

CONTENTS

PREFACE	vii
CONTENTS	xi
LIST OF FIGURES	xix
LIST OF TABLES	xxvii
NOMENCLATURE	xxxii
CHAPTER 1 GENERAL INTRODUCTION	1
<i>Introduction</i>	1
1.1 INTRODUCTION TO THE ISSUE OF ACIDIFICATION	1
<i>Dutch Priority Programme on Acidification</i>	3
1.2 HISTORY OF ATMOSPHERIC DEPOSITION RESEARCH	8
1.2.1 NITROGEN COMPOUNDS	9
<i>Wet deposition</i>	9
<i>Dry deposition</i>	11
1.2.2 SULPHUR COMPOUNDS	12
<i>Wet deposition</i>	12
<i>Dry deposition</i>	14
1.2.3 THROUGHFALL MEASUREMENTS	15
1.2.4 LONG-RANGE TRANSPORT	15
1.2.5 SYNTHESIS	17

1.3 ATMOSPHERIC DEPOSITION RESEARCH IN THE NETHERLANDS	18
1.4 OBJECTIVES AND OUTLINE OF THE BOOK.....	20
CHAPTER 2 EMISSION, TRANSFORMATION AND TRANSPORT	23
<i>Introduction</i>	23
2.1 EMISSION OF NITROGEN AND SULPHUR COMPOUNDS	23
2.1.1 ATMOSPHERIC SULPHUR AND NITROGEN COMPOUNDS	24
2.1.2 EMISSIONS	24
2.1.3 EVOLVEMENT OF ANTHROPOGENIC EMISSIONS SINCE 1900.....	26
<i>Emissions between 1900 and 1990</i>	26
<i>Emissions in the Netherlands and Europe during recent years</i>	28
2.2 ATMOSPHERIC CHEMISTRY	30
<i>SO₂</i>	32
<i>NO_x</i>	32
<i>NH₃</i>	33
2.3 FACTORS AFFECTING TRANSPORT	34
2.4 LONG-RANGE TRANSPORT MODELLING	39
2.5 SPATIAL VARIATION IN CONCENTRATION	41
2.5.1 THE NETHERLANDS.....	41
2.5.2 EUROPE.....	43
CHAPTER 3 DEPOSITION PROCESSES AND MEASUREMENT.....	49
<i>Introduction</i>	49
3.1 WET DEPOSITION	49
3.1.1 PROCESS DESCRIPTION	49
3.1.2 MEASURING METHODS	51
3.2 DRY DEPOSITION.....	55
3.2.1 PROCESS DESCRIPTION	55
3.2.2 FRAMEWORKS FOR THE DESCRIPTION OF ATMOSPHERE - SURFACE	
EXCHANGE	57
<i>Resistance analogy for trace gases</i>	57
<i>Particles</i>	60

3.2.3 MEASURING METHODS FOR DRY DEPOSITION.....	62
<i>Micrometeorological methods for estimating dry deposition.....</i>	62
<i>Surface wash methods to estimate dry deposition.....</i>	72
<i>Watershed mass balance method.....</i>	74
<i>Inferential technique.....</i>	74
<i>Chamber methods.....</i>	74
3.3 CLOUD AND FOG DEPOSITION AND DEW	76
3.3.1 PROCESS DESCRIPTION.....	76
3.3.2 MEASURING METHODS.....	76
3.4 EVALUATION AND COMPARISON OF DIFFERENT METHODS FOR ESTIMATING DEPOSITION	78
3.4.1 WET DEPOSITION.....	78
3.4.2 DRY DEPOSITION.....	78
<i>Sulphur.....</i>	79
<i>Nitrogen.....</i>	80
<i>Base cations.....</i>	81
3.4.3 CLOUD AND FOG DEPOSITION.....	82
3.4.3 SYNTHESIS.....	83
<i>Process-oriented studies.....</i>	83
<i>Evaluation of models.....</i>	83
<i>Detection of trends.....</i>	84
CHAPTER 4 MEASUREMENT RESULTS AND DRY DEPOSITION.....	85
<i>Introduction.....</i>	85
4.1 MEASUREMENT RESULTS	85
4.1.1 SO ₂	85
<i>Physiological Control.....</i>	86
<i>Physico-chemical control.....</i>	86
<i>Deposition to soil and litter.....</i>	88
4.1.2 NO _x	89
4.1.3 HNO _x	90
4.1.4 PAN.....	91
4.1.5 NH ₃	91
4.1.6 HCl.....	93
4.1.7 PARTICLES.....	93
4.1.8 METEORITES.....	94

4.2 SURFACE RESISTANCE PARAMETRISATIONS.....	98
<i>Introduction</i>	98
4.2.1 SURFACE RESISTANCE PARAMETERISATION FOR GASES.....	98
<i>Stomatal and mesophyll resistance</i>	99
<i>External leaf uptake</i>	100
<i>In-canopy transport</i>	104
<i>Deposition to soil and water surfaces</i>	105
4.2.2 PARTICLES	107
4.2.3 SYNTHESIS	109
<i>Uncertainties</i>	111
CHAPTER 5 GENERALISATION OF DEPOSITION.....	113
<i>Introduction</i>	113
5.1 LOCAL-SCALE DEPOSITION MAPS, WHAT'S THE USE?.....	114
5.2 DEPOSITION MODELLING IN THE NETHERLANDS.....	116
5.2.1 DEADM.....	116
5.2.2 WET DEPOSITION	118
<i>Dry deposition in bulk samplers</i>	118
<i>Neutral salts</i>	118
<i>Calculation procedure</i>	119
<i>Wet deposition estimates</i>	120
5.2.3 DRY DEPOSITION.....	122
<i>Roughness length maps</i>	122
<i>Dry deposition of acidifying components</i>	128
<i>Dry base cation deposition</i>	132
5.2.4 TOTAL DEPOSITION.....	136
<i>Acidifying components</i>	136
<i>Total base cation deposition</i>	141
5.3 DEPOSITION MODELLING IN EUROPE.....	146
5.3.1 EDACS	146
5.3.2 WET DEPOSITION	147
<i>Data collection and data quality</i>	148
<i>Interpolation</i>	149
<i>Description of spatial patterns</i>	150
5.3.3 DRY DEPOSITION.....	157
<i>Acidifying components</i>	157
<i>Dry base cation deposition</i>	161
5.3.4 TOTAL DEPOSITION.....	164

<i>Acidifying components</i>	164
<i>Base cations</i>	172
5.4 VARIATION IN DEPOSITION OVER SEVERAL YEARS	176
5.4.1 DEPOSITION AS A RESULT OF NATURAL SOURCES	176
5.4.2 HISTORICAL MEASUREMENTS OF WET DEPOSITION	177
<i>Nitrogen compounds</i>	177
<i>Sulphur</i>	181
<i>Base cations</i>	182
<i>The Netherlands</i>	183
5.4.3 NON-LINEARITIES IN TEMPORAL VARIATIONS	188
5.5 SYNTHESIS	193
CHAPTER 6 EVALUATION OF DEPOSITION ESTIMATES	195
<i>Introduction</i>	195
6.1 EVALUATION OF SURFACE EXCHANGE PARAMETERS FOR SO₂	196
6.1.2 EXPERIMENTAL PROCEDURE	196
<i>Deciduous forest</i>	196
<i>Coniferous forest</i>	196
<i>Grassland</i>	197
<i>Heathland</i>	197
6.1.3 MODELLED V _D COMPARED WITH MEASUREMENTS	198
6.1.4 DISCUSSION	204
<i>Uncertainties</i>	205
<i>Comparison with other parameterisations</i>	208
<i>Representativeness of parameterisation for European pollution climates</i>	208
6.2.5 SYNTHESIS	209
6.2 RELATION BETWEEN ATMOSPHERIC DEPOSITION AND SOIL LOADS	211
<i>Introduction</i>	211
6.2.1 THEORETICAL CONSIDERATIONS REGARDING CANOPY EXCHANGE	212
6.2.2 RESEARCH RESULTS FROM THE SPEULDER FOREST SITE	213
<i>Throughfall fluxes at the Speulder forest</i>	213
<i>Atmospheric deposition at the Speulder forest</i>	213
<i>Comparison of throughfall fluxes with atmospheric deposition estimates</i>	216
<i>Canopy exchange processes in the Speulder forest</i>	216
<i>Synthesis</i>	219
6.2.3 THROUGHFALL FLUXES COMPARED TO DEADM DEPOSITION ESTIMATES	220

<i>Acidifying components</i>	220
<i>Base cations</i>	222
6.3 UNCERTAINTY IN DEADM RESULTS	225
6.3.1 DRY DEPOSITION MEASUREMENTS.....	225
6.3.2 COMPARISON WITH OTHER MODEL RESULTS.....	228
6.3.3 ESTIMATION OF UNCERTAINTY RANGES.....	230
<i>Wet deposition</i>	231
<i>Dry deposition</i>	233
<i>Total deposition</i>	236
6.4 UNCERTAINTY IN THE EDACS RESULTS	238
6.4.2 WET DEPOSITION.....	238
<i>Total uncertainty in the wet deposition maps</i>	243
6.4.2 DRY DEPOSITION.....	244
6.4.3 TOTAL DEPOSITION.....	245
6.5 GENERAL SYNTHESIS	248
CHAPTER 7 THREE CASE STUDIES	253
<i>Introduction</i>	253
7.1 THE ELSPEETSCHÉ VELD EXPERIMENT ON SURFACE EXCHANGE OF TRACE GASES	254
7.1.1 INTRODUCTION.....	254
7.1.2 STUDY AREA AND METHODS.....	254
<i>Study area</i>	254
<i>Measurement methods and approach</i>	255
7.1.3 CALCULATION OF DEPOSITION PARAMETERS.....	256
<i>SO₂</i>	256
<i>NO₂</i>	259
<i>NH₃</i>	259
<i>Throughfall and stemflow</i>	262
<i>Co-deposition of SO₂ and NH₃</i>	264
7.1.4 CONCLUSIONS.....	265
7.2 THE UTRECHTSE HEUVELRUG EXPERIMENT ON THE IMPACT OF CANOPY STRUCTURE AND FOREST EDGE EFFECTS ON DEPOSITION	267
7.2.1 INTRODUCTION.....	267
7.2.2 METHODS.....	269
<i>Study area</i>	269

<i>Throughfall and bulk precipitation sampling procedure</i>	272
<i>Canopy and edge structure measurements</i>	274
7.2.3 THE IMPACT OF CANOPY STRUCTURE: RESULTS AND DISCUSSION ..	280
<i>Evaluation of canopy structure parametrisation</i>	280
<i>Relationships between dry deposition and canopy structure</i>	283
<i>Predicting net throughfall using simple regression models with canopy structure and information on pollution climate</i>	288
7.2.4 THE IMPACT OF FOREST EDGES: RESULTS AND DISCUSSION	290
<i>Evaluation of canopy structure parametrisation</i>	290
<i>Dry deposition gradients in the forest edges</i>	292
<i>Impact of canopy/edge structure and edge aspect</i>	298
<i>The impact of edge effects on dry deposition amounts to forests in the Netherlands</i>	303
7.2.5 CONCLUSIONS.....	307
<i>The impact of forest canopy structure on deposition amounts</i>	307
<i>The impact of forest edge effects on deposition amounts</i>	308
7.3 THE SPEULDER FOREST EXPERIMENTS TO DETERMINE THE INPUT AND RELATED IMPACTS TO DOUGLAS FIR.....	310
7.3.1 INTRODUCTION	310
<i>Deposition research</i>	310
<i>Assessment of relations between loads/levels and effects</i>	311
7.3.2 SITE DESCRIPTION	312
7.3.3 RESEARCH PROJECTS	313
7.3.4 DEPOSITION MONITORING OF GASEOUS COMPONENTS.....	314
<i>Introduction</i>	314
<i>Experimental procedure</i>	314
<i>Theory and interpretation</i>	315
<i>Dry deposition parameters for the Speulder forest</i>	316
7.3.5 THE AEROSOL PROJECT	325
<i>Introduction</i>	325
<i>Experimental set-up</i>	326
<i>Experimental determination of the acidifying aerosol and base cation input onto Speulder forest</i>	329
<i>Modelling particle deposition</i>	331
7.3.6 ANNUAL AVERAGE GAS AND PARTICLE DEPOSITION AND CHANGES WITH TIME	338
7.3.7 ASSESSMENT OF THE EFFECTS OF ACIDIFICATION, EUTROPHICATION AND OZONE	341
<i>Critical levels and loads at the Speulder forest site</i>	341
<i>Effect parameters and observed effects</i>	344
<i>Synthesis</i>	345

CONTENTS

7.3.8 CONCLUSIONS..... 350
 Gaseous deposition 350
 Deposition of particles..... 351
 Assessment of the relation between loads/levels and effects 353
7.3.9 EVALUATION..... 355

REFERENCES 357

INDEX 397