CarboEurope
- The Carbon Cycle Research Programme of the European Union
- the Move Towards More Remote Sensing Input

3rd Science Advisory Panel Meeting
October 2002 in Jena, Germany

Reiner Zimmermann
TCOS-Siberia (EU) and FORCAST (EU) project manager

Fifth EU Framework Programme
Key Action: Global Change, Climate and Biodiversity

Cluster chairman: Han Dolman
Vrije Universiteit
Amsterdam, Netherlands

Cluster office: Annette Freibauer
Max Planck Institute for Biogeochemistry
Jena, Germany
European carbon sink uncertainty:

European carbon sink (Gt C) positive sign: sink

CarboEurope Objectives:

- To develop methodologies for quantifying the European and Northern Eurasian carbon balance
- To develop a prototype of a consistent monitoring and verification system which will allow the calculation of the carbon balance of Europe and Northern Eurasia
- Provide necessary data for implementing the Kyoto Protocol of the UN Climate Change Convention
Space and time coverage of existing carbon observing networks

- **Time:**
  - Centuries
  - Decadal
  - Inter-annual
  - Seasonal
  - Synoptic

- **Space:**
  - 1 ha
  - 1 km²
  - Regional 10⁶ km²
  - Continents
  - Globe

- **Methods:**
  - Forest
  - Soil carbon
  - Ecological site studies
  - Eddy Flux Towers
  - Remote sensing
  - Atm stations
  - Flask network

- **Notes:**
  - * uneven geographic coverage
  - ** pilot studies only

The CarboEurope Project

- Emphasis on regional and continental scales
- Consideration of different ecosystem types and biomes
- Integration of spatial and temporal scales
- Use of data from complementary methodologies
CarboEurope uses a dual constraint approach for full carbon accounting

Top down: atmospheric methods

Bottom up: carbon inventories and models

COORDINATION
Steering Committee and CarboEurope Office
CARBOEUROPE ACCOMPANYING MEASURE
Coordination and dissemination of carbon research results

INTEGRATION
CARBO-EUROPE GNG
European greenhouse gas budget
CAMELSS
Carbon emissions and modelling
CARBODATA
Ecosystem models
CARBOINVENT
Forest inventories

OBSERVATIONS in Europe
AEROCARB
Airborne regional observations of European carbon balance
RECAB
CBL measurements and modelling
CARBOEUROFLUX
Carbon and energy exchange of forests
CARBOAGE
Age dynamics of C exchange in forests
FORCAST
Forest carbon-nitrogen studies
GREENGRASS
Greenhouse gas management in grasslands

Elsewhere
CHIOTTO
Tall tower observations
TCOS - SIBERIA
Carbon observations in Siberia
CARBON-SINK LBA
Carbon cycling in Amazonia

INFRASTRUCTURE
TACOS
Terrestrial and atmospheric carbon observation infrastructure
CarboEurope study regions:

- FORCAST: Ecosystem fluxes & budgets
- CARBOAGE: Changes with stand development
- CARBOEUROFLUX: Canopy flux observation (Eddy-towers)
- RECAB: Regional CBL-Budgeting
- AEROCARB: Inversion modelling based on tropospheric CO2 observations
- CARBODATA: Data integration, ecosystem modelling

TCOS - Siberia

CarboEurope Project Synergy:

- Ecosystem component
- Methods applied
- Project scale
FORCAST Study Design:

- FORCAST studies soil and biomass carbon and nitrogen turnover processes in forests.
- FORCAST works at a series of sites with different stages of vegetation development, climate conditions, and nitrogen deposition along a North-South transect.
- All FORCAST sites are also CARBOEUROFLUX sites where climate and NEE are monitored continuously.

The FORCAST project focuses on the dynamics of carbon fluxes in the vegetation-soil interface:

![Diagram showing carbon fluxes in forest ecosystems.](image-url)

- CO₂ and NPP: 6 ± 2
- Litter: 3 ± 1
- Wood: 3 ± 1
- NEP: 5 ± 1
- Mineralization: 1.4 ± 0.7
- Harvest: 1.5 ± 0.9
- Soil C flux: 1.4 ± 0.7

Fluxes in t C ha⁻¹ yr⁻¹

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>NPP</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>Litter</td>
<td>3 ± 1</td>
</tr>
<tr>
<td>Wood</td>
<td>3 ± 1</td>
</tr>
<tr>
<td>NEP</td>
<td>5 ± 1</td>
</tr>
<tr>
<td>Mineralization</td>
<td>1.4 ± 0.7</td>
</tr>
<tr>
<td>Harvest</td>
<td>1.5 ± 0.9</td>
</tr>
</tbody>
</table>

- MRT (Mean Residence Time): 80 years

Fluxes in t C ha⁻¹ yr⁻¹

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter</td>
<td>&lt;1-3</td>
</tr>
<tr>
<td>Wood</td>
<td>1-250</td>
</tr>
<tr>
<td>Products</td>
<td>15-20</td>
</tr>
<tr>
<td>O layer</td>
<td>14-52</td>
</tr>
<tr>
<td>A horizon</td>
<td>70-170</td>
</tr>
</tbody>
</table>

Source: Dolman et al. 2001
FORCAST Questions:

- Which ecosystem components have large mean residence times for carbon?
- What is the effect of vegetation age on carbon storage?
- How does nitrogen availability affect carbon storage?
- Which processes drive the carbon sequestration?
Objectives of TCOS Siberia:

- Implementation of the first components of a continental scale observing system for determining the net carbon balance of Siberia and its variation from year to year.

- Integration of the project observational network with the networks of surface flux and atmospheric concentration measurements.

- Integration with continuous trace gas measurements from a tall tower (250 m) to be operational in central Siberia within the next year.
TCOS-Siberia Methodology:

(1) Continuous surface flux measurements in key ecosystems at four locations

Long-term surface flux monitoring systems are set in place at each measurement station (Example: Fjedorovskoje)

TCOS-Siberia Methodology:

(2) Regular vertical profile measurements from aircraft in the lower troposphere at six locations.

Regular vertical profiling (every 2-4 weeks) and isotopic analysis of CO₂ and other carbon cycle relevant tracers by aircraft at the sites
TCOS-Siberia combines data sources:

(3) Combination of tower measurement data, physiologic process data, air sample information, updated climatic data, and land cover information for modeling.

Exchange process studies are supported by an Eurasian landscape characterization combining remote sensing approaches with terrain analysis and associated edaphic properties.

Science issues

- What drives interannual variation?
- How are biogeochemical cycles of C, N, P, H₂O linked?
- How to scale up consistently local measurements?
- How to disaggregate atmospheric measurements?
Open issues:

- Development of carbon data assimilation systems for Kyoto Protocol monitoring.

Biomass up-scaling from tree to stand
Site selection for study areas is based on uniform conditions

**Site:** Wetzstein, Thuringia

**3-D:** Stockmann Kuhpfahl, Reche 2002

Biomass assessment is by applying algorithms for typical tree species

- **Leaves**
  - 70 years: 3.3 Mg ha⁻¹

- **Branches**
  - 70 years: 30.4 Mg ha⁻¹

- **Stem**
  - 70 years: 293 Mg ha⁻¹

**Aboveground woody biomass**
- 70 years: 325.5 Mg ha⁻¹

**Aboveground total biomass**
- 70 years: 328.7 Mg ha⁻¹

From Matteucci & Baschetti, University of Viterbo
Biomass up-scaling for large areas

For biomass upscaling, the stand biometry of potentially corresponding forest units is used from literature and associated with mapping units.

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Location</th>
<th>Elevation (m a.s.l.)</th>
<th>Above-ground biomass (m³ha⁻¹)</th>
<th>Stand Height (m)</th>
<th>Basal area (m²ha⁻¹)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical forest</td>
<td>Rio Xingo, Brazil</td>
<td>-</td>
<td>25.4</td>
<td>-</td>
<td>-</td>
<td>HEINSDIJK (1958)¹</td>
</tr>
<tr>
<td>Tropical forest</td>
<td>Sao Miguel de Ocampo, Brazil</td>
<td>-</td>
<td>25.5</td>
<td>-</td>
<td>-</td>
<td>GUSPEN &amp; SIMP (1963)²</td>
</tr>
<tr>
<td>Dry montane rain forest</td>
<td>Drying, Wet Province, Thailand</td>
<td>500</td>
<td>28.7</td>
<td>20</td>
<td>20.4</td>
<td>DANKER et al. (1989)³</td>
</tr>
<tr>
<td>Low montane rain forest</td>
<td>Lagoa do Rei, Forest, Puerto Rico</td>
<td>510</td>
<td>1.68 x 0.405-7</td>
<td>36</td>
<td>36.0-41.0</td>
<td>DVORTSCHENKO et al. (1979)⁴</td>
</tr>
<tr>
<td>Tropical forest</td>
<td>Panama</td>
<td>-</td>
<td>28.8</td>
<td>-</td>
<td>-</td>
<td>DVORTSCHENKO et al. (1979)⁴</td>
</tr>
<tr>
<td>Tropical montane rain forest</td>
<td>Magdalena Valley, Colombia</td>
<td>-</td>
<td>28.8</td>
<td>-</td>
<td>-</td>
<td>DVORTSCHENKO et al. (1979)⁴</td>
</tr>
<tr>
<td>Low montane rain forest</td>
<td>Barbadillo-Chaco, Guayana</td>
<td>500</td>
<td>0.97 x 0.99</td>
<td>&lt; 46</td>
<td>40.0</td>
<td>DVORTSCHENKO et al. (1979)⁴</td>
</tr>
<tr>
<td>Tropical montane forest</td>
<td>Alaska</td>
<td>-</td>
<td>40.7</td>
<td>-</td>
<td>-</td>
<td>DVORTSCHENKO et al. (1979)⁴</td>
</tr>
<tr>
<td>Production forest (mixed forest)</td>
<td>Tropical America</td>
<td>-</td>
<td>15.5</td>
<td>-</td>
<td>-</td>
<td>BRIDLE &amp; LIND (1990)⁵</td>
</tr>
<tr>
<td>Tropical montane sub-montane forest</td>
<td>Brazil</td>
<td>-</td>
<td>28.8</td>
<td>-</td>
<td>-</td>
<td>KRAUFSCHETZ et al. (1990)⁵</td>
</tr>
<tr>
<td>Tropical montane wet forest</td>
<td>Las Colinas de Los Negros, Venezuela</td>
<td>-</td>
<td>31.6</td>
<td>-</td>
<td>-</td>
<td>KRAUFSCHETZ et al. (1990)⁵</td>
</tr>
<tr>
<td>Premontane rain forest</td>
<td>Alto Mayo, Peru</td>
<td>920-1100</td>
<td>239</td>
<td>&lt; 30</td>
<td>30.1</td>
<td>DIETZ (2002)</td>
</tr>
</tbody>
</table>

¹) Tropical moist forest
²) Tropical seasonally evergreen forest
³) Lower montane rain forest
⁴) Tropical montane wet forest
⁵) Premontane rainforest

ALT O MAYO, PERU

13
Seven estimates of storage of carbon in forest biomass for the Brazilian Amazon


Requirements to meet Kyoto Protocol Carbon accounting needs in forest areas

- Spatial Resolution: 0.5 Ha = 5000m$^2$ = Boxplot or pixel size of 70x70m
- Temporal Resolution: every 4 years (2008-2012)

Average Tree Height Change in 4 Years: 1-4 meters

Differential Height Accuracy: 1 meter

From: Metz et al. 2002
Intra -Vegetation Unit Variation
Vegetation classes and biomass distribution are typically not well correlated.

From Rignot et al. 1995

Above-Ground Biomass of major Vegetation Types – Rio Manu Region, Peru

Neotropical Rainforest, 290-350 m a.s.l.,
sub-humid (dry) season June to September, Precipitation 2100-2400 mm yr⁻¹

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Age (years)</th>
<th>Canopy Height (m)</th>
<th>Standing biomass* (t ha⁻¹)</th>
<th>Leaf area index* (m² m⁻²)</th>
<th>SE ** (m²) (t ha⁻¹)</th>
<th>Max. Biomass* (t ha⁻¹)</th>
<th>Gap Biomass* (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oyacuira</td>
<td>0...3</td>
<td>3-10</td>
<td>44</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tesaria</td>
<td>1...5</td>
<td>8-12</td>
<td>40</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cecropia</td>
<td>5...20</td>
<td>12-20</td>
<td>&gt;45</td>
<td>&gt;1.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mosaic Forest</td>
<td>20...&gt;150</td>
<td>25-35</td>
<td>310</td>
<td>6.7</td>
<td>32</td>
<td>812</td>
<td>101</td>
</tr>
<tr>
<td>Dry Palm Agajal</td>
<td>15...&gt;80</td>
<td>26-26</td>
<td>170</td>
<td>3.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mature Floodplain Forest</td>
<td>150...1000</td>
<td>40-53</td>
<td>504</td>
<td>8.2</td>
<td>99</td>
<td>1142</td>
<td>137</td>
</tr>
<tr>
<td>Mature Upland Forest</td>
<td>50...&gt;300</td>
<td>28-34</td>
<td>280</td>
<td>6.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hill Forest</td>
<td>50...&gt;300</td>
<td>35-40</td>
<td>460</td>
<td>6.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* after Ogawa et al. (1965)
+++ J. Terborgh, Duke Univ.; Plotsize 225 500 m² * 625 m² plus
Inter-vegetation unit variation:

Edaphic effects on vegetation and biomass

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Biomass (t/ha)</th>
<th>Basal Area (m²/ha)</th>
<th>Growth Density (stems/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm forest</td>
<td>197 (62)</td>
<td>32</td>
<td>462</td>
</tr>
<tr>
<td>Ficus swamp</td>
<td>216 (59)</td>
<td>33</td>
<td>700</td>
</tr>
<tr>
<td>Alluvial plain forest</td>
<td>192 (58)</td>
<td>32</td>
<td>412</td>
</tr>
<tr>
<td>Valley forest</td>
<td>246 (103)</td>
<td>40</td>
<td>637</td>
</tr>
<tr>
<td>Montane forest</td>
<td>244 (105)</td>
<td>40</td>
<td>623</td>
</tr>
<tr>
<td>Semi-deciduous hill forest</td>
<td>113 (45)</td>
<td>32</td>
<td>4392</td>
</tr>
<tr>
<td>Fern woodland</td>
<td>36 (14)</td>
<td>1</td>
<td>712</td>
</tr>
<tr>
<td>Slope heath forest</td>
<td>69 (46)</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Dry heath forest</td>
<td>25 (17)</td>
<td>9</td>
<td>920</td>
</tr>
<tr>
<td>Peat heath forest</td>
<td>14 (6)</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

* Determined with respect by BITTERLICH

Biomass parameters for ten vegetation types at the East Andean slope, Alto Mayo, Peru.
Example: Small scale variation of vegetation and biomass in tropical areas.

View across natural forests from the Cerro Tambo, Alto Mayo, North Peru.

<table>
<thead>
<tr>
<th>Slope (°)</th>
<th>Area (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>56</td>
<td>3</td>
</tr>
<tr>
<td>2-7</td>
<td>587</td>
<td>17</td>
</tr>
<tr>
<td>7-12</td>
<td>830</td>
<td>26</td>
</tr>
<tr>
<td>12-25</td>
<td>765</td>
<td>26</td>
</tr>
<tr>
<td>&gt;25</td>
<td>226</td>
<td>11</td>
</tr>
</tbody>
</table>
| Total    | 2302      | 100%

Source: Dietz et al. 2002.
Forests in the hill area of Alto Mayo

240 (103) t/ha

113 (45) t/ha

Open vegetation types of the Alto Mayo

25 (17) t/ha

14 (6) t/ha

Dietz et al. 2002
Dendrogram of topographic position and drainage preconditions over vegetation height driving actual forest cover in the Alto Mayo hill area.

Distinction of clusters was confirmed by statistical analysis (cf. ANOVA-Analyis).

Hierarchical Cluster Analysis

Biomass Estimation Parameters

Biomass = \( f(h, \text{dbh}, \text{wd}) \)

(biomass as total aboveground dry weight of standing trees)

\[ h = \text{total tree height} \]

\[ \text{dbh} = \text{tree diameter at breast height (1.3 m)} \]

\[ \text{wd} = \text{tree wood density} \]
Tree height vs. DBH using Ogawa’s algorithms (1965) for neotropical vegetation:

![Graph showing tree height vs. DBH relationships for different biometric forest units.](image)

Tree height vs. DBH relationships for different biometric forest units:

![Graph showing tree height vs. DBH relationships for different biometric forest units.](image)
Schneeberg, Germany

Forest canopy height variation within pure spruce forests

Canopy height (m)

http://www.bgc-jena.mpg.de/public/carboeur/