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Research opportunities in wood science as part of the international framework of forestry, wood industry and nature conservation

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GHENT UNIVERSITY - Belgium

UGent WOODLAB

Premières journées scientifiques du
GDR 3544 “Sciences du Bois”
Montpellier , France – 26-28 November 2012

UGCT Centre for X-ray Tomography

Forestry

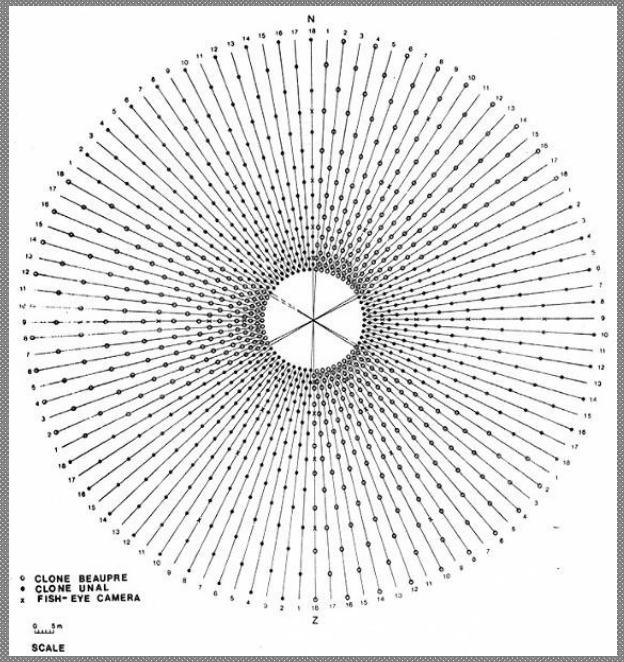
WHAT ARE THE NEW OPTIONS TO SUPPLY WOOD?

Forestry or/and agriculture

Legal frame – Agroforestry – Biomass production – Planted forest

WHAT ARE THE NEW OPTIONS ?

Need for more lignocellulosic material in general initiates renewed interest in plantations



Centrum voor de studie van de Biomassa (1982)

IR areal picture -BELFOTOP (1976)

Demographic pressure: focus on wood production on ‘arable land’… China / India

WHAT ARE THE NEW OPTIONS ?

Quality trees and quality wood?

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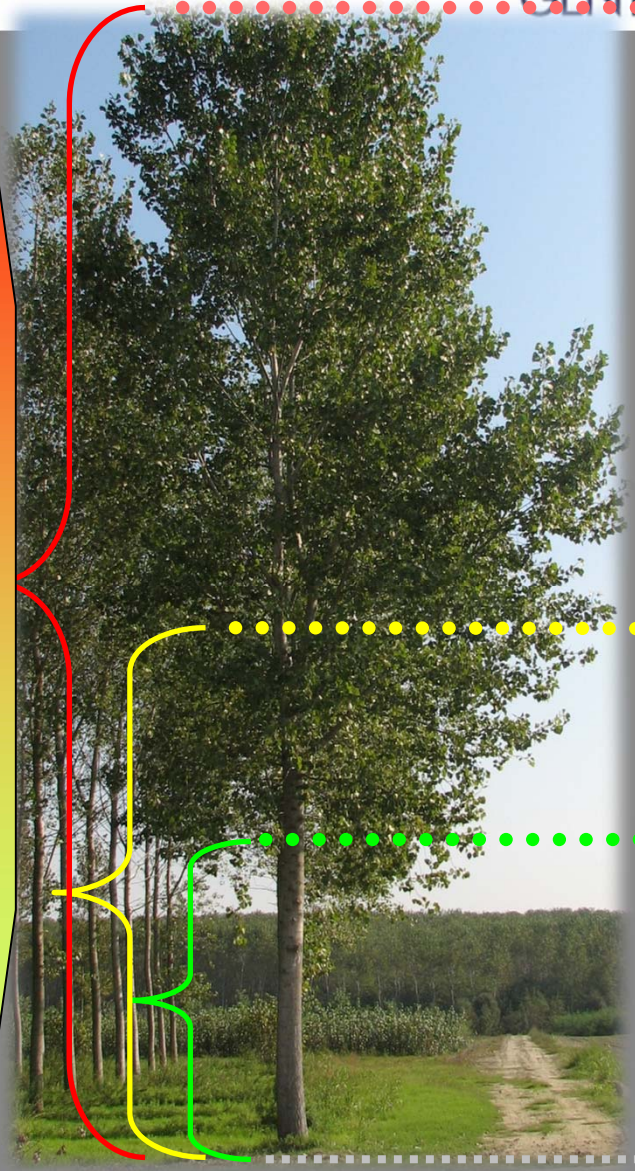
+ + + defects - - -



CHIPPING

Particleboard and fibreboard
Paper
Biomass for energy

Blockboard core
Pallets and industrial packaging
Doors and windows frames
Components for furniture

SAWING

PEELING

Small packaging for fruits

Plywood

Adapted from Fioravanti (2007)

WOOD QUALITY

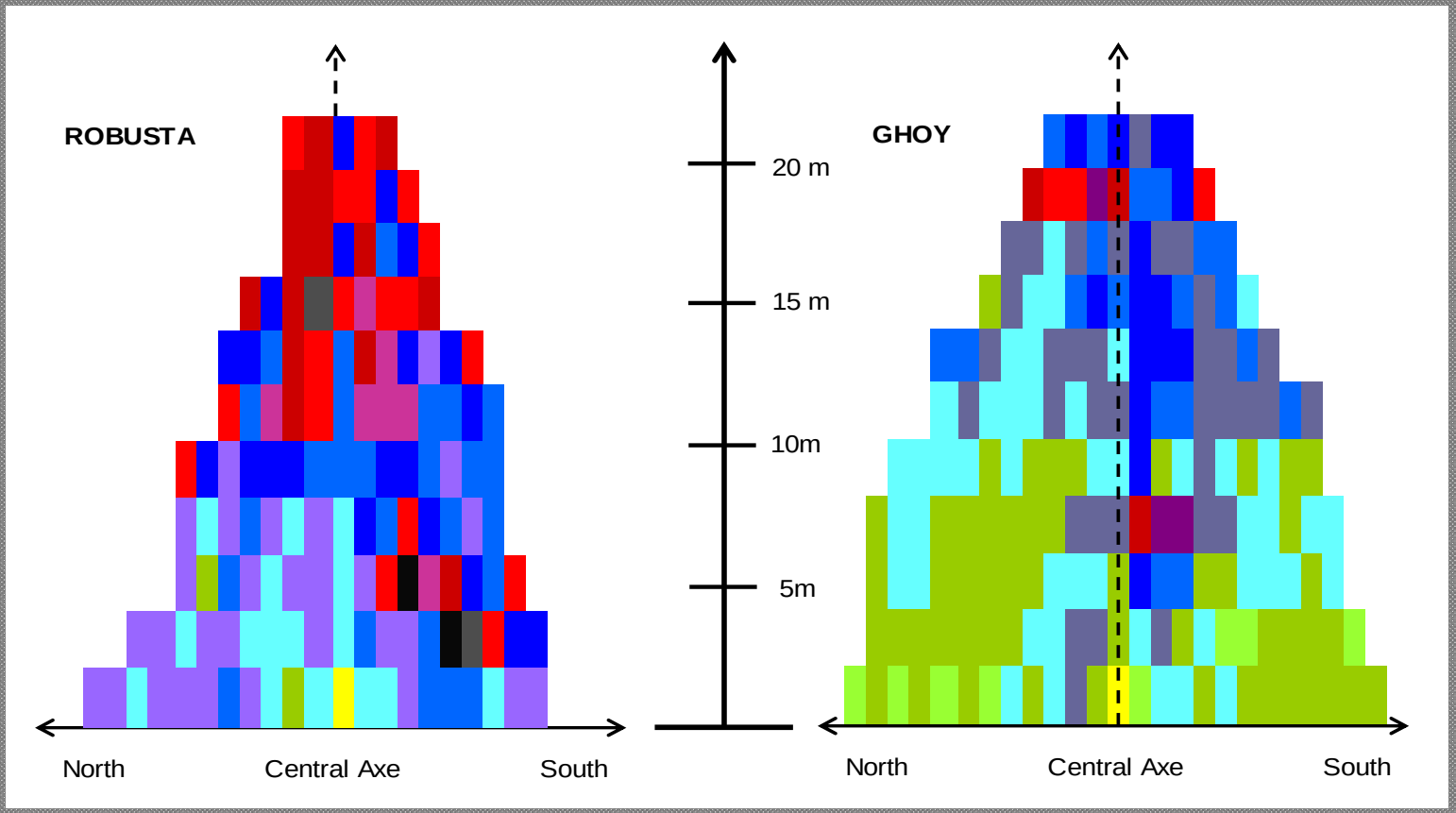
Mean annual increment is important...

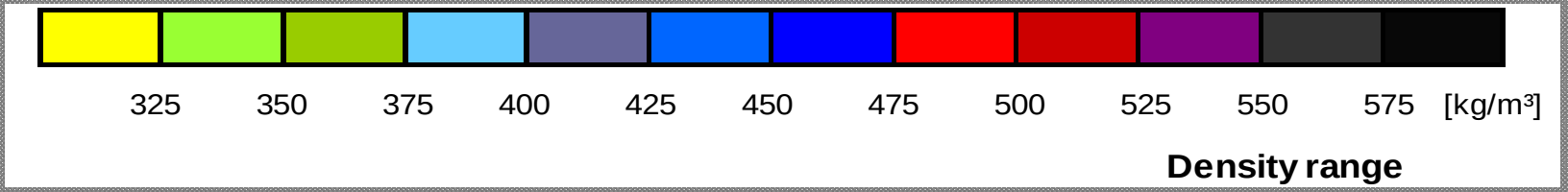
BUT intrinsic wood quality defines END USE

- Density
- Fibre properties
- Reaction wood (amount & distribution)
- Cellulose content
- Specific strength / MOE
- Biological durability

...

Density


ROBUSTA
20 m
15 m
10m
5m
GHOY
North
Central Axe
South
North
Central Axe
South


325
350
375
400
425
450
475
500
525
550
575
[kg/m³]
Density range

TREE QUALITY

BUT tree quality defines processing options....

- Straightness
- Low Taper
- Limited branchiness
- Heartwood amount (coloured or durable)
- Limited ovality & eccentricity
- Moisture content
- Bark thickness

Wood industry

MATERIALS and / or ENERGY

- Large tree are less available... Glued wood products
- In forestry only for bioenergy feasable?
- Multipurpose plantations ?
- Integrated processing: both material & energy

and / or

MATERIALS USE and/or ENERGY USE

Use of the energy content of wood in conflict with material uses based on pulping

- Pulp & paper
- Biorefineries for chemicals
- Medium Density Fiberboard (MDF)

Resource competition with products like particleboard (chipboard) and wood plastic composites (WPC)

TREE QUALITY and WOOD QUALITY

Mass
Volume
Moisture Content
Chemical Composition
Energy content
Physical characteristics
Microstructure

CONSTRUCTION PRODUCTS

So-called traditional wood products: Lumber and plywood

Cross-laminated timber (CLT)

Glulam (glued-laminated timber)

Oriented strand board (OSB)

Engineered wood products (EWP) … I-joists

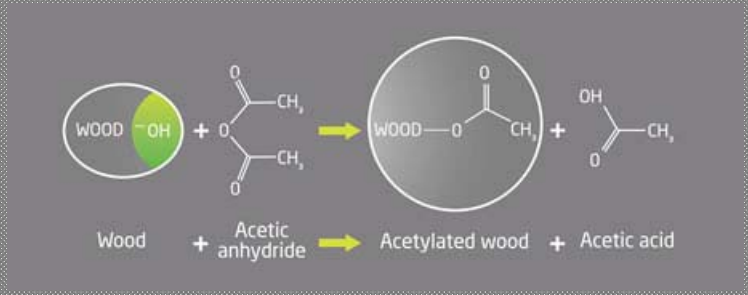
Structural composite lumber (SCL):

- *laminated veneer lumber (LVL)*
- *parallel strand lumber (PSL)*
- *laminated strand lumber (LSL)*
- *oriented strand lumber (OSL)*

PRESERVATIVE TREATED & MODIFIED WOOD

Vacuum pressure treatment

Acetylation



TMT Thermally Modified Timber

Nature conservation

ECOSYSTEM SERVICES

Multipurpose forestry

Forest protection

Natural forest – plantation forest

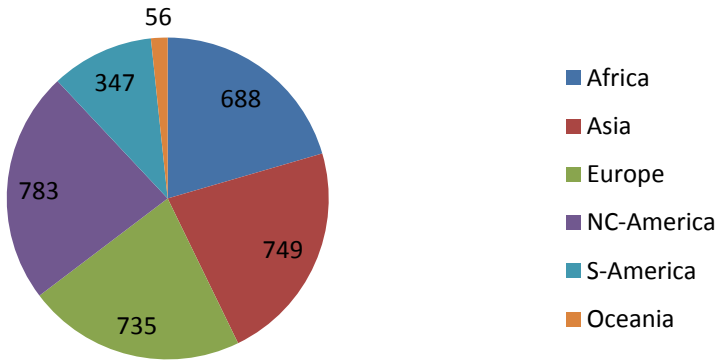
Wood supply

Quality trees

Biodiversity

Forest certification

Wood removals (3,36 million m³)
FAO 2005



FOCUS ON TROPICS

REDD – Climate change

Biodiversity

Lesser known species

Sustainability

Forest management systems

Logging

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

http://www.ipcc.ch/

International framework

INTERNATIONAL NETWORKS

http://www.forestplatform.org/

Forest-Based Sector
Technology Platform

http://www.innovawood.com/

INNOVAWOOD

http://www.iufro.org/

IUFRO

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INTERNATIONAL RESEARCH NETWORKING

http://www.cost.eu/domains_actions/fps

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Forests, their Products and Services (FPS)

FP0802 | Experimental and Computational Micro-Characterisation Techniques in Wood Mechanics |

FP0902 | Development and harmonisation of new operational research and assessment procedures for sustainable forest biomass supply |

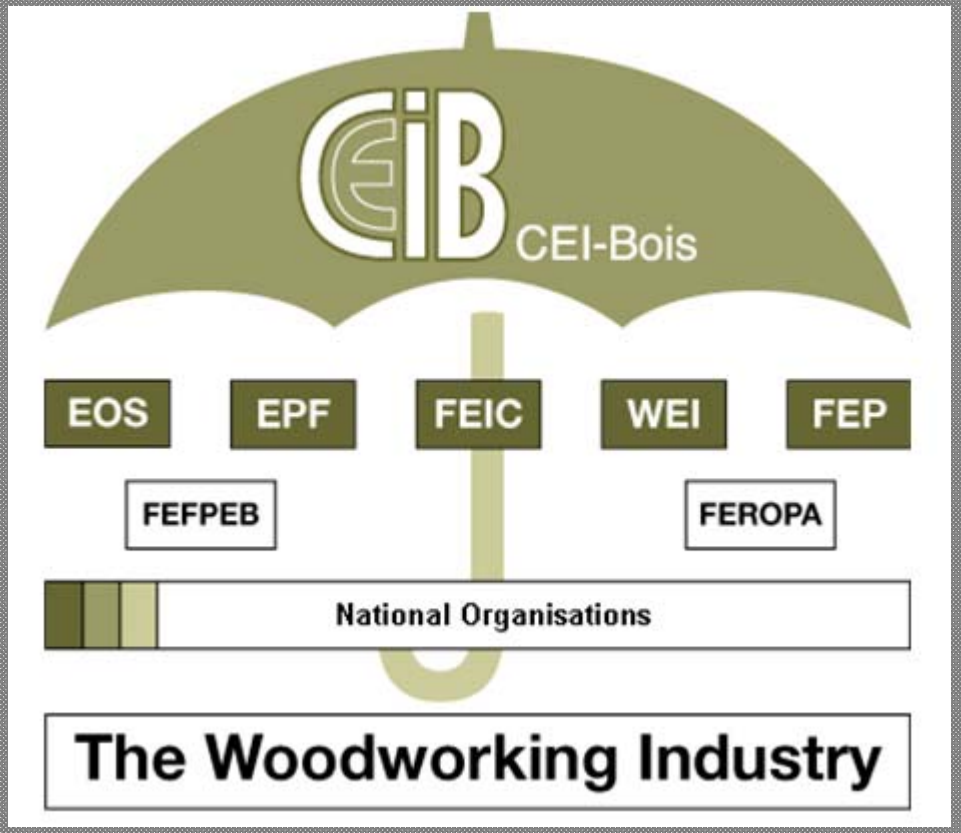
FP0904 | Thermo-Hydro-Mechanical Wood Behaviour and Processing |

FP1006 | Bringing new functions to wood through surface modification |

FP1101 | Assessment, Reinforcement and Monitoring of Timber Structures |

FEDERATIONS

http://www.cei-bois.eu/



FEDERATIONS

http://www.cepi.org/

The Confederation of European Paper Industries (CEPI)

http://www.cepf-eu.org/

The Confederation of European Forest Owners (CEPF)

http://www.eustafor.eu/

European State Forest Association

INTERNATIONAL STATISTICS... POLICY

http://www.fao.org/

Food and Agriculture Organization of the United Nations
for a world without hunger

http://www.unece.org/

UNECE
United Nations Economic Commission for Europe

http://www.itto.int/

ITTO
International Tropical Timber Organization

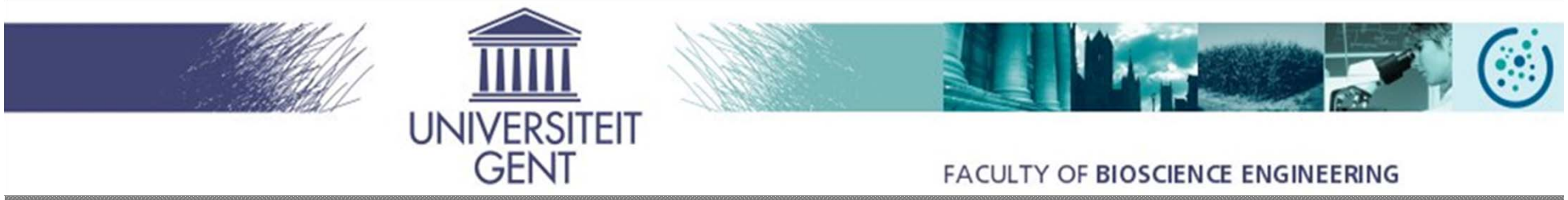
FORESTRY WOOD CHAIN CERTIFICATION

http://ic.fsc.org/

Forest Stewardship Council

http://www.pefc.org/

Programme for the Endorsement of Forest Certification



Research opportunities in wood science

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TREE SPECIES
PROCESSING
END USE

Case study:
Moisture dynamics of plywood
(PLYWOODMOISTURE)

Veneer products

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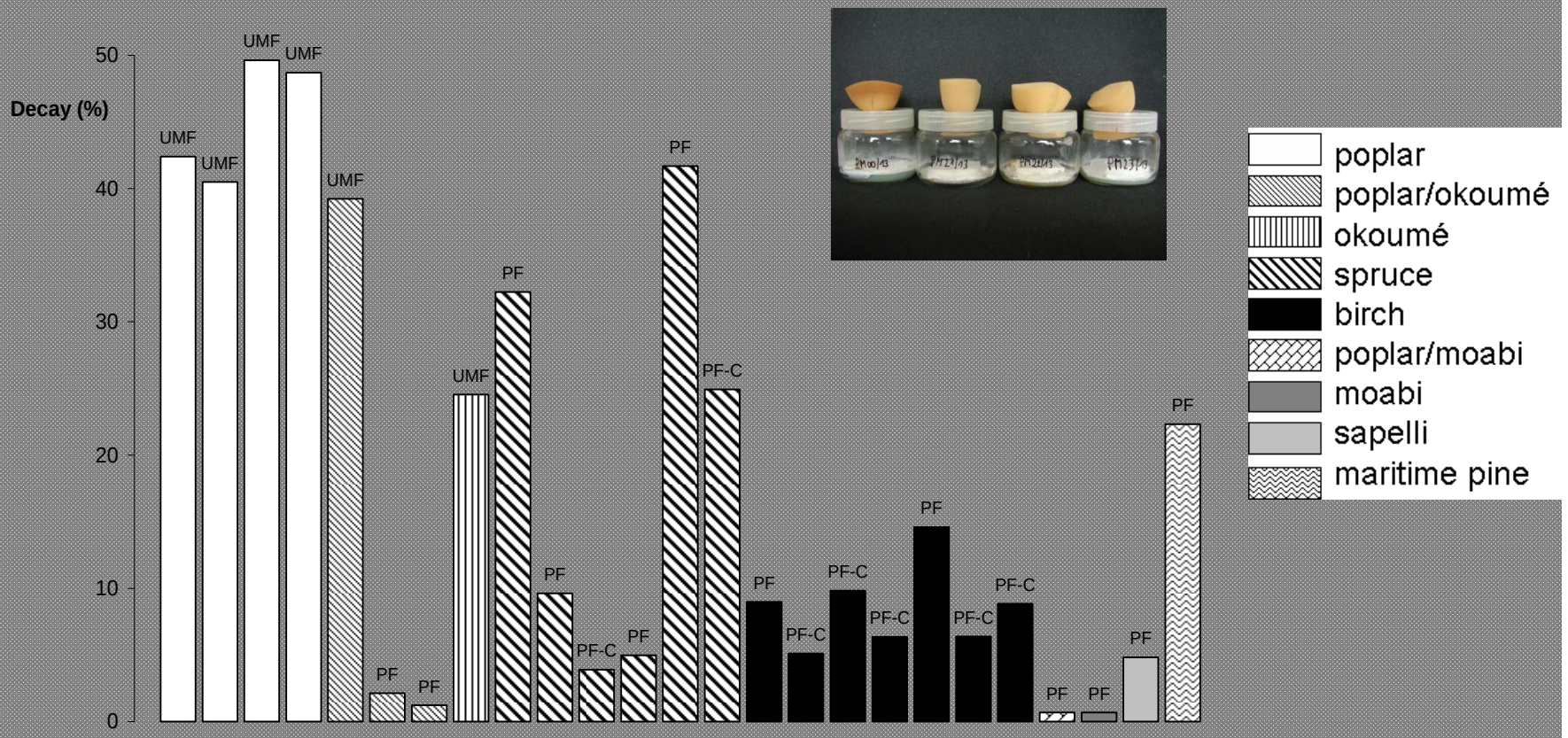
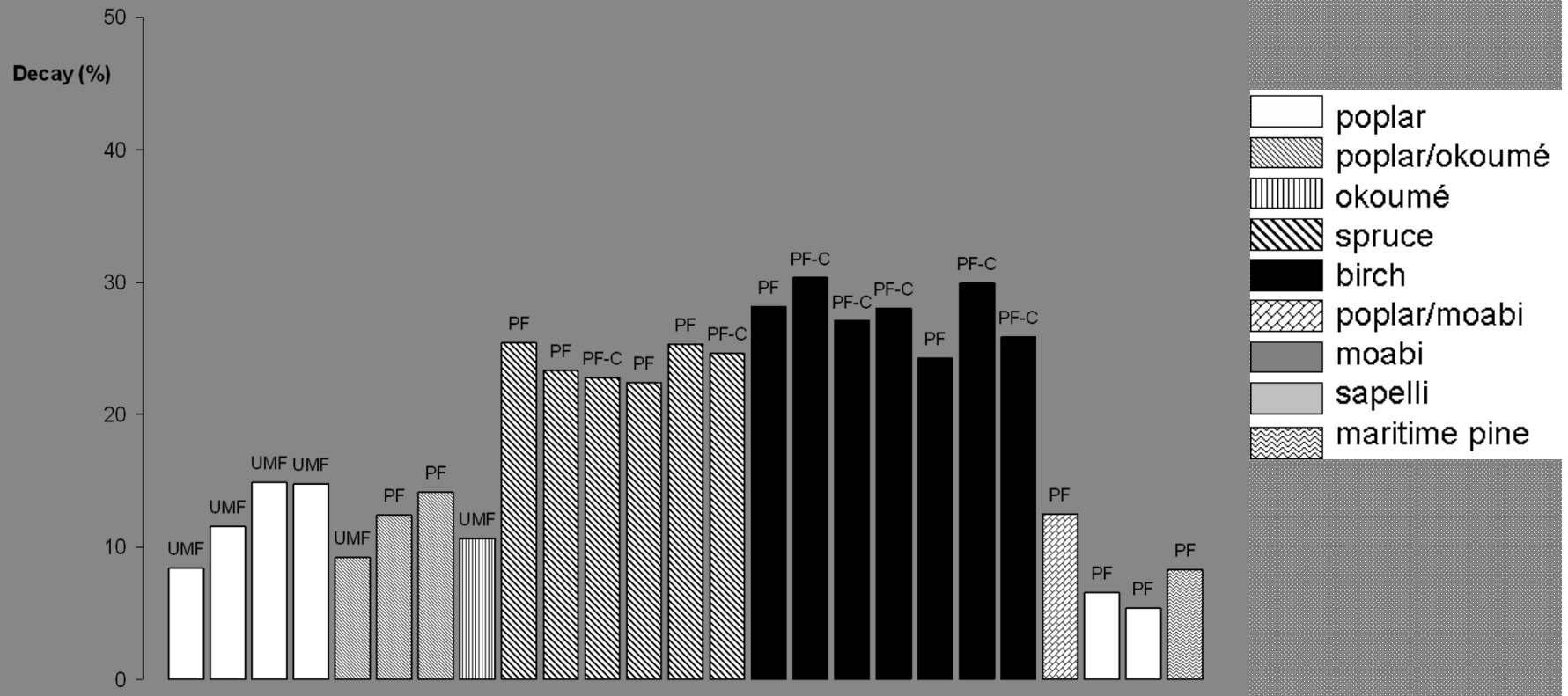
Decay (% mass loss) by *Coniophora puteana* (brown rot)



UMF – Melamine fortified urea formaldehyde glue
PF – Phenol formaldehyde glue
C – Coating present

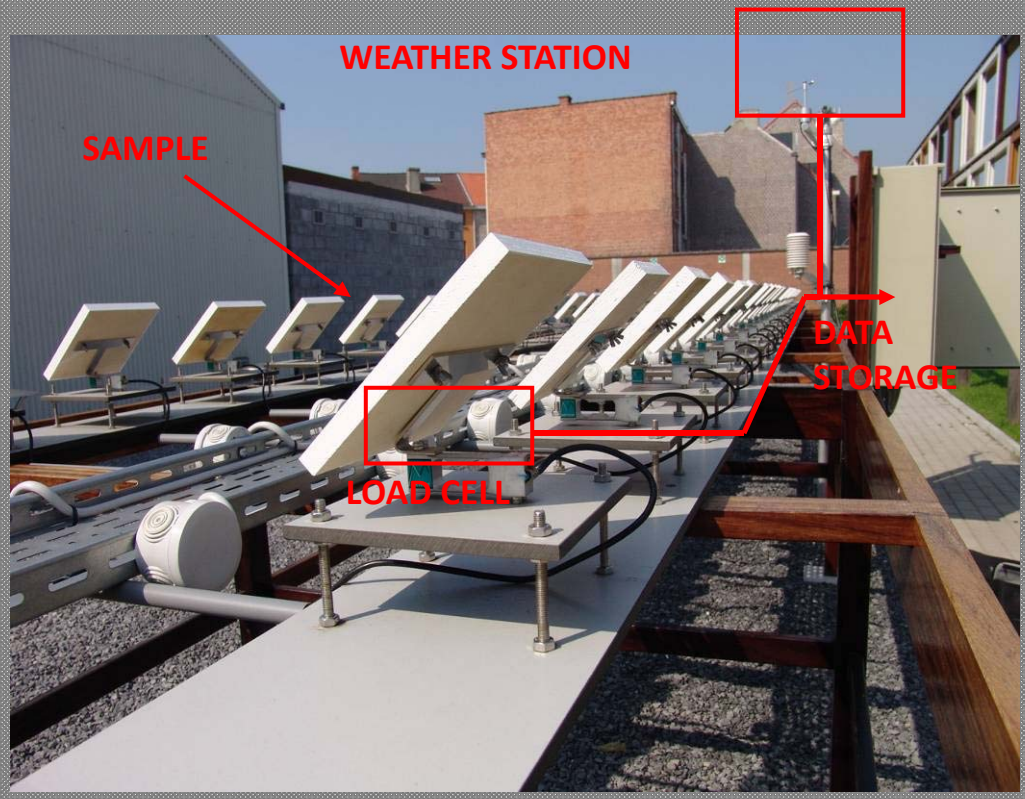
Decay (% mass loss) by *Pleurotus ostreatus* (white rot)



UMF – Melamine fortified urea formaldehyde glue
PF – Phenol formaldehyde glue
C – Coating present

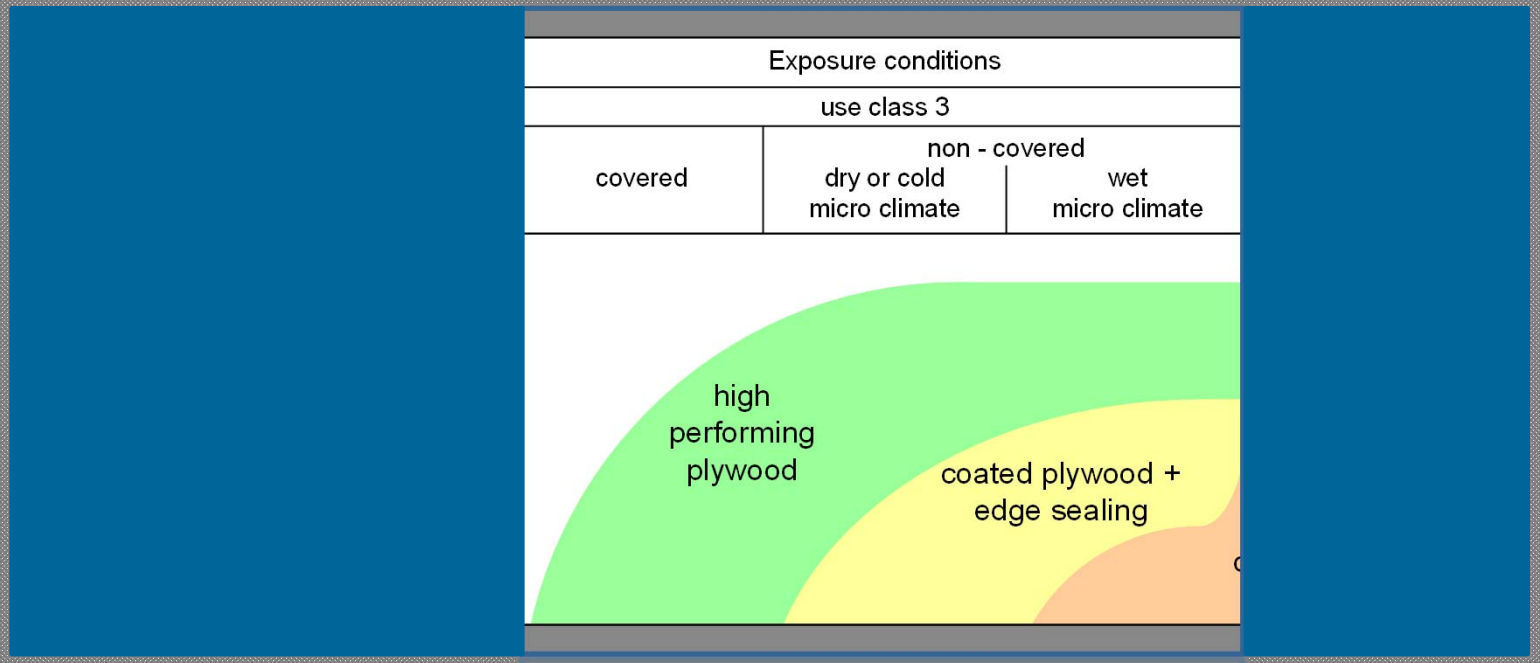
CMM (Continuous Moisture Measurement)

- rain (mm)
- solar radiation (W/m²)
- wind (m/s)
- relative humidity (%)
- biological agents



Monitoring TIME OF WETNESS (ToW) for SERVICE LIFE PREDICTION (SLP)

Plywood & use classes



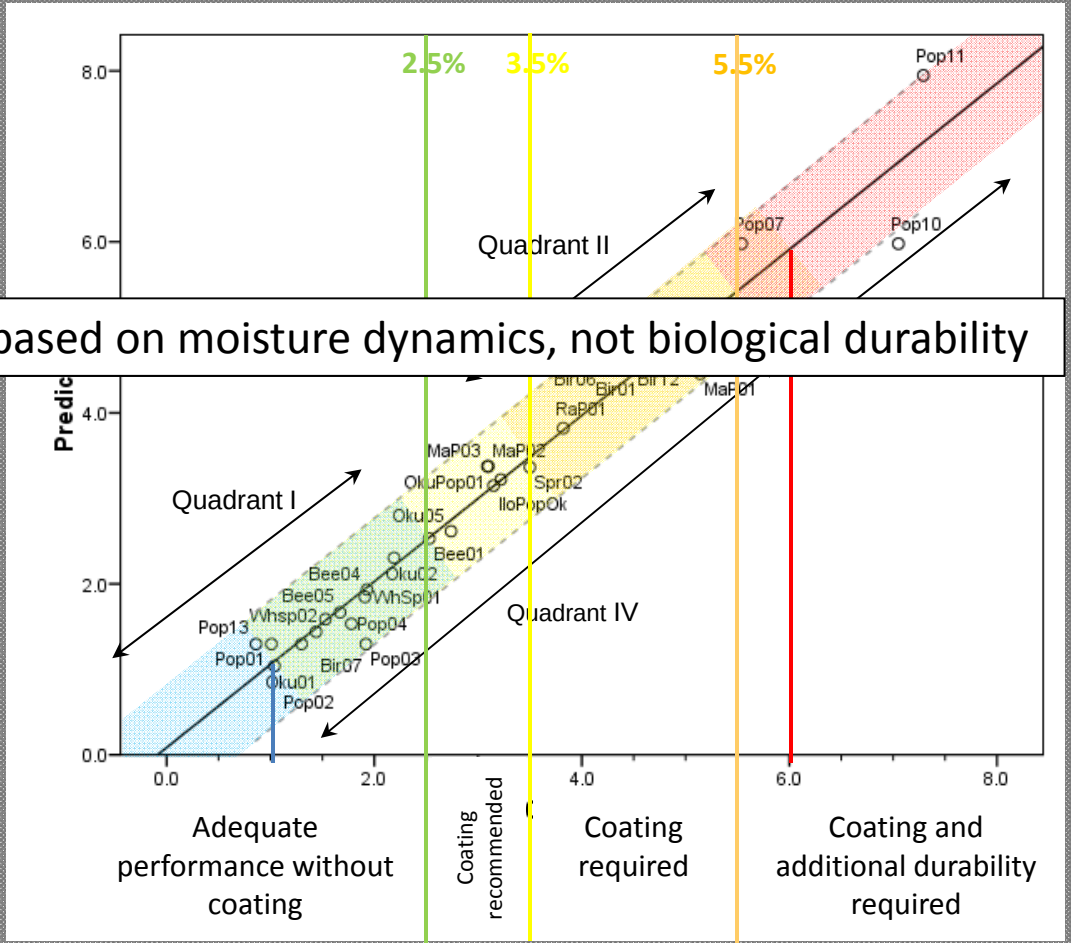
- fit for purpose
- use class 3

outdoor, out of ground application

Uncoated plywood specimens

Classification based on floating test – soaking/drying

Predicting potential service life based on moisture dynamics, not biological durability



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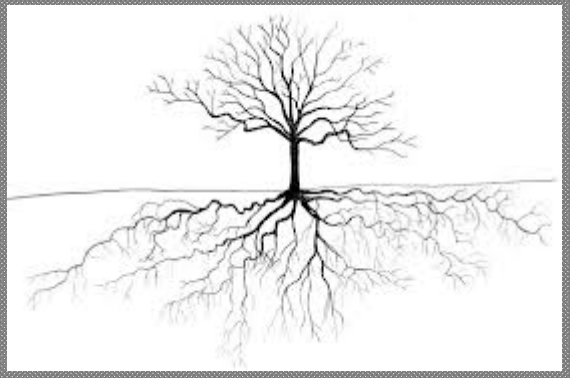
ECOPHYSIOLOGY OF TREES

TREE GROWTH

Case study:

Micro CT scanning – conductive potential



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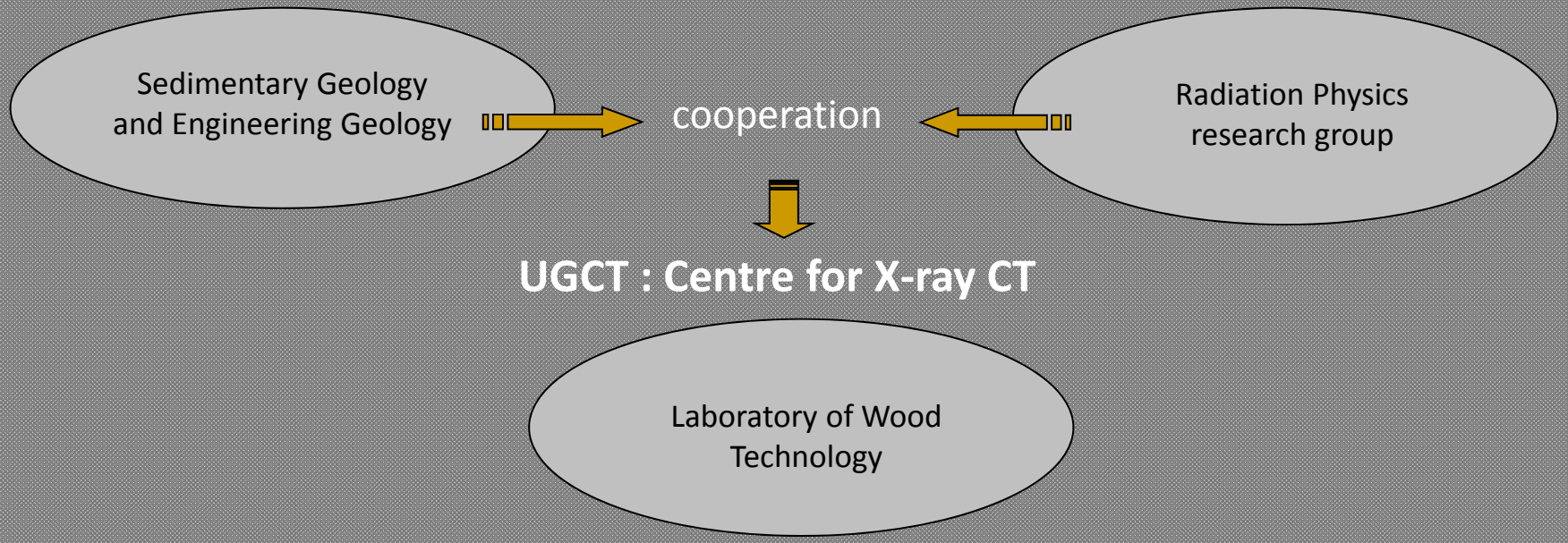
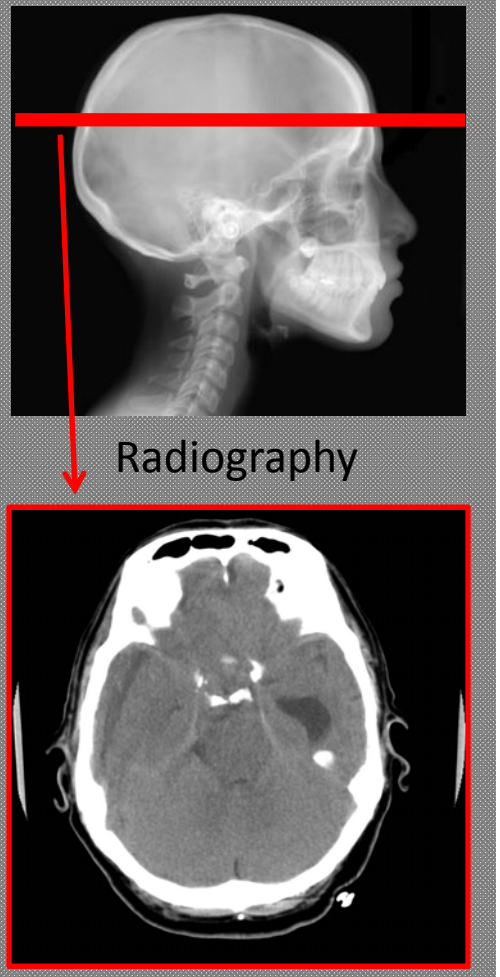
NanoWood CT-scanner
UGent built flexible multi resolution CT scanner

UGCT consortium



- Group of people with different backgrounds:
  Civil Engineers, Physicists, Geologists, Wood / Bio scientists
- Set of complementary X-ray scanners
- Research on Tomography (hardware & software)
- Research with Tomography (internal and services)

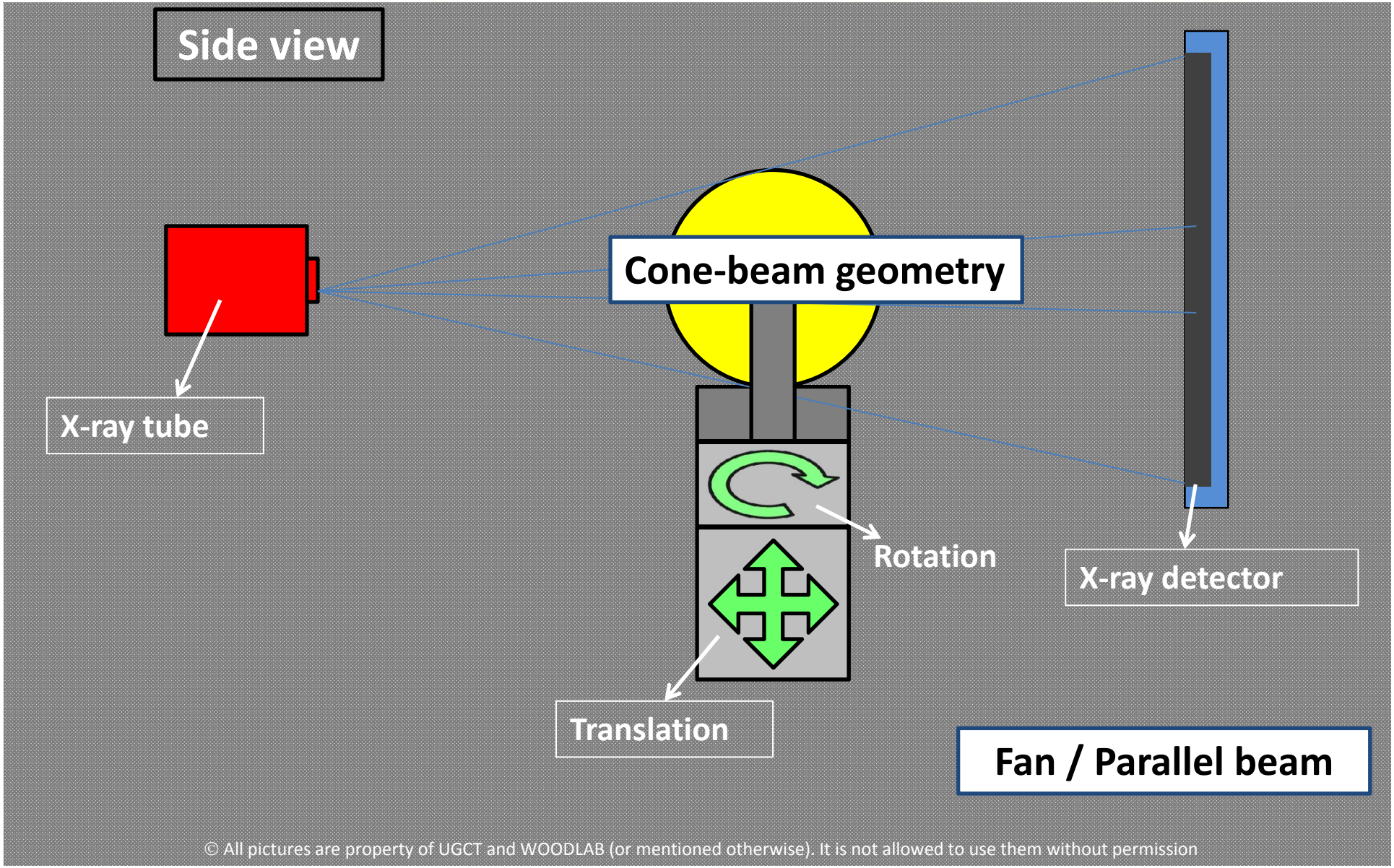
- X-ray radiography:
  - Measure X-ray attenuation of object
  - Projection image: 2D representation of 3D volume
- X-ray computed tomography:
  - Acquire series of radiographies at different angles
  - Combine to obtain full 3D representation
  - Non-destructive
- Best known from medical imaging (CT- or CAT-scanner)
  - resolution limited to ~ 0.1 - 0.2 mm

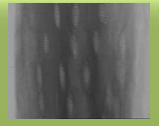
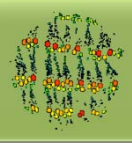


Radiography

Tomography

HIGH-RESOLUTION TOMOGRAPHY: DOWN TO 400 NM



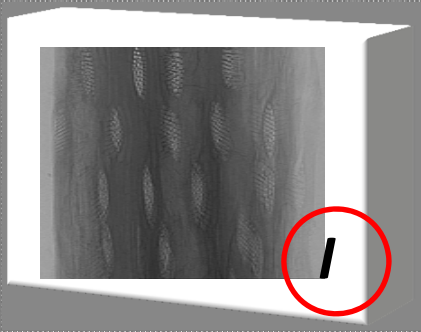
1. • Data acquisition 
2. • Reconstruction 
3. • Visualization 
4. • Analysis 

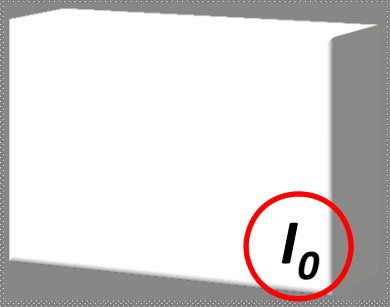
Data acquisition

- Acquiring good data is a necessity
  - Signal to noise ratio
  - Sufficient number of projections
  - Appropriate energy
  - Mechanical accuracy
  - …
- Acquisition takes some minutes up to a couple of hours
  - Stability (thermal expansion, spot drift, …)
  - …

Reconstruction

For each detector pixel, the integrated linear attenuation coefficient can be retrieved:





$$\int_{\mathcal{L}} \mu(x)ds = -ln\left(\frac{I}{I_0}\right)$$

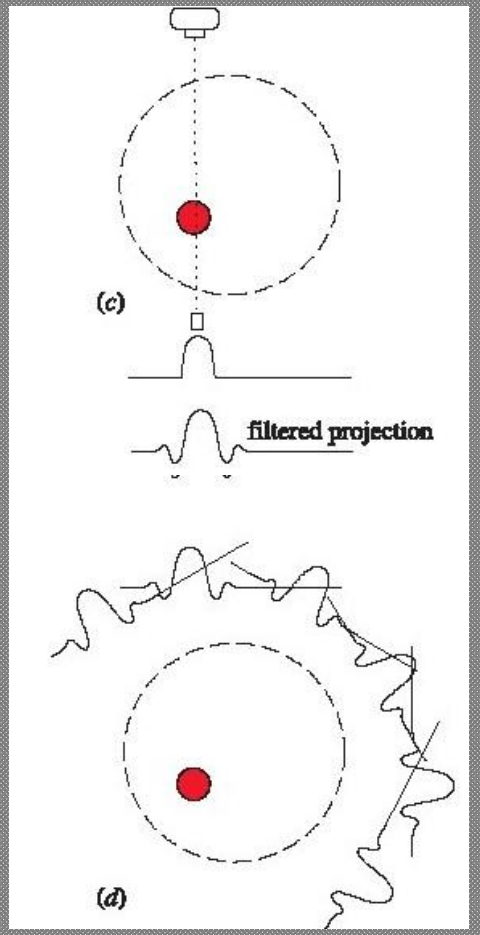
I → With sample

I_0 → Without sample

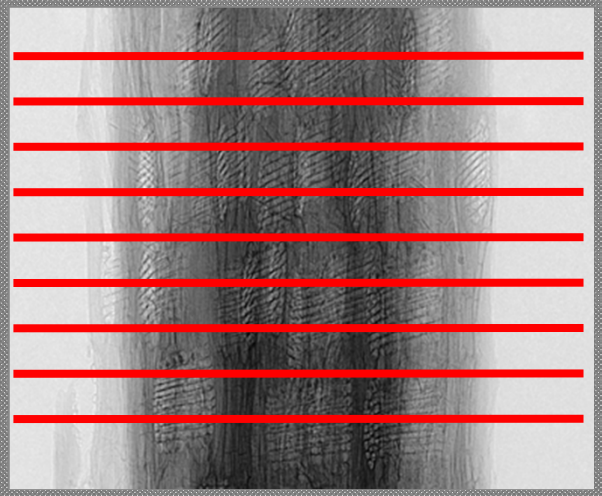
Reconstruction

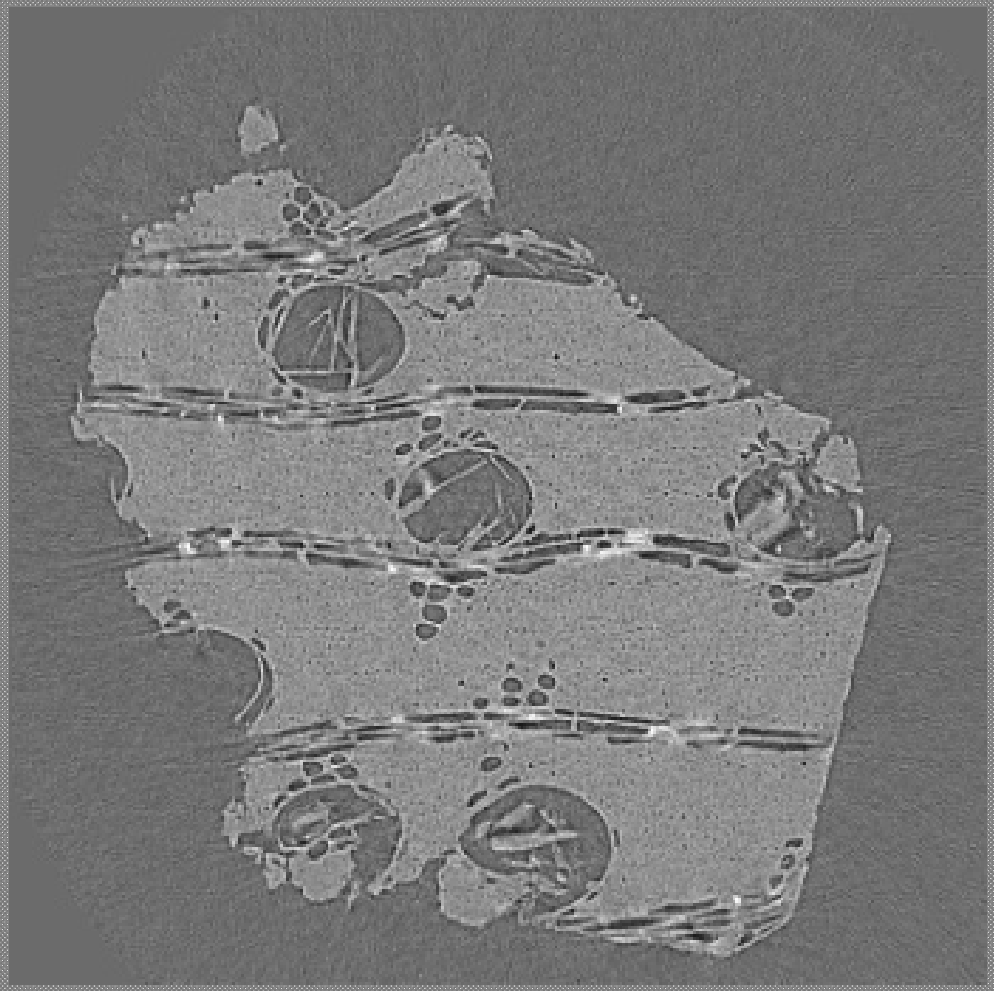
- $\mu \sim E, \rho$ and Z
- Filtered backprojection:
  convolve attenuation profile with filtering function before backprojection

68 projections

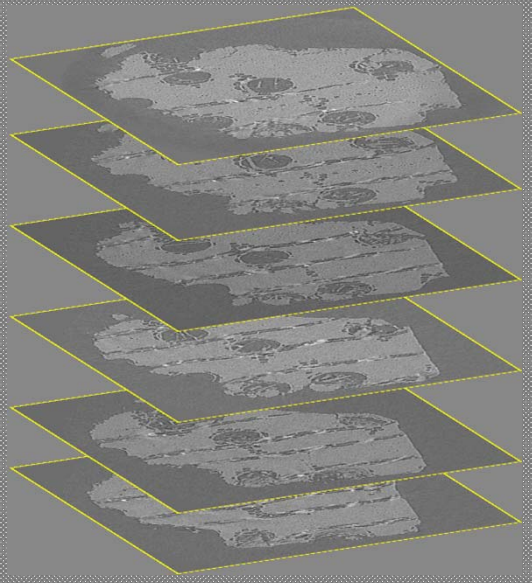


Reconstruction

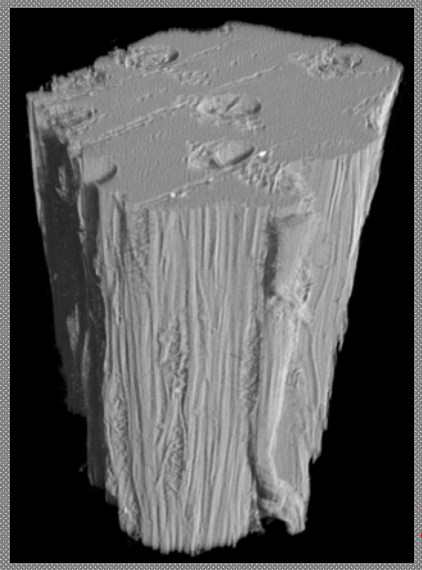


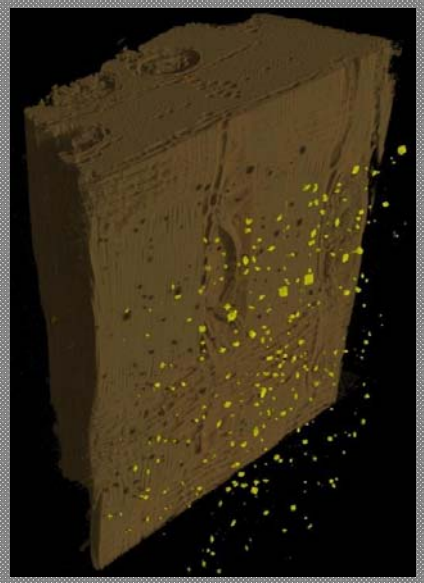


Visualization

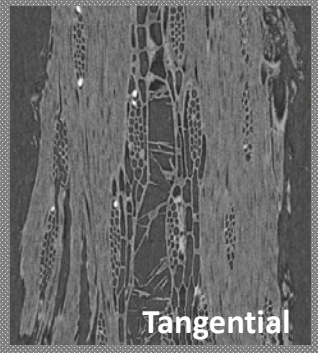


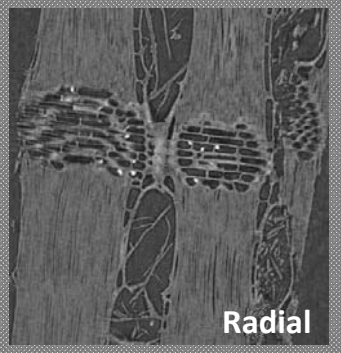
2D



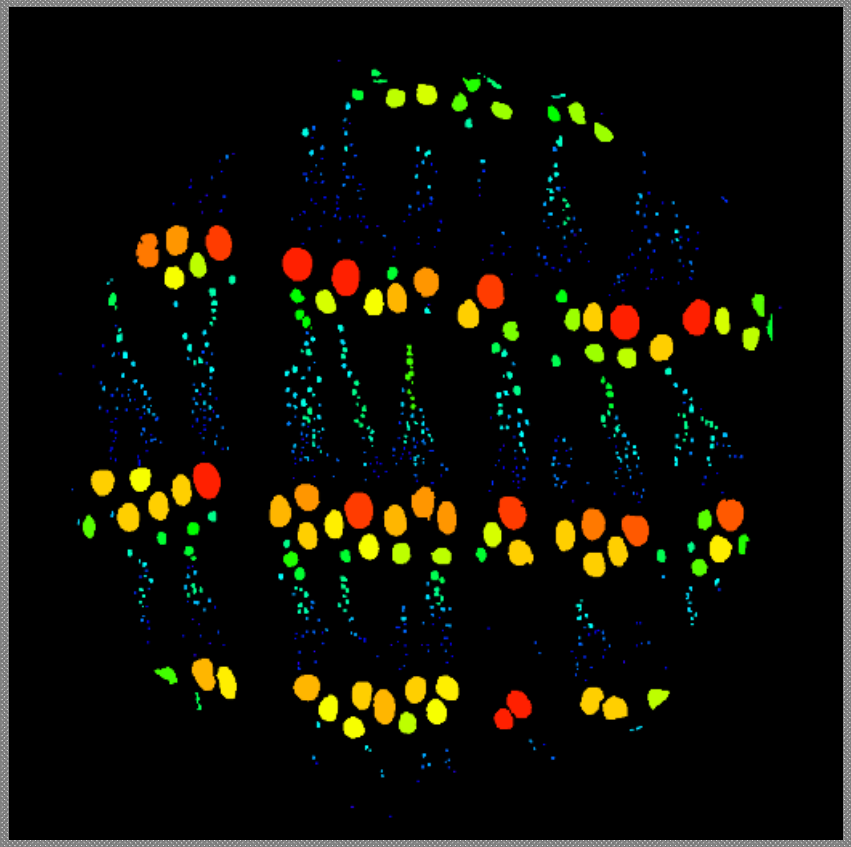


3D



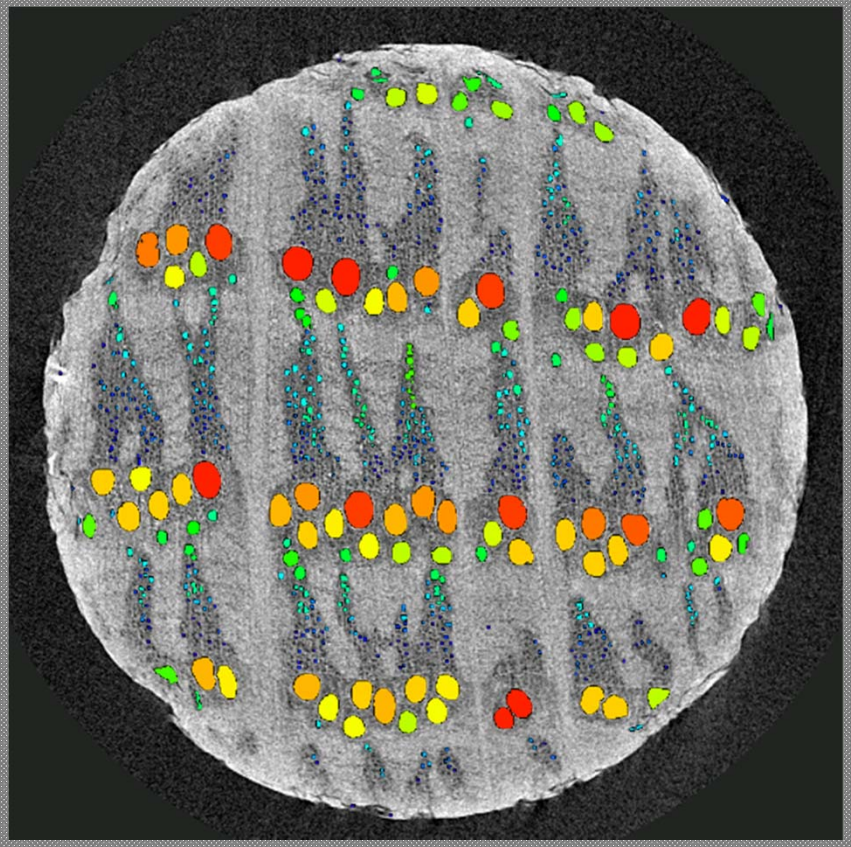


3D analysis work-flow



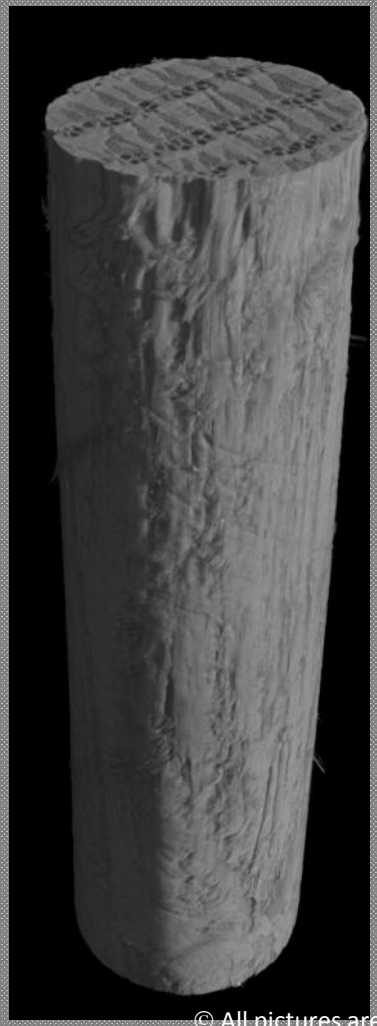
- Noise filter
- Thresholding
- Binary operations
- Labelling
- Euclidian distance transform
- Watershed separation & size labelled

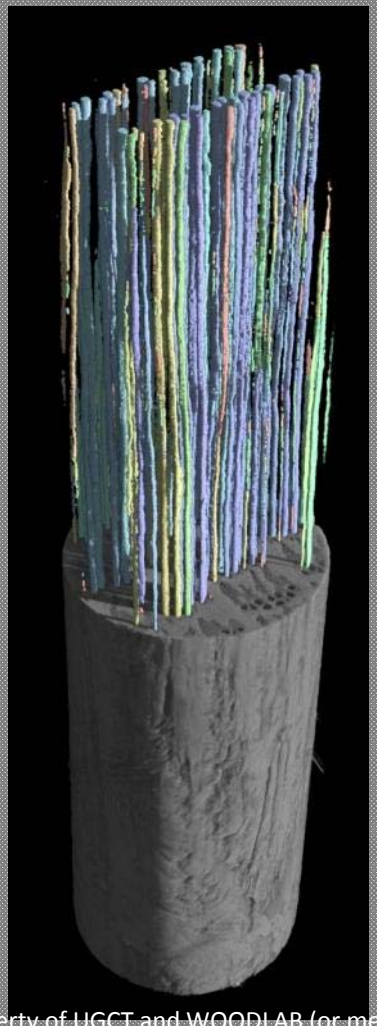
3D analysis work-flow

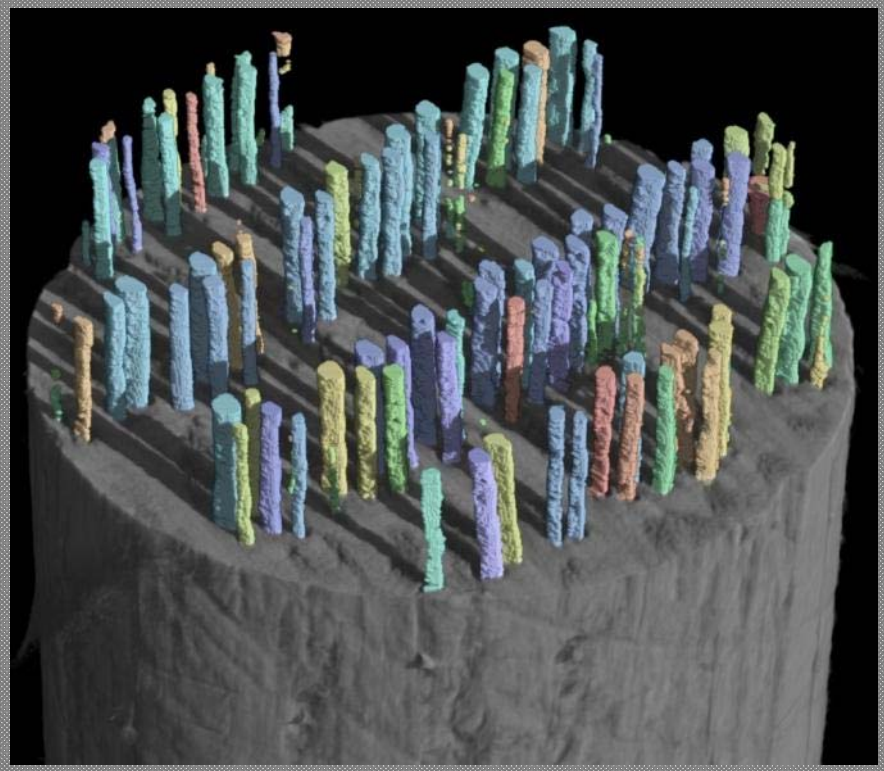


- Noise filter
- Thresholding
- Binary operations
- Labelling
- Euclidian distance transform
- Watershed separation & size labelled

3D quantitative results & visualization







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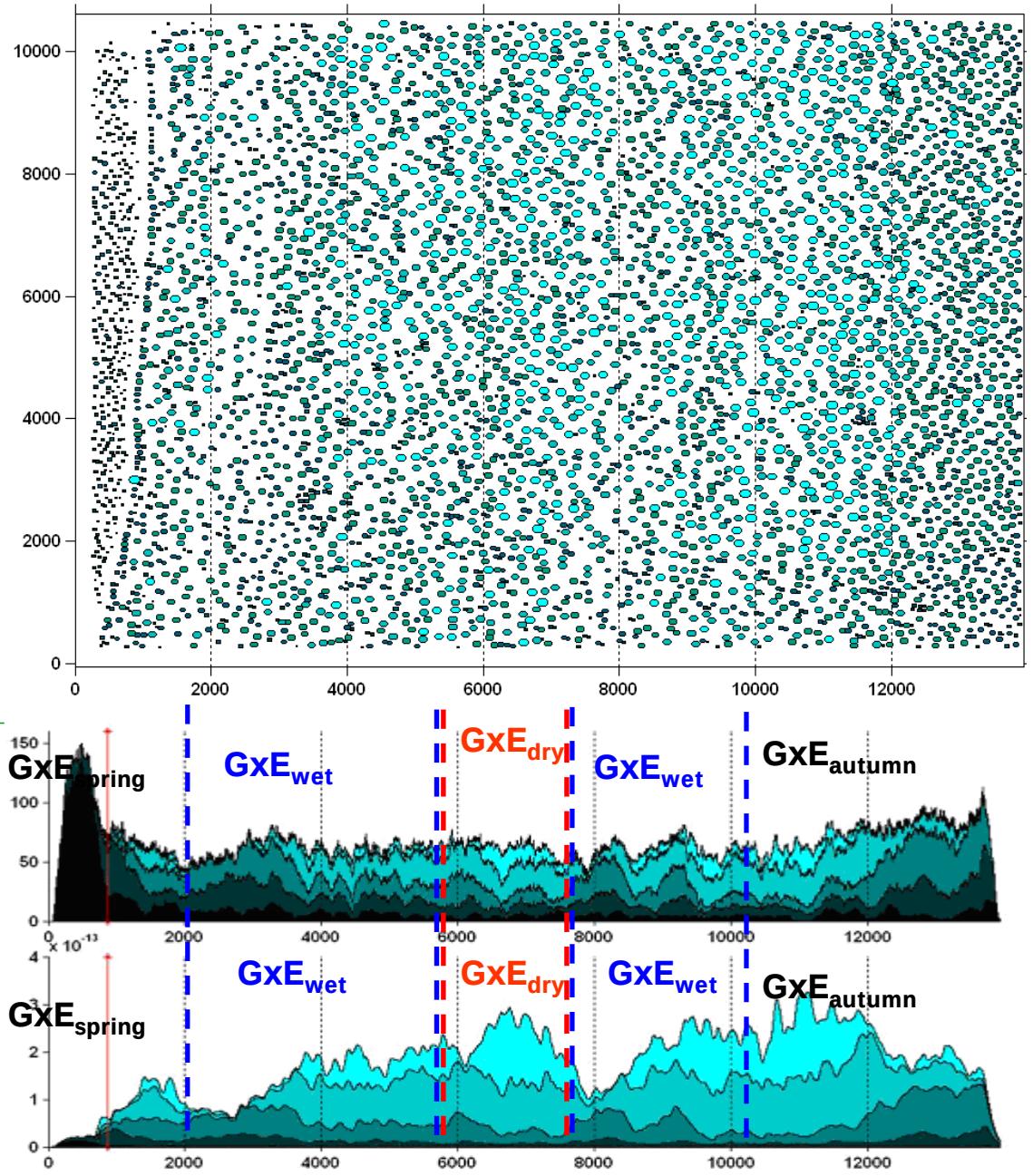
Eco-physiology conductive potential

> 1 cm²
> 4500 vessels
5 diameter classes

Willow from INBO Collection - Woodlab (2007)

Vessel frequency

Vessel conductivity



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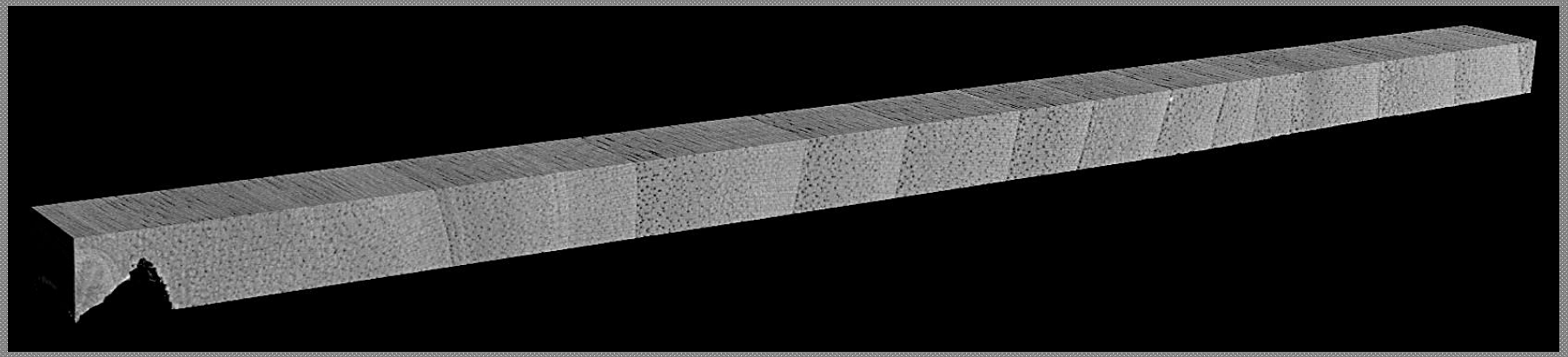
GROWTH RING ANALYSIS
MICRODENSITOMETRY

Case study:
Dendroclimatology in Africa



Long objects scanning

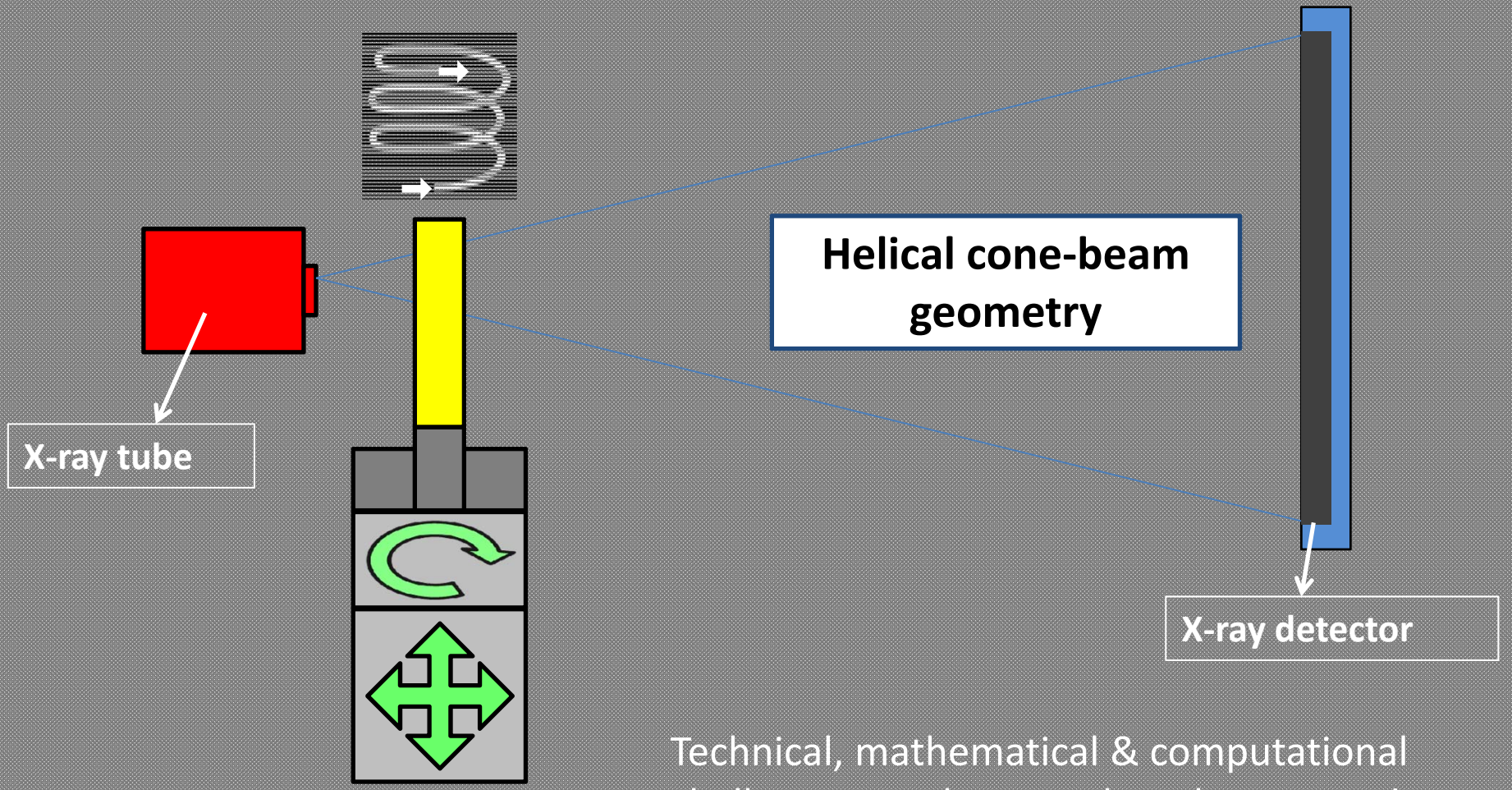
- Wood cores
- Small stems
- Branches
- …
- Violin bows

- Scanning long objects:
  - Reduce magnification to capture entire object

    → reduced resolution
  - Perform multiple scans and stitch resulting volumes

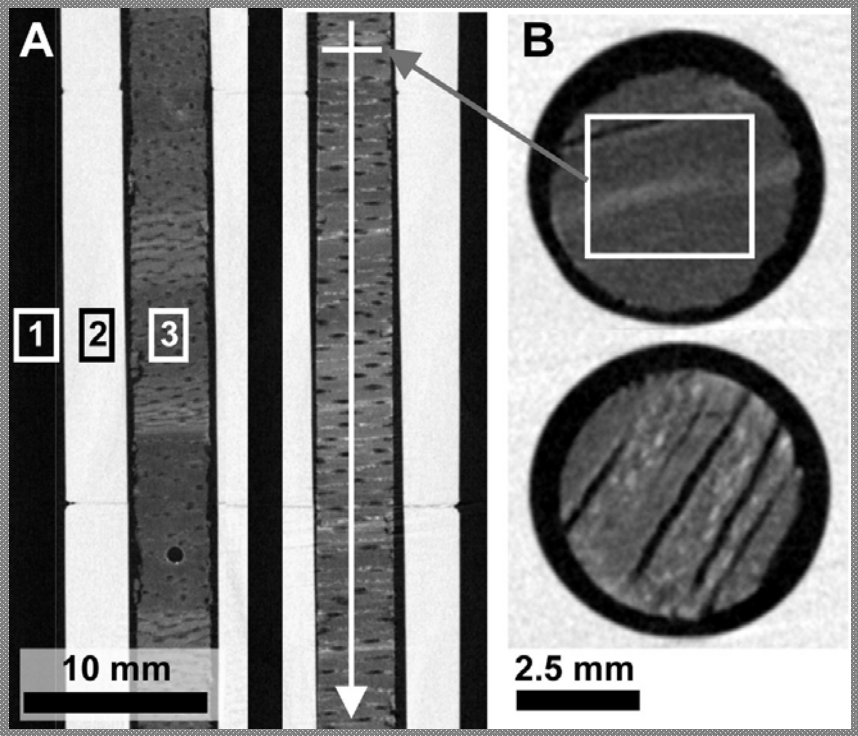
    → cumbersome and not ideal (cone artefacts)

Helical cone-beam

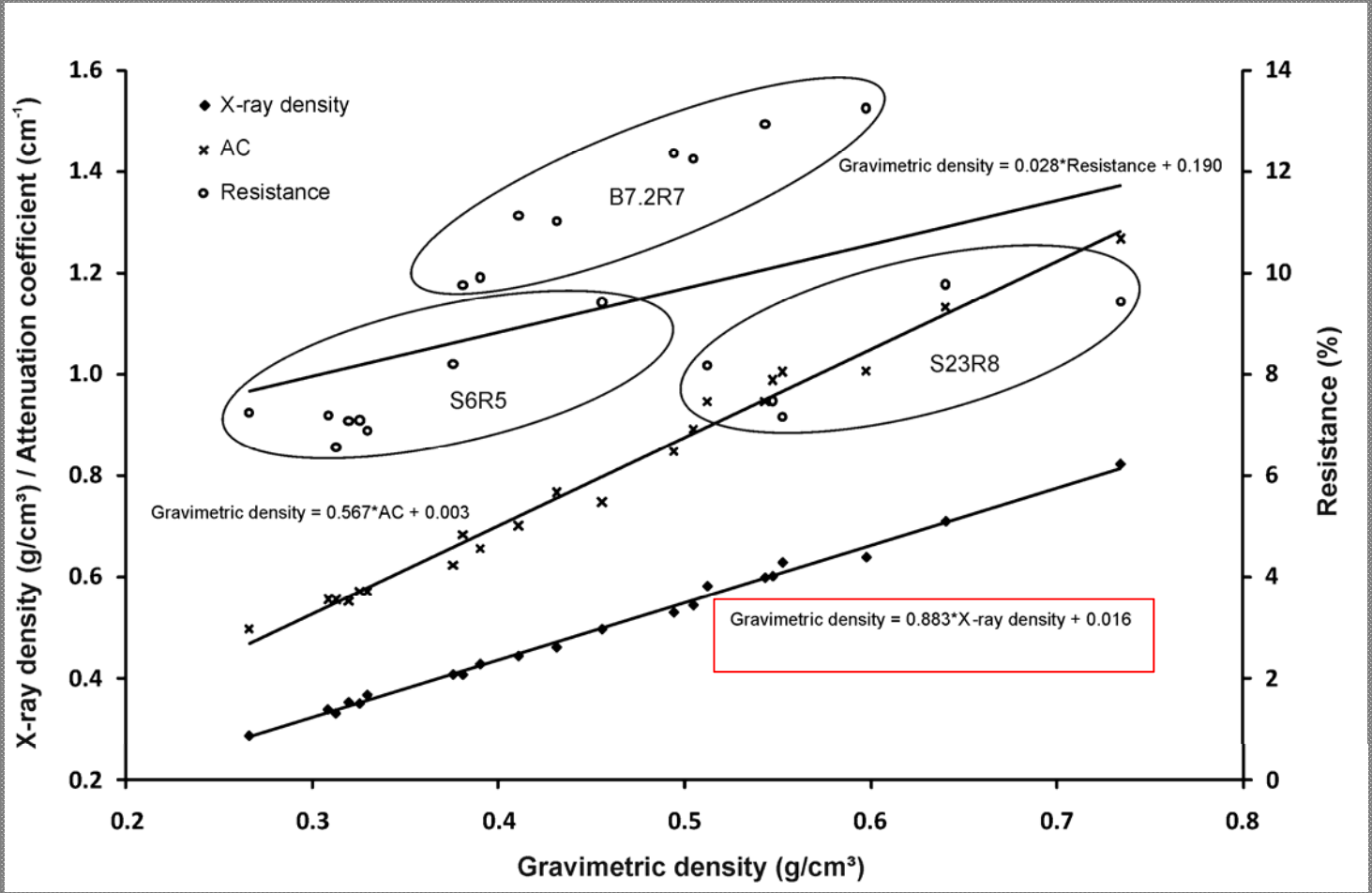


Technical, mathematical & computational challenge - Implemented on the scanner!

Helical cone beam with Nanowood on wood cores & microdensitometry



Terminalia superba (Limba)
(Maaike De Ridder - DRCongo)



De Ridder et al. (2011). Annals of Botany

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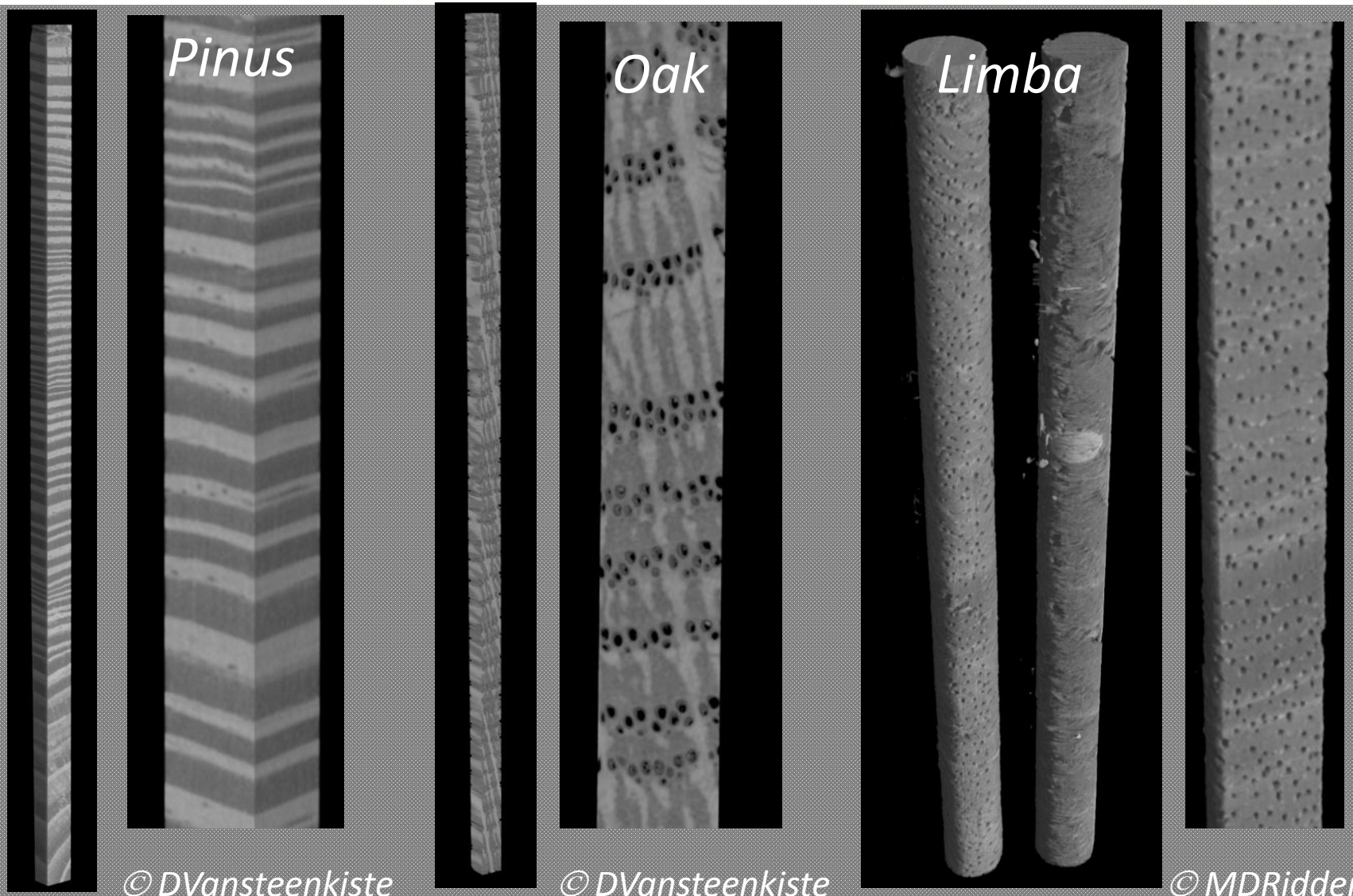

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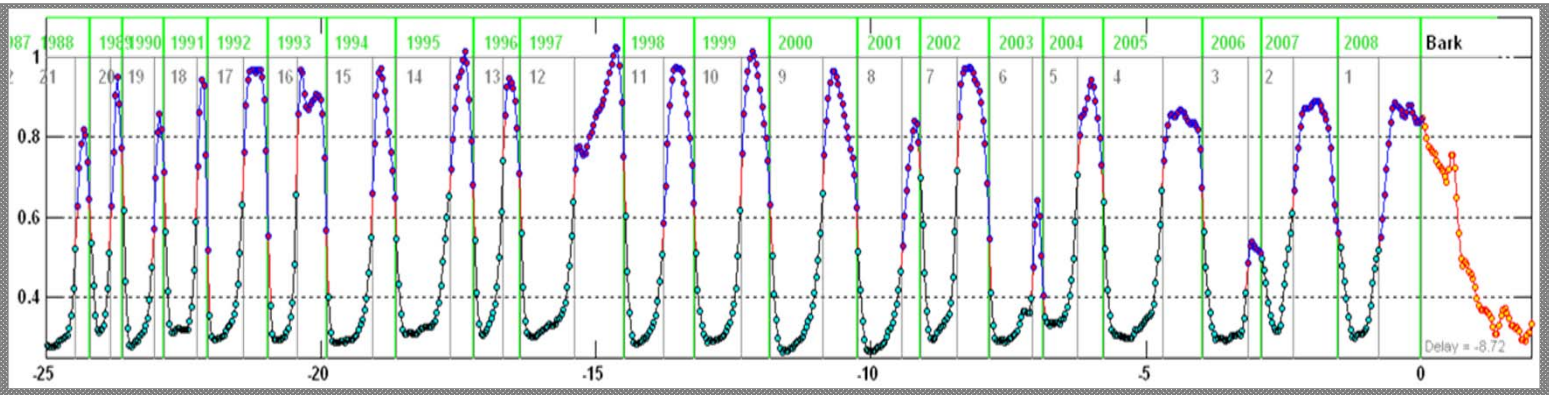
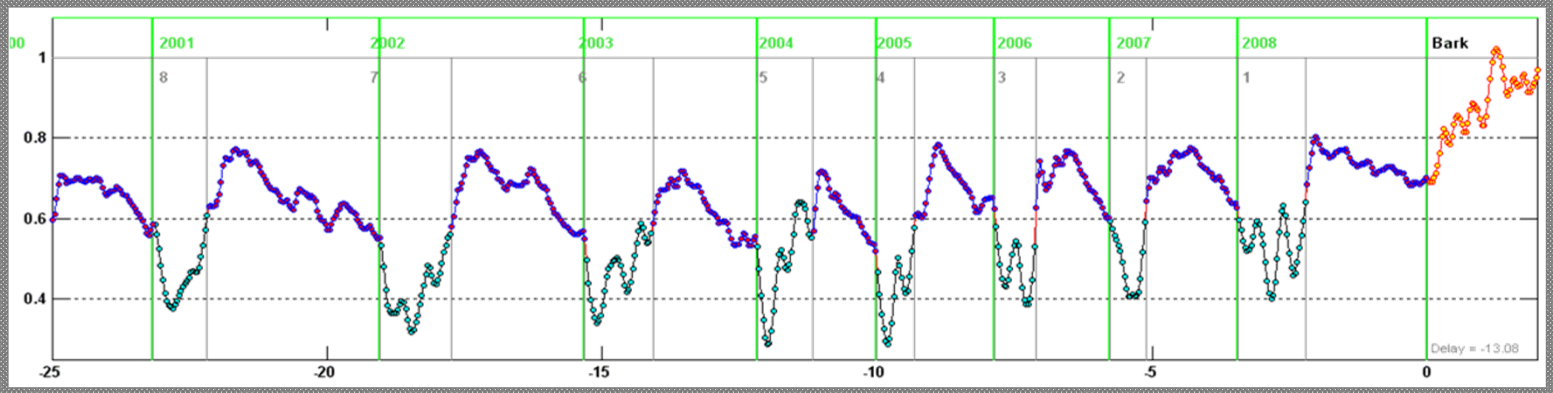
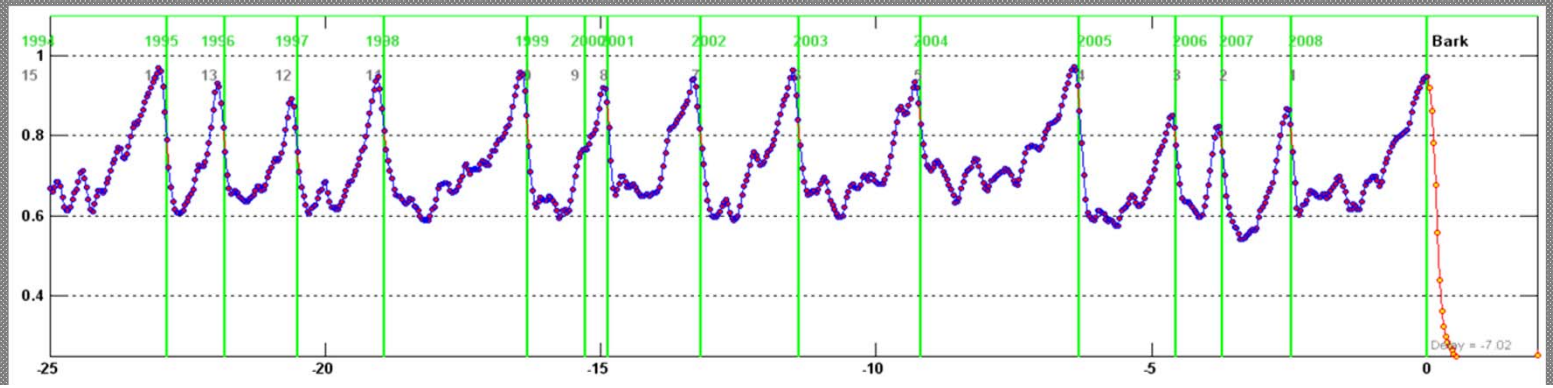
Pine



Oak



Beech



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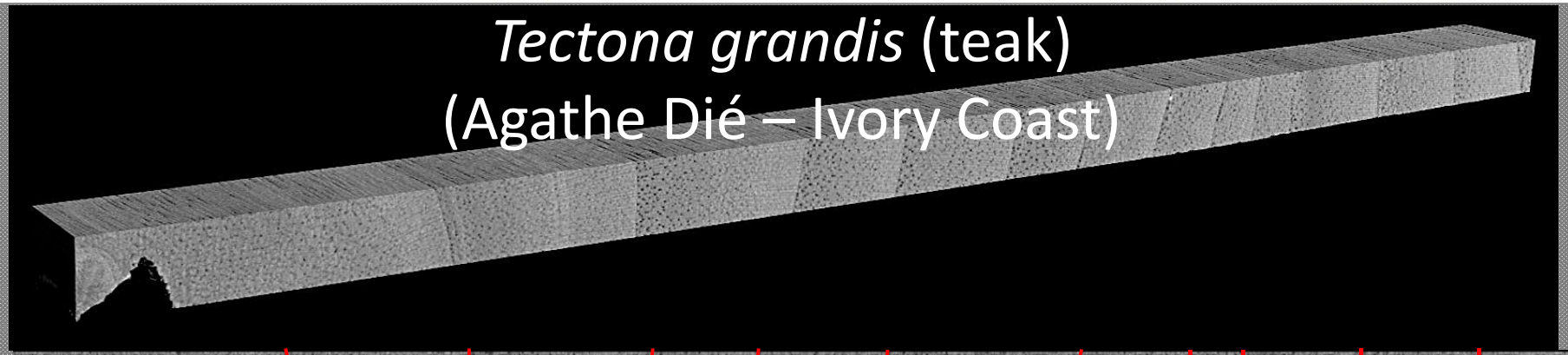
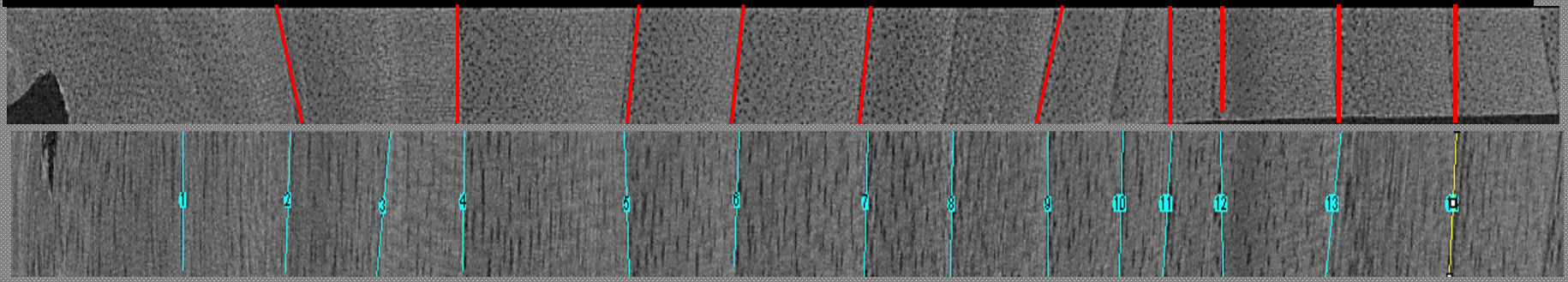
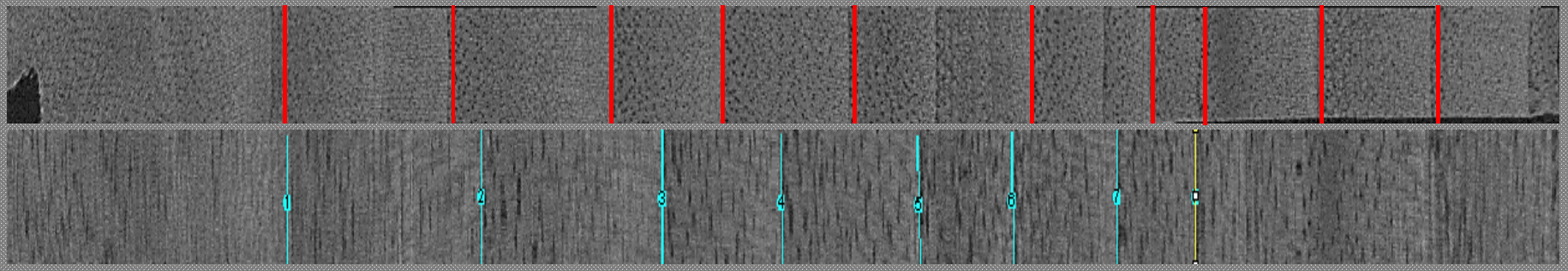
Tectona grandis (teak)
(Agathe Dié – Ivory Coast)





Ring & fibre transformation



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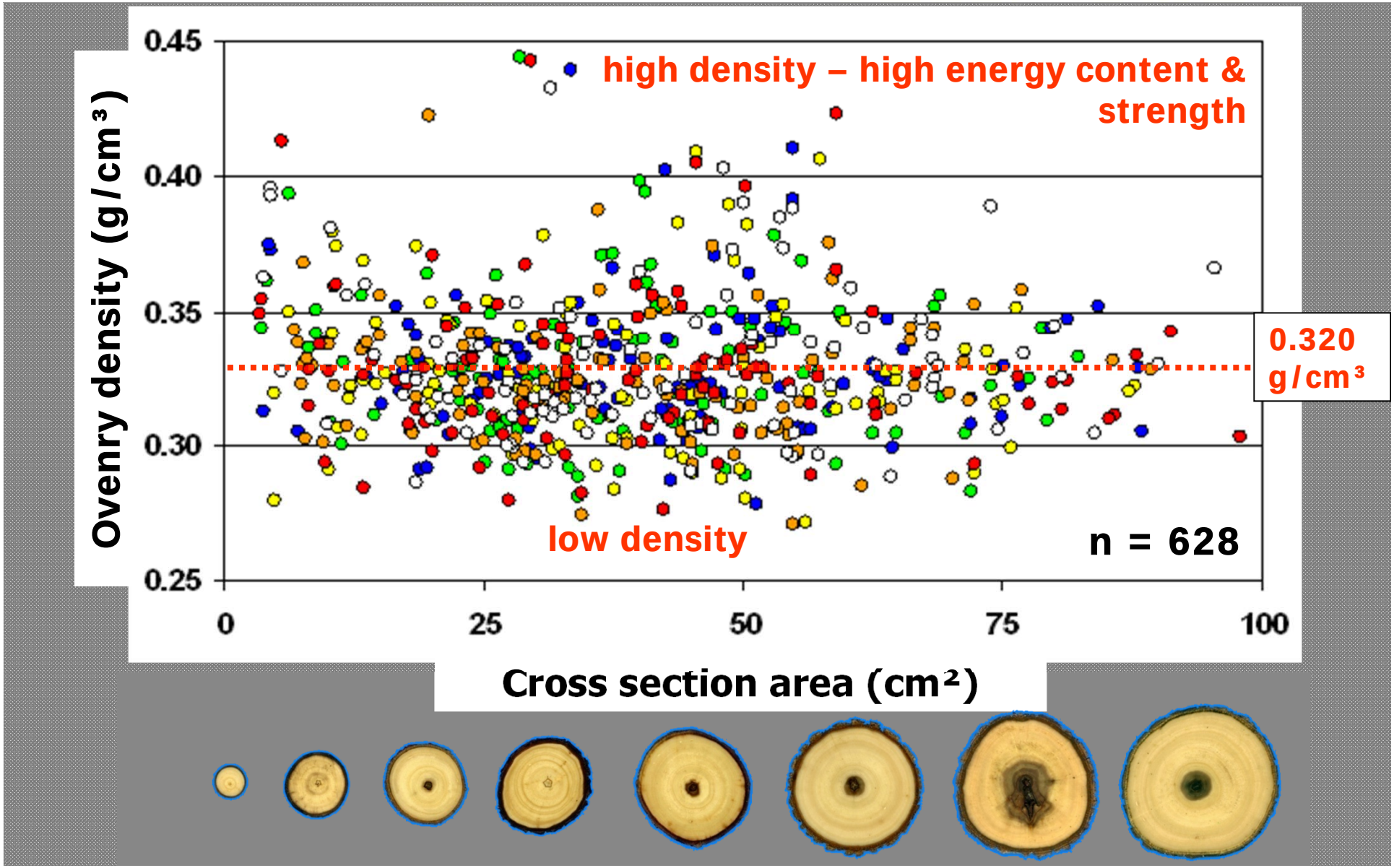
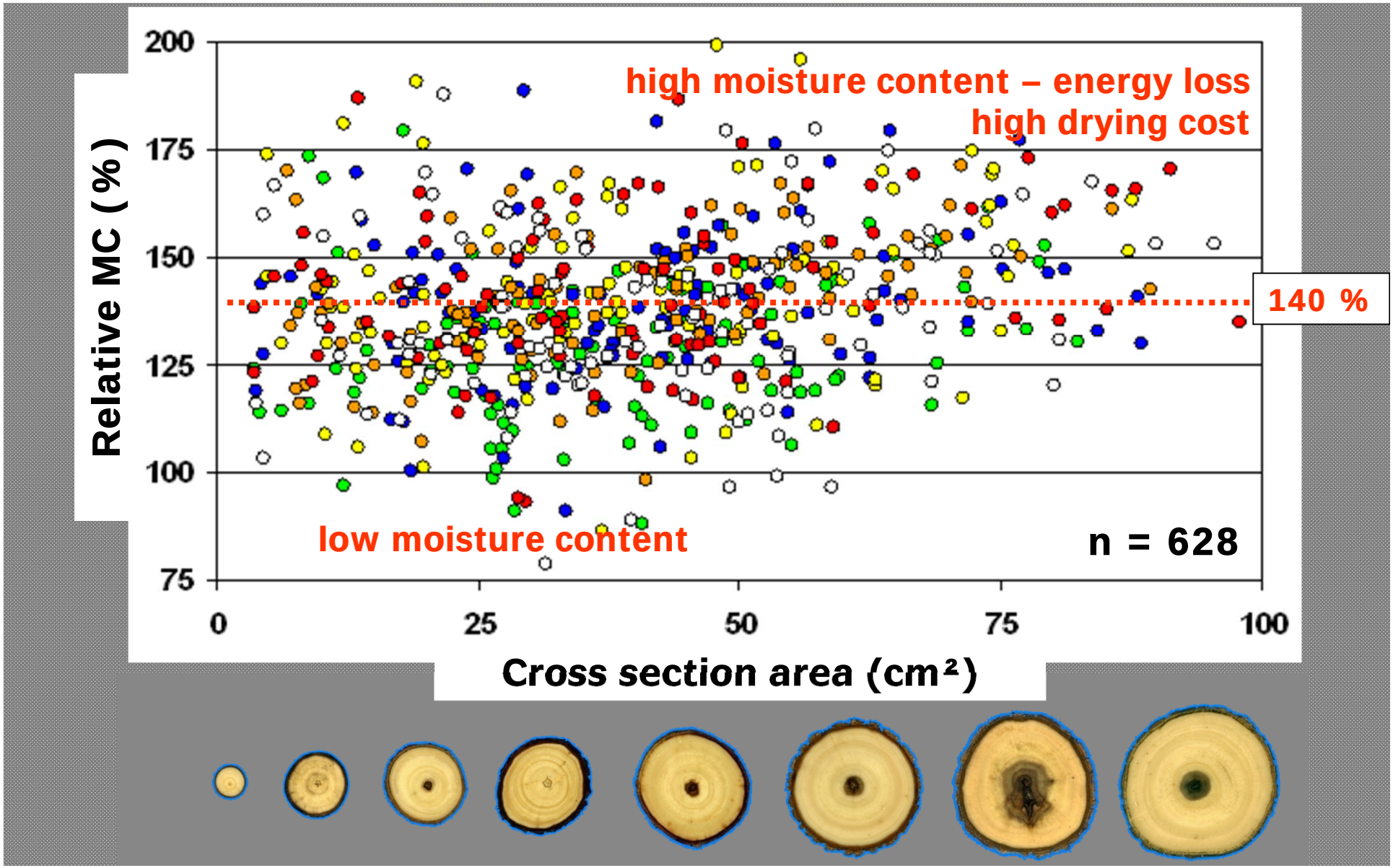
SELECTION & BREEDING FOR WOOD QUALITY

Case study:

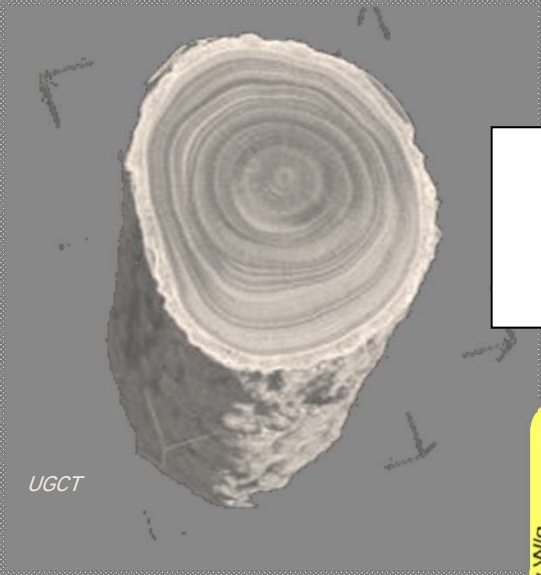
Poplar clones

(NOVELTREE)

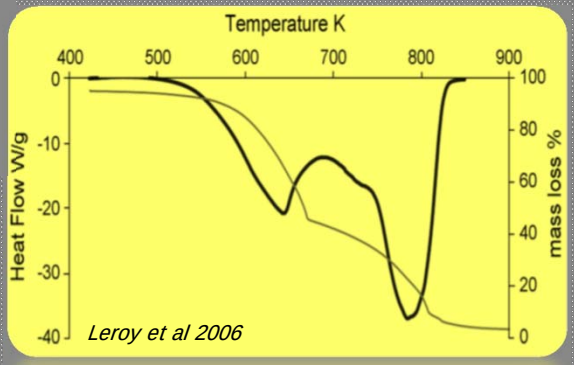

high density – high energy content & strength
low density
n = 628
0.320 g/cm³
Ovenry density (g/cm³)
0.45
0.40
0.35
0.30
0.25
0
25
50
75
100
Cross section area (cm²)


Relative MC (%)
200
175
150
125
100
75
0
25
50
75
100
Cross section area (cm²)
high moisture content – energy loss
high drying cost
140 %
low moisture content
n = 628

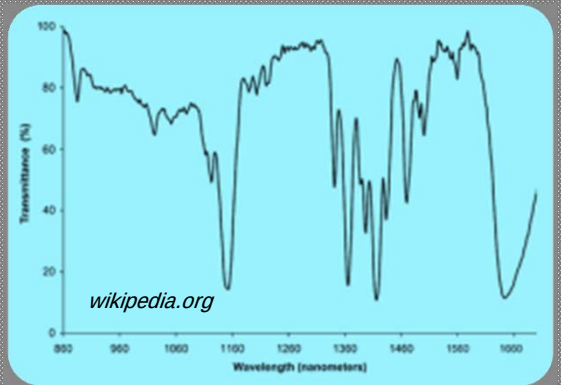
HIGH THROUGHPUT SYSTEMS



X-ray Computer Tomography



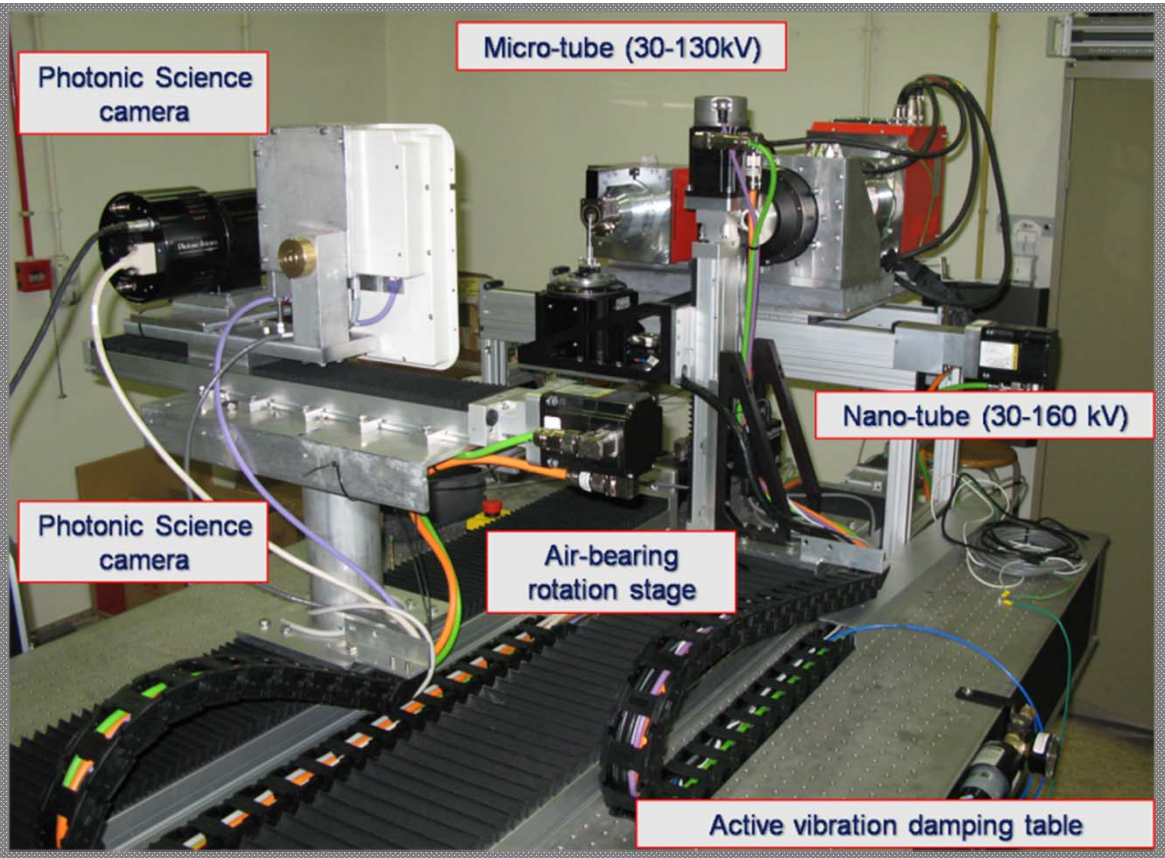
Thermal analysis



NIR spectroscopy

X-ray Computer Tomography …

Noveltree EU project & Trees4future



Poplar

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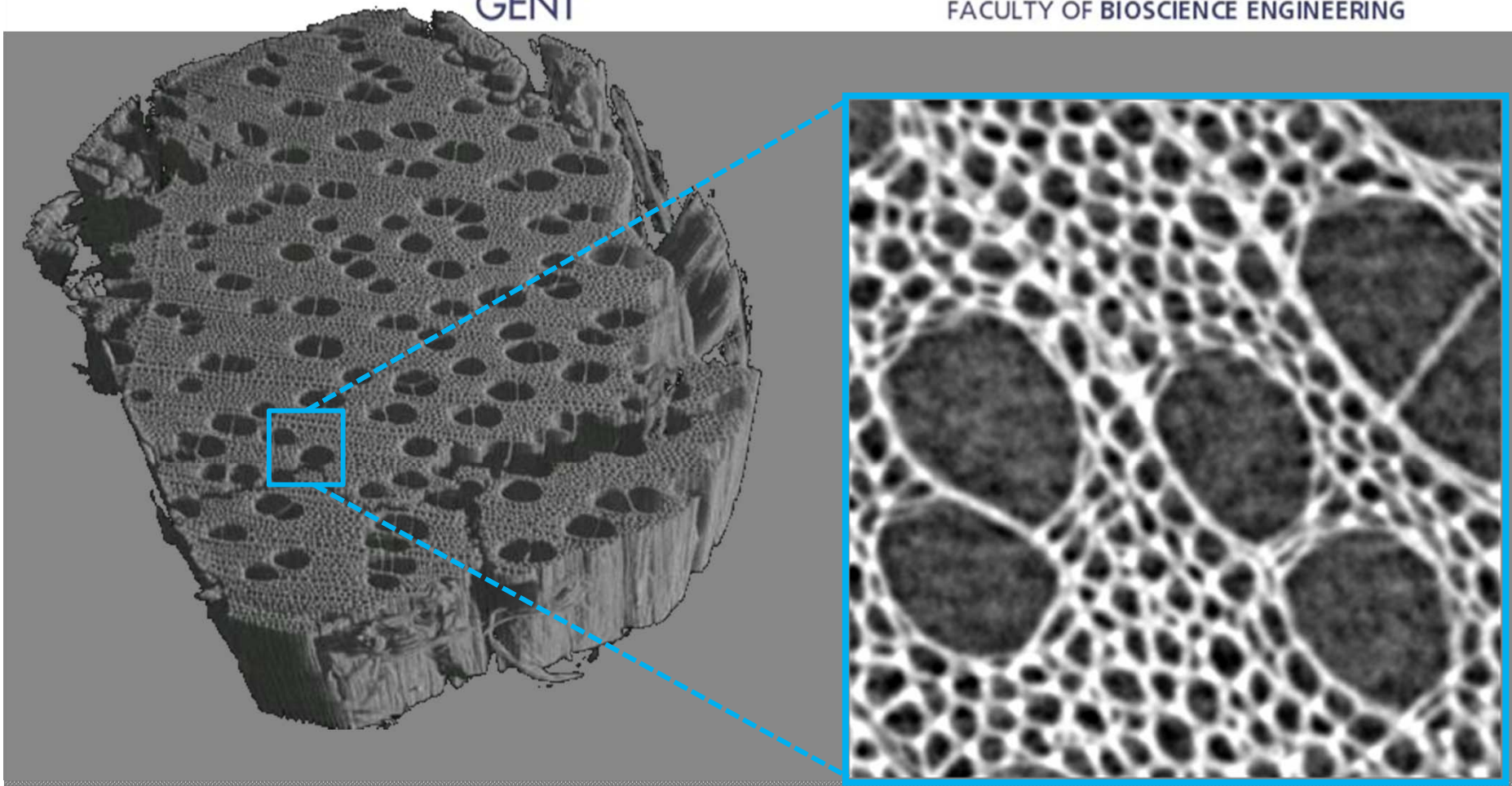
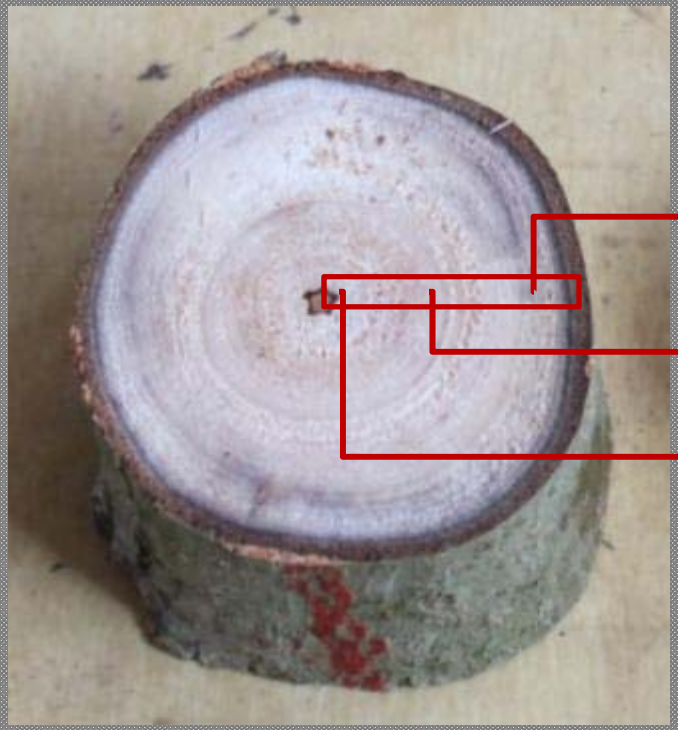


3D-rendering

2D-slice (transversal)

Thermal analysis …

Noveltree EU project & Tree4Future project



Coupled DSC-TGA

***Populus nigra* L12229N45**

NIR analysis

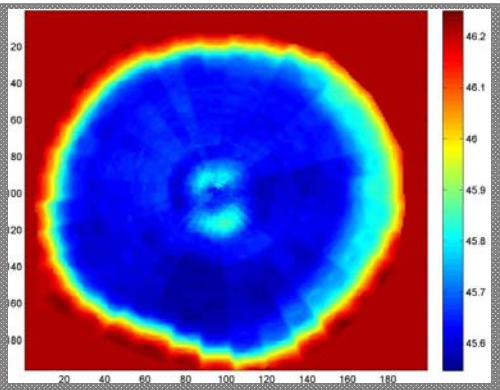
(SWIR = short wave infrared)

Trajectory scanning with temporary NIR set-up

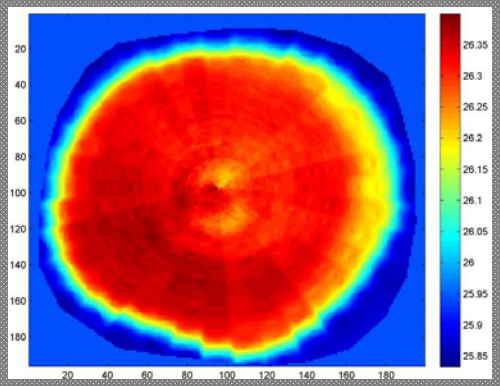
***Populus nigra* L12229N45**

Flatbed scan

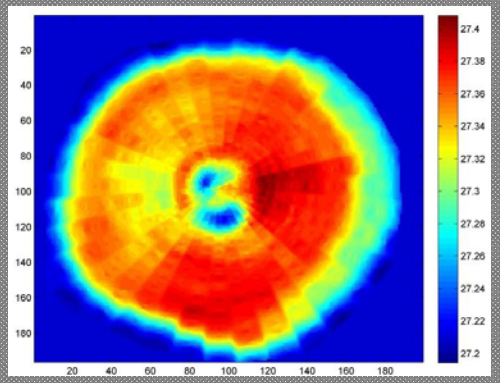
X-ray scan



Cellulose



Lignin (energy)



Hemicellulose

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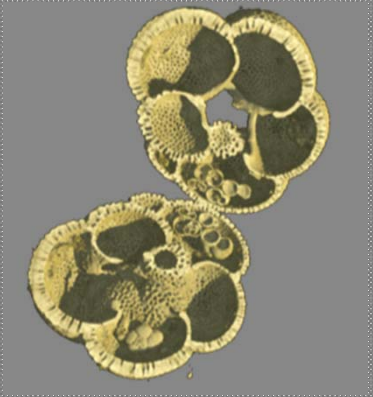
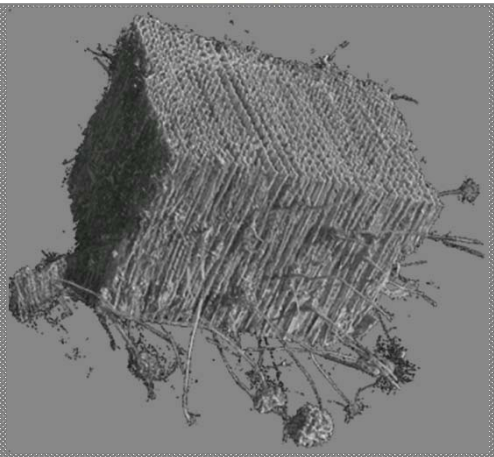
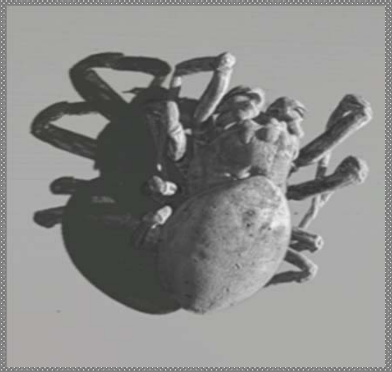
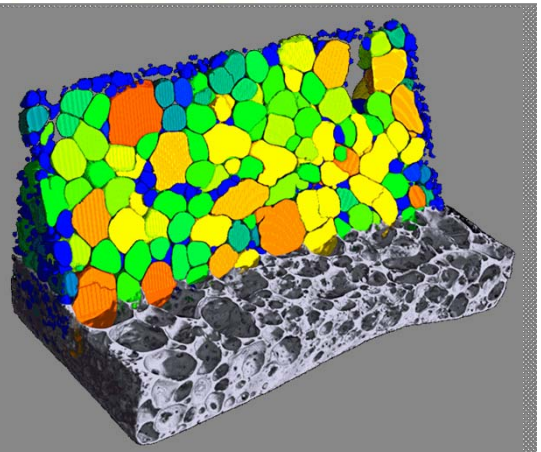

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www.woodlab.be

www.ugct.ugent.be

www.inCT.be (spin-off)

www.xre.be (spin-off)

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X-ray tomography and DSC-TGA

EU project for funded research access – **Trees4Future** project
http://www.trees4future.eu/transnational-accesses.html

TREES 4 FUTURE

SEVENTH FRAMEWORK PROGRAMME

Call is open!

Designing Trees for the Future