Field protocol on Radiation measurements and Leaf Area Index (LAI)
D1, D2, D3

(corresponds to second draft from 25th May 2009)

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1. Introduction and Data Requirements

Leaf area index (LAI) is defined as the total one-sided foliage area per unit ground surface area (Chen and Black 1991). Data requirements within the FutMon project are depending on the focus of the Demonstration actions D1 – D3. An overview is made by the following table:

Action	D1	D2	D3
Action Objectives	Develop new tree vitality parameters which are comparable with defoliation. Such could be e.g. transparancy, foliage biomass, gap fraction or, as a parameter which is related to the foliage biomass, the LAI	In D2 action a parameter contributing to the estimation of leaf biomass need to be tested and developed.	Parameterisation of water budget models (interception, transpiration, soil evaporation) Improvement of transfer functions
Action Data Requirement	Relation to crown condition sites and the growth measurements; measurement synchronized with Crown condition assessment in annual repetition; additional winter assessment recommended for deciduous tree species	A general value for the plot linked to throughfall deposition and soil solution and litterfall measurements; no annual variation needed	Representative value for plot(&species) in case of deciduous tree species summer and winter value; annual repetition recommended; measurements should be related to throughfall and soil moisture measurements.

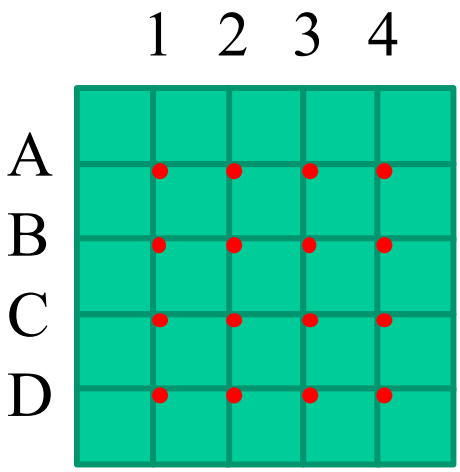
In order to get an impression on the variation and comparability of produced parameters a field exercise will be held during summer 2009 in Bavaria (to be confirmed).

Assessments are mandatory to be made during crown condition assessment starting in 2009. The used methodology has to be described by each Associated Beneficiary or project participant, respectively. This description (MS Word document) according with the LAI values for each site has to be submitted to the FutMon data centre. All settings during field observation and later data analysis have to be documented by the project participants (e.g. settings for definition of evaluated part of image, Initial Point and Final Point, if necessary to define for used equipment).

2. Sampling design

Beneath the direct determination of LAI from the litterfall samples (direct method) it is possible to make respective assessments from various radiation measurement methods (indirect methods). In order to get an estimate of the variation of the leaf area and so of the crown structure and light conditions under crown a systematic sampling design is recommended. Due to the data requirements of D1 it is necessary to include that part of the plot where crown condition and growth assessments are performed. The possibility to link the results with other surveys are to be documented. Thus, for D2 action it is essential to link the measurements to throughfall, soil solution, and litterfall measurements. For D3 the linkage to throughfall and soil moisture measurements is essential. Sensitive areas which have to be protected against disturbances (e.g. ground vegetation and soil solution sampling) have to be excluded from the measurements.

Due to restrictions of measurement methods the sampling design should use a grid net of at least 10x10m resolution to cover an area of 0.25ha which is defined in the manual of ICP Forests to be the minimum size of the Level II plots excluding the edges of the area. A denser grid net than 10x10m may be used. This is described in the following sketch:



If a measurement point is lying within a distance less than 2m from an obstacle (e.g tree or bolder) the measuring point is moved so that it is at least 2m away from all obstacles. Each point must be marked permanently.

A measurement height of 1.5m is defined in order to avoid disturbances by lower shrubs or installed litterfall or deposition samplers which could disturb the radiation measurements.

The location of each measurement point has to be documented. This will be done by relative coordinates. The origin is the lower left measurement point (in general the point situated most south west; point D1 in sketch above), the adjustment of the system is north to south (A to D) and east to west (1 to 4). If another metric coordinate system is already established the respective coordinates may be submitted instead.

In order to have a quantification of the spatial situation of the surveys the coordinates of sampling devices have to be documented in the same way: For instance, a litterfall sampler situated 18m west and 15 m south of the origin of the coordinate system has to be documented with the coordinates X = -18 and Y = -15. This has to be done for the following surveys:

Litterfall, throughfall, soil solution, ground vegetation (lower left corner or south west corner of Ground Vegetation plot area), crown condition trees, foliar chemistry trees, growth trees. (coordinates of 100 plots were stored under ForestBiota)

Coordinates are submitted to the data centre using form XX2009.LAC.

3. Direct methods

3.1. Litterfall analysis

The direct method for LAI determination is described in the Field Protocol on litterfall.

4. Indirect methods

Indirect methods use radiation measurements below the crown for the assessment of LAI. Some of those methods lead to the assessment of further parameter as e.g. crown biomass or gap fraction. In order to get reliable values for LAI some uniform settings for field work and

for the analysis and correction of the resulting values have to be defined. In addition to LAI some of the indirect methods produce values as gap fraction or biomass indices and photo documentation.

Experts on all methods described in this document can be contacted by sending an e-mail to Volker.Mues@vti.bund.de at the FutMon data centre or to Stephan.Raspe@lwf.bayern.de who will organize a direct contact to the experts.

Spatial settings for field survey on LAI:

In order to get reliable values and an indication for the comparability with results from other surveys the sampling design and the submission of coordinates are already described in section 2.

With all field observations the following parameters have to be documented as they are needed for latter evaluations:

latitude & longitude, altitude, magnetic exposition, and slope.

They are submitted to the data centre using form XX2009.PLA (see FutMon forms document).

Time frame for LAI determination (field survey):

All measurements are made in the following time frame:

- summer measurements: during crown condition assessment, 16th July to 15th August recommended in order to increase comparability (mandatory)
- winter measurements on deciduous tree species: during time without leaves (optional)

4.1. Canopy analyzers

4.1.1. LAI 2000

Instrument Name: Li-Cor LAI-2000 Plant Canopy Analyzer

Pre-defined settings of the equipment during field work

- preferably uniform overcast sky without any direct radiation contribution; alternatively on sunny days around sunrise and sunset (theoretically);
- 30 seconds logging on clearing or above canopy measurement; use closest-in-time measurement for linkage with below canopy measurements;
- clumping factors, shoot/needle index, and woody area need to be retrieved from hemispherical photographs, TRAC measurements, direct methods, and/or from literature.
- follow strictly the advices given in the manual ftp://ftp.licor.com/perm/env/LAI-2000/Manual/LAI-2000_Manual.pdf
- Date and time as well as the weather conditions have to be specified as precise as possible. A form concluding the data on documentation of field situation will be used for this.
- If view caps are used, it should be recorded which one and towards what direction the measurement was performed.

Data management and Parameter Outcome

Clumping factors, shoot/needle index, and woody area need to be retrieved from hemispherical photographs, TRAC measurements, direct methods, and/or from literature.

FV2000 Data File Viewer (new Windows program) is recommended and should be preferably used instead of older versions under DOS.

Recompute Transmittance:

- A is Above
- use the Closest in time Above record
- Transmittance not allowed to exceed 1
- In general, the horizontal canopy model should be used (default), unless the stand is too small or has a very heterogeneous upper surface.
- In general, the 5th ring should be skipped when calculating the LAI (see manual)

Output:

LAI 2000G (output of this programme is the effective LAI)

4.1.2. TRAC (Chen)

Another indirect method is the Tracing Radiation and Architecture of Canopies (TRAC). A handheld instrument is used in the forest, the latest software version at moment of Protocol preparation is TRACWin (2.3.4, 11.2007). The respective homepage is:
http://faculty.geog.utoronto.ca/Chen/Chen's%20homepage/res_trac.htm

At moment of protocol preparation the manual version 2.1.3 could be downloaded from this site (LEBLANC ET AL., 2002):

http://faculty.geog.utoronto.ca/Chen/Chen's%20homepage/PDFfiles/tracmanu.pdf

Predefined conditions:

- clear sky
- optimal solar zenith angle: 30-60° (best - close to 57°)
- position of transect perpendicular to sunbeams (transect has to be documented according to the coordinate system described in section 0).

For the calculations and settings of the instrument following information must be known and documented:

- Mean element width (mm)
- Needle-to-shoot ratio
- Woody to total area ratio
- Spacing between markers of the transect (m)
- PPFD above
- Zenith angle
- Coordinates (geographical)
  Latitude
  Longitude
- Time longitude reference

- Computer clock

In addition to gap fraction (i.e. the share of caps in a crown at a given solar zenith angle) gap size distribution is determined (i.e. the physical dimension of a gap in the crown). This allows for the direct determination of the clumping factor and the integration of it during LAI determination which is underestimated if the clumping effect is neglected.

<u>data output</u>

- photosynthetic flux density (PPFD) along a transect as way to obtain the mean value of the transmitted light through the canopy; used to quantify the fraction of photosynthetically active radiation (FPAR) absorbed by the canopy (Chen, 1996b);
- gap size distribution (Chen and Cihlar, 1995b)
- parameter outcome (summary):
- Mean Gap fraction
- PAIe
- Mean PAIe
- Mean LAI
- OMEGA(T)
- OMEGA(L)
- OMEGA(T+L)
- OMEGA(M)

4.2. Hemispherical images analysis

- For all photos it is essential that the direction of the top of the photograph is directly to north measured with magnetic compass.
- Ideal conditions: uniform overcast sky
  Alternatives: before sunrise & at/after sunset
- use aperture of 5.0 to 5.5
- start with measurements / photography with the darkest measurement point
- use -2 underexposure to the automatically exposure under canopy.
  alternatively use +2 overexposure to the automatically exposure over canopy or at open area can be chosen and fixed for photography under canopy; this presumes constant weather and light conditions during the field observation; the use of a Notebook during field observation for direct control of photo quality is recommended. Also a set of photographs from - 2 under exposure to +2 overexposure in the stand could be taken in order to select afterwards the best image from each measurement point for further operating.
- image format standard: .jpg (high image quality settings)

- name of image will be for submission:
  XXPPPPNNDDDDDDTTTTTTC.jpg
  XX – country code (ICP Forests manual)
  PPPP – plot number (ICP Forests manual); replaced by "9" and 3 further letters which define a location not being a ICP Forests / FutMon plot
  NN – measurement point number (LAI Field Protocol)
  DDDDDD – date of image production (DayMonthYear: e.g. 140509)
  TTTTTT – time of image production (HHMMSS)
  C – counter/number in case that more than one photo is made in the same second (1, 2, 3, …)
- Filter usage: In their standard setting, many digital cameras apply a software filter to sharpen the picture. This filter should be turned off in order to avoid small errors and increase reliability of photos.
- Diffusion model must be documented with each photo evaluation settings.

General guidelines for data processing:

- use automatic mode to determine threshold values; underestimation is accepted here, comparability of outcome of higher importance?
- use colour mode instead of black/white if any available

For photo operating three methods are recommended after the discussion at the combined meeting on phenology and LAI measurement in Slovenia, May 2009:

WinScanopy, HemiView, and Gap Light Analyzer.

Those methods for interpretation of hemispherical photographs are briefly described below. Any method used during the FutMon project has to be documented in order to allow for a linkage to each resulting LAI value and photo document which is submitted during the project. If settings have to be changed from one photo to the other or e.g. from one site to the other, they have to be documented in addition.

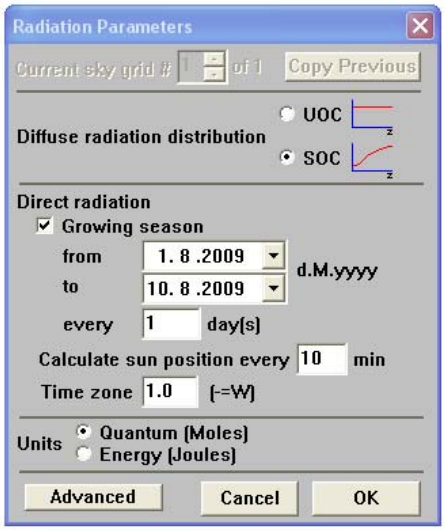
4.2.1. WinScanopy

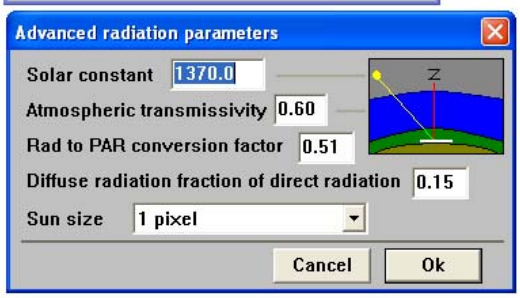
A link to the WinScanopy system is specified with:

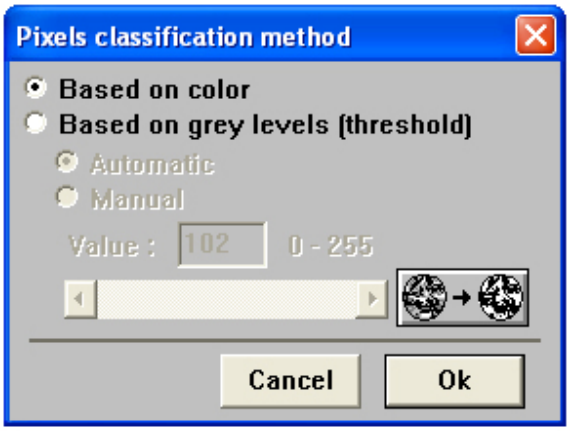
http://www.regentinstruments.com/products/Scanopy/Scanopy.html

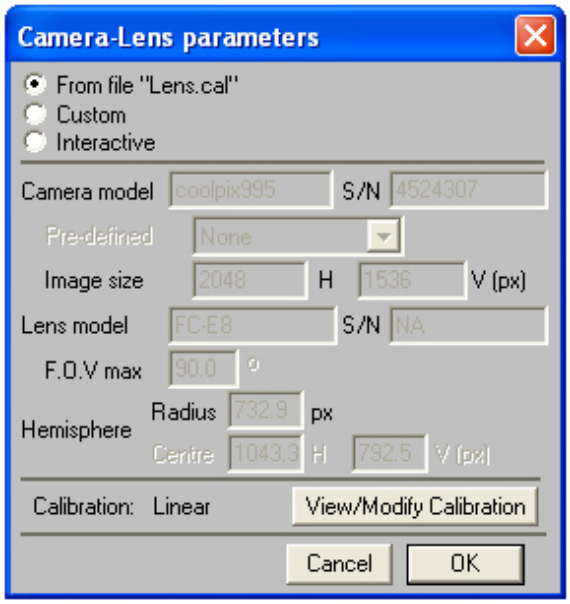
The WinScanopy system concludes all instruments which are needed for the determination of LAI starting with the camera, lens, and specific tripod up to the evaluation programme. All recommendations made in the manual and in this field protocol should be followed during field work.

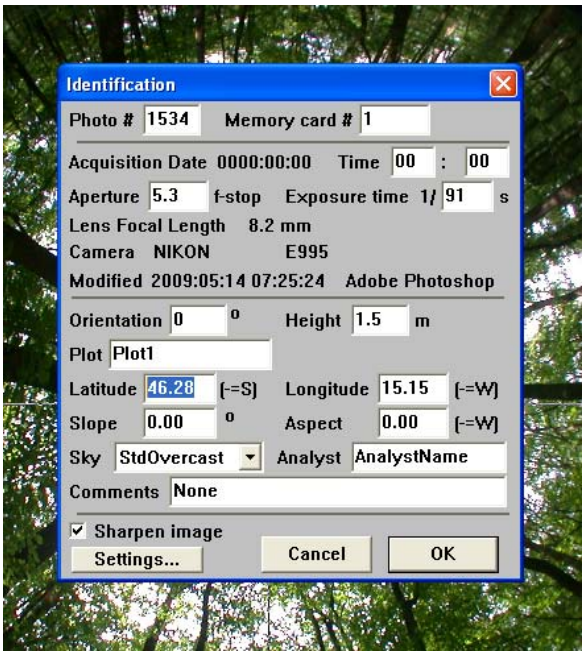
The recommended version of the Software is WinScanopy pro 2003 d pro version, which makes possible to evaluate photos in batch mode. Some screenshots of the programme showing settings for data processing:

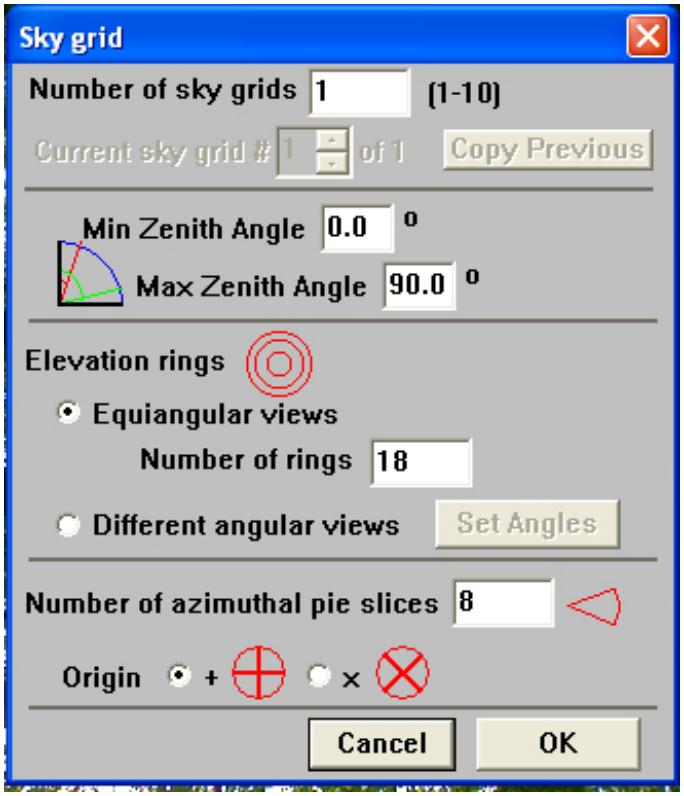

Radiation Parameters
Current sky grid # 1 of 1
Copy Previous
Diffuse radiation distribution
UOC
SOC
Direct radiation
Growing season
from 1. 8 .2009
to 10. 8 .2009
d.M.yyyy
every 1 day(s)
Calculate sun position every 10 min
Time zone 1.0 (-=W)
Units
Quantum (Moles)
Energy (Joules)
Advanced
Cancel
OK


Advanced radiation parameters
Solar constant 1370.0
Atmospheric transmissivity 0.60
Rad to PAR conversion factor 0.51
Diffuse radiation fraction of direct radiation 0.15
Sun size 1 pixel
Z
Cancel
Ok


Pixels classification method
Based on color
Based on grey levels (threshold)
Automatic
Manual
Value : 102 0 - 255
Cancel
Ok


Camera-Lens parameters
From file "Lens.cal"
Custom
Interactive
Camera model coolpix995 S/N 4524307
Pre-defined None
Image size 2048 H 1536 V (px)
Lens model FC-E8 S/N NA
F.O.V max 90.0 °
Hemisphere
Radius 732.9 px
Centre 1043.3 H 792.5 V (px)
Calibration: Linear
View/Modify Calibration
Cancel
OK


Identification
Photo # 1534 Memory card # 1
Acquisition Date 0000:00:00 Time 00 : 00
Aperture 5.3 f-stop Exposure time 1/ 91 s
Lens Focal Length 8.2 mm
Camera NIKON E995
Modified 2009:05:14 07:25:24 Adobe Photoshop
Orientation 0 ° Height 1.5 m
Plot Plot1
Latitude 46.28 (-=S) Longitude 15.15 (-=W)
Slope 0.00 ° Aspect 0.00 (-=W)
Sky StdOvercast Analyst AnalystName
Comments None
Sharpen image
Settings...
Cancel
OK



A basic scheme for the colour settings is stored in the attached file " Example_WinScanopy.CAC". Settings for the DOS version available in file " Any deviations have to be documented and reported in a data accompanying word document.

4.2.2. HemiView (link to manual and webpage)

- Camera systems which are recommended: Nikon, Canon, Minolta
  used by respective expert in project: Nikon Coolpix 4500 with FC-E8 (Zhang et al., 2005 protocol)
- Common Lenses: predefined - FC-E8/Coolpix 4500 (990 series), FC-E9/Coolpix 8400 series, Sigma/Canon SLR; possible to add any hemi-lens, based on few parameters
- Useful additional devices:
- Self Leveling Mount System: SLM6-UM-1, Delta-T Devices Ltd.
- Tripod: Manfrotto 681B.
- Software: Hemiview 2.1
- A description of the system can be downloaded from:

  http://www.delta-t.co.uk/groups.html?group2005092332185

  Manual: ftp://ftp.dynamax.com/Manuals/HemiView_Manual.pdf
- Aperature: preferred 5.3 or similar

Data processing:

Software: Hemiview 2.1 (Delta-T Devices Ltd.)

http://www.delta-t.co.uk/groups.html?group2005092332185

Manual: ftp://ftp.dynamax.com/Manuals/HemiView_Manual.pdf

Outcome:

- LAI in Skymap Sectors (LAI)
- LAI by Angle Class (LAD)

4.2.3. Alternative photo devices and Gap Light Analyser (Freeware)

In principle many cameras and lenses may be used in order to get hemispherical photographs. These may be evaluated using specific software as the proposed systems above do or using available Freeware. In this chapter an additional system is proposed in order to underline that alternative devices may be used and in order to give an example for a respective documentation of the devices and methods which are applied in the field.

Overcast sky condition are recommended to avoid reflections on the lens and also to avoid blooming effect. Overcast sky conditions are present by an uniform cloudiness or in the hourn before sunrise or after sunset, when no direct solar radiation is present.

Camera: Nikon CoolPix E8700

Camera_Manual: http://www.nikonusa.com/pdf/manuals/coolpix/CP8700_en.pdf
Nikon Fisheye Converter FC-E9

Lens_Manual:
http://www.nikonusa.com/pdf/manuals/tnirp/Coolpix_Accessories/Coolpix_Converter_lenses/FCE9.pdf

Basic camera settings:

- Aperture: 5,0
- Exposure: -2 steps or follow up from -2 steps to automatic exposure under canopy.
- In their standard setting, many digital cameras apply a software filter to sharpen the picture. This filter should be turned off, because it can also introduce small errors.
- "fish-eye setting" of the used camera means the zoom is fixed at widest angle and focus is fixed at infinity

Software:

Gap Light Analyzer 2.0 (GLA)

Software homepage: http://www.ecostudies.org/gla/

Software Manual: included in the installation (GLAV2UsersManual.pdf)

Outcome:

Initial and final point of evaluation have to be documented with each LAI value or photo interpretation, respectively.

Total Openess, Gap Fraction, LAI 2000G

4.2.4. Other systems used in the programme

Have to be described by the project participant and documented with all settings during field observation or data management in order to allow for retrospective analyses.

4.3. Planar Mosaic photographs

Description; instruments; sampling method see:

Korhonen, L. & and Heikkinen, J. 2009. Automated Analysis of in Situ Canopy Images for the Estimation of Forest Canopy Cover. Forest Science 55(4):323-334.

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