May 2003. T Randle (FR) visit to UIA.
- 1 Jul 2003. Sam Evans liaison meeting with co-ordinators of FP5 project STRAIGHT (K Maun – BRE, UK).

Year 3

1. **Project staff**. The list project participants is at Annex 1-A. And an updated list of project participants can be on the project web site www.efi.fi/projects/mefyque. A number of undergraduates, post-graduates and post-doctoral fellows (not listed on the web pages) continue to be involved in the project.

2. **Consortium meetings**. One full consortium meeting was held during the Third year of MEFYQUE, and one sub-group meeting (modelling) was held.:

21-23 January 2004 at European Forestry Institute, Joensuu, Finland. Sub- meeting to discuss modelling. The principal outputs from the meeting were:

- Presentation progress of respective research activities.
- Discussion of results and initial integration of project data into process-model development
- Management activity to resolve delays in WP 6.
- Planning of future activities and satellite meetings

27-28 May 2004 Hotel Aurora, Helsinki, Finland. (P1, P2, P3, P7) The principal outputs from the meeting were as follows:

- Presentation progress of respective research activities.
- Discussion of results and initial integration of project data into process-model development
- Management activity to resolve delays in WPs 1 and 6.
- Planning of future activities and satellite meetings.

2. **Satellite meetings**. A number of satellite meetings have also been held between individual partners to discuss particular aspects of the work schedule, as follows:

- 1 July 2003 Meeting at BRE, Watford, UK (P7) to discuss commonality with parallel project (Compression-wood). Representatives from P1 and P7.
- 17 March 2004 Meeting at BRE, Watford, UK (P7) to discuss data and modelling. Representatives from P1 and P7.
- 13 April 2004. Meeting at FR (Farnham UK) to discuss data and database. P1, P7
- 26-30 April 2004 Meeting at University of Antwerpen: Bruno deCiniti and Alberto to learn how to use the model and to parametrise for the Italian Collolongo site.

Extended Period

1. **Project staff**. The list project participants is at Annex 1-A. And an updated list of project participants can be on the project web site www.efi.fi/projects/mefyque. A number of undergraduates, post-graduates and post-doctoral fellows (not listed on the web pages) continue to be involved in the project.

2. **Consortium meetings**. One full consortium meeting was held during the extended period, aligned with the dates adjacent to the conference held in Edinburgh.

4

4. EXPLOITATION AND DISSEMINATION ACTIVITIES

Year 1

1. Project web site. The project web site pages has been established at www.efi.fi/projects/mefyque and provides an overview of the project and the Partners. Through the web site consortium partners can access the Forestry Commission secure web site that allows restricted access to secure web pages. Since November 2001 the site has received 857 visits (statistics are missing for the period December 2001 to February 2002), with the busiest month being March 2002.

2. EU showcase project. The ESN has produced a website for the European Commission's Key Action 5 *Quality of Life and Management of Living Resources* Programme of the Commission's Fifth Framework for research into sustainable agriculture, forestry, fisheries and rural development. The website will be called EU-AgriNET and contains all the policy and project information relevant to KA5 and will also address wider issues relating to this field of research. One important section will be called *Project Showcases*. The MEFYQUE project has been chosen for inclusion in the *Project Showcases* section, one of twelve projects selected from the extensive KA5 catalogue.
The web site is located at http://europa.eu.int/comm/dgs/research/index_en.html and goes live in September 2002. Details of the project can also be found on the European Commission web site at: http://europa.eu.int/comm/research/quality-of-life/ka5/en/00345.html.

3. Project brochure. A project brochure has been produced and distributed to the EU Scientific Officer and to all Partners, outlining key project objectives and activities. The brochure is being distributed to external organisations and can be downloaded from the project web site (at www.efi.fi/projects/mefyque).

4. Project publications. Relevant publications in international scientific journals (with peer review) published with co-funding from MEFYQUE are provided on the project web site (at www.efi.fi/projects/mefyque).

5. Other project activities.
- Prof. R. Ceulemans participated at the International Symposium on 'Forests at the Land-Atmosphere Interface' in Edinburgh, United Kingdom (17-19 September 2001). He was chairman of the Carbon Sequestration session at this symposium.
- Prof. R. Ceulemans, Dr. I.A. Janssens, Dr. Arnaud Carrara and J. Curiel Yuste participated in CarboEurope conference in Budapest (4-8 March 2002).
- G. Deckmyn presented a paper on forest modelling using the SECRETS model at the IUFRO workshop on modelling in Sessimbra (Portugal) (2-6 June 2002).

Year 2

1. **Project web site**. The project web site pages (www.efi.fi/projects/mefyque) will be updated in September 2003 with extracts from the Annual Report for Year 2.

2. **Project publications**.

a. Relevant publications in **international scientific journals** (with peer review) published with co-funding from MEFYQUE will be provided on the project web site (at www.efi.fi/projects/mefyque) and include the following:

Anselmi N., Mazzaglia A., Nasini M., Corvi R., Falessi T., Vannini A., Scarascia Mugnozza G., De Angelis P. & Sabatti M. 2003. Influenza dell'incremento della CO_2 atmosferica sugli attacchi di patogeni in piante forestali. *In: P. De Angelis, A. Macuz, G. Bucci & G. Scarascia Mugnozza – Società Italiana di Selvicoltura ed Ecologia Forestale (eds.), Atti SISEF* **3**: 363-367.

C.W. Xiao, J. Curiel Yuste, I. A. Janssens, P. Roskams, L. Nachtergale, A. Carrara, B.Y. Sanchez and R. Ceulemans (2003). *Above- and belowground biomass and net primary production in a 73-year-old Scots pine forest.* Tree Physiology. Vol. 23: 505-516.

Calfapietra C., De Angelis P., Kuzminsky E. & Scarascia-Mugnozza G. 2003. Impact of elevated CO_2 concentration on leaf development in *Populus nigra*, in A "Free Air CO_2 Enrichment" experiment.

In: P. De Angelis, A. Macuz, G. Bucci & G. Scarascia Mugnozza – Società Italiana di Selvicoltura ed Ecologia Forestale (eds.), Atti SISEF **3**: 357-362.

Calfapietra C., Gielen B., Galema A.N.J., Lukac M., De Angelis P., Moscatelli M.C., Ceulemans R., Scarascia-Mugnozza G. (2003). Free-air CO_2 enrichment (FACE) enhances biomass production in a short-rotation poplar plantation (POPFACE). *Tree Physiology* 23: 805-814

Cotrufo M.F., Anniciello M. & De Angelis P., (2003). Decomposizione della lettiera di foglie di pioppo in un 'mondo ad elevata CO_2': uno studio nell'ambito del progetto Europeo POPFACE. *In: P. De Angelis, A. Macuz, G. Bucci & G. Scarascia Mugnozza – Società Italiana di Selvicoltura ed Ecologia Forestale (eds.), Atti SISEF* **3**: 375-379.

Del Galdo I., Squeglia A., Cotrufo F., De Angelis P. 2003. C sequestration in afforested soils under elevated CO_2 concentration: preliminary results. *In: Proceedings of the first Italian IGBP Conference, Paestum (SA), November 2002.*

Gielen B., Liberloo M., Bogaert J., Calfapietra C., De Angelis P., Miglietta F., Scarascia-Mugnozza G., Ceulemans R. (2003). Three years of free-air CO_2 enrichment (POPFACE) only slightly affect profiles of light and leaf characteristics in closed canopies of *Populus. Global Change Biology* in press.

Hovenden M.J. (2003). Photosynthesis of coppicing poplar clones in a free-air CO_2 enrichment (FACE) experiment in a short-rotation forest. *Functional Plant Biology* 30(4): 391-400.

J. Curiel Yuste, I.A. Janssens, A. Carrara and R. Ceulemans (2003). Strong relation between deciduousness and annual Q10 of soil respiration in a mixed temperate forest. Revised version submitted to *Global Change Biology*.

J. Curiel Yuste, I.A. Janssens, A. Carrara and R. Ceulemans (2003). Temporal and spatial variability in the contribution of Soil Respiration to Total Ecosystem Respiration in a mixed temperate forest. Submitted to *Agricultural and Forest Meteorology*.

J. Curiel Yuste, I.A. Janssens, A. Carrara, L. Meiresonne and R. Ceulemans (2003). Interactive effects of temperature and precipitation on soil respiration in a temperate maritime pine forest. Accepted in *Tree Physiology*.

Lukac M., Calfapietra C. & Godbold D., (2003). Production, turnover and mycorrhizal colonization of root systems of three *Populus* species grown under elevated CO_2 (POPFACE). *Global Change Biology* **9**: 838-848.

Moscatelli MC., De Angelis P., Vilardo V., Larbi H., Grego S. & Scarascia Mugnozza G. (2003). Risposte microbiologiche ed ecofisiologiche del suolo in un pioppeto mutliclonale esposto ad un'elevata concentrazione di CO_2 atmosferica: risultati preliminari. *In: P. De Angelis, A. Macuz, G. Bucci & G. Scarascia Mugnozza – Società Italiana di Selvicoltura ed Ecologia Forestale (eds.), Atti SISEF* **3**: 369-374.

Overdieck D. (2002). Effects of elevated CO_2 concentration on stomatal conductance and respiration of beech leaves at darkness. *Botanical Congress* in Freiburg, Germany, Sept. 22-27, 2002. In press.

b. **<u>Conference presentations</u>.**

Curiel Yuste J. 3rd CARBOEUROPE Meeting "The continental carbon cycle". Lisbon, Portugal (19-21 March, 2003).

Curiel Yuste J. COST E21 4th whole action meeting. "Contribution of forests and forestry to the mitigation of greenhouse effects". Valencia, Spain (7-8 October 2002).

Deckmyn G. Oral presentation at the Society of Experimental Biology meeting. P7:'Carbon balance in forest biomes', Southampton, UK (1-4 April 2003).

Maun K et al. Workshop for Sawmillers, Edinburgh UK (May 2002).

Maun K. COST E13 and E15 meetings (2002-2003)

Overdieck D. et al. Poster presented at the Experimental Ecology Working Group of the Society of Ecology (German speaking countries), Stuttgart-Hohenheim (April 8-10, 2003).

c. **<u>Technical papers</u>.**

Maun K. The MEFYQUE project has been featured in the last 2 issues (Summer 2001 and Winter 2001/2002) of BRE's *'BEST UTILISATION: News of BRE-CTTC's work on UK Timber'*.

Year 3

1. **Project web site**. The project web site pages (www.efi.fi/projects/mefyque) will be updated in September 2003 with extracts from the Annual Report for Year 2.

2. **Project publications**.

a. Relevant publications in **international scientific journals** (with peer review) published with co-funding from MEFYQUE will be provided on the project web site (http://www.efi.fi/projects/mefyque/) and include the following:

Curiel Yuste J., I.A. Janssens, A. Carrara and R. Ceulemans 2004. The annual Q10 of soil respiration reflects plant phenological patterns as well as temperature sensitivity. Global Change Biology 10: 161-169.

1. Carrara A., I.A. Janssens, J. Curiel Yuste and R. Ceulemans. Seasonal changes in photosynthesis, respiration and NEE of a mixed temperate forest. *Agricultural and Forest Meteorology, in press*

1.
Curiel Yuste J., I.A. Janssens, A. Carrara and R. Ceulemans. Temporal and spatial variability in the contribution of Soil Respiration to Total Ecosystem Respiration in a mixed temperate forest. Accepted in Tree Physiology.

Curiel Yuste J., B. Konopka, K. Coenen, C. W. Xiao, I.A. Janssens and R. Ceulemans. Contrasting differences in NPP and Carbon distribution between neighboring stands of Quercus robur (L.) and Pinus sylvestris (L.). Accepted in *Tree Physiology*.

Curiel Yuste, J., I.A. Janssens and R. Ceulemans. Calibration and validation of an empirical approach to model soil CO_2 efflux in a deciduous forest. Accepted in Biogeochemistry (especial issue 'Recent Advances in Soil Respiration').

Deckmyn G., Ceulemans R., Rasse D., Sampson D.A., Garcia J. & Muys B. (2003) Modelling the carbon sequestration of a mixed, uneven-aged, managed forest using the process model SECRETS. In: Modelling Forest Systems (eds. A.Amaro, D.Reed and P.Soares) CAB international

Deckmyn G., I. Laureysens, J. Garcia, B. Muys and R. Ceulemans 2004. Poplar growth and yield in short rotation coppice: model simulations using the process model SECRETS. Biomass and Bioenergy 26: 221-227.

Deckmyn G., Muys B., Garcia Quiano J., Ceulemans R. (2004) Carbon sequestration following afforestation of agricultural soils: comparing oak/beech forest to short rotation poplar coppice combining a process and a carbon accounting model. *Global Change Biology* 10, 1482-1491.

1. Deckmyn G., S. P. Evans and T. J. Randle. Refined pipe theory for mechanistic modelling of wood development. Tree physiology, submitted

Hibbard K.H., B.E. Law. M. Reichstein and J. Sulzman, M. Aubinet, D. Baldocchi, C. Bernhofer, P. Bolstad, A. Bosc, J. L. Campbell, Y. Cheng, J. Curiel Yuste, P. Curtis, E. A. Davidson, D. Epron, A. Granier, T. Grünwald, D. Hollinger, I.A. Janssens, B. Longdoz, D. Loustau, J. Martin, R. Monson, W. Oechel, J. Pippen, R. Ryel, K. Savage, B. Schlesinger, L. Scott-Denton, J.-A. Subke, J. Tang, J. Tenhunen, V. Turcu, C. Vogel. *An Analysis of Soil Respiration Across Northern Hemisphere Temperate Ecosystems.* Accepted in *Biogeochemistry* (especial issue 'Recent Advances in Soil Respiration').

Ziche D. & Overdieck, D., 2004: CO_2 and temperature effects on growth, biomass production and stem wood anatomy of juvenile Scots pine (Pinus sylvestris L.). Journal of Applied Botany (in press).

b. **Conference presentations.**

Deckmyn, G, Evans, S. and Randle, T. Refined Pipe Theory for Mechanistic Modelling of Wood Development. IUFRO Vienna Conference April 2004.

Ziche, D., & Overdieck, D., 2003: CO_2 and temperature effects on biomass production and stem wood anatomy of Scots pine (*Pinus sylvestris* L.), 33. Annual conference of the Ecological Society (GFOE), Halle/Saale.

Ziche, D., Calfapietra, C., Overdieck, D., Scarascia-Mugnozza, G., 2004: Impact of CO_2 enrichment on fibre length of poplar in short rotation cultures, International symposium of wood science, Montepellier (abstract submitted).

Ziche, D., Evans, S., Deckmyn, G., Overdieck, D., 2004: Influence of tree dominance on wood anatomical properties of Scots pine, Meeting of the Central European Botanical Society, Braunschweig (abstract submitted).

c. **Technical papers.**

Maun K. The MEFYQUE project has been featured in the last 2 issues (Summer 2001 and Winter 2001/2002) of BRE's *'BEST UTILISATION: News of BRE-CTTC's work on UK Timber'*.

3. International Conference

As part of the consortium outputs an international conference is being organised: 'The Forestry Woodchain', to be held at Edinburgh Conference Centre, Heriot-Watt University, Edinburgh Scotland. 28-30 September 2004. Over 60 Submissions for Presentations have been made from within the consortium and from other international scientific organisations.

Extended Period

1. **Project web site.**

The project web-site (www.efi.fi/projects/mefyque) has been updated at periodic intervals. It will have a final update identifying result highlights, when the final project report has been accepted.

2. Project Publications

a. Relevant publications in international scientific journals include:

Curiel Yuste, J., Konopka, B., Coenen, K., C. W. Xiao, Janssens, I.A. and Ceulemans, R. Contrasting differences in NPP and Carbon distribution between neighbouring stands of *Quercus robur* (L.) and *Pinus sylvestris* (L.). Accepted in *Tree Physiology*.

Curiel Yuste, J., Nagy, M., Janssens, I.A., Carrara, A. and Ceulemans, R. Soil respiration in a mixed temperate forest and its contribution to total ecosystem respiration. Accepted in *Tree physiology*

Deckmyn, G., Evans, S. P. and Randle, T.J. Refined pipe theory for mechanistic modelling of wood development. *Tree physiology*, submitted

Overdieck, D. (2004): Effects of elevated CO_2 concentration on stomatal conductance and respiration of beech leaves in darkness. In: Forests at the Land-Atmosphere Interface, eds M. Mencuccini, J. Grace, J. Moncrieff, and K.G. McNaughton. CABI Publishing, Wallingford, UK, 29-35.

OverDieck, D., Ziche, D., Böttcher-Jungclaus, K. Impact of elevated CO2 Concentration and temperature increase on growth and the vessel/parenchyma content in stem wood of juvenile European beech. Submitted, Tree Physiology

b. Conference presentations

De Angelis, P., Forests Under Changing Climate, Enhanced UV And Air Pollution (IUFRO), Oulu, Finland

Calfpietra, C., Forests Under Changing Climate, Enhanced UV And Air Pollution (IUFRO), Oulu, Finland

Several oral and poster presentations at the projects' international conference.

c. Technical Papers

Evans, S., Randle, T., Henshall, P., Arcangeli, C., Pellenq, J., Lafont, S. and Vials, C. Recent Advances in the mechanistic modelling of forest stand and catchments. In: *Forest Research Annual Report and Accounts 2003-2004.* 98-111, The Stationery Office, Edinburgh, UK.

3. International Conference

An international conference was held at 28-30 September 2004 at Heriot-Watt University, Edinburgh. *The Forestry Woodchain* Conference attracted over 120 international participants, primarily from Europe, but with also from further afield (eg Canada, New Zealand). Approximately 30 oral presentations were made, together with 50 poster presentations in addition.

The conference was primarily a result of presenting results from 3 EU projects, working on various aspects of the wood chain. (MEFYQUE, COMPRESSION WOOD (QLK5-2000-001) and, STRAIGHT (QLK5-2000-00276).