General project information

English title	Intensive forest condition monitoring (Level II)
program	ICP Forests: the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
goal	Providing insight into causes affecting the condition of forest ecosystems and into effects of different stress factors for the major forest ecosystems in Europe. Intensive monitoring of tree vitality (cf. Level I), tree growth and nutrient status, vegetation, composition of precipitation and soil water, and the soil condition.
ecosystem service	regulating – nutrient cycling
keywords	forest condition, tree vitality, deposition, tree growth, soil

Project information on level II Flanders

goal	- Study of the impact of stress on forest ecosystems. - Description of the present condition and changes in forest ecosystems. - Formulation of suggestions for policy recommendations.
time period	1988–
chronological	**1988**: start project in 10 plots **1991**: 2 extra plots **1999**: start litter sampling **2002**: start sampling phenology beech **2003**: plot 22 no longer sampled
plots	10 plots (**1988–1990**) - 2 plots per province: Wijnendale (Ichtegem, plot 1 or 11), Houthulstbos (Houthulst, 2 or 18), Aelmoeseneiebos (Gontrode I, 3 or 16), Buggenhoutbos (Buggenhout, 4 or 17), Hallerbos (Essenbeek, 5 or 13), Meerdaalwoud (St.-Joris-Weert, 6 or 12), De Inslag (Brasschaat, 7 or 15), Ravels-Noord (Ravels, 8 or 14), Pijnven (Hechtel, 9 or 19), Heiwijk (Maasmechelen, 10 or 20) 12 plots (**1991–2002**) - 2 extra plots: Aelmoeseneiebos (Gontrode II, 22), Zoniën (Groenendaal, 21) - 6 standard plots (12, 13, 17, 18, 19, 20), 6 intensive monitoring plots (11, 14, 15, 16, 21, 22) 11 plots (**2003**–) - plot 22 was excluded - 5 intensive (11, 14, 15, 16, 21), 6 standard (12, 13, 17, 18, 19, 20)
sampled species	*Pinus sylvestris* (plot 15, 20), *Pinus nigra laricio* (plot 14, 19), *Quercus robur* (plot 12, 16, 18), *Fagus sylvatica* (plot 11, 13, 17, 21), *Fraxinus excelsior* (plot 22)
set-up	circular plot in each stand, 25 are (r = 28.20 m) <u>all plots</u> - crown condition: each year - nutrient condition (leaves/needles): each 2 years - vegetation inventory: each 5 years - forest inventory: each 5 years - soil condition: each 10 years <u>intensive monitoring plots</u> - atmospheric deposition: continuous - soil water: continuous - litter fall: continuous
data collection	<u>crown conditions</u> - since **1988** o 2 transects, central part plot

    - trees and shrubs taller than 2 m (n see VanDenBerge_etal_1992_report p 10)
    - height max crown width, crown radius NESW, social position (Kraft), % leaf/needle loss, % leaf/needle discolouration, damage
    - no data for 1989, June-August 1988
    - extra trees designated in 1996 by the IBW

<u>soil</u>

- **1988**
    - 3 series per plot, 0–5, 5–15, 25–35, 45–55 cm, F + H (April-May 1988, litter layer in October, litter mass again in fall 1991)
    - OM: pH-H_2O, pH-KCl, C/N, N, C, S, P, Ca, Mg, Na, Al, Fe
    - mineral soil: pH-H_2O, pH-KCl, CEC (K, Ca, Mg, Na, Al, Fe), mineral reserve (P, Ca, K, Mg, S, NO_3, NH_4, N_{tot})
- **1991 or 1992**
    - litter layer: EC, $CaCO_3$, pH-$CaCl_2$, pH-H_2O, CEC, base saturation, C, P, K, Ca, Mg, Na, Al, Fe, Mn, Zn, Cu, Pb, Cd, N, S, OM
    - 0-7, 7-45, 45-60, 60-105 cm: EC, $CaCO_3$, pH-$CaCl_2$, pH-H_2O, CEC, C, P, N, S
    - mixed sample of 36 samples per plot
- **1992**
    - changes in NO_3 & NH_4 in the soil profile: 2-monthly in the 12 plots
- **1993**
    - mineral soil: mixed sample (36 samplings) per layer (layer depths differ between the 12 plots): pH H_2O, pH $CaCl_2$, H+Al, K, Ca, Mg, Na, Al, CEC, P, Fe, C
    - changes in NO_3 and NH_4 in the soil profile: 2-monthly in plot 11, 15, 16, 20, 21, 22
- **1994**
    - changes in NO_3 and NH_4 in the soil profile: 2-monthly in plot 22

<u>deposition</u>

- **1988**
    - bulk (4 collectors), throughfall (4 collectors below dominant trees), stem flow (4 trees)
    - each 2 weeks (01/02/1988–30/01/1989)
    - pH, NO_3, NH_4, SO_4, K, NA, Ca, Mg, Cl, P
- **1992**
    - throughfall
    - collected each month (Feb 1992–Jan 1993)
    - volume, Ca, Mg, K, Na, SO4, Cl, Cd, Cu, Mo, Pb, Zn, H^+, Al, Fe, N
    - 12 plots
- **1993**
    - bulk (4 collectors), throughfall (4 collectors)
    - volume, pH, Al, HCO_3, SO_4, Na, K, Ca, Mg, Fe, Cl, N, NO_3, NH_4, OM
    - plot 11, 14, 15, 16, 21, 22
    - collected 2-weekly
- **1994– 1995 (1996?)**
    - bulk precipitation, throughfall
    - stem flow: 5 trees (since 1996 only in plot 11, 16, 21, 22)
    - pH, conductivity, alkalinity, DOC, cations (Ca, K, Mg, Na, NH4, Al_{tot}, Fe_{tot}), anions (Cl, NO_3, NO_2, PO_4, SO_4)
    - collected each 2 weeks
    - plot 11, 14, 15, 16, 21, 22
- since **1996**
    - bulk precipitation: 4 collectors (open field at < 1500 m from the

forest)
    - throughfall: 10 collectors
    - stem flow: min 5 trees (mean d, mean d ± sd, mean d ± 2sd) of the main tree species, not in pine stands
    - pH, conductivity, alkalinity, DOC, cations (Ca, K, Mg, Na, NH_4, Al_{tot}, Fe_{tot}), anions (Cl, NO_3, NO_2, PO_4, SO_4)
    - collected each 2 weeks
- since **2007**
    - stem flow only measured for beech trees

<u>soil water</u>

- **1988**
    - 10, 30, 50 cm (2 series per plot)
    - collected each month (Feb 1988–June 1989)
    - pH, NO_3, NH_4, SO_4, K, Na, Ca, Mg, Cl, P, Al, Fe
- **1992**
    - A, B, C
    - Al, Ca, Mg, K, Na, SO_4, Cl, Cd, Cu, Co, Mo, Pb, Zn, H^+, Al, Fe, N, pH, NO_3, NH_4, OM, HCO_3
    - collected monthly
- since **1993**
    - H, A, B, C: 2-weekly mixed sample of 2 sample points (depth layers VanRanst_etal_1994 p 1)
    - pH, Al, Fe, Ca, Mg, K, Na, NH4, HCO_3, SO_4, NO_3, Cl, N, OM
    - plot 11, 14, 15, 16, 21, 22

<u>litter</u>

- **1988**
    - 5 litter traps
    - collected 2-weekly (June 1988-June 1989)
    - sorted into leaves, scales, flowers, seeds
    - dry mass
- since **1999**
    - 10 litter traps
    - collected 2-weekly during September-November, monthly during December-August
    - sorted into: leaves/needles, fruits/seeds/flowers, woody parts, other
- since **2005**
    - bud scales distinguished from the rest fraction

<u>leaf/needle analysis</u>

- **1988**
    - 10 dominant trees per plot (6 in plot 14), mixed sample per species for the broadleaved species, sample per tree for the coniferous species
    - S, N, F, P, Cl, Na, K, Ca, Mg, Fe, Al
- **1991**
    - 20 trees in plot 11 (beech), 18 (oak), and 15 (pine): 10 with little leaf/needle loss, 10 with much needle/leaf loss
    - 28/08/1991 leaves, 21/10/1991 needles
- **1995, 1997, 2005**
    - 5 trees per plot
    - dry mass, ash content, pH, OM, N, S, P, cations, heavy metals
    - needles October/November, leaves August

<u>forest inventory</u>

- **1988**

- min d = 7 cm
- diam in 2 directions at 1.3 m height, tree height, crown height
- March–May 1988
- plots 11–20 (diam again in 1989, 1990, 1991 & 1993)
- plots 21-22: first inventory in 1991

- **winter 1995/1996, fall 1999, winter 2004/2005, winter 2009/2010**
  - min d = 5 cm
  - diameter and circumference at 1.3 m height, tree height, crown height

<u>tree growth</u>

- since **2007**
- 20 trees per plot with a permanent measuring tape

<u>vegetation inventory</u>

- **1988** (plot 11-20)
  - 5 plots of 5 m x 5 m
  - 15/05–08/06/1988
  - Braun-Blanquet
- **1991** (plot 21-22)
  - Barkman
- **1996** (12 plots)
  - 2 permanent plots of 1 are
  - shrub, herb, moss layer
  - Londo

<u>soil fauna</u>

- April 1988, B. Muys
- 5 soil samples of 25 cm x 25 cm x 25 cm, hand sorting
- number, species, life stage, fresh biomass

<u>physical soil conditions</u> (VanderVelden&VanOrshoven_1993_report)

- moisture retention, hydraulic conductivity, soil density
- not in plot 20 (stony soil)

<u>phenology beech</u>

- since 2002
- spring: weekly evaluation of flowering and leaf development
- autumn: leaf discolouration, and litter fall
- hemispherical photographs

<u>root sampling</u>

- 1994 (dates VanLangenhove_etal_1995 p 37-38)
- plot 16 & 18 (oak), plot 14 & 15 (pine)
- trees outside the permanent plots: 3 vigorous, 3 less vigorous trees
- circumference at 1.3 m, height, tree cores at 1.3 m in N and E direction, mycoflora below the crown (crown radius each 45°) in plot 16 & 18 (28/09, 30/09, 4/10 1994), tree vitality
- pine roots d < 2 mm, oak roots d 0-0.5, 0.5-1, 1-3 mm
- soil samples (754 cm^2) halfway the crown projection: 30, 45, 60 cm depth
- roots sorted out, dry mass, starch and sugar content, Ca+Al+Mn content

<u>ammonia concentration: 1997, 2000, 2001</u>

- air
  - open-field sampling near plot 11, 14, 15, 16, 21
  - citric acid papers
  - 15/05/1997-06/01/1998
- crown
  - measuring tower in plot 15 (1.7, 11, 17.5, 21.8, 25, 33 m), 16 (1.7, 7.5, 14.6, 21.6, 28.8, 36 m)
  - citric acid papers

	o 15/05/1997-06/01/1998
institution	Laboratory of Forestry, Ghent University (Study group 'Sociale en economische betekenis van het bos') AROL – Dienst Groen – Waters en Bossen, AMINAL (Afdeling Bos&Groen) IBW Bodemkundige dienst van België (chemical soil characteristics – **1991/1992**, N profiles – **1992, 1993, 1994**) Laboratory of Soil Science, Ghent University (water analysis – **1992, 1993, 1996, 1997** Institute Land and Water Management, K.U.Leuven (physical soil characteristics – **1992?**) Laboratory of Forest and Nature Management, Dept Land Management, K.U.Leuven (roots & tree vitality – **1994**)
remarks	- plots are thinned (see Verstraeten_etal_2007_report) - numbering plots (10–22) based on the plot numbers in Muys&Lust_1992_SoilBiolBiochem - prestudies: VanMiegroet&Dua_1984_SilvGand, VanMiegroet_etal_1987_report - Bussche_1998_th: nutrient concentrations in woody parts of oak/beech

Project information level II Aelmoeseneie

study area	5n (scientific zone) = plot 16 & 22
time period	1988– (plot 16), 1991–2002 (plot 22)
tree species	*Fagus sylvatica*, *Fraxinus excelsior*, *Quercus robur*
set-up	stem flow: collectors on 3 beech trees (1 collector with tipping-bucket) throughfall: 10 collectors litterfall: 10 collectors humus water: 4 collectors soil water (3 depths, 3 sample locations): 18 collectors soil water content/soil temperature: TDR probes vegetation: 4 plots of 10 m x 10 m tree growth: permanent measuring tapes on 20 trees ground water level: 3 piezometers soil profile pit passive samplers for NH_3, O_3 precipitation (open field): 4 collectors
data collection	
remarks	

Results

Roskams&VanDenBerge_1988_report	**1988**: forest inventory (p 25), tree vitality (p 26-27), vertical/horizontal projection of the transects (p 44–58), vegetation data (p 61), earthworm biomass (p 68) for 10 plots
VanDenBerge_etal_1992_report (+ Roskams_1993_report)	**1988**: vegetation data (p 22), forest inventory (p 29), nutrient concentrations leaves (p 81–82, 86), deposition (p 88–91), soil pH (p 103), CEC (p 107), soil nutrient concentrations (p 114-115), litter production (p 119-120, 122-125), litter layer (126-127), soil water (130-133), transects (annex 1-2), water analyses (annex 3a-b), soil water (annex 4a-b)

	1988-1992: tree vitality (p 48, 55–57, 62, 73)
VanderVelden&VanOrshoven_1993_report	**1991-1992**: moisture retention (p 21-31), hydraulic conductivity (p 9-19), soil density (p 32-33) for 11 plots (not for 20)
DeConinck_etal_1993_report	**1992**: soil texture, soil water nutrient concentrations/pH per month (annex) for 12 plots
Roskams_etal_1997_report	**1988 & 1993**: stem density, basal area (p 24) **1988–1992**: crown condition (p 123, 145) **19??**: vegetation data per vegetation plot (p 36–39), soil texture (46-47), soil profile (48-58), soil chemistry (p 74-85) **1991**: leaf/needle nutrient concentrations in plot 11, 15, 18 (p 171, 176–178) **1991-1992**: soil density (p 63), water retention capacity (p 64), hydraulic conductivity (p 65) **1992**: throughfall (p 92, 96) & soil water (p 107-109) **1992**: root sampling in plot 15 (p 158)
Vandendriessche_etal_1993_report	**1991 or 1992**: chemical soil characteristics (annex) **1992**: N profile 12 plots (annex)
Maddelein_etal_1994_report	**1988**: forest/vegetation inventory plot 11–20 **1991**: forest/vegetation inventory 21-22 (p 3-4) **1991**: nutrient content of leaves (beech, oak) and needles (pine) (p 10, 15-16) **1992**: deposition and soil water (p 18, 24, 27-29)
Vanongeval_etal_1994_report	**1993**: chemical soil characteristics (p 4-15), N profile 6 plots (p 16-21)
VanRanst_etal_1994_report	**1993**: throughfall and open-field volume (annex 1), concentrations (annex 3) for 6 plots
Neirynck&Sioen_1994_report	**1993**: volume open-field & throughfall water (p 4), bulk deposition, throughfall (p 6-10), soil water (p 27, 31) for 6 plots **1988**: forest inventory plot 11-20 **1991**: forest inventory plot 21-22
Vanongeval_etal_1995_report	**1994**: N profile plot 22 (p 6)
VanLangenhove_etal_1995_report	**1994**: tree vitality (p 40), tree h & d (p 42), growth (p 43-46), crown projection area (p 47) for 4 plots, root mass for 3 plots (p 48-50), carbohydrate content (p 53, 55-58) for 4 plots, mycoflora (p 60-61) for 2 plots, Cd/Al/Mn (p 64, 67) for 3 plots
Neirynck&DeKeersmaeker_1995_report	**1994**: open-field, throughfall, stem flow, humus percolation, soil water at three depths for 6 plots (p 6, 8, 9, 16-17, 27-28, 31, annex 1) **1995**: forest inventory for 8 plots, leaf/needle nutrient concentration for 12 plots (annex)
DeConinck&VanRanst_1997_report	**19??**: chemical composition of the litter layer (5 plots) and the upper soil layer, 0-10 cm (6 plots) (p 23-26, 29)
Hubrechts_etal_1997_report	**1990–1995**: modelling of the water balance with WAVE for 11 plots (not for plot 20)
Neirynck_1996_report	**1995**: open-field, throughfall, stem flow, humus percolation, soil water at three depths for 6 plots (annex 1, annex 3) **1996**: vegetation for 12 plots
VanMechelen&VanRanst_1997_re	**1996**: volume free-field, throughfall (p 5), concentrations (annex)

port	
DeSchrijver_1997_report	**1996**: calculated potential/actual evapotranspiration in plot 16 & 22 **1996**: precipitation, throughfall, stemflow, humus percolation, soil water for 6 plots (p 32, 35-43, 94-95)
VanRompaey_etal_1998_report	**1997**: precipitation, throughfall, stemflow, humus percolation, soil water for 6 plots (p 5, annex)
DeSchrijver&Lust_1998_report	**199?**: water balance WAVE model (10 plots) **1997**: N, S, K, Ca, Mg, Na, Al, Fe, Cl, H+, CO3 concentrations in open-field, throughfall, stemflow, and soil water for 6 plots (p 72, 80, 85, 87, 92-93, 100-101, 107, 111-112, 116-118, 121-122) **1997**: free-field ammonia concentration (p 134-135), ammonia concentrations at different crown heights (p 141-148)
DeSchrijver&Lust_1999_report	**1998**: volumes and nutrient concentrations precipitation, throughfall, stemflow (p 4-7, 8, 10, 13, 18-19); humus percolation, soil water (p 30-34); calculated water balance WAVE model; comparison WAVE model and Cl balance; ammonia concentrations (p 61-63) in 6 plots; ammonia concentrations at different heights in plot 15 & 16); litter quantity and quality in plot 15, 16, 22 (p 54-56)
Neirynck&Roskams_1999_WaterAirSoilPoll	**1988-1997/1991-1997**: crown condition beech (plot 11, 16, 21) **1988 + 1992-1997**: deposition (plot 11, 16, 21) **19??**: radial growth beech
Neirynck_2000_report	**1992-1997**: trend analysis & budget water data **1988-1998** (without 1989): crown condition **1991/1992**: chemical soil characteristics **1996-1997**: humus balance **1988, 1991, 1995, 1997**: nutrient content leaves/needles **1988 & 1996**: vegetation inventory **19??**: tree cores & stem disks of 4-12 trees per plot
DeConinck&VanRanst_2001_report	**13/03/1998**: comparison water data for plot 15 and 21 (p 50-52) **02/07/1997–16/02/2000**: overall pH, acidity, NH_4, Al, NO_3, Cl, SO_4, base cations in the different water samples for 6 plots (p 59-63, 66-68)
DeSchrijver&Lust_2000_report	**1999**: water and nutrient fluxes for 6 plots; forest inventory for 12 plots (p 147)
DeSchrijver_etal_2001_report	**2000**: volumes and nutrient concentrations precipitation, throughfall, stemflow (p 1, 5, 8, 9, 12, 16-17); humus percolation, soil water (p 21-23, 25-26); calculated water balance WAVE model; comparison WAVE model and Cl balance; ammonia concentrations (p 73) in 6 plots; ammonia concentrations at different heights in plot 15 & 16 (p 78, 80); litter mass and quality (p 83-106)
Nachtergale_etal_2002_report	**2001**: volumes and nutrient concentrations precipitation, throughfall, stemflow (p 3, 6-12), humus percolation, soil water (p 17, 19, 21-22), calculated water fluxes WAVE model (p 24-25), ammonia concentrations (p 39-41) in 6 plots; ammonia concentrations at different heights in plot 15 & 16 (p 42-43); litter mass and quality (p 44-59)
Genouw_etal_2003_report	**2002**: precipitation, throughfall, stemflow, humus percolation, soil water, litter

Neirynck_etal_2004_IBWMed	**1992-2002**: trends in water sample data for 6 plots
VanRompaey_etal_2004_report	**2003**: water sample data for 5 plots (annex)
Genouw_etal_2004_report	**2003**: water sample data (p 2, 4-12, 34-37), litter quality & quantity (p 47-51) for 5 plots
Genouw_etal_2005_report	**2004**: water sample data (p 4, 6-12, 36, 38-40), litter quality & quantity (p 52-56) for 5 plots
Genouw_etal_2006_report	**2005:** precipitation, throughfall, stemflow, humus percolation, soil water, litter, leaf/needle, forest inventory (p 25-39)
Verstraeten_etal_2007_report	**2006**: precipitation, throughfall, stemflow, humus percolation, soil water, phenology beech, litter (p 37-57)
Verstraeten_etal_2008_report	**2007**: precipitation, throughfall, stemflow, humus percolation, soil water, litter (p 52-83)
Verstraeten_etal_2010_report	**2008 & 2009**: precipitation, throughfall, stemflow, humus percolation, soil water, litter, forest inventory (p 50-84)
Verstraeten_etal_2012_AtmEnv	**1994–2010**: throughfall, stemflow (for beech), humus percolation, soil water

<u>Flanders</u>

VanDenBerge_etal_1992_report
Tree vitality varied between the years (1988-1992), and no clear correlation with air pollution could be found. The bulk deposition had a pH 6.1 and rather high concentrations of SO_4, Cl, and NO_3; no differences in concentration were found between the different plots (except for pH, correlated with NH_3 input). Stem flow and throughfall showed higher concentrations than bulk deposition, except for Ca and Mg in plot Wijnendale. Stem flow was more acid for the pines than for the broadleaved trees. The SO_4 and NO_3 concentrations were also higher below pine trees than below broadleaved trees; K was found mainly below broadleaved trees, with a clear seasonal effect. No seasonal effect was found for Ca and Mg. The highest nutrient deposition values were found in Brasschaat, Ravels (higher pollution) and Buggenhout. All soils were rather poor, with a pH around 4 and low CEC, and were situated on the transition between the Al exchange and buffer ranges. The soil water is characterized by high concentrations (compared to the throughfall water) of SO_4, NO_3, Mg, Ca. Nutrient deficiencies in the leaves occur for Mg and P and sometimes for Ca. The high availability of N results in an unbalanced nutrient availability.

Vandendriessche_etal_1993_report
The soil pH lay between 3 and 4.4. The upper soil layers were in the Al buffer range, the lower soil layers in the ion exchange range. The CEC was lowest in the pine forests, followed by the beech forest, and then by the oak forests. The base saturation value is low on the sandy soils, moderate on the loamier soils, and > 50 % in the ash stand – Gontrode 2. The C content decreases with sample depth; the P content is low and also decreases with sample depth; N decreases with soil depth, and was high for 4 of the plots, extremely high in the ash stand. The pH values of the litter layer lay between 3.2–4.3 ($CaCl_2$) and 3.8–4.8 (H_2O). The ash stand showed remarkable results: high K, Ca, Mg, pH, Al, and Fe.

Verstraeten_etal_2010_report

PRECIPITATION

The wettest years between 1993 and 2009 were 2001 and 2002, the driest was 2003. In 2008 and 2009, precipitation was lowest in Gontrode. Interception varies between 20 and 25 %. In Gontrode, the interception in 2007, 2008, and 2009 was higher than before, because of a developing shrub layer?

The pH of the precipitation decreased between 1996 and 2004 and increased between 2004 and 2009. The concentrations of SO_4 and NH_4 decreased between 1996/1997 and 2009. The concentrations of NO_3, Mg, K, Ca remained relatively stable. The deposition of NH_4 and SO_4 decreased between 1998 and 2009; the deposition of NO_3 remained stable between 1995 and 2009.

THROUGHFALL/STEMFLOW

70-75 % of the precipitation reaches the forest floor. Stemflow amounts to 1 up to 14 %, depending on the tree species (beech > oak > pine). Concentrations of Mg, K, Ca were largest in Gontrode. The pH remained nearly constant during the measuring period. SO_4 and NH_4 concentrations decreased between 1998 and 2009; NO3 concentrations remained ca. constant. Crown leaching of K was largest in Gontrode; Mg was taken up by the crown (except for Gontrode); crown uptake of Ca occurred in all plots.

TOTAL DEPOSITION

Deposition of anorganic nitrogen is high compared to other European countries (mean: 23.3 kg/ha/yr in 2008 and 26.0 kg/ha/yr in 2009). For S, the mean deposition in 2008 and 2009 was 13.8 and 11.4 kg/ha/yr. The deposition of N and S decreased between 1994 and 2009.

SOIL WATER

The pH of the water below the litter/humus layer decreased between 1998 and 2009. The pH of the water in the A horizont decreased between 1992 and 2000, but remained constant between 2000 and 2009. In the B and C soil layers, the pH remained relatively constant. In 2009, the NO_3 concentration in the soil water in Gontrode was just below the drinking-water standard. Soil leaching of Al and Fe was largest in coniferous forests.

LITTER

Leaves/needles are 50 % of the litterfall (1.5-3 ton needles/yr, 2.5-4 ton leaves/yr). The amount of fruits and seeds shows the largest variation between years, because of the mast years of beech and oak (2000, 2002, 2004, 2006, 2009). The litter fall of woody parts fluctuates largely between years (i.e., 100-1000 kg/ha/yr)

Verstraeten_etal_2012_AtmEnv

Potentially acidifying N and S depositions on Flemish forests decreased significantly between 1994 and 2010, but forest soils in Flanders are still in an unfavourable condition. Critical loads and levels were still exceeded and soil acidification due to human disturbances continued, because a simultaneous decline of base cation depositions and short-term soil buffering processes such as $SO_4{}^{2-}$ desorption delay recovery.

PUBLICATIONS (ARTICLES)

1 Neirynck J, Roskams P (**1999**) Relationship between crown condition of beech (*Fagus sylvatica* L.) and throughfall chemistry. Water, Air and Soil Pollution 116, 389–394 (hardcopy/pdf)

2 Verstraeten A, Neirynck J, Genouw G, Cools N, Roskams P, Hens M (2012) Impact of declining atmospheric deposition on forest soil solution chemistry in Flanders, Belgium. Atmospheric Environment 62, 50–63 (hardcopy/pdf)

PUBLICATIONS (REPORTS)

1 Roskams P, Van Den Berge K (**1988**) Analyse van de luchtverontreiniging en de gevolgen daarvan op het bosecosysteem. Eerste interimrapport. RUG - Onderzoekscentrum voor Bosbouw, AROL – Dienst Groen – Waters en Bossen, 71 p (hardcopy)

2 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 n° 19 (met annexen). Aminal Dienst Waters en Bossen, Rijksuniversiteit Gent - Laboratorium voor Bosbouw, 169 p (hardcopy)

3 De Coninck F, Van Ranst E, Baert G, Vanmechelen L (**1993**) Project bodemmeetnet in de bossen van het Vlaamse Gewest. Verslag wateranalysen jaar 1992. Universiteit Gent - Laboratorium voor Regionale Bodemkunde en Landevaluatie, 32 p (hardcopy)

4 Van der Velden M, Van Orshoven J (**1993**) Bodemmeetnet in de bossen van het Vlaamse Gewest. Fysische karakterisatie van de proefvlakken (vochtretentie, hydraulische conductiviteit). K.U.Leuven - Instituut voor Land en Waterbeheer, Aminal - Dienst Waters en Bossen, 37 p (hardcopy)

5 Vandendriessche H, Billiau K, Geypens M (**1993**) Project bodemmeetnet in de bossen van het Vlaamse Gewest. Eindrapport. Bodemkundige Dienst van België, Leuven, 51 p (hardcopy)

6 Maddelein D, Neirynck J, Sioen G (**1994**) Werkgroep Actueel Bodemkundig Onderzoek Aktiviteitenverslag 1993: Activiteiten binnen de werkgroep ad hoc bodemonderzoek. Rijksuniversiteit Gent, Laboratorium voor Bosbouw, 34 p (hardcopy)

7 Neirynck J, Sioen G (**1994**) Activiteitenverslag 1994: Bosvitaliteit - Werkgroep ad hoc Bodemonderzoek. Rijksuniversiteit Gent - Laboratorium voor Bosbouw & Aminal - Dienst Waters & Bossen, 50 p (hardcopy)

8 Van Ranst E, Vanmechelen L, Groenemans R (**1994**) Evolutie van de samenstelling van de neerslag en het bodemwater in een aantal bosecosystemen in Vlaanderen tijdens 1993. Universiteit Gent, Vakgroep Geologie en Bodemkunde, Laboratorium voor Bodemkunde, 7 p (hardcopy)

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