EXPERIMENTAL SET-UP FOR BIOGEOCHEMICAL RESEARCH IN THE MIXED DECIDUOUS FOREST AELMOESENEIE (EAST-FLANDERS)

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1. Introduction

The forest Aelmoeseneie, a deciduous forest of 28 ha, is located in Gontrode (f=50°58'35", EL=3°49'30"), 15 km in the South-East of Ghent (Belgium). The forest is situated between 11 and 21 m above sea level. It belongs to the University of Ghent and is managed by the Laboratory of Forestry. The main management option is scientific research. Therefore a specific scientific zone, of 1.83 ha was fenced, where research is concentrated. Two level II plots and a measuring tower are installed in this zone. The interesting part of the zone is the transition between two different populations, an ash population and an oak-beech population.
The climatic conditions are typical for the Flanders Region (Table 1).

Table 1: *Mean values for some climatological parameters measured during the period 1984-1993 (Kruishoutem, East-Flanders)*

Parameters	Mean value
Yearly temperature	10.1 °C
Temperature coldest month (February)	2.8 °C
Temperature warmest month (July)	17.4 °C
Date first frost	10 Nov. (14 Oct. - 8 Dec.)
Date last frost	13 Apr. (16 Mar. - 29 Apr.)
Days with frost	47 days
Yearly precipitation	791 mm

1.1. History of the forest

Before the Early Middle Ages, the part of the Flanders where the forest Aelmoeseneie is located, was covered with a large forest complex. The need for agricultural land caused deforestation all over the region. The name of the village Gontrode, where the forest is located refers to these deforestations.

The first time the forest Aelmoeseneie was mentioned is in 864, in a document of the abbey of St-Baafs. From the year 1220 the forest belonged to the 'Almoesenei', which was a charity institution of

the abbey. This situation stayed that way until the secularisation in the French period. From that time the forest was property of the OCMW; the commission of public welfare of the city Ghent.
After 4 years of overfelling in WW I, a replantation was necessary. Nowadays only 3 beeches are older than 75 year. In the year 1968, the old forest (20 ha) and 10 ha wet pastures next to the forest was bought by the Ministry of National Education. From 1968 to 1973 the pastures were forested. The actual forest is managed by the Laboratory of Forestry and used for scientific research by different laboratories of the University of Ghent (RUG). In the year 1973 an arboretum with the main West European species was constructed (Muys & Van Eleghem 1994). For an appropriate management of the forest, the Laboratory of Forestry worked out a management plan for the forest in 1988.

1.2 Description of the Forest Aelmoeseneie

1.2.1 General

The basic layer of the forest exists out of tertiary clay-loam complexes of the Paniseliaan. In the Glacial Period of the Quartair, a loamy layer covered the tertiary layer. Loam was mixed with the local sand, which caused a sandloamy covering of 50 to 100 cm depth.
Two brooks cross the forest. The Molenbeek flows in the young part of the forest, the Bloedbeek in the older part. The texture near these brooks is alluvial clay. All of the soils are more or less gleyic, what is an indication of the temporal wetness of the soils.
The main part of the forest, about 25 hectares, is an individually mixture of mainly broad-leaved species. The exploitation system used is plenter and femel cut. The mean stem number per ha is 380 and is divided over 26 tree and shrub species. The importance for stem number and basal area is given in Table 2 for the main tree species.

Table 2: *Percent of total stem number and diameter of tree with mean basal area of the main tree species*

Tree species	Percent of stem number	Diameter of tree with mean basal area (cm)
Quercus robur	35	28
Quercus rubra	12	36
Fagus sylvatica	12	35
Fraxinus excelsior	10	29
Acer pseudoplatanus	9	18
Larix Leptolepis	5	34
Populus sp.	2	39
Castanea sativa	2	24
Prunus avium	2	16
Betula pendula	2	13
Tilia cordata*	2	15
Quercus palustris*	2	17
Ulmus sp.	1	15
Populus alba	2	27
Other species	2	-

**:these species are used in young homogeneous groups on former pasture land*

1.2.2 The scientific zone

In the Aelmoeseneie forest, a fenced zone of 1.83 ha was chosen for intensive scientific monitoring of mixed deciduous forest ecosystems (Fig. 1). This experimental site is situated on the northern exposure of a hill, including the highest part of the forest (21 meter above sea-level), the relative steep slope towards the Blood Brook and the depression of this brook. Because of the presence of two different site types, mainly because of differences in soil conditions, large differences in vegetation can be noted. The two main forest types are an oak-beech forest and an ash forest. The dominating trees of both forest types are all about 70 years old.

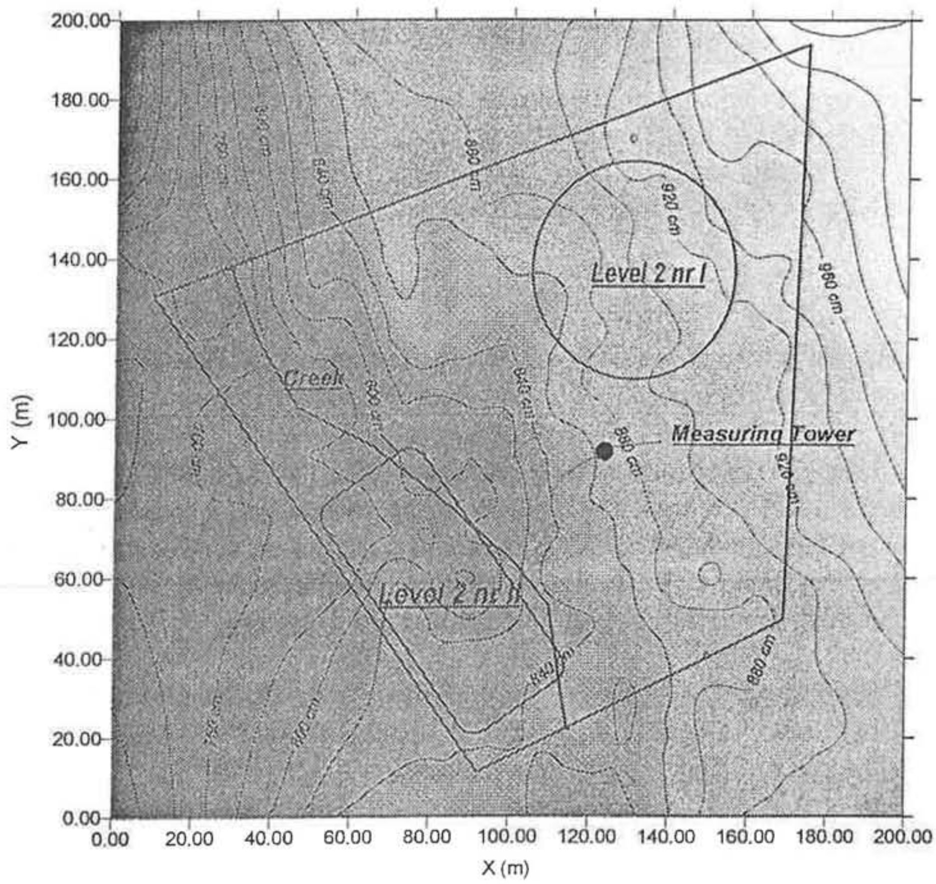

Figure 1: Overview of the scientific forest zone with indication of the relative height and the position of the level 2 plots and the measuring tower

The oak-beech forest type or the slope site (1.1 ha) is a typical thin quaternary layer of sand loam with a spotted texture B horizon on a shallow impermeable clay and sand complex of tertiary origin (uLdb - uLub). Every ten meter, shallow drains occur which accumulate litter. The upper story is a mixture of Pedunculate oak (*Quercus robur*), Common ash (*Fraxinus excelsior*), Common beech (*Fagus sylvatica*) and less frequent also Japanese larch (*Larix leptolepis*) and Sycamore (*Acer pseudoplatanus*).

In the shrub layer Rowan (*Sorbus aucuparia*), Hazel (*Corylus avellana*), Alder buckthorn (*Frangula alnus*) and seedlings of Sycamore and Beech are the main species. The herb layer is dominated by Bramble (*Rubus sp.*) and Bracken (*Pteridium aquilinum*) and to a lesser degree Yellow archangel (*Lamium galeobdolon*), Honeysuckle (*Lonicera periclymenum*) and Salomon's seal (*Plygonatum multiflorum*). The percentage of vegetation cover is between 60 and 90. The humus layer is of a moder type. The mean basal area of this forest stand amounts to 25.7 m^2 ha^{-1}, the standing volume reaches 278.6 m^3 ha^{-1}, the stem number equals 672 per ha and the maximal LAI (Leaf Area Index) is 5.52.

In the obvious ground water dependent alluvial part (Ldp - Lhp) where the impermeable layer ceases, or the ash forest type, Ash is the main species mixed with Pedunculate oak, Sycamore and sporadically Poplar sp. The shrub layer is very dense with mostly Hazel and regeneration of Sycamore. Also the herb layer is well developed, especially the vernal vegetation: Primrose (*Primula elatior*), Yellow archangel, Moschatel (*Adoxa moschatellina*), Wavy hair-grass (*Deschampsia caespitosa*), Greater stitchwort (*Stellaria holostea*) and Lords-and-ladies (*Arum maculatum*). The moss layer that is nearly absent in the first part (2% of cover), is well developed in the second with a cover of 50 to 80 %. Seedlings of Sycomare are abundant. The humuslayer is of a mull type with a litter layer that already is degraded before the start of the growing season.
The mean basal area of this forest stand is 38.0 m^2 ha^{-1}, the standing volume is 397.24 m^3 ha^{-1}, the stem number per ha is 544 and the maximal LAI amounts to 4.53.

2. Scientific research

Because it was situated in the direct proximity of the Laboratory of Forestry and because of its individual mixture of several tree species, the described scientific site has a long tradition of research. Starting from the early fifties, a broad range of topics was covered: sylviculture, fytosociology, soil science and soil biology (Beeckman 1982, Boterdaele 1983, De Coninck 1972, Hoet 1972, Ramon 1981, Van Miegroet 1978, Verlinde 1995). Only in the second half of the eighties the research became more coherent and the scientific zone was considered as an ecosystem of which all compartments had to be analysed. As ecosystem research is a multi-disciplinary task, a strong co-operation was established between the Laboratory of Forestry and the Laboratory of Plant Ecology.

At first, most of the studies focused the soil compartment. Local differences in humus layer were profoundly studied, analysing chemical, physical and biological (faunistic and floristic) processes for causal relations (Sterken 1993) by monitoring 88 parameters (Muys 1993)
In 1988 a first part and in 1992 a second part of the scientific zone, both 25 acres, were chosen as permanent level II plots for the national forest soil monitoring grid (E.U. decree 1091/94). The main goal of these national grids is the monitoring of forest vitality in relation to nutrient and water cycling (see paragraph 3)(Van den Berge et al. 1992).
In 1993, a measuring tower of 35 meter high was constructed (see paragraph 5), allowing in situ ecophysiological measurements (gas exchange, stomatal conductance) on adult trees on different heights. It is also possible to measure a whole range of climatological parameters on the tower, determining the microclimate by which the different processes in the forest take place.
Based on the actual microclimate, Lootens (1995) and Samson and Lemeur (1995a,b) tried to predict the response of respectively trees and stands to global change.
In 1993, the entire scientific zone was measured topographically and pH, total N, C and texture type were determined at several depths (Haleplis & Vakalopoulos 1993) as well as the depth of the tertiary aquifer layer (Zahedi in prep.). These data were interpolated by use of kriging to a spatial continuum.

Based on the acquired expertise in monitoring evolution of carbon sequestration for the characteristic humus and forest types (Schauvlieghe 1995, Van Camp 1995), and the micro-climatological data registered on the measuring tower, a more complete project on C is started, where all pools and fluxes of C are studied in detail.

The carbon content of the different pools (leaf, branch, stem, root, soil) are determined, as well as allometric relations between above and below ground tree biomass. The fluxes between the different compartments is or will also be measured: leaf fall and LAI dynamics (Mussche 1997), photosynthesis (Follens 1997), soil respiration and the carbon exchange between the canopy and the atmosphere using the flux profile method (see 4.3.2).

At present, most attention is paid to the integration and modelling of the water, nutrient and carbon cycles in relation to Global Change and Sustainable Development (Claeys 1997, Van Linthout 1996). In December 1996 a project financed by the Belgian government, was launched: "Bio-geochemical Cycles of Forest Ecosystems in Relation to Global Change and Sustainable Development". Seven other Belgian teams participate in this project.
As a consequence of this multi-disciplinary project all fluxes and pools of the nutrient, water and carbon cycle will be accurately examined.

3. Level II plots

3.1. Introduction

In the perspective of the European forest decline and forest dieback as it occurred most dramatically in the beginning of the eighties in Germany and later also in other countries, the need to start an international forest monitoring web was recognised. From the beginning, air pollution was considered as a main cause and an important monitoring subject.
In 1985, the "International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests" (ICP Forests) started as a part of the Convention on International Air Pollution of the United Nations. Initially the main task was an annual inventory of the forest health situation in accordance to a common methodology. In the European Community the EC Regulation 3528/86 was issued, by which the EC member states were obliged to supply these inventory data. In Flanders this inventory started in 1987.
Though these inventories could give important information on regional differences and on the evolution of the forest health state in Europe, they didn't supply enough information to find the causes of the changes and most certainly not enough to determine the role of air pollution. Therefore a more detailed research programme called "permanent monitoring of the forest ecosystem" was started. The main goal was to find the causal factors and processes in the changes of forest health situation in general and the impact of air pollution more specifically. In Flanders this research started in 1988 in 11 forests, chosen for their representativity for each province.
One of these forest zones is the Level II plot in the Oak-Beech part of the scientific forest part. In 1992, a twelfth plot in the Ash part of the scientific zone was selected.

3.2. Description

Each monitoring plot includes 25 acres.

In both plots the soil compartment was profoundly analysed. A profile description was done by means of a profile pit and eight additional profile drillings, soil texture was determined as well as soil physical characteristics : water retention, hydraulic conductivity and volumetric weight. Chemical analyses of litter (E.C., $CaCO_3$, pH-$CaCl_2$, pH-H_2O, C.E.C., C, S, total N, total P, K, Ca, Mg, Na, total Al, Fe, Mn, Cu, Pb and Cd) and mineral layer (E.C., $CaCO_3$, pH-$CaCl_2$, pH-H_2O, C.E.C., C, S, total N, total P, Na, K, Ca, Mg, Al, Fe) are repeated yearly. Mineral N (NO_3-N, NH_4-N in litter and mineral layer) is measured every two months. From 1994 the frequency is raised to monthly sampling. Samples of the mineral soil (three repetitions) are taken by means of a root auger at 5-15 cm, at 25-35 cm and at 45-55 cm depth. These depths correspond to the depths of the lysimeters. For the analyses of the litter layer, only the F and H layers are considered to correct for seasonal variation.

Every two weeks, the constitution of open field precipitation is obtained by 4 pluviometers with an opening diameter of 14 cm. Throughfall is collected by 10 pluviometers in each plot. The funnels of these pluviometers are placed at 1 meter height in order to avoid the influence of herbs and the recipients (2 liter) are placed below ground to keep them cool and dark to avoid growth of algae. Stemflow is collected by 4 gutters fixed around 4 dominant trees of the two main species. In each plot 2 humus percolation meters (zero tension meters with a surface of 600 cm^2) are installed and soil water is collected by 3 sets of 3 lysimeters at 10, 30 and 50 cm depth. Analyses are done for pH, acidity, Al, Ca, Mg, K, Na, Fe, SO_4, PO_4, Cl, HCO_3, organic matter, Zn, Cu, Co, Pb, Mo, Kjel-N, NO_3-N and NH_4-N.

Forest vitality is monitored yearly since 1988 and analysis of the composition of the assimilation organs (N, P, K, Ca, Mg, S, Cl, Na, Fe, Mn, Zn, Cu, Pb, Al, B and Cd) started in 1995.

Also a silvicultural and a phytosociological inventory is repeated every five years. Measured parameters are diameter at breast height (1.3 m), total tree height, crown height and 4 crown radii and stem number. Based on these data, the evolution of mean diameter, height, basal area per tree and per ha, volume per ha, annual increment per ha and procentual share in the basal area and the volume can be deducted.

4. Description of the measuring tower and apparatus

4.1. Introduction

During the last decade forest research became more ecologically orientated. The forest is considered as an ecosystem, which means that all compartments (below and above ground) must be taken into account.

Of all the different compartments, the crown compartment is a very important one. Exchange of CO_2 and water vapour between stand (leaves) and atmosphere mainly occurs in this compartment through the processes of photosynthesis and transpiration respectively.

Inversely related with the importance of this compartment, is its accessibility, certainly when in situ measurements like gas exchange have to be conducted.

Moreover, the study of all processes, be it on the level of the stand, individual tree, leaf or soil, require a thorough knowledge of the environmental (climatological) parameters.

Above arguments, combined with the fact that several foreign groups had the disposal of a tower, led to the construction of a measuring tower in the forest Aelmoeseneie in autumn 1993.

As most towers are built in monocultures of pines, the measuring tower of the Aelmoeseneie forest is rather unique.

4.2 Measuring tower

The measuring tower (Fig. 2) is a metal construction of 36 m high. There are 5 protected working platforms at respectively 7.5, 14.6, 21.6, 28.8 and 36 m. The names that will be used in the following description for the respective working platforms and their corresponding height are given in Table 3. Each platform can be reached with a stair from the former platform. The height of the platforms is chosen as such that platform 1 correspond with the base of the crowns of the surrounding trees. Platform 2 and 3 are situated in the crowns. Platform 4 is constructed just above the canopy and platform 5 is constructed more or less ten meters above the canopy. The latter platforms are situated in the turbulent boundary layer of the forest.
The base of the tower is 16 m² (4 x 4 m). The tower is placed on a concrete foundation, and stabilised with stretch cables moored in concrete blocks. At the base of the tower (platform 0) a logcabin is constructed where the datalogger and the gas analysers are installed.

Table 3: *Indication of the different working platforms on the measuring tower and their corresponding height above ground level (in m)*

Name platform	Height (m)
0	0.0
1	7.5
2	14.6
3	21.6
4	28.8
5	36.0

The location of the measuring tower (Fig. 1) has been chosen as such that in the nearby surroundings of the tower three major tree species of the Aelmoeseneie forest are growing which allows *in situ* measurements on those different species. These species are Pedunculate oak, Beech and Ash.
Another criterion for the positioning of the tower is the distance from the edge of the forest. As the main wind direction is west, the tower is erected at the east side of the forest. This is necessary for having a satisfactory fetch in the west direction, which is important for monitoring CO_2, water vapour and air pollutants using a flux-gradient or eddy-covariance method.
Furthermore, the tower is situated at the border between the oak-beech and the ash forest type.
To avoid storm damage of the tower the surrounding trees are moored.

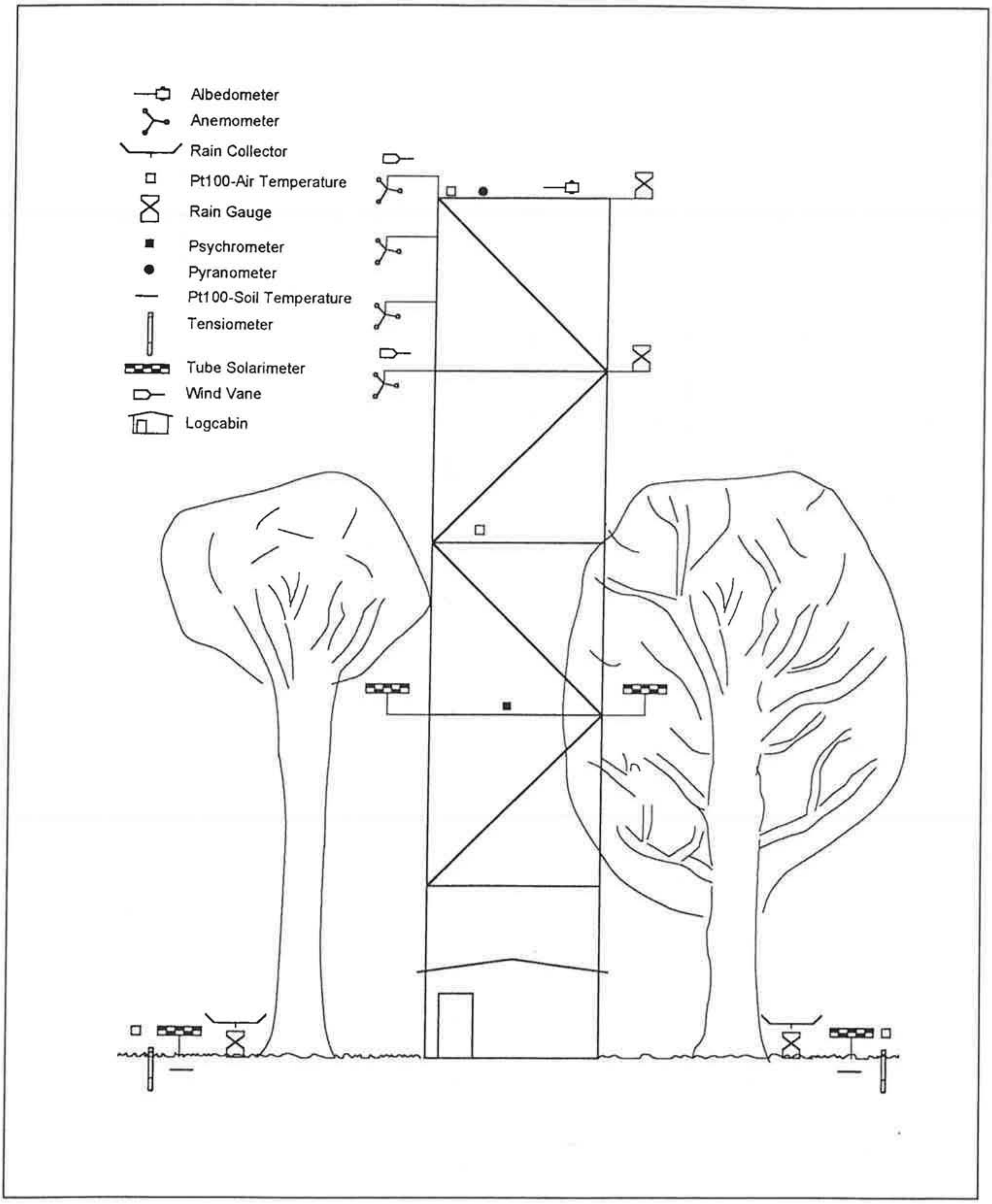

Figure 2: *Schematic representation of the measuring tower in the Aelmoeseneie forest with indication of the actual present apparatus and the logcabin with data-logging systems and gas-analysers*

4.3 Measuring apparatus

The measuring tower is a useful tool in a lot of forest-ecological and eco-physiological experiments. Each experiment requires its own specific apparatus. To be able to use these specific types of apparatus, electricity is available on the ground level and on each platform.
Beside these experiment specific apparatus, climatological parameters are continuously measured during the growing season (May-November) providing a basic dataset which is used in a whole range of experiments.
The measuring tower is equipped with the following climatological sensors: (i) radiation sensors, (ii) temperature sensors, (iii) sensors for the wind speed and wind direction, (iv) rainfall sensors, (v) an air humidity sensor, and (vi) sensors for measuring the humidity of the soil.
From growing season 1997 on, beside meteorological parameters, also the flux of water vapour and carbon dioxide (CO_2) will be monitored using a flux-gradient method.
In the next description the numbering of the platforms is as described in Table 2. With "east-side" (ES) and "west-side" (WS) the fixed experimental set-up at ground-level is meant, respectively in the oak-beech forest and in the ash forest. A differentiation for both forest types is made as they have a completely different understorey.

4.3.1 Measured climatological parameters

4.3.1.1 Radiation

The short-wave radiation (0.3-3.0 mm) is measured at several heights: above, in and under the canopy.
Above the canopy the short-wave radiation is measured on platform 5. As the short-wave radiation is an important ecological parameter, two sensors are installed. The first sensor is a circular star-type (PHILLIPP SCHENK, type 358) pyranometer and measures incoming short-wave radiation. The second sensor measures beside the incoming short-wave radiation also the reflected part, and hence gives an idea of the albedo. The albedometer of Delta-T (GS2) is used. The mean albedo during the growing season is 14%.
Knowing the incoming and reflected short-wave radiation, the net incoming shortwave radiation can be calculated.
The penetrated short-wave radiation in the canopy is measured on platform 2. On this level, three tube solarimeters of Delta-T (type TSL)are used to measure the shortwave radiation. Because of their linear form, each sensor gives an integration of the light regime in the sun and shade flecks. The tube solarimeters are fixed on a horizontal bar reaching out of the measuring tower. The three sensors are mounted under respectively the ash, the oak and the beech trees that are surrounding the tower. This experimental set-up permits to characterise the light regimes in canopies of different trees.
Tube solarimeters (Delta-T, type TSL) are also placed on the ground level (ES and WS). The data obtained from these sensors allow to calculate the short-wave radiation absorbed by the canopy. The solarimeters are orientated south-north.
All sensors are based on the thermopile principle. The radiation is measured each minute, and averaged over one hour. Values are given in MJ m^{-2} $hour^{-1}$.

4.3.1.2 Temperature

Temperature is measured using Pt100 temperature sensors. The sensors are shielded from the sun, by an aluminium housing insulated at the inner side. This protection avoids warming up of the sensors due to direct exposure to sun radiation, or cooling down due to direct exposure to precipitation.
The air temperature is measured above the canopy, on the fifth platform. A second sensor is installed on platform 3. At this level, the air temperature in the crown is measured.
The air temperature is also measured at the ground level (ES and WS).
The measurement of the temperature at different levels in the vegetation is important to have an idea about the microclimatological conditions, by which eco-physiological and phenological processes take place.
The temperature of the soil (ES and WS) is also measured at a depth of 30 cm.
The temperature is expressed in degrees Celsius (°C) and is measured every half hour.

4.3.1.3 Wind

Two kinds of wind measurements are performed: (i) windspeed measurements and (ii) measurements of the direction of the wind.
For the measurement of the wind speed, cup anemometers of Delta-T (type AN1) are used. Four anemometers are installed above the canopy, at respectively 37.0, 32.7, 30.6 and 28.6 m. The data obtained thus allow to calculate the wind profile and the roughness of the forest, which is an important parameter for exchange processes between the forest and the atmosphere. The mean wind speed is measured during one hour and is expressed in m s^{-1}.
For the measurement of the wind direction two vanes (Delta-T, WD1) are mounted on respectively platform 5 and platform 4.
The mean wind direction is measured during an hour, and is expressed in degrees (°) from 0 to 360.

4.3.1.4 Rainfall

To measure the precipitation of water, tipping bucket (0.1 mm) raingauges are installed on different heights.
Above the canopy, raingauges (Delta-T, RG1) are installed on platform 5 and also, for control, on platform 4. With these gauges the free field precipitation is measured.
Under the canopy, at the ground level, the throughfall and stemflow is measured in both forest types (ES and WS). This way the influence of the trees and the understory on the quantity of water entering the forest soil can be evaluated. At the ground level the throughfall is cached in gutters of 6 m to 0.28 m. The gutters are connected with a raingauge (Delta-T, RG1). This experimental set-up allows to quantify the throughfall on an integrated manner, based on the same principal as a tube solarimeter versus a star type pyranometer.
A typical problem for this kind of experimental set-up is the large amount of dust, leaves and branches falling down in the gutter and blocking up the raingauge. This problem can be avoided by putting a gauze over the basin of the gauge. Attention should be paid to the width of the meshes. Large meshes don't prevent dust to enter the gauge, fine meshes stop the dust but finally even prevent the rain to enter the gauge. In our case meshes of 1 mm^2 are used.
As mentioned before, stemflow is collected by gutters fixed around the dominant trees of the main species (see 3.2.).

Every hour the amount of water fallen in (above the canopy) or fallen through (under the crowns) is registered, and expressed in mm of water.

4.3.1.5 Air humidity

The humidity of the air is measured inside the canopy, on platform 3. For this purpose a psychrometer of Delta-T (WVU/TC) with forced ventilation is used. The psychrometer has as an output dry bulb or air temperature and wet bulb temperature (in °C). These temperatures allow to calculate the relative (in %) as well as the absolute humidity (vapour pressure in mbar) of the air.
Per hour the relative humidity is measured during 5 minutes at the end of the hour. Five minutes before the measurement the fan is switched on, in order to establish an equilibrium in the psychrometer. No continuous measurements of the air relative humidity during the hour are done because the reservoir with distilled water, necessary to wet the wet bulb thermometer, is limited in capacity.

4.3.1.6 Soil water potential

For measuring the soil water potential, and thus the water availability for plants, tensiometers are installed in the soil.
In both forest types (ES and WS) six tensiometers (Delta-T, type SWT6) are placed at different depths. The respective measuring depths are 10, 25, 50, 75, 100 and 150 cm.
Each hour the soil water potential is measured, and expressed in hPa.

4.3.1.7 Data acquisition and data handling

All data are registered in one datalogger (Delta-T, type DL2). The datalogger is installed in the logcabin at the base of the measuring tower. The memory capacity of the logger is 192 kbytes or 98304 readings. The datalogger is provided with:

- 1 counter card DLC1 (15 channels for pulse or frequency measurements; e.g. raingauge);
- 2 analogue input cards LAC1 (30 channels for analogue input in total);
- 1 LFW1-card: 4-wire card (6 Pt100 - 4 wire).

During the first day of every week the data are collected using a portable PC and the software of Delta-T. The software of Delta-T decodes the data from the binary format to the ASCII-format. After converting the data to the ASCII-format, the files are imported in a spreadsheet (quatro or excel). The obtained files are subsequently imported in prepared 'calculation spreadsheets', which convert the raw data to the correct unit for the considered parameter. The data are also filtered.
Four different 'calculation spreadsheets' exists: (i) one for radiation data, (ii) one for temperature measurements, (iii) one for rain, wind and relative humidity measurements and (iv) one for the soil water potential measurements. The output of these files are hourly and daily values.

4.3.2. Flux-gradient measurements of carbon dioxide and water vapour

From the 1997 growing season on, a system is installed on the measuring tower to analyse the exchange of carbon dioxide and water vapour between the atmosphere and the forest (Fig. 3).

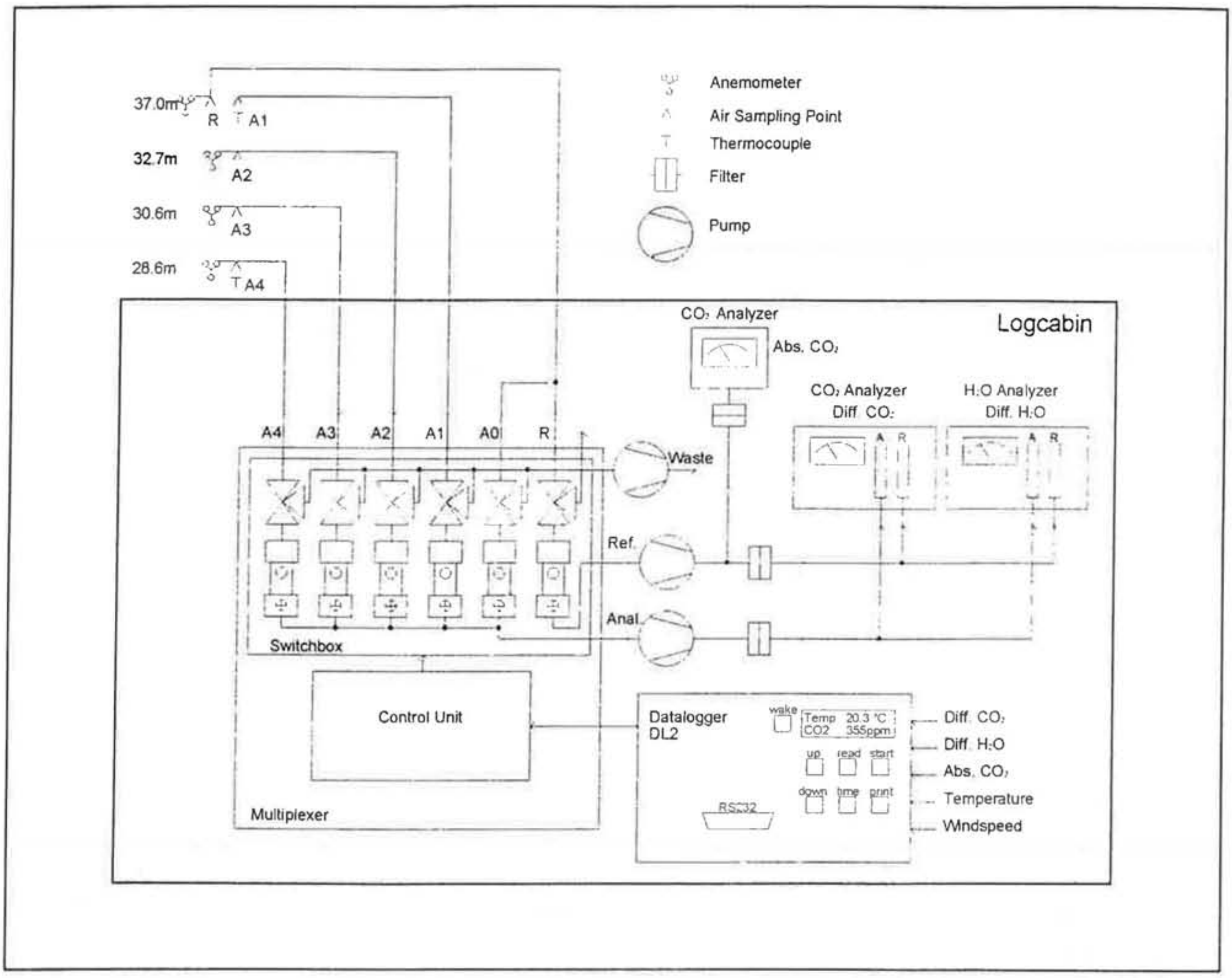

Figure 3: *Schematic representation of the CO2 and water vapour analysing system used for the determination of flux-gradients, with A0-A4 being the air sampling lines and R the reference line*

4.3.2.1 Experimental set-up

Air is supplied, from five sampling points above the canopy (wind speed is measured at the same heights), via PVC pipes to CO_2 and water vapour analysers in the log cabin. All pipes have the same length, namely ± 40 meter.

The supply pipes have an inner diameter of 10 mm and an outer diameter of 16 mm. The supply pipes are led to the log cabin and the gas analysers through a large discharge pipe of 125 mm. The supply pipes are heated, using a resistance wire, in order to avoid condensation. A thermocouple is fixed between the central resistance wire and the supply pipes to control the pipe temperature, and to allow adjustment of the temperature by a feed-back mechanism.

A membrane pump (KNF, MW 71/4) is used to suck air, of all the supply pipes together, with a flow rate of 50 l min^{-1} to the multiplexer (see Figure 3). From the multiplexer the air of the selected supply pipe is pumped (Hartmann Braun, type 2) to the gas analysers, with a flow rate of ± 4 l min^{-1}.

4.3.2.2 Measuring cycle

Both for water vapour as for carbon dioxide, the measurements are done on a differential basis. The reference (R: see Fig. 3) is the air sampled at the highest sampling point (37.0 m). From the reference the atmospheric CO_2 concentration is also measured on an absolute basis.
Each measuring cycle starts by analysing the air sampled by the reference line at 37.0 m (zero point measurement). Consecutively the air sampled at 37.0 m, 32.7 m, 30.6 m and 28.6 m is analysed. Each sampling point is analysed during two minutes. At the end of this period the CO_2 and water vapour concentration are measured , and the values are stored in the data-logger. Simultaneously the temperature difference between the highest (37;0 m) and lowest (28.6 m) sampling point is measured.
When the CO_2 and water vapour concentration is measured, after two minutes of stabilisation, a multiplexer changes the analysed supply pipe.

Thus, a complete measuring cycle lasts for 10 minutes, and every 30 minutes a new measuring cycle starts.

4.3.2.3 Analysers and data acquisition

To analyse the CO_2 concentration in the air an ADC analyser (225 MK3) is used. The principle of the analyser is based on IR-absorption using an IRGA.
Simultaneously, the water vapour concentration is analysed also using an ADC analyser (225 MK3).
All data are registered in a second Delta-T datalogger (type DL2).

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6. Bibliography

Beeckman, H. (1982). Morfologische karakteristieken, structuur en concurrentieverhoudingen in dichtwassen van es (Fraxinus excelsior L.). Afstudeerwerk, Gent,Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 114 p.
Boterdaele, B. (1983). Structuur en opbouw van een dichtwas van witte els (Alnus incana, M.). Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 137 p.
Claeys, K. (1997). Bepaling van de actuele evapotranspiratie van het proefbos Aelmoeseneie op basis van de oppervlakte-temperatuur. Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 147 p.
De Coninck, E. (1972). Bijdrage tot de vergelijkende oecologische studie van de coleopterenfauna van een bos en een weide te Gontrode (O.VL.). Afstudeerwerk, Gent, Faculteit Wetenschappen, 78 p.

Follens, S. (1997). Fotosynthetische CO_2-uitwisseling van een gemengd loofbos, en de mogelijke invloeden van "Global Change". Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 140 p.

Haleplis, K.D. & Vakalopoulos, V.S. (1993). Carbon accumulation and pH variation in a mixed hardwood stand. Laboratory of Forestry, Ghent, 74 p.

Hoet, L. (1972). Fenologische studie van de spinnenfauna van het Aelmoeseneiebos en aangrenzende weide. Afstudeerwerk, Gent, Faculteit Wetenschappen, p.

Lootens, P. (1995). Invloed van verhoogd atmosferisch CO_2-gehalte op de fotosynthese , de groei en de ontwikkeling bij *Populus x interamericana* 'Beaupré', *Quercus robur* en *Pinus sylvestris*. Doctoraatswerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 186 p.

Lust, N., Van Miegroet, M., Roskams, P., Van Den Berghe, K. & Verlinden, A. (1988). Model van intergraal beheersplan voor het Aelmoeseneiebos te Gontrode-Landskouter. Laboratorium voor Bosbouw, Gent, 209 p.

Mussche, S. (1997). Bepaling en dynamiek van de bladoppervlakte-index in een gemengd loofbos (proefbos Aelmoeseneie). Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 144 p.

Muys, B. (1994). Synecologische evaluatie van regenwormactiviteit en strooiselafbraak in de bossen van het Vlaamse Gewest als bijdrage tot een duurzaam bosbeheer. Doctoraatswerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 355 p.

Muys, B. & Van Eleghem, B. (1994). Het Aelmoeseneiebos te Gontrode-Landskouter. De Boskrant, 5, 12-19.

Ramon, J. (1981). Initiële ontwikkeling en ontwikkelingsverhoudingen van kers, olm, berk en esdoorn in een tienjarig bosbestand. Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 117p.

Samson, R. & Lemeur, R. (1995a). Effect of increased atmospheric CO_2 concentration on primary productivity and carbon allocation in typical Belgian forest ecosystems: Biomass accumulation and photosysnthetic conversion efficiency at different levels of the modelsystems. Progress report no.4 for the Belgian Impulse Programme "Global Change", OSTC, 26 p.

Samson, R. & Lemeur, R. (1995b). Effect of increased atmospheric CO_2 concentration on primary productivity and carbon allocation in typical Belgian forest ecosystems: Effects of increased atmospheric CO_2 concentration on the C/N ratio observed in the model systems and on estimated carbon fixation in the Forests of the Belgian Provinces. Progress report no.5 for the Belgian Impulse Programme "Global Change", OSTC, 29 + vii p.

Sterken, G.J.A.M. (1993). Analyse van de kruidvegetatie in relatie tot boomsoort en bodemkwaliteit. Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 58 p.

Van den Berge, K., Maddelein, D., De Vos, B. & Roskams, P. (1992). Analyse van de luchtverontreiniging en de gevolgen daarvan op het bosecosysteem. Werkgroep Sociale en Economische betekenis van het Bos, rapport nr. 19, 169 p.

Van Linthout, K. (1996). Evaluatie van de hydrologische balans in relatie tot de aanrijking van nutriënten in het Proefbos Aelmoeseneie (Gontrode). Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, Gent. 104 p.

Van Miegroet, H. (1978). Differentiatieverschijnselen in spontane verjongingen van esdoorn. Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 91 p.

Verlinde, R. (1995). Zaadpredatie en -verspreiding van eikels door muizen. Afstudeerwerk, Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 96 p.