Integrated modelling for simulating nitrogen deposition effects and estimating critical loads of nitrogen based on changes in the ground vegetation

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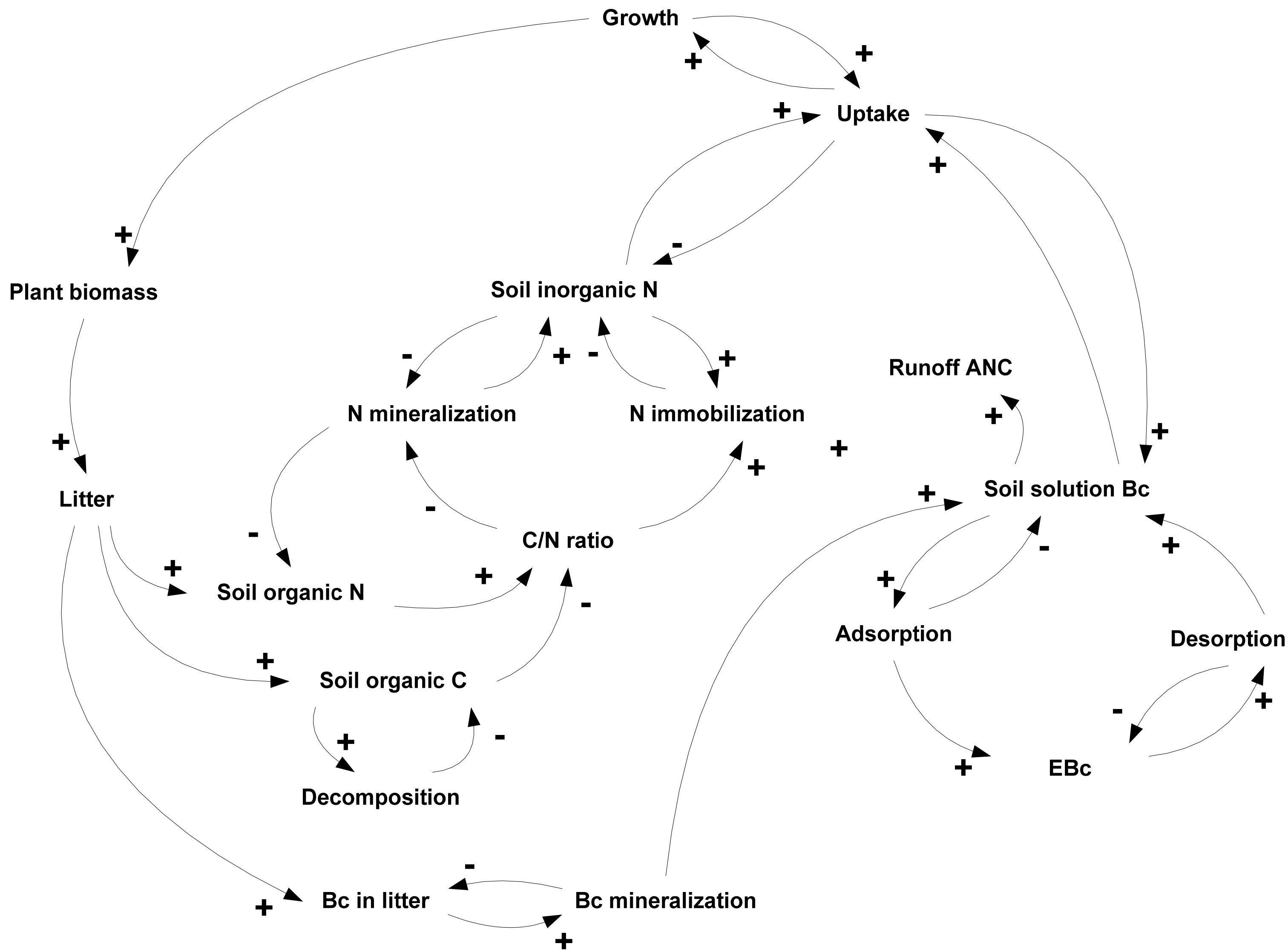
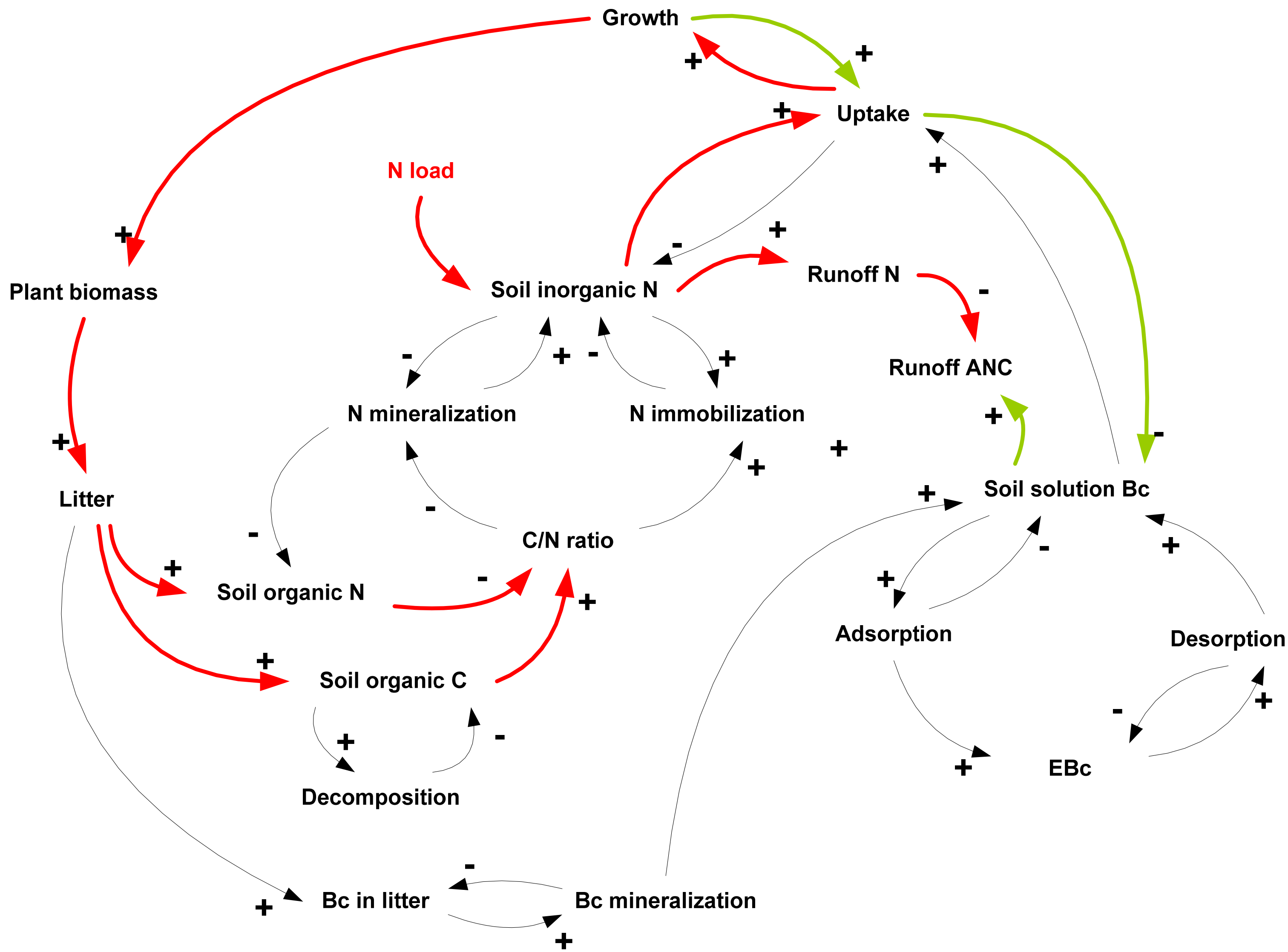
Salim Belyazid, Harald Sverdrup, Cecilia Akselsson, Annika Nordin, Peringe Grennfelt


Growth
Uptake
Plant biomass
Soil inorganic N
N mineralization
N immobilization
Runoff ANC
Litter
Soil solution Bc
C/N ratio
Soil organic N
Adsorption
Desorption
Soil organic C
EBc
Decomposition
Bc in litter
Bc mineralization



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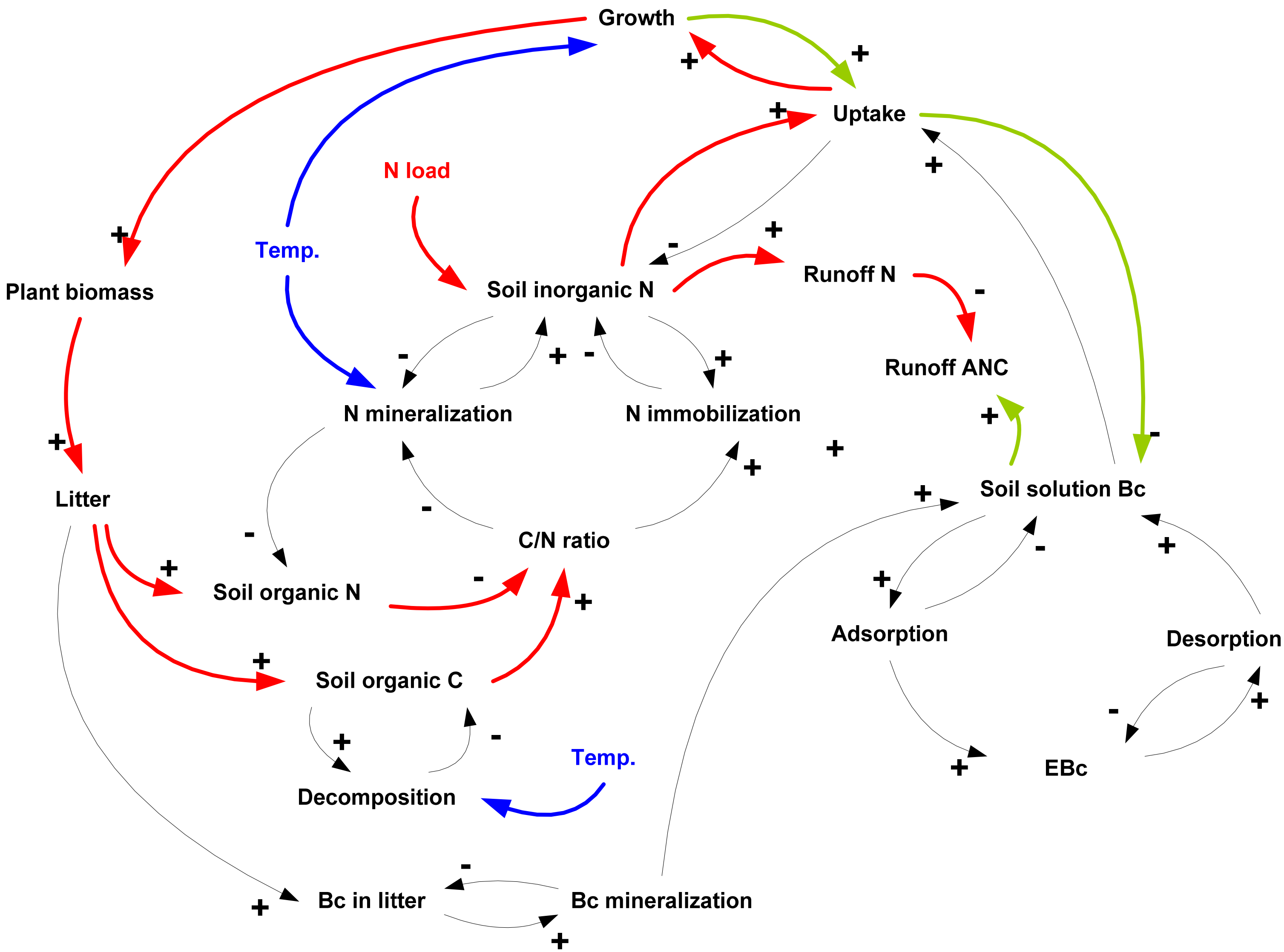

Growth
Uptake
N load
Temp.
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Soil inorganic N
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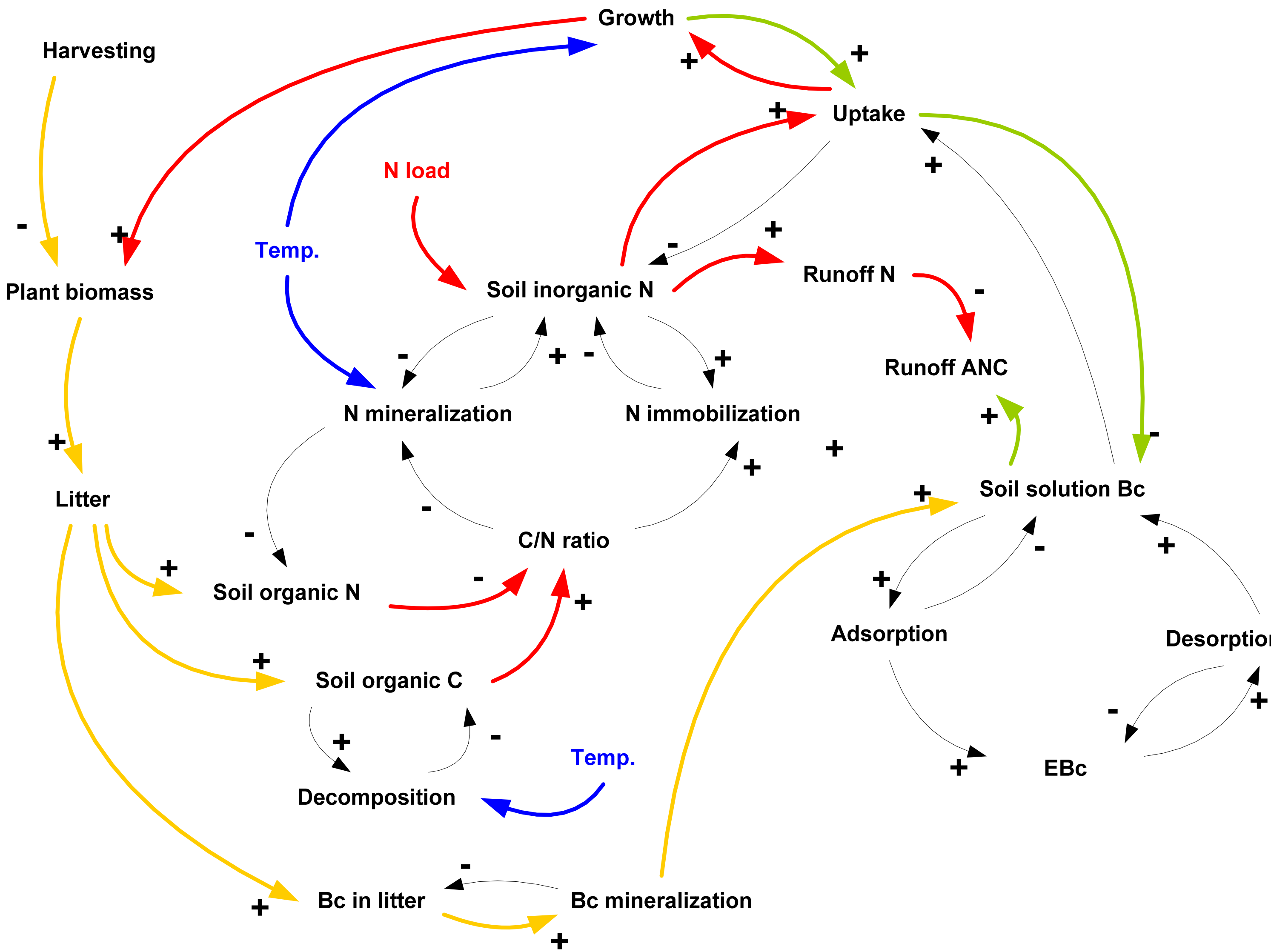
Growth
Harvesting
Uptake
N load
Temp.
Plant biomass
Soil inorganic N
Runoff N
Runoff ANC
N mineralization
N immobilization
Litter
Soil solution Bc
C/N ratio
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Adsorption
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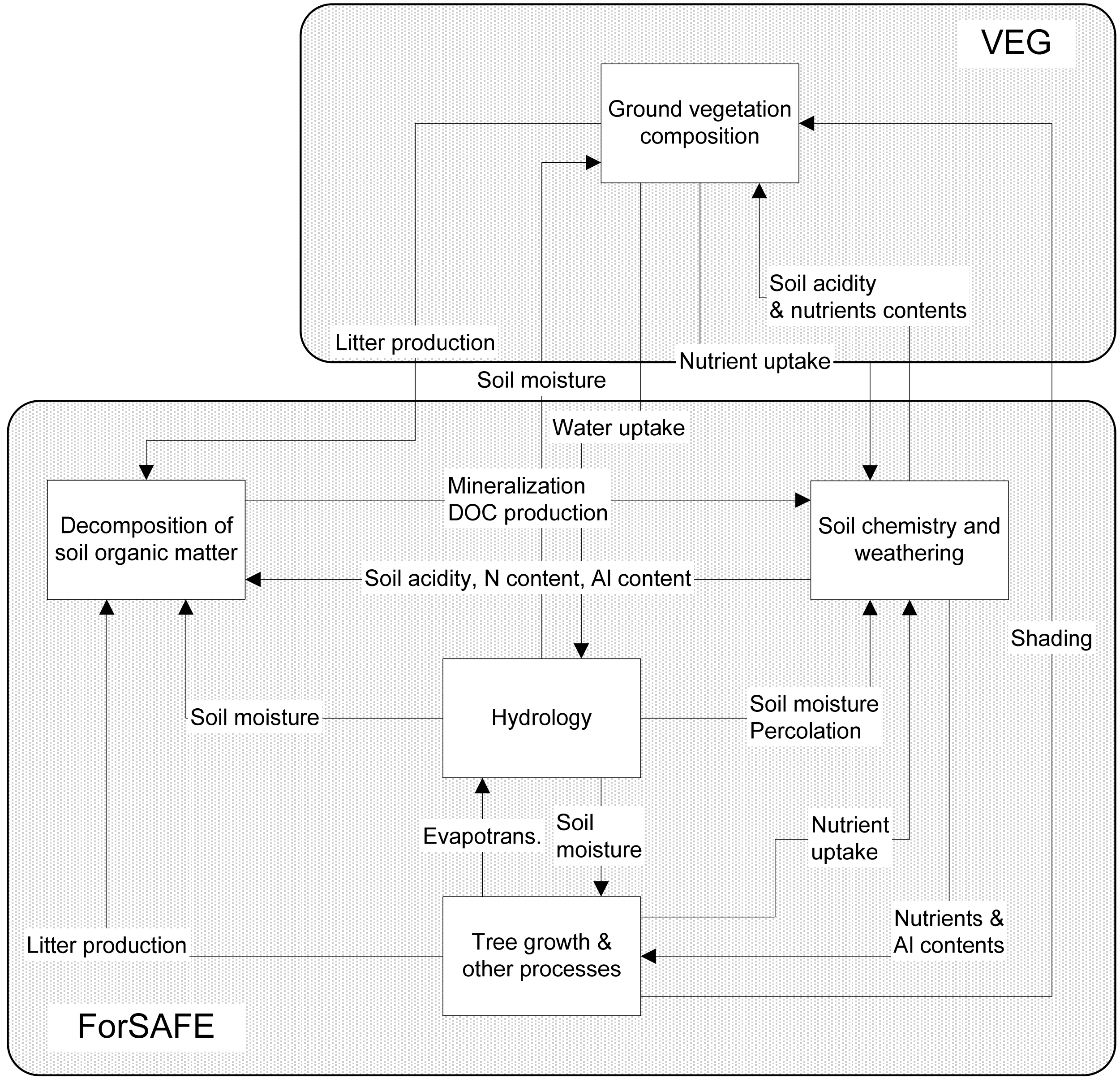
Decomposition
Temp.
Bc in litter
Bc mineralization

ForSAFE-Veg

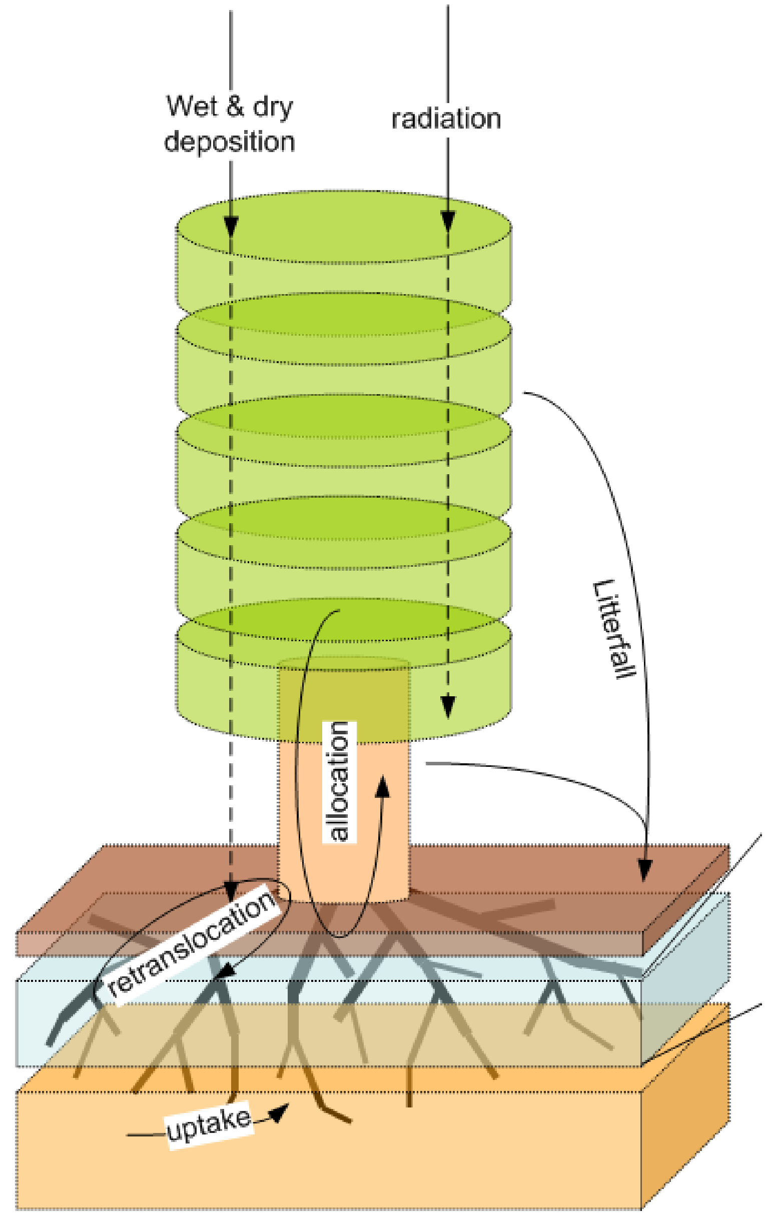

VEG
Ground vegetation composition
Soil acidity & nutrients contents
Litter production
Nutrient uptake
Soil moisture
Water uptake
Decomposition of soil organic matter
Mineralization DOC production
Soil chemistry and weathering
Soil acidity, N content, Al content
Shading
Hydrology
Soil moisture
Soil moisture Percolation
Evapotrans.
Soil moisture
Nutrient uptake
Nutrients & Al contents
Litter production
Tree growth & other processes
ForSAFE

From PnET (Aber et al., 1992)

$$TotalGrossPsn = \sum_{Layer=1}^{50} LayerGrossPsn$$

$$LayerGrossPsn = GrossA\max \cdot LightEff \cdot FolMass/50$$

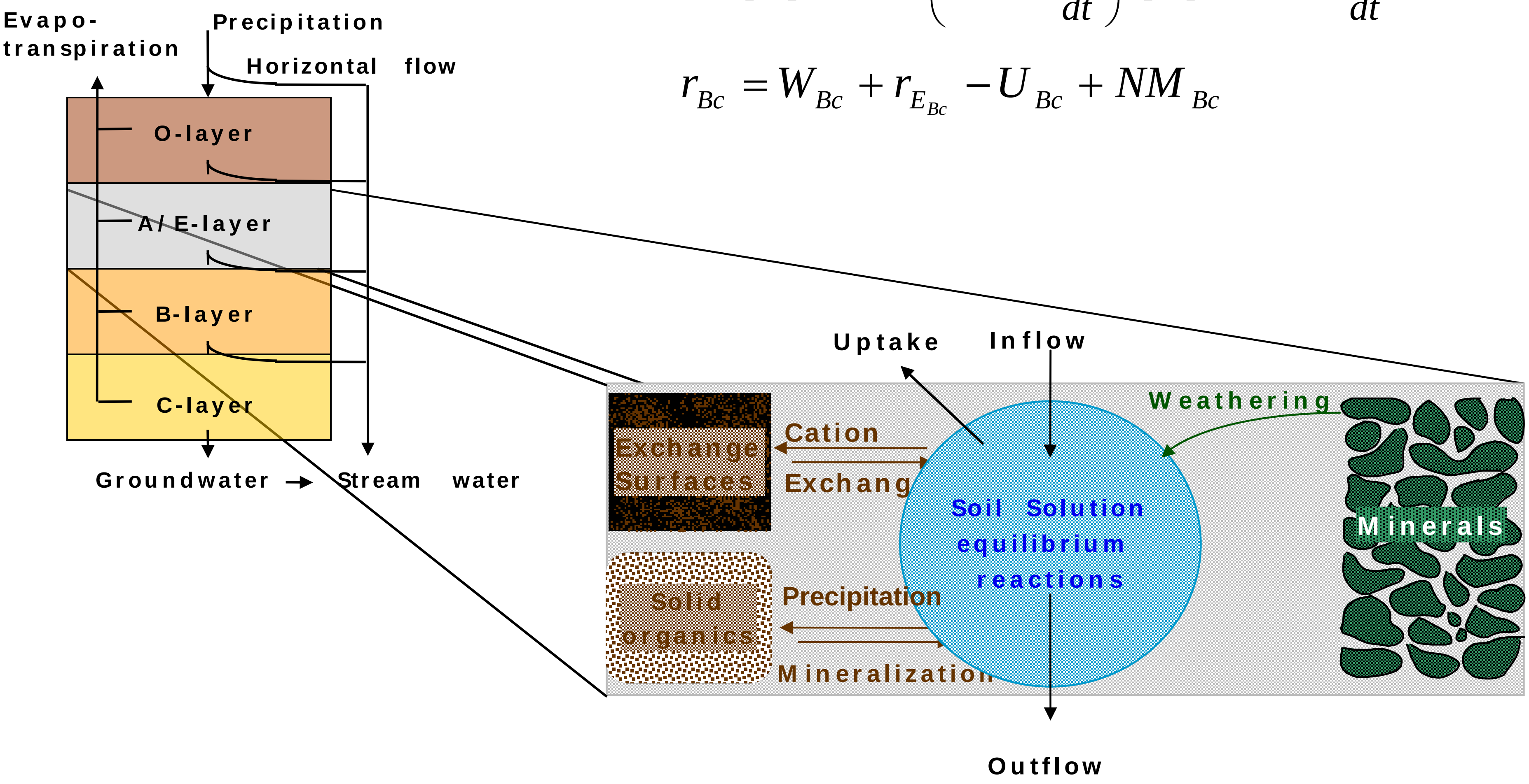
$$GrossA\max = A\max A + A\max B \cdot [N]_{foliar}$$



From SAFE (Alveteg, 1995)

$$Q_0 \cdot [X]_0 + r_X = \left(Q + z \cdot \frac{d\theta}{dt} \right) \cdot [X] + z \cdot \theta \cdot \frac{d([X])}{dt}$$

$$r_{Bc} = W_{Bc} + r_{E_{Bc}} - U_{Bc} + NM_{Bc}$$



From Decomp (Walse et al, 1998)

$$\frac{dSOM_i(t)}{dt} = in - r_i \cdot SOM_i(t)$$

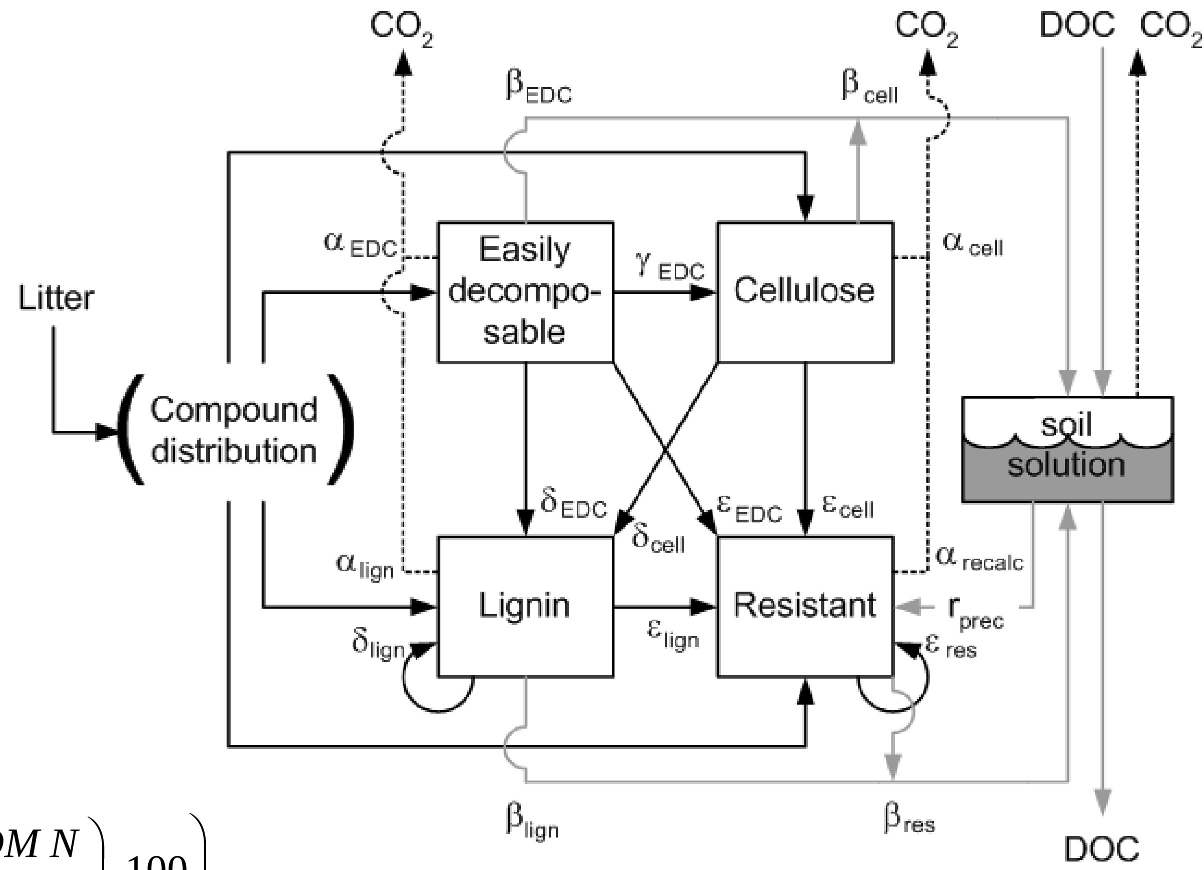
$$r_i = k_i \cdot f_i(T) \cdot g_i(\theta) \cdot h_i(pH)$$

$$g_i(\theta) = \frac{K_w \cdot \theta^{n_w}}{1 + k_w \cdot \theta^{n_w}}$$

$$fi(T) = e^{\left(E_a / R \cdot T_r - E_a / R - T \right)}$$

$$h_i(pH) = \frac{1}{1 + k_{pH} \cdot \left[H^+ \right]^m}$$

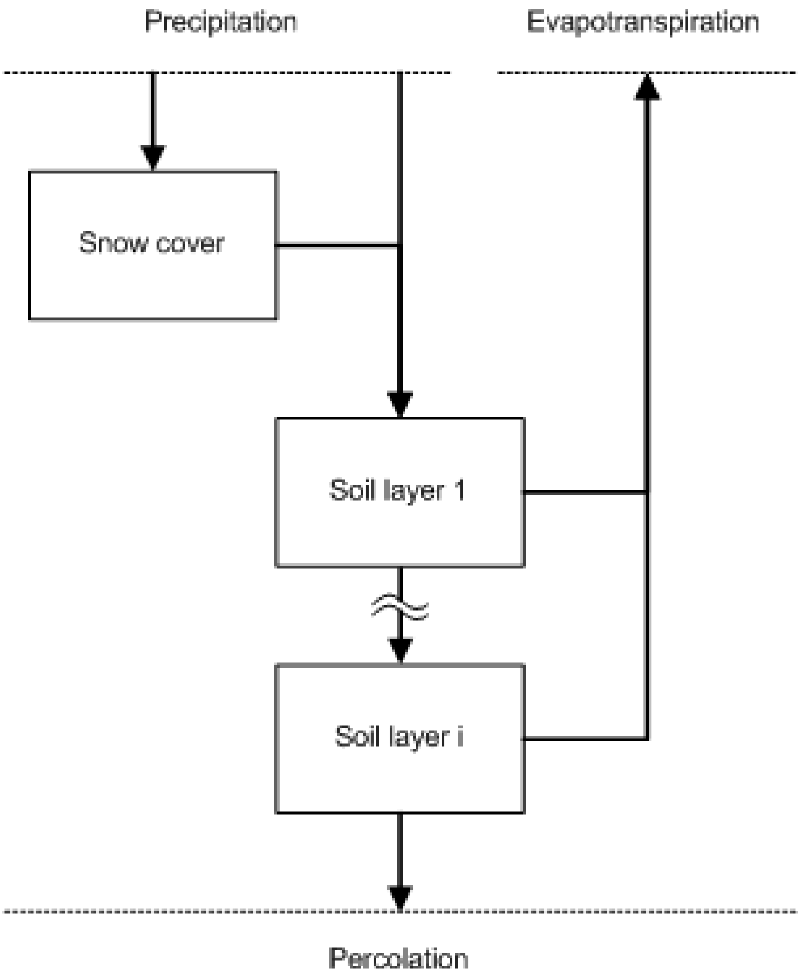
$$N_{imm} = \frac{1}{100} \cdot \left(NimmA + NimmB \cdot \left(\frac{SOM\,N}{SOM\,C} \right) \cdot 100 \right)$$



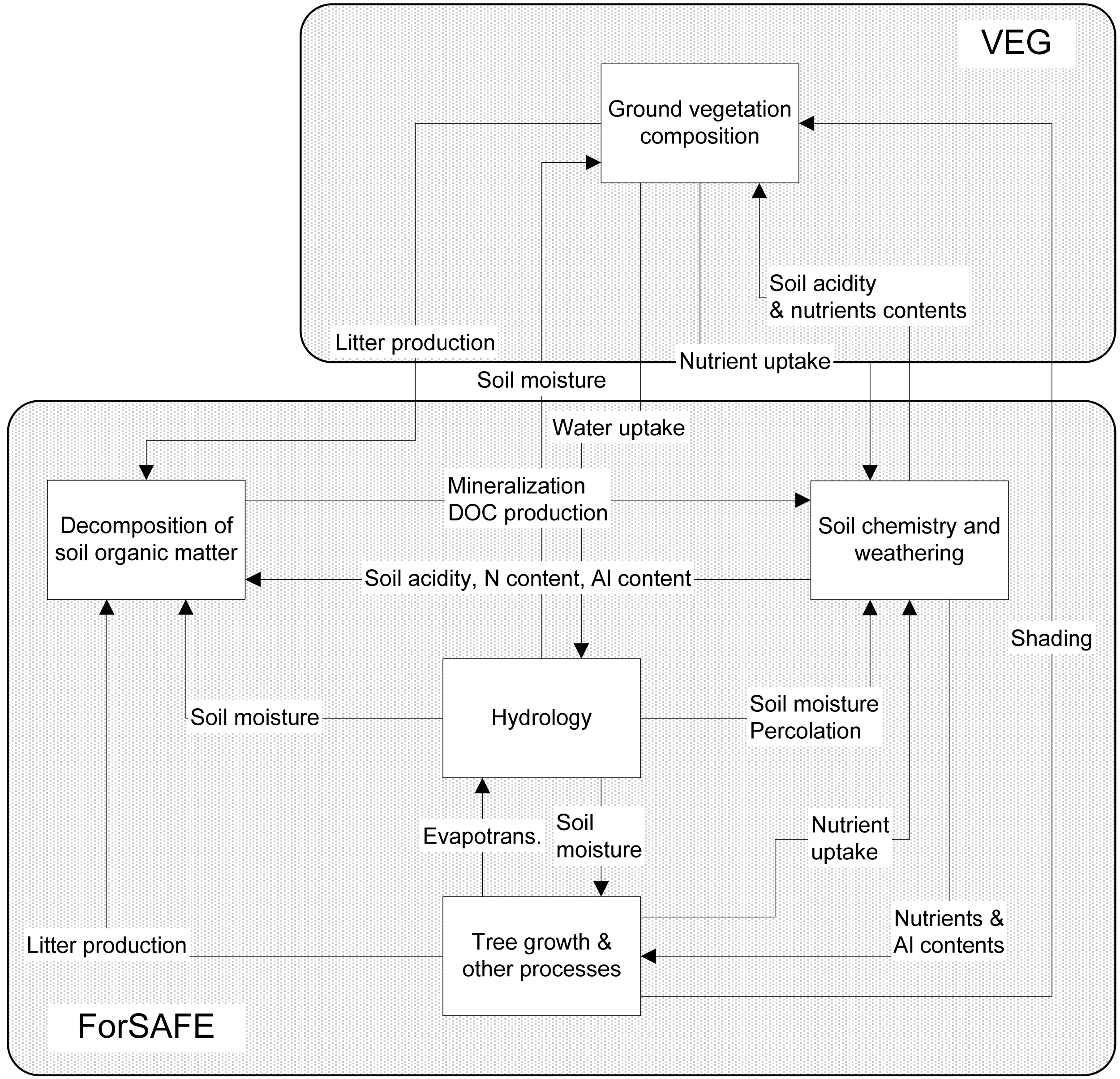
From PULSE (Lindström & Gardelin, 1992)

$$Percol_i = MAX\left(0, \left(\frac{SoilMoist_i - WiltPnt_i}{FieldCap_i - WiltPnt_i}\right)^{\beta} \cdot In_i\right)$$

$$ActEvap_i = MAX\left(\frac{SoilMoist_i - WiltPnt_i}{LimitEvap_i - WiltPnt_i}, 1\right) \cdot PotEvap_i$$



ForSAFE-Veg



VEG
Ground vegetation composition
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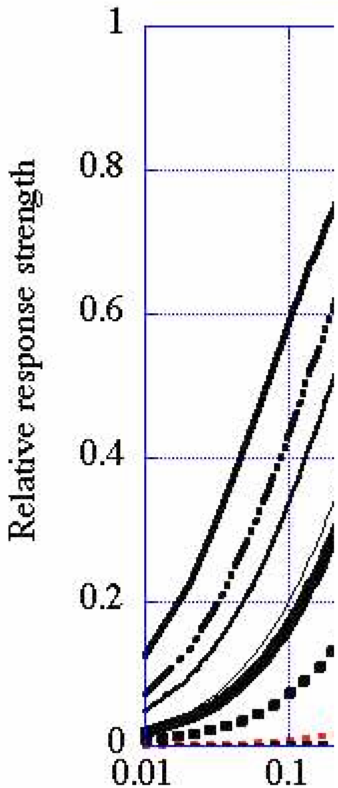
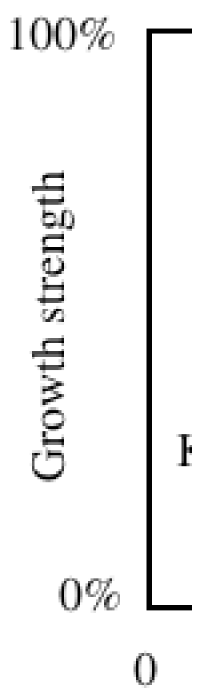
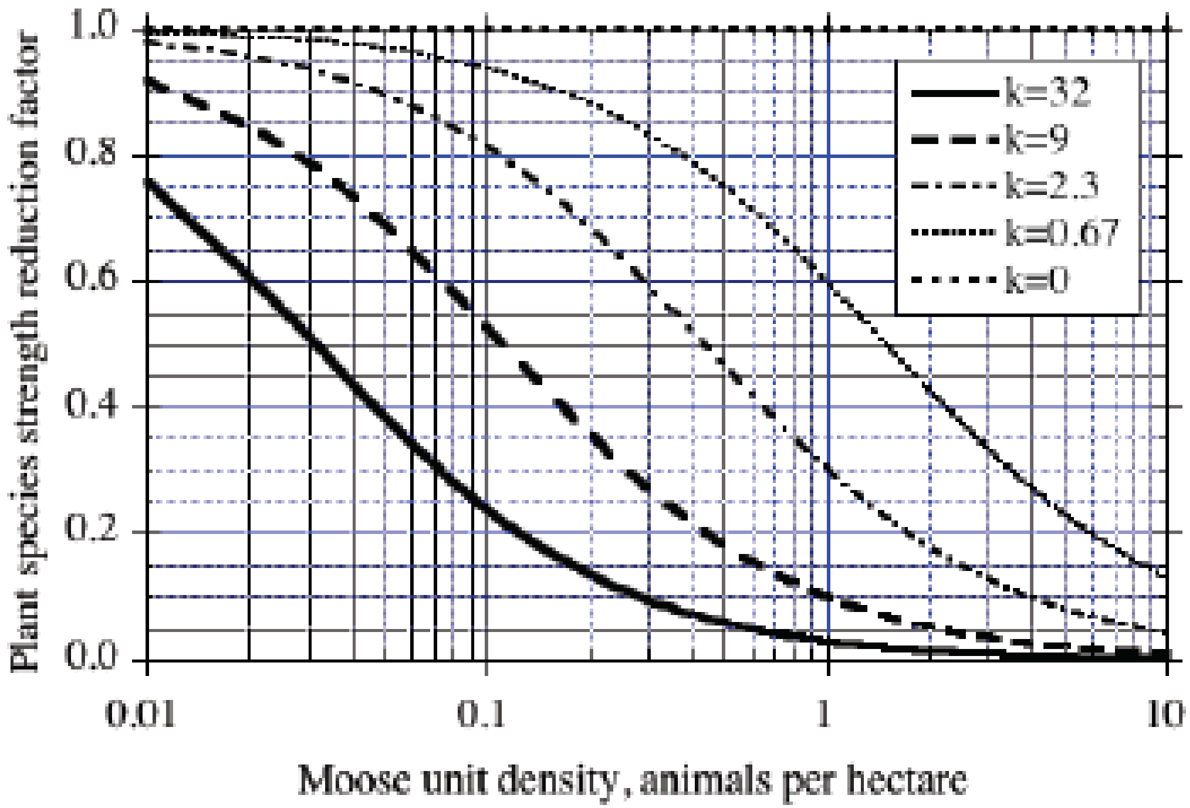
Percolation
Evapotrans.
Soil
moisture
Nutrient
uptake
Nutrients &
Al contents
Litter production
Tree growth & other processes
ForSAFE

Latin name	t years	[N] a0	k+	w+	k-	w-	[H+] kbc/al	kbc	kph	W min	top	max	T min	top	max	I min	max	h(m)	root class	kP	kG
Cladonia_lichen		1	0.01	1	0.003	3	0.07	0	1050	-0.2	0.05	0.25	-2.5	5.5	13.5	500	2500	0.05	0	0.1	0.7
		1	0.03	1	-	-	0.07	150000	1050	0.05	0.15	0.35	-1	7	15	100	2500	0.02	0	3	0
Milium_mosses		1	0.3	2	-	-	0.4	0	6000	0.15	0.25	0.6	0	8	16	50	2500	0.02	0	3	0
Sphag																					
Callun																					
Empe																					
Erica_																					
Vacci																					
Vacci																					
Agros																					
Brach																					
Bromus_benekenii			20	2	-	-	12	0	180000	0.1	0.2	0.4	5	13	21	250	3000	0.6	2	30	9
Calamagrostis_arundi			0.5	2	-	-	1.8	0	20800	0.1	0.2	0.4	2	10	18	750	3500	0.5	2	3	0.67
Deschar																					0
Deschar																					2.3
Festuca																					0.67
Milium_e																					9
Molinia_																					2.3
Nardus_																					0
Poa_ner																					9
Dryopter																					2.3
Pteridiur																					0
Aconitur																					0
Allium_u																					0
Anemon																					2.3
Antenna																					0
Arnica_r																					0
Epilobiur																					32
Galium_																					0.67
Geraniur																					9
Hepatica																					0
Mercuria																					0
Origanur																					0.67
Oxalis_a																					0
Trientalis																					0.67
Trifolium																					32
Urtica_d																					0
Norway																					0.7
Sitka sp																					0.7
Scots pi																					0.7
Larch																					0.7
Birch																					9
Beech																					2.3
Oak																					9
Ash																					9
Norway																					9
Myrica_																					0.67
Rhodode																					0
Rubus_i																					9
Salix_la																					2.3
Salix_m																					9

[N]			[H+]	W				I	h(m)	roo	kG
a0	t years		kbc/al	min	top	min	top	min			
		0.01	0.07	-0.2		-2.5			0.05		0.7
	20										





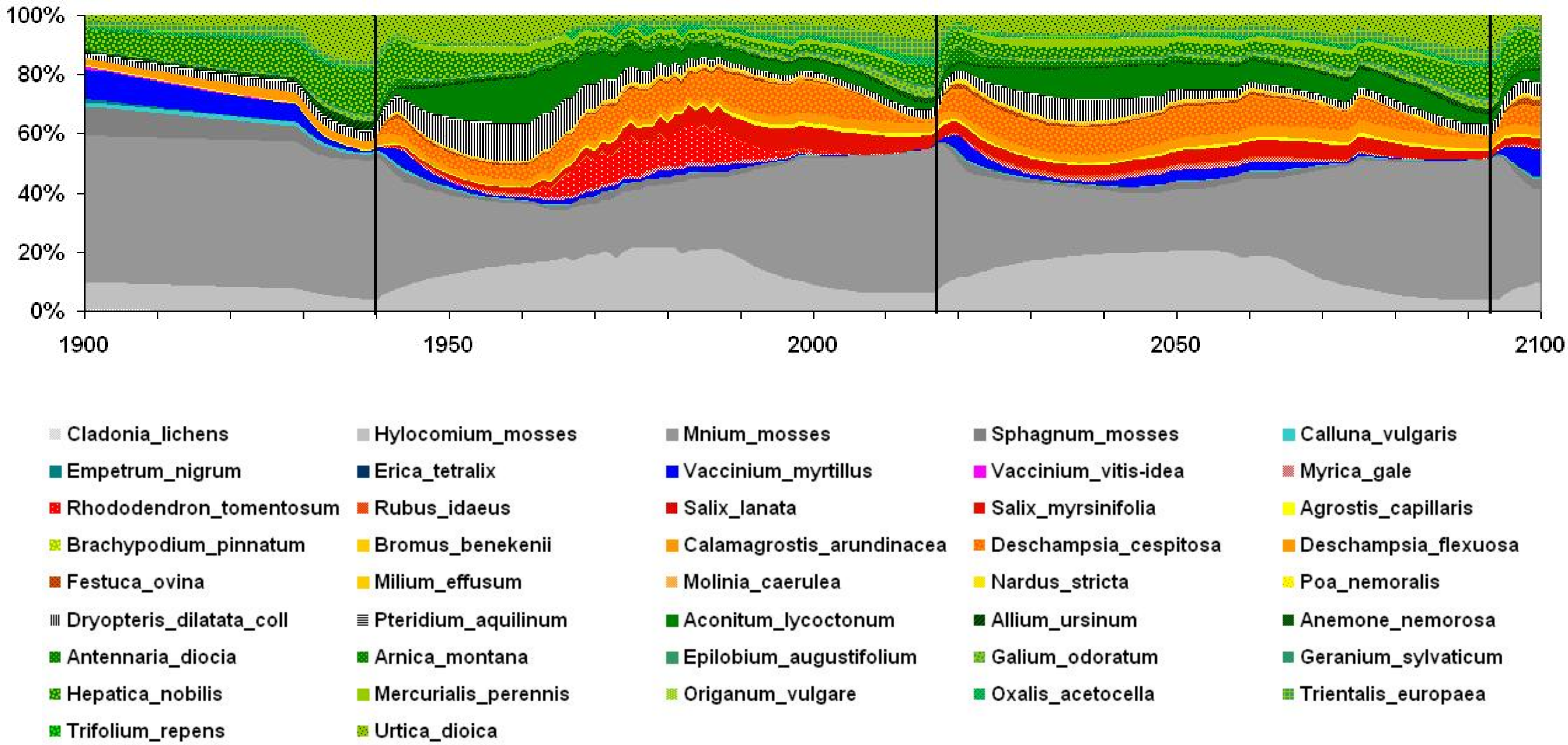


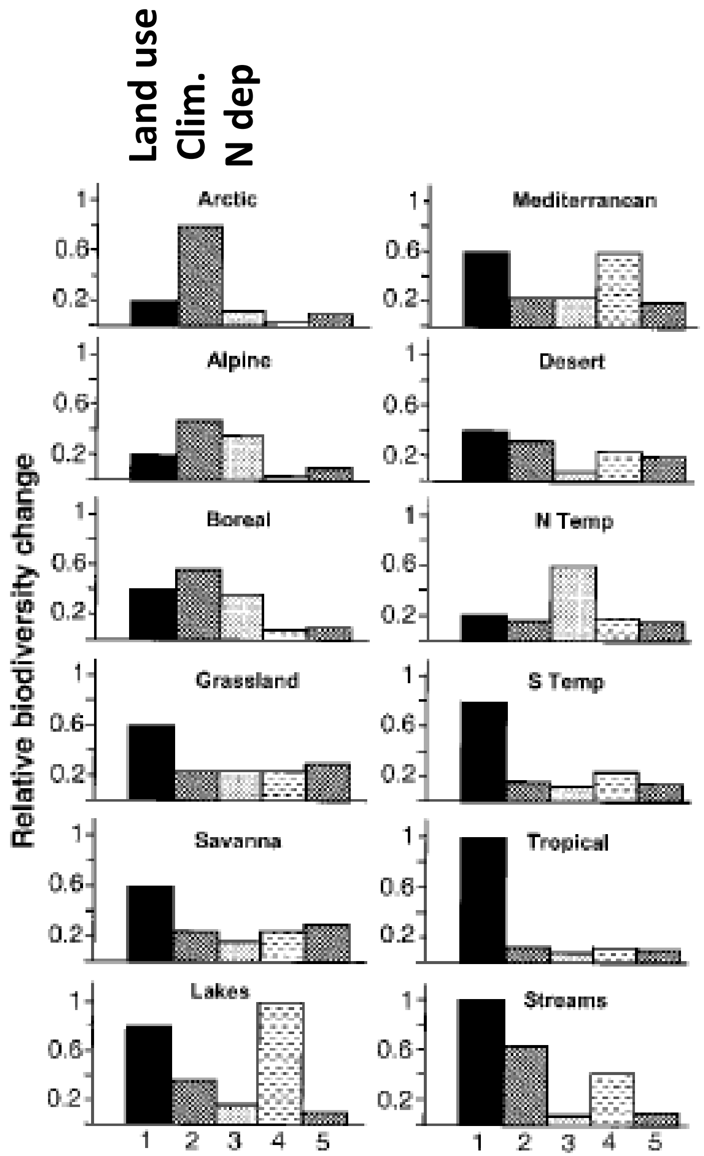
Start threshhold

Saturation threshhold

Decline threshhold

Changes in the composition of the ground vegetation at a central Swedish forest site





Sala et al., Science 2000

Fig. 2. Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of the expected change of each driver times its impact for each terrestrial biome or freshwater ecosystem. Expected changes and impacts are specific to each biome or ecosystem type and are presented in Tables 1 to 4. Values are relative to the maximum possible value. Bars: 1, land use; 2, climate; 3, nitrogen deposition; 4, biotic exchange; 5, atmospheric CO_2.

Multi-driver effects on growth, 1- N dep

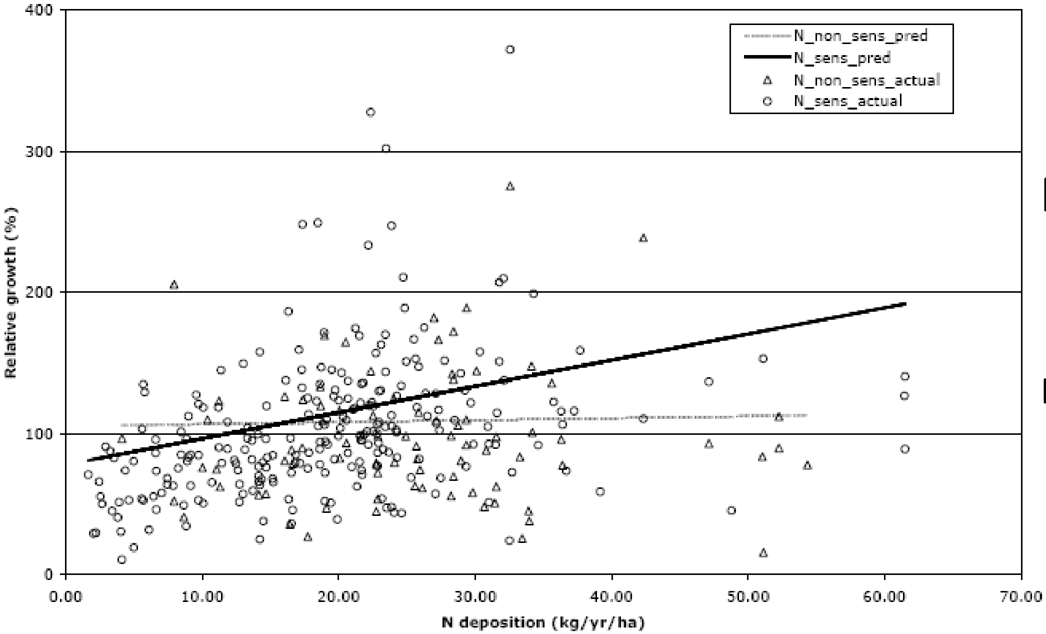


Figure 1.4 Relationships between nitrogen deposition and relative growth using the mean site index curve values. Regression lines represent the results of analyses of covariance (Table 1.9).

N-sensitive sites
+ 10 kgN/ha,yr => + 18.5% growth

non-N-sensitive sites
+ 10 kgN/ha,yr => + 1.40% growth

DeVries et al., 2007 Alterra report 1538

Multi-driver effects on growth, 2- Temp

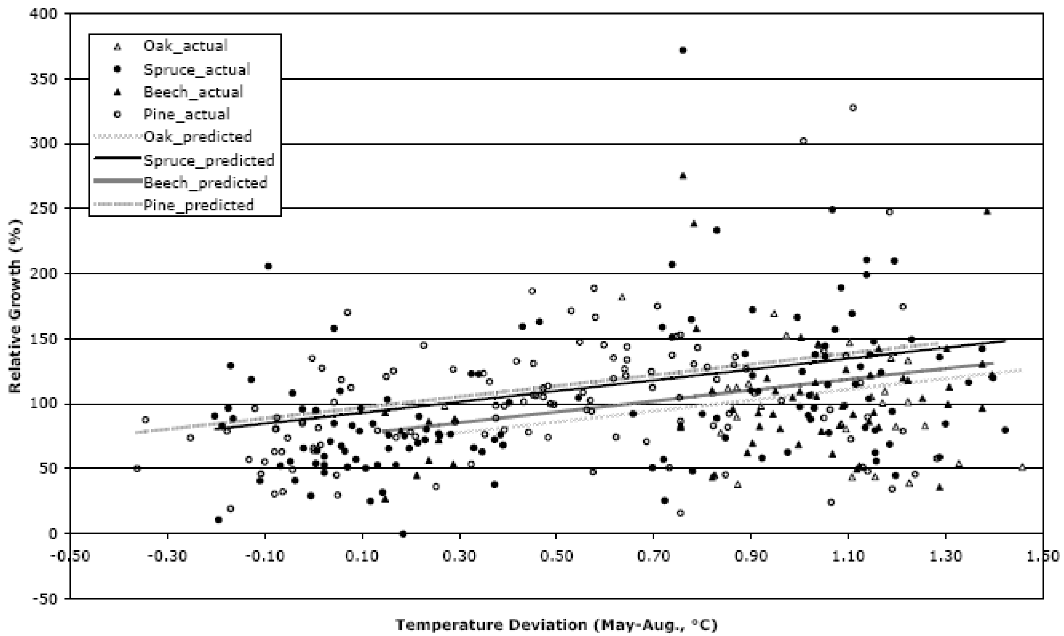
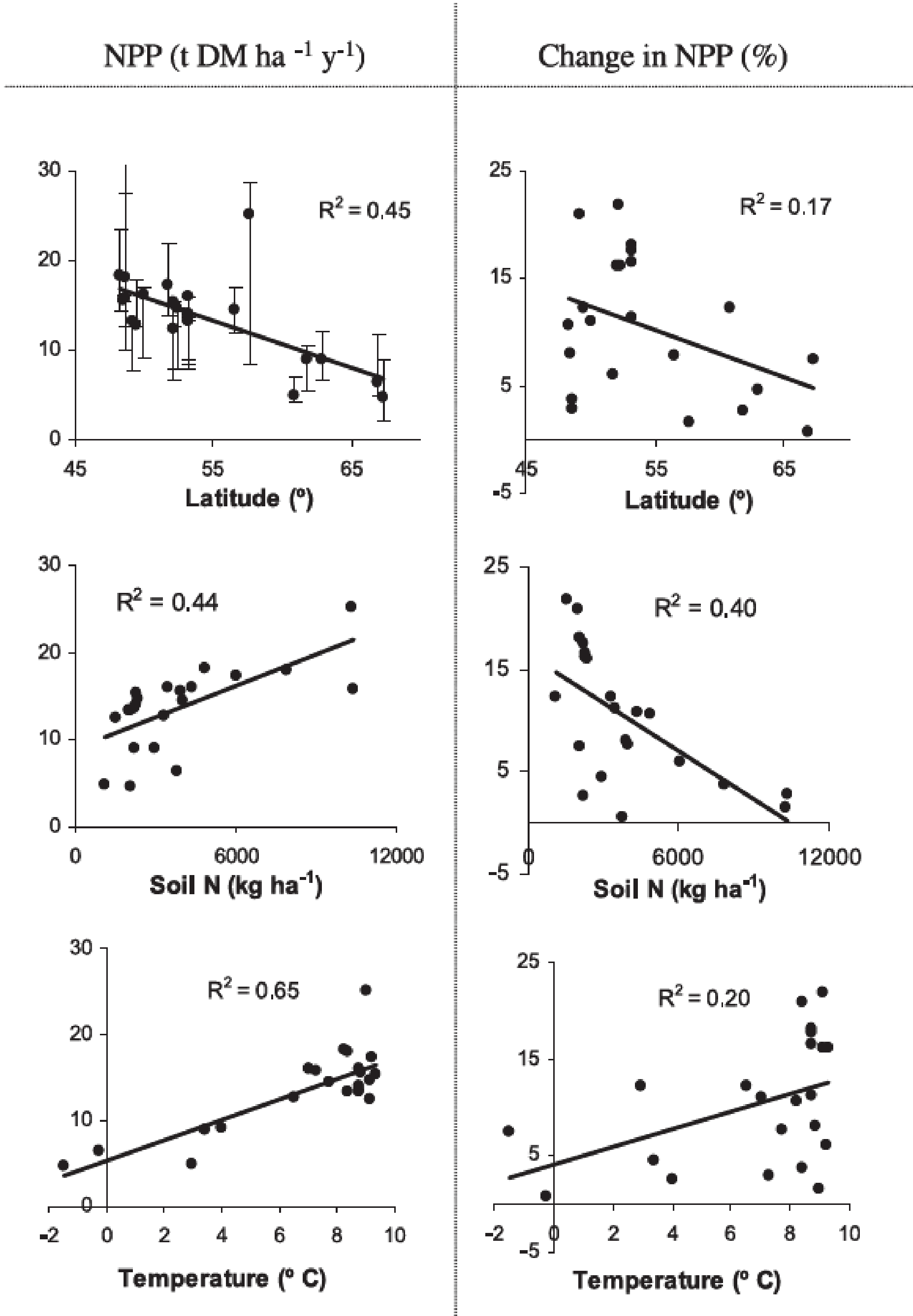


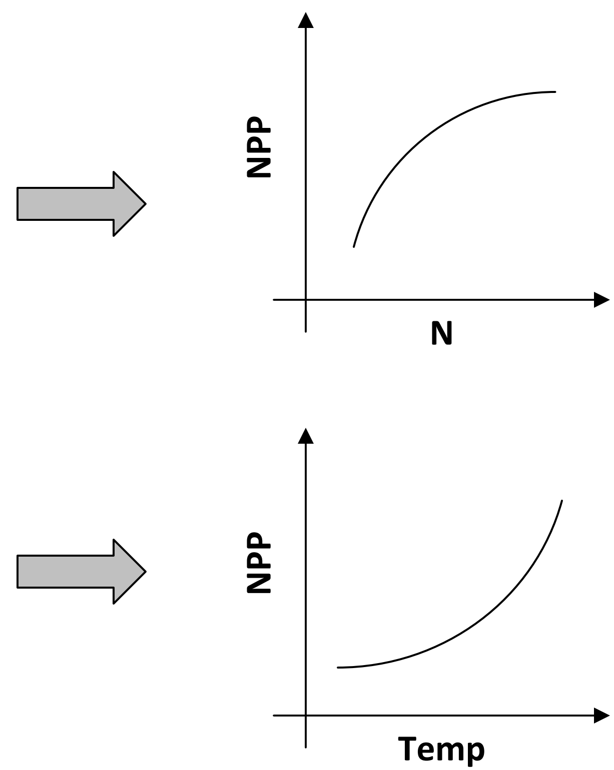
Figure 1.5 Relationships between relative growth and summer temperature deviation from the 1961-90 normal values. The regression lines represent the results of analyses of covariance (Table 1.10).

+ 1°C => + 42% growth

Did we account for anything more than once?

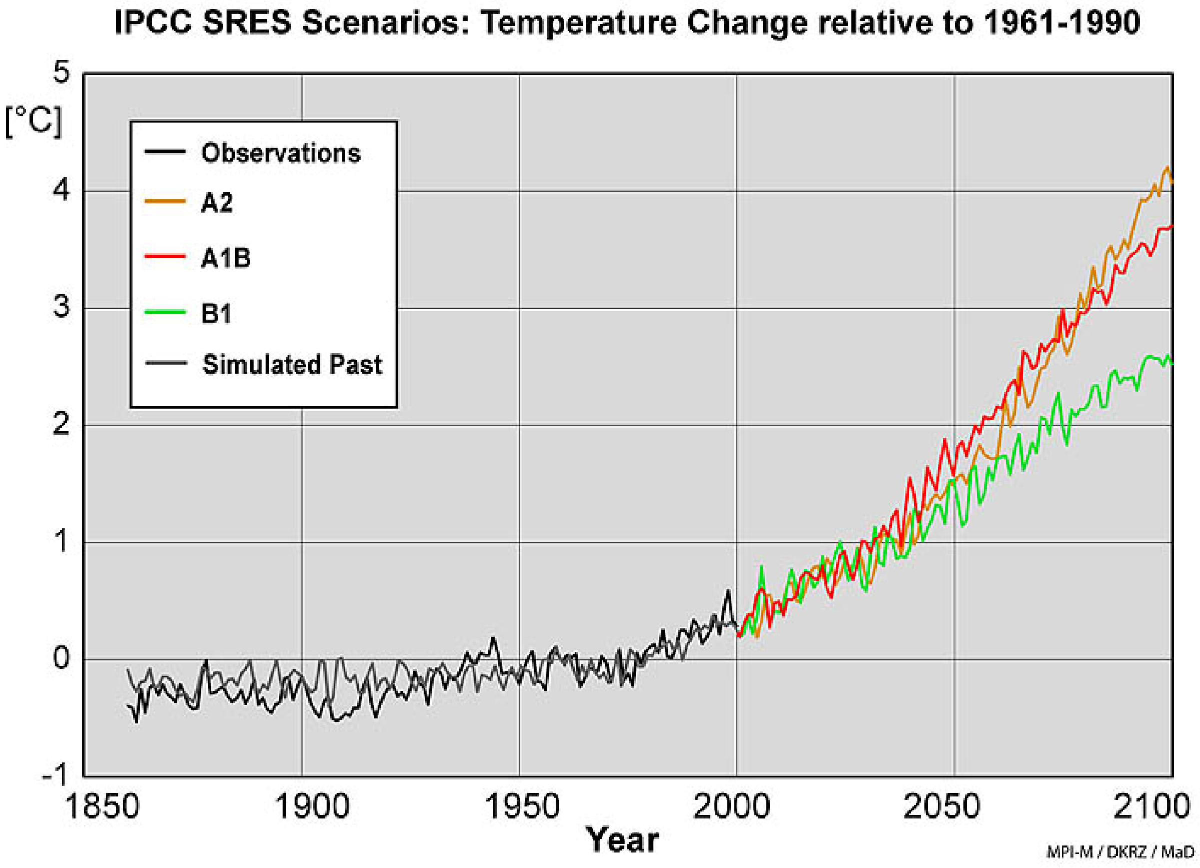
DeVries et al., 2007 Alterra report 1538



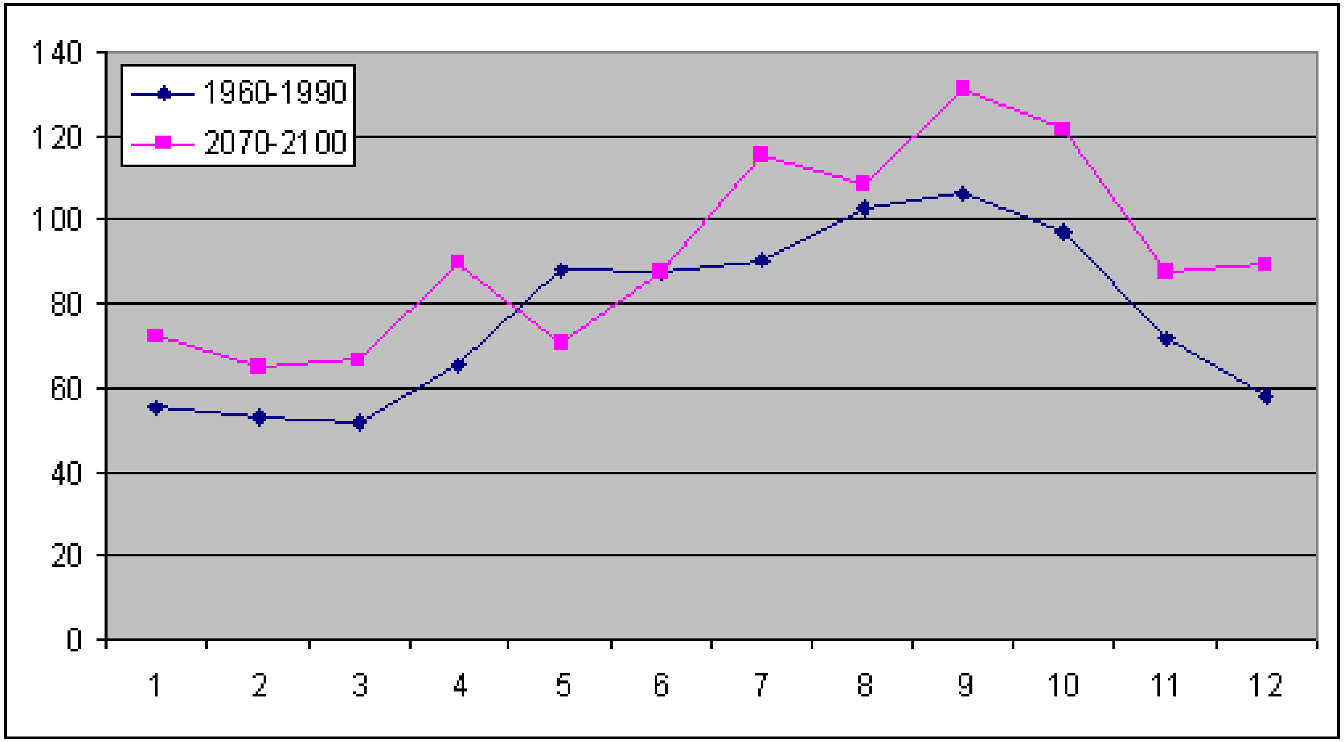


Milne & Van Oijen, 2005

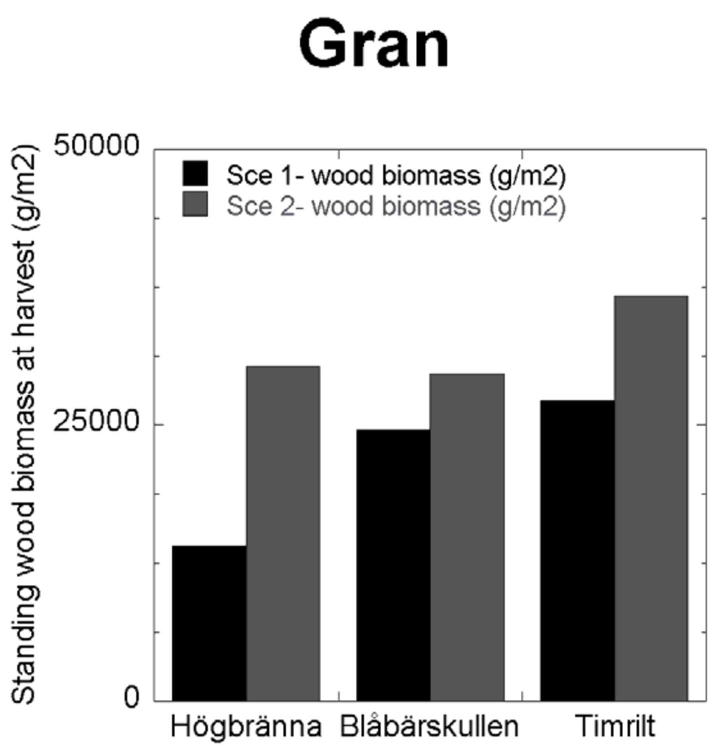
Nobel peace price

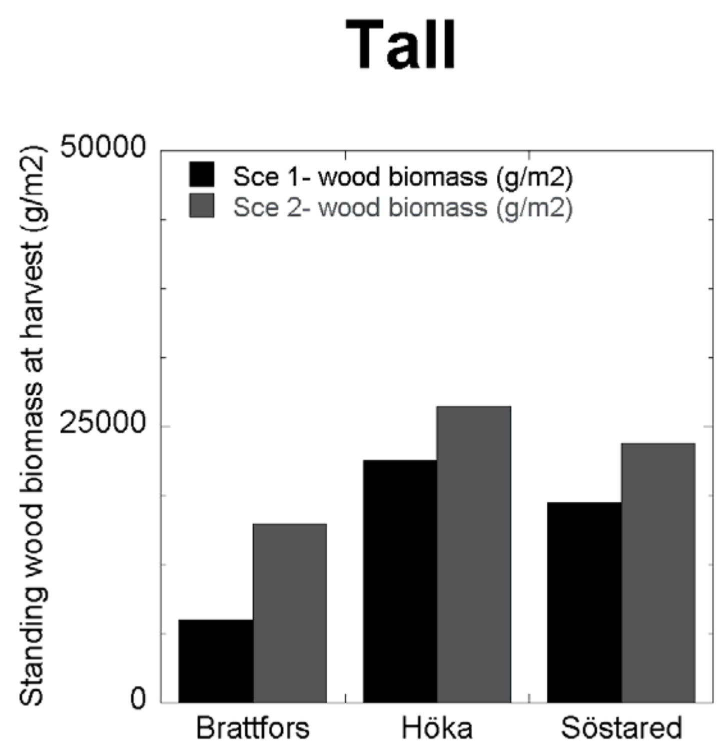


intra-annual varriations in precip. (Sce. A2, Max Planks Inst. modell)



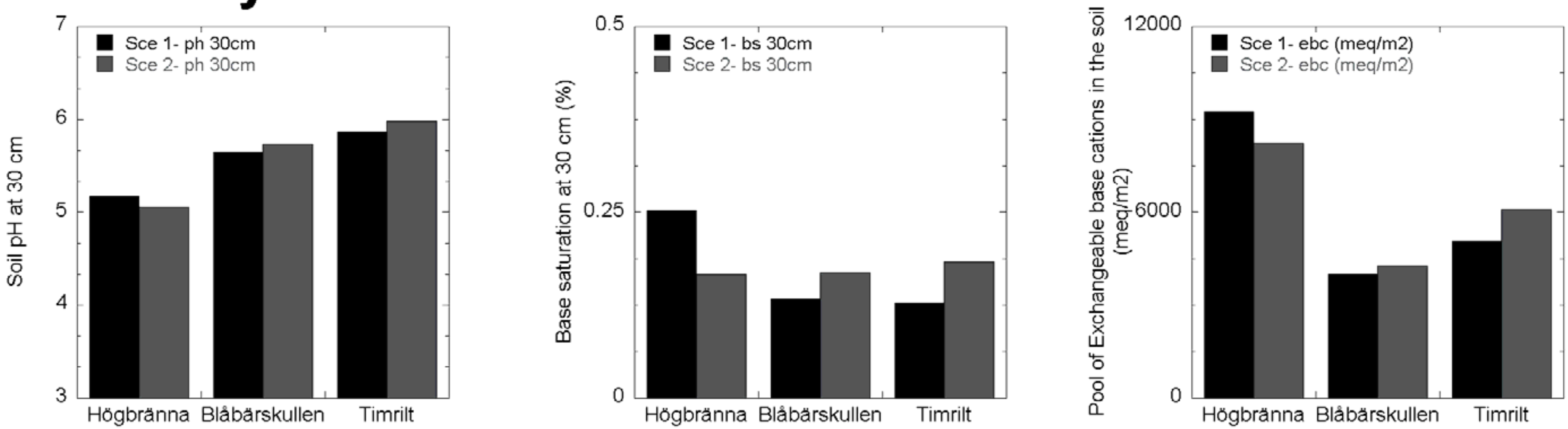
Climate effects on growth



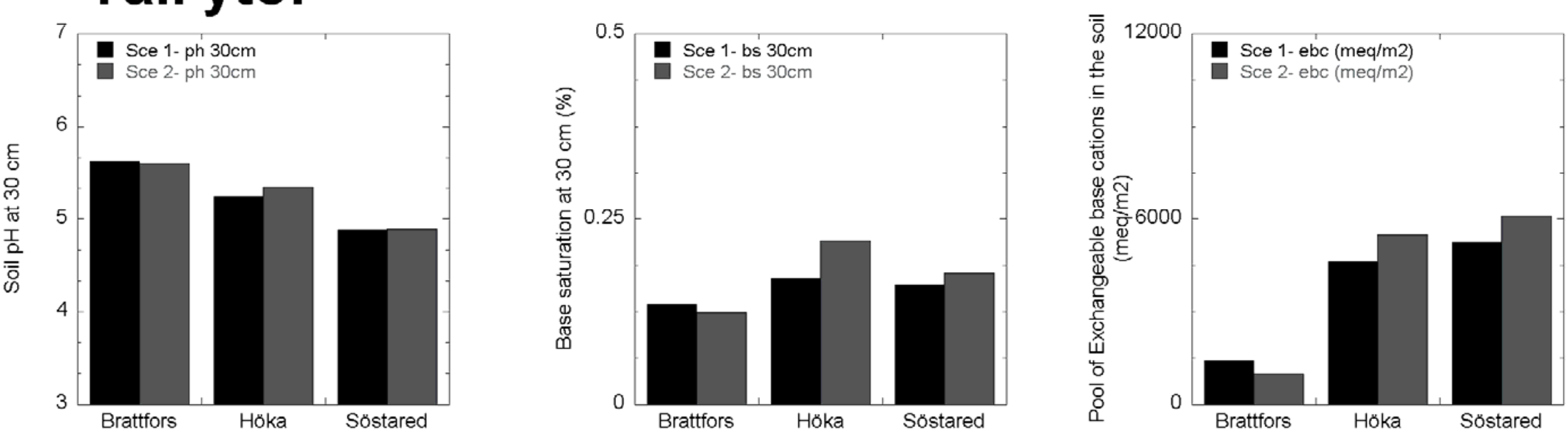


climate change effects on alkalinity

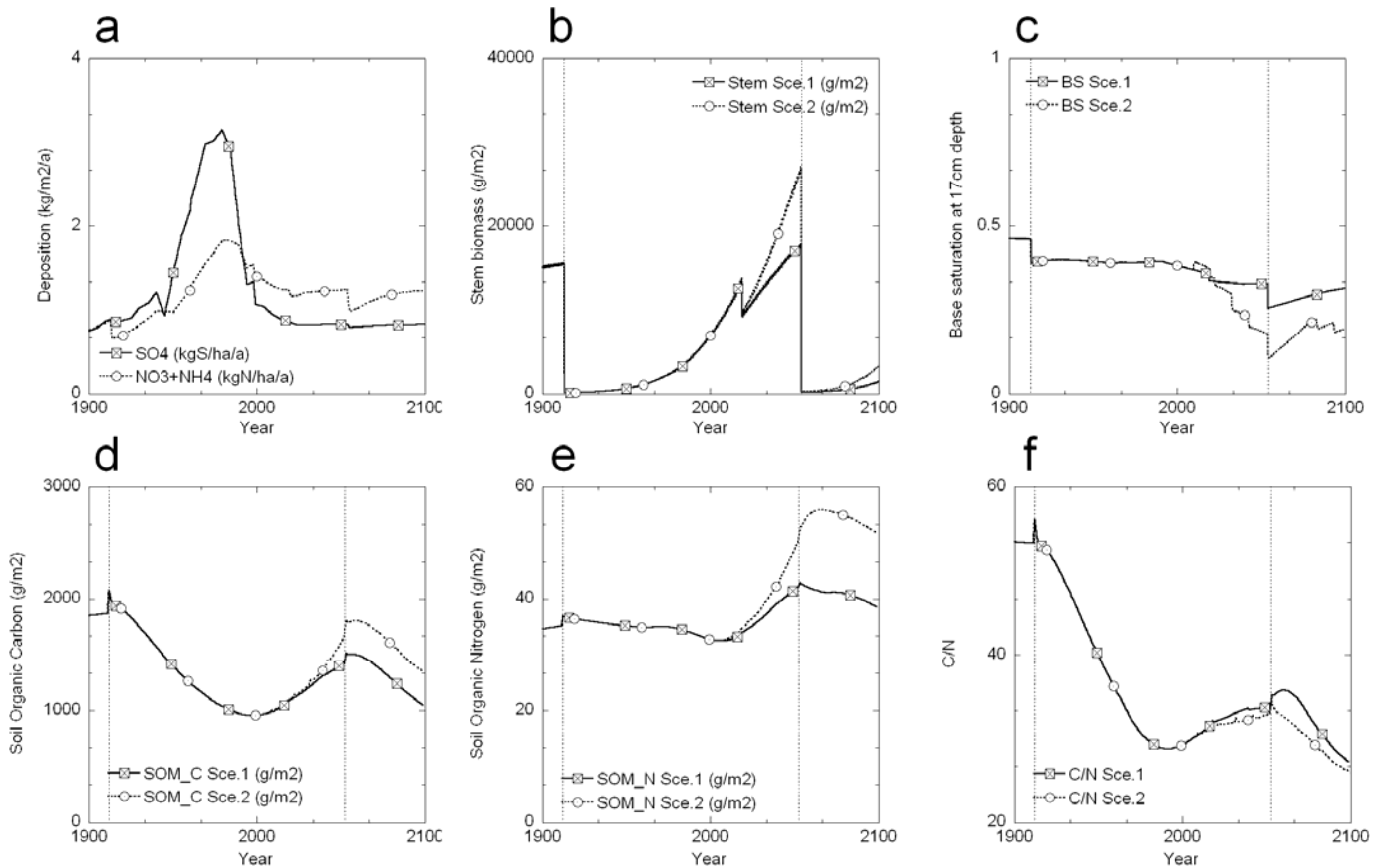
Gran ytor



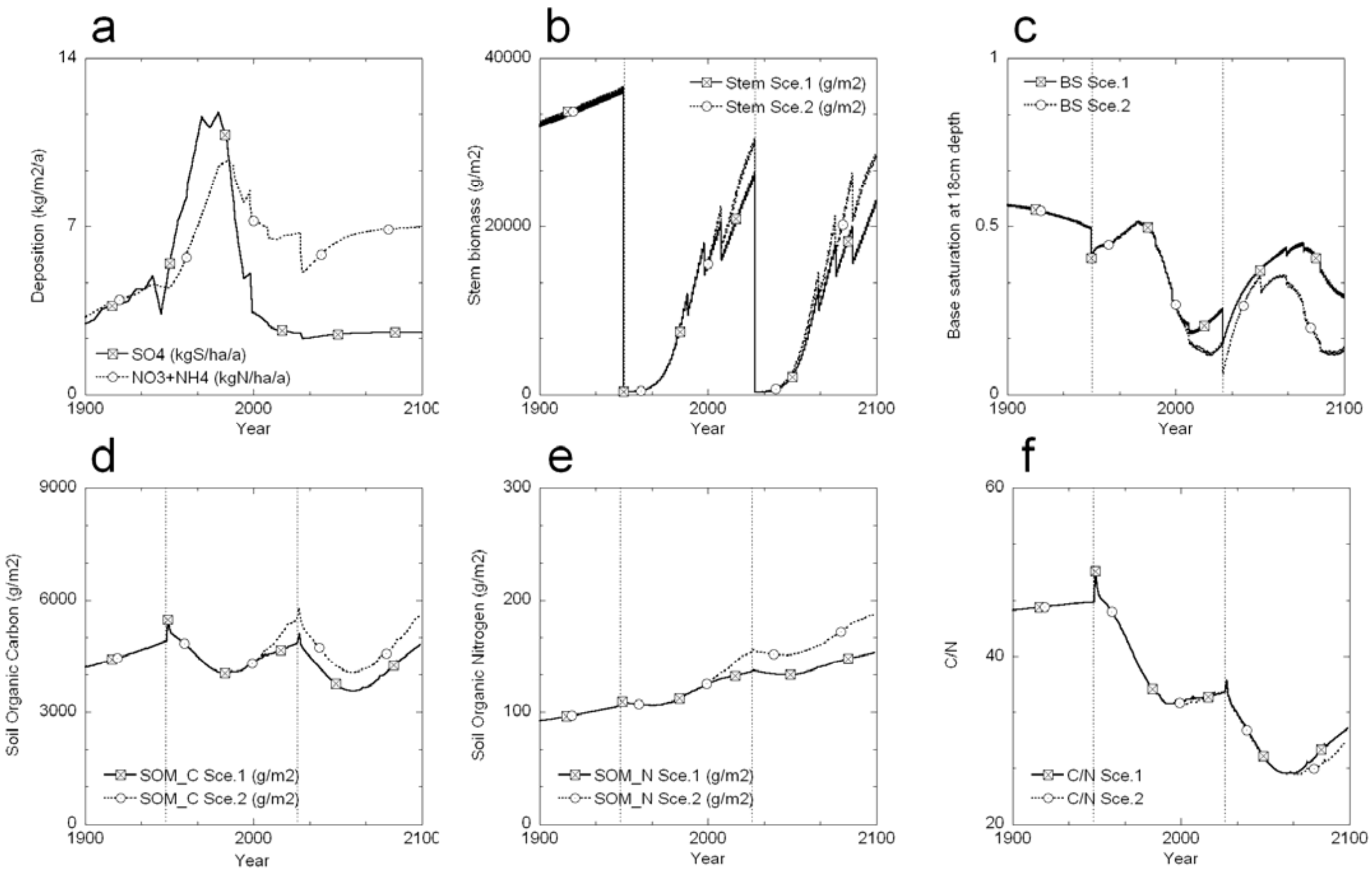
Tall ytor



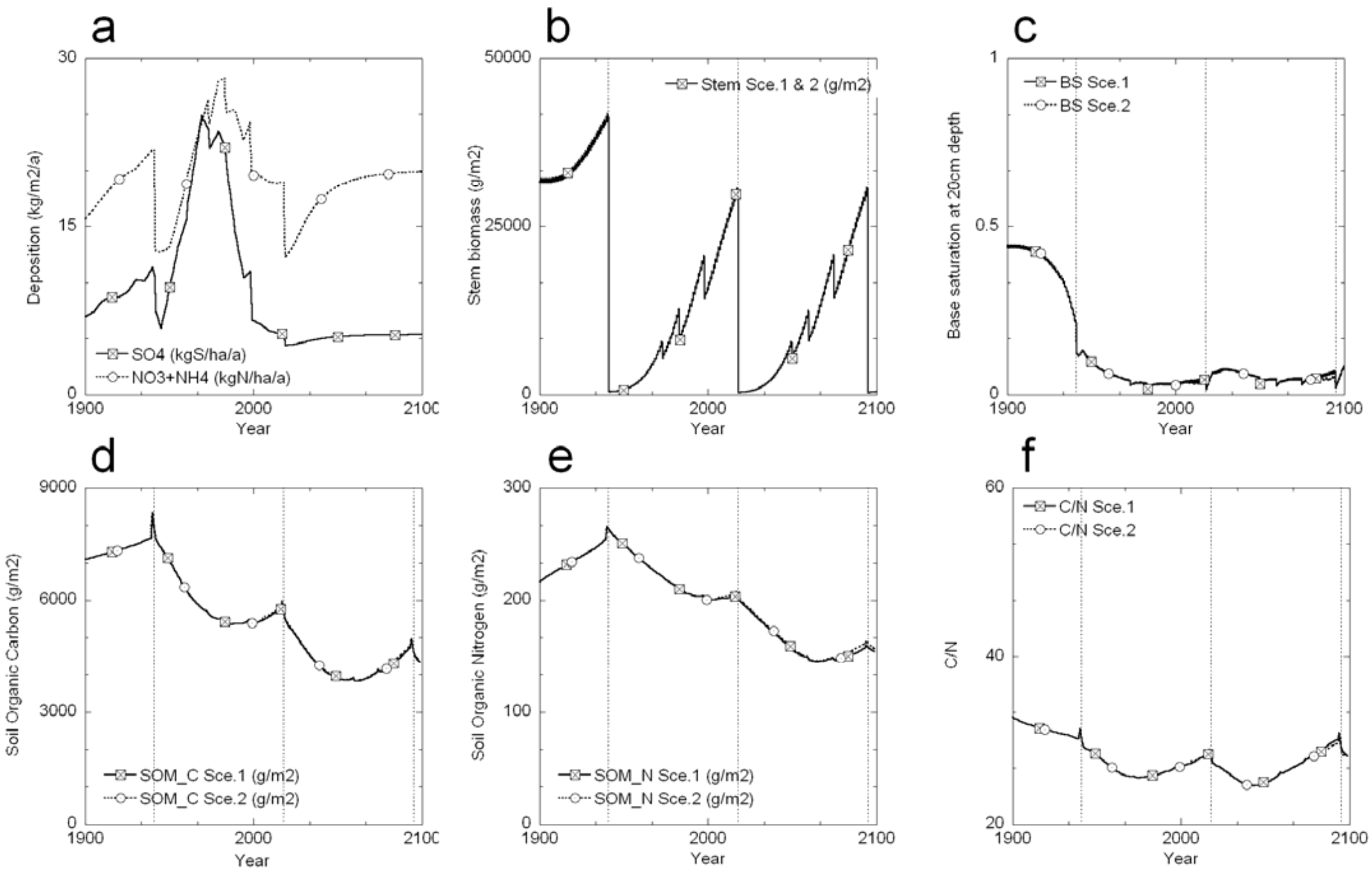
N addition effects at a northern Swedish site



N addition effects at a central Swedish site

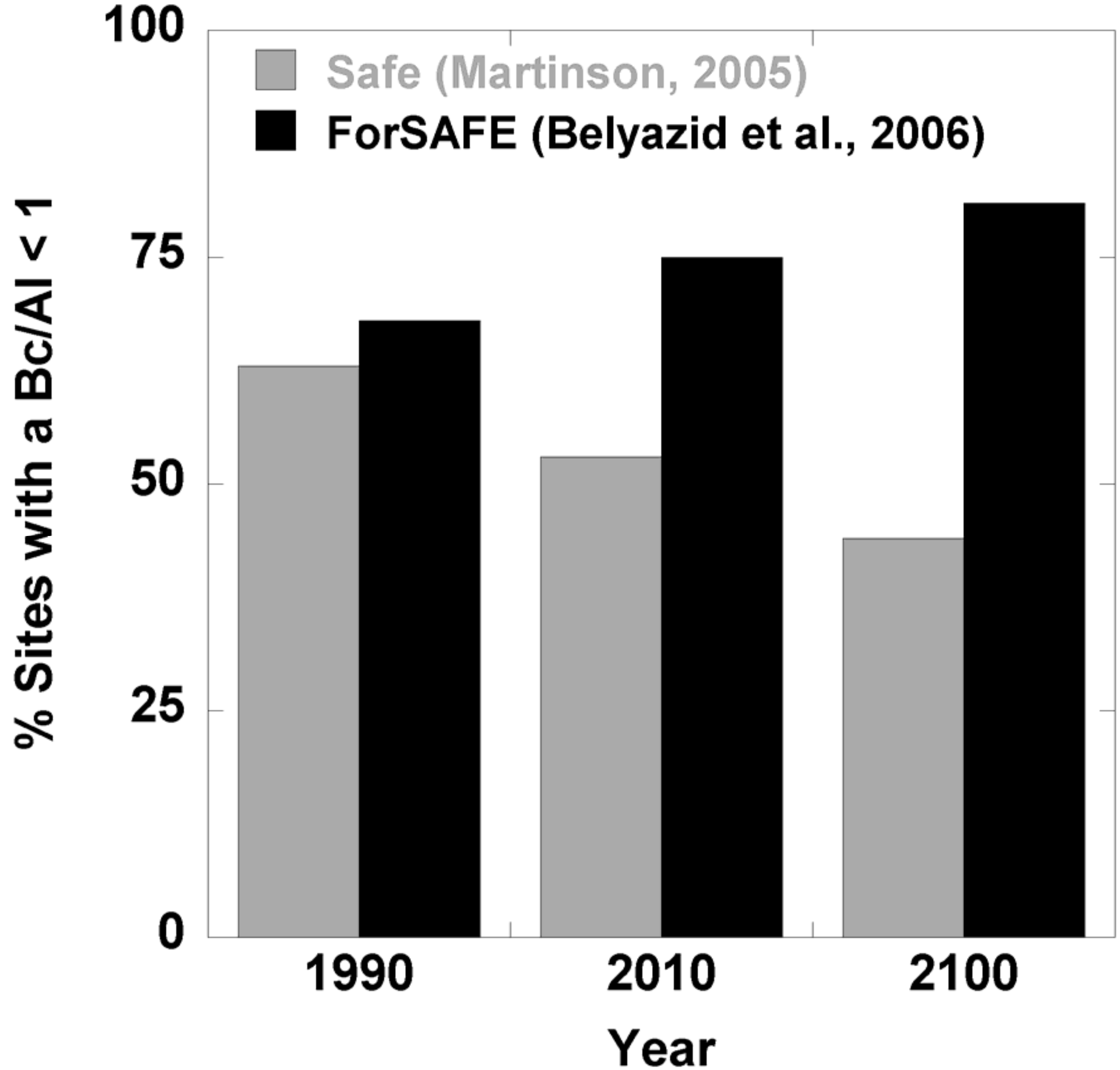


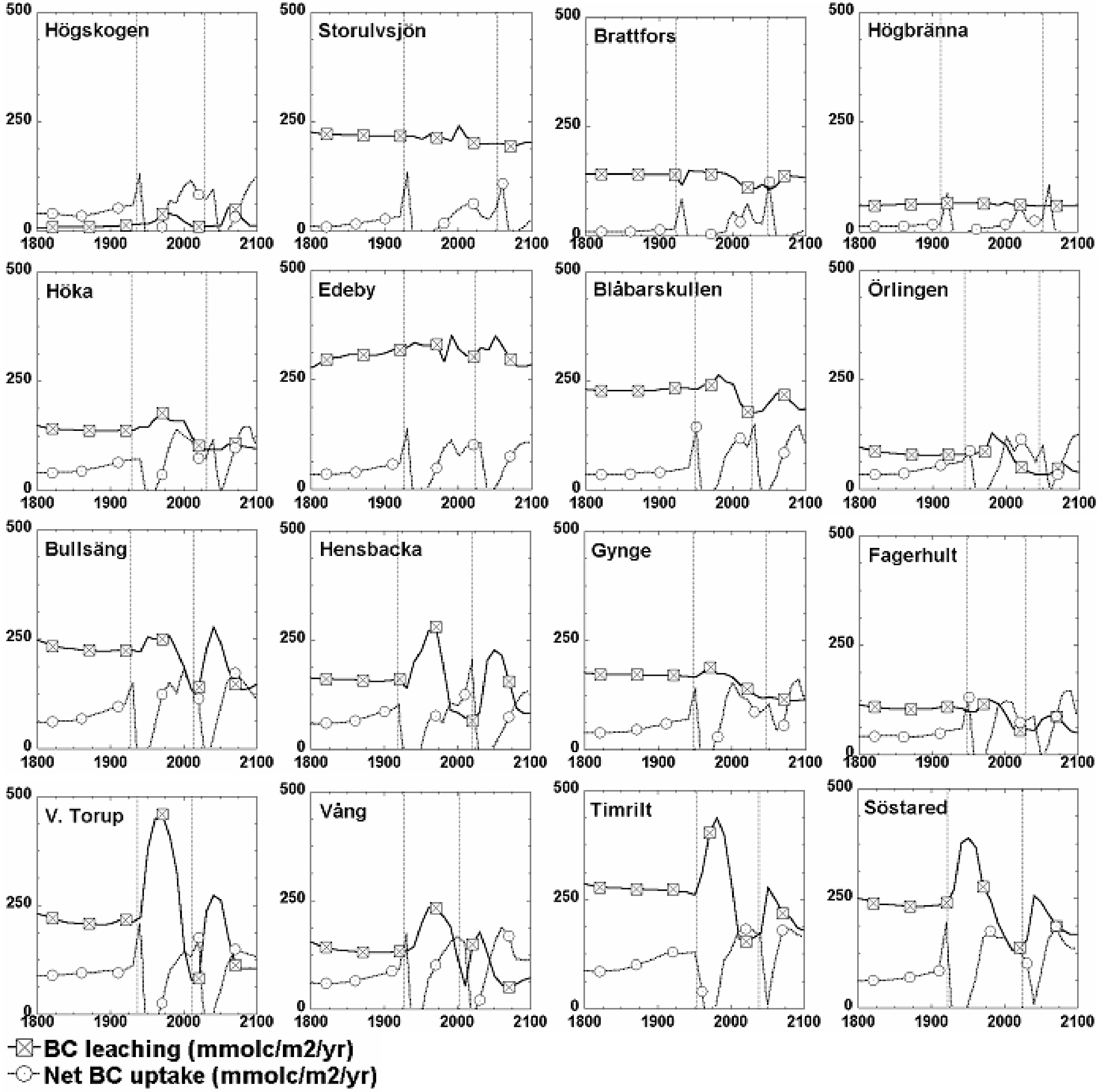
N addition effects at a southern Swedish site

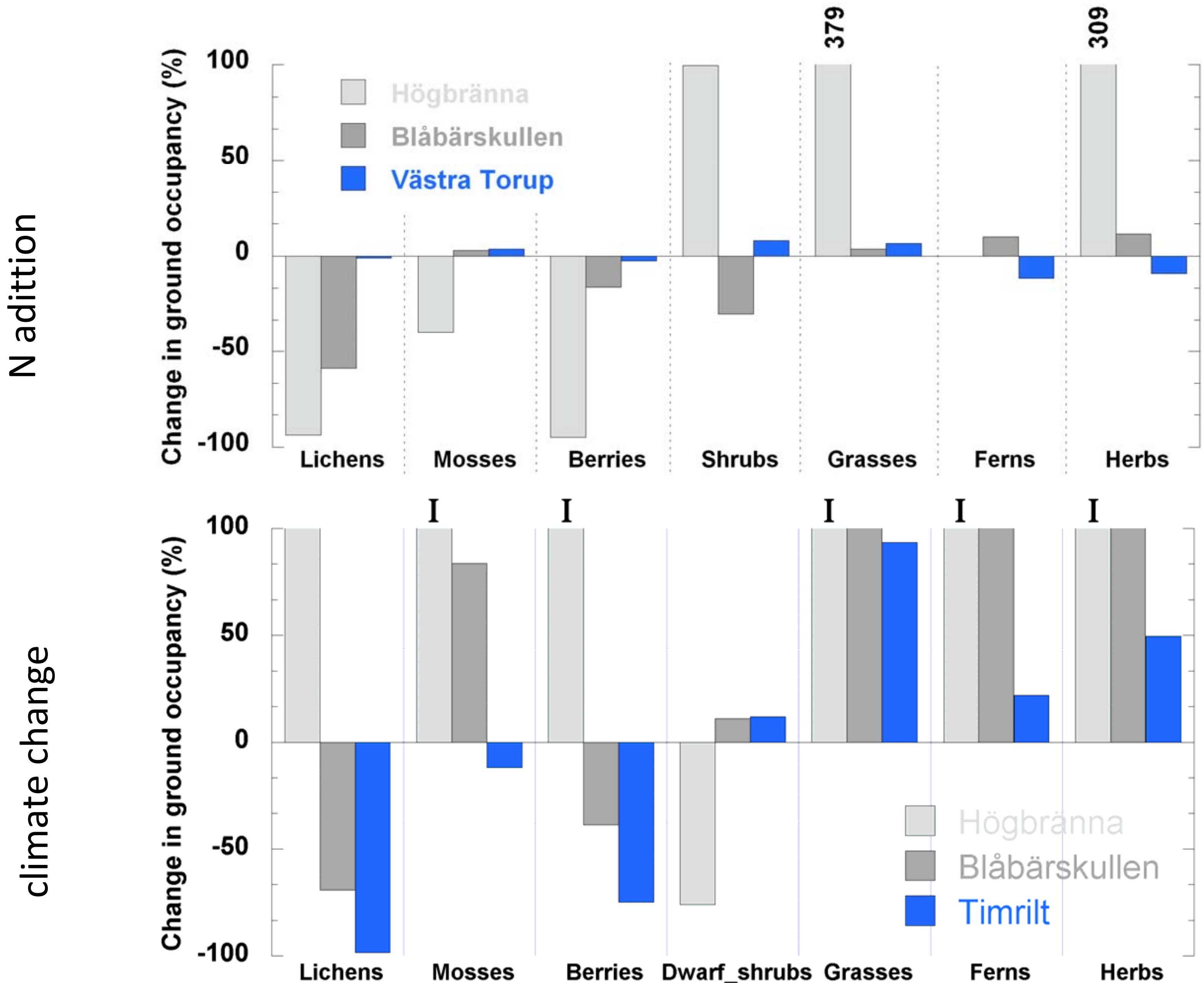


Indirect effect of N dep on soil acidification

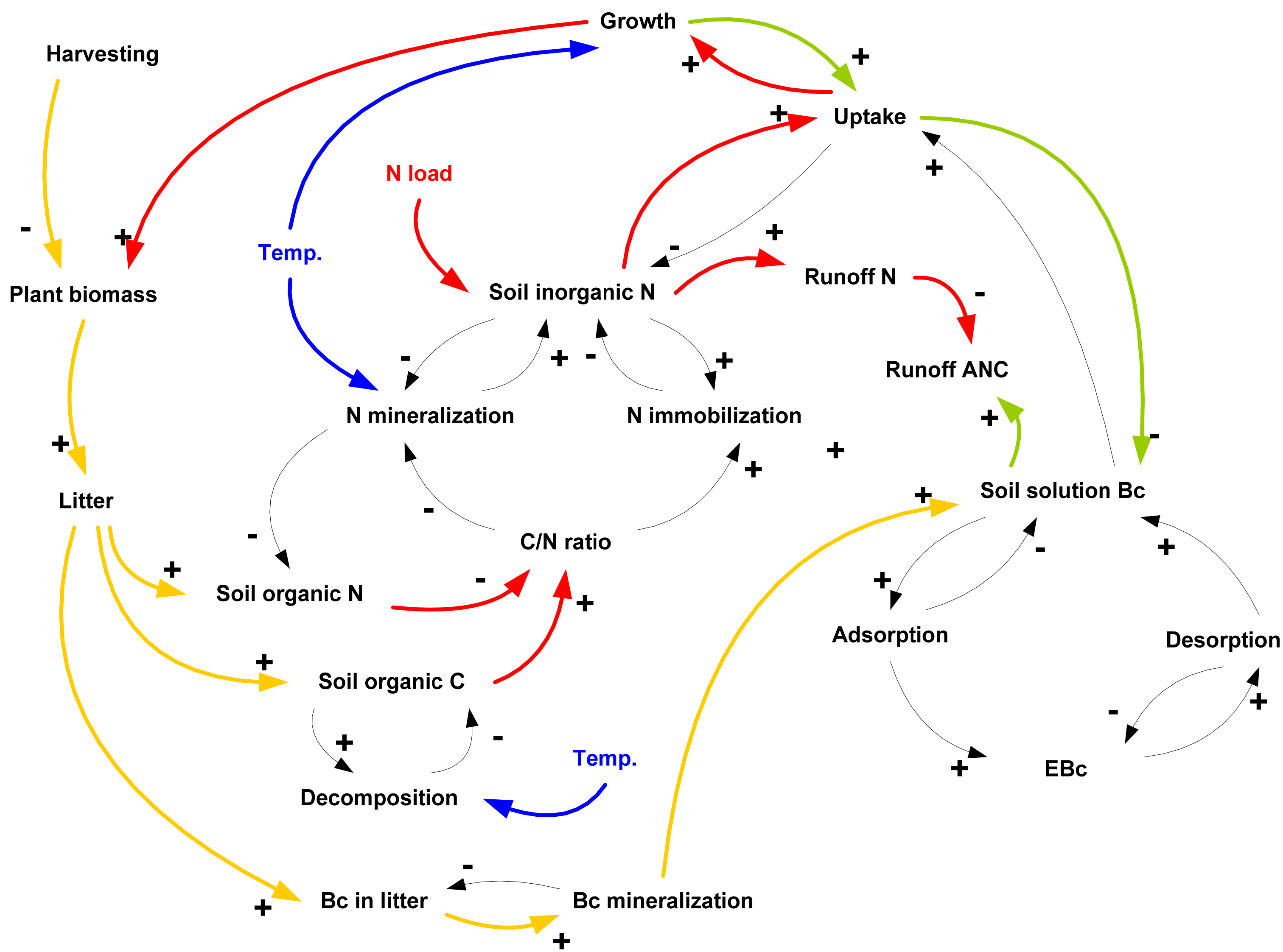
Modelling results from 16 forest sites in Sweden



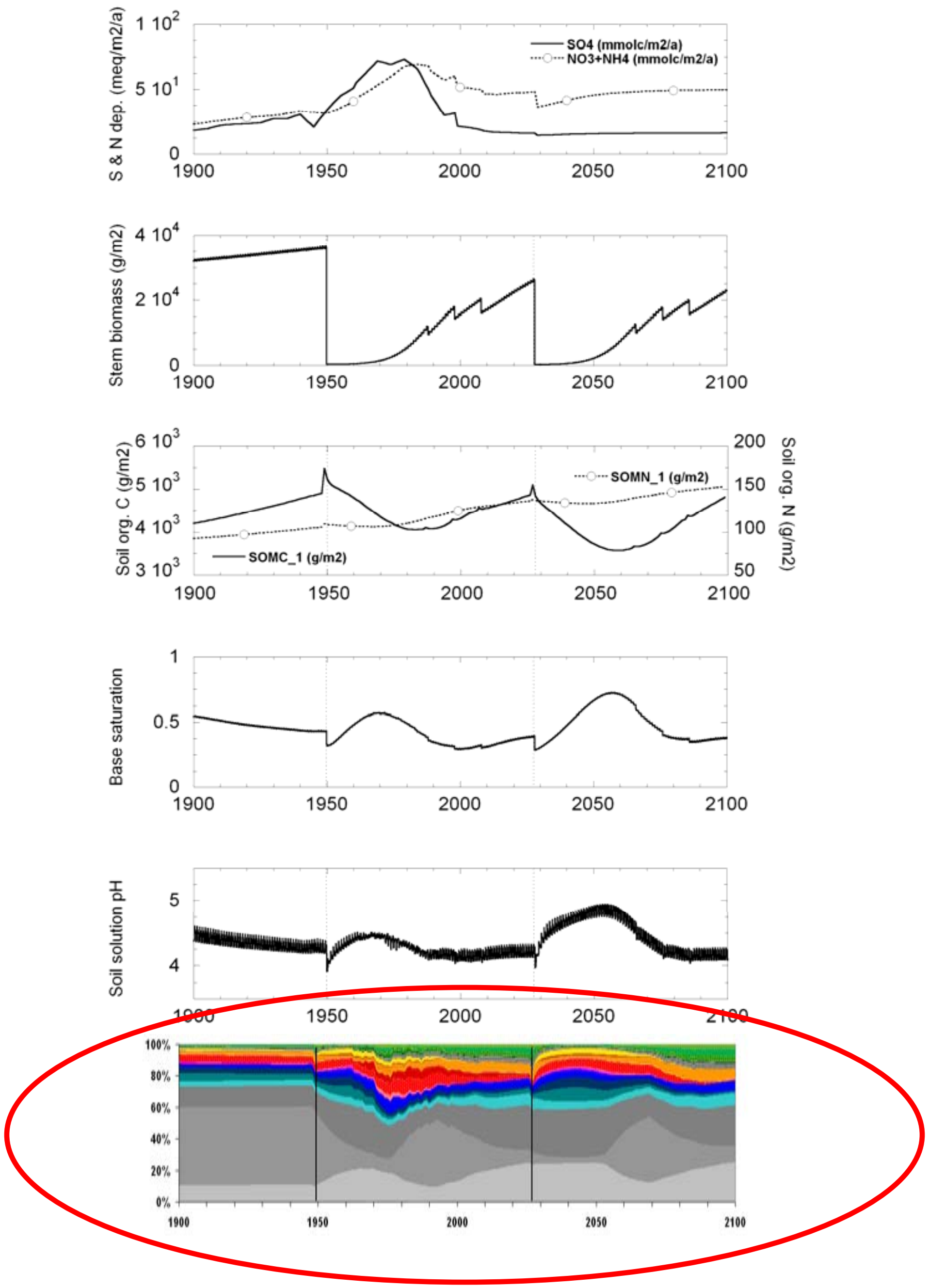

Högskogen
Storulvsjön
Brattfors
Högbränna
Höka
Edeby
Blåbarskullen
Örlingen
Bullsäng
Hensbacka
Gynge
Fagerhult
V. Torup
Vång
Timrilt
Söstared
BC leaching (mmolc/m2/yr)
Net BC uptake (mmolc/m2/yr)


N adittion
Change in ground occupancy (%)
100
50
0
-50
-100
379
309
Högbränna
Blåbärskullen
Västra Torup
Lichens
Mosses
Berries
Shrubs
Grasses
Ferns
Herbs
climate change
Change in ground occupancy (%)
100
50
0
-50
-100
Högbränna
Blåbärskullen
Timrilt
Lichens
Mosses
Berries
Dwarf_shrubs
Grasses
Ferns
Herbs

Conflicting or mutually enforcing drivers?

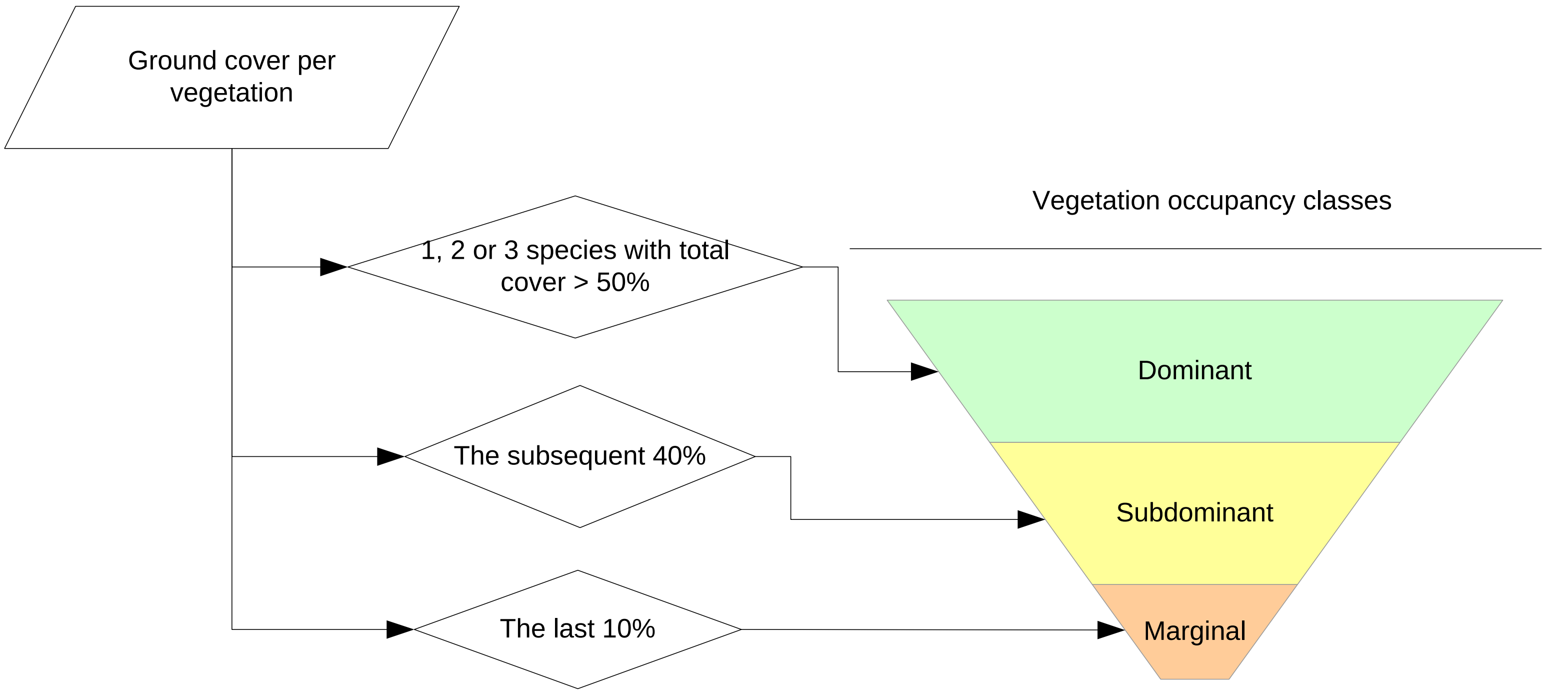


looking for a **synthesizing indicator of effects**, but still **keeping the drivers separate**



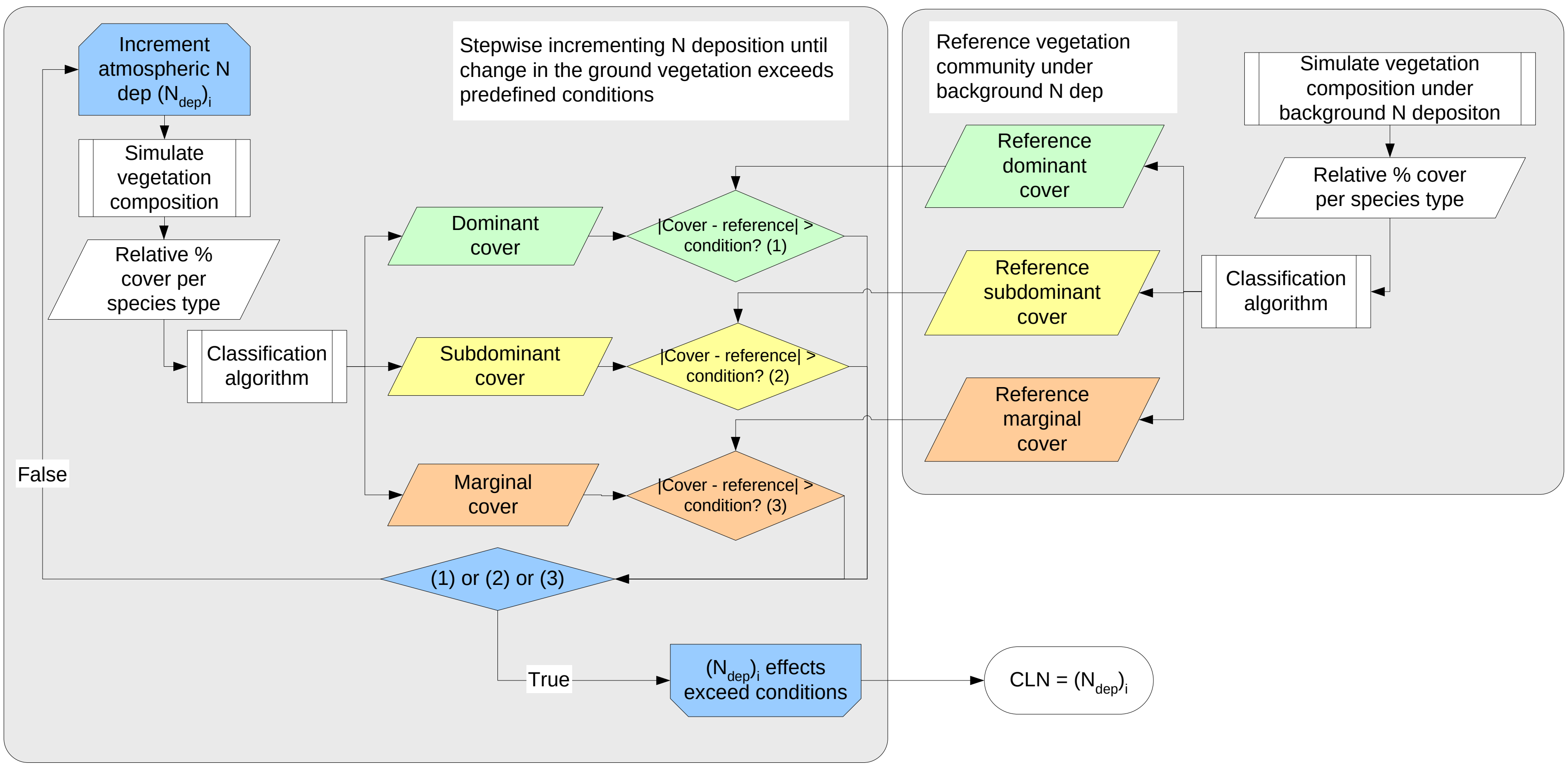
Indicator:

relative ground cover per species or plant type sorted into three groups



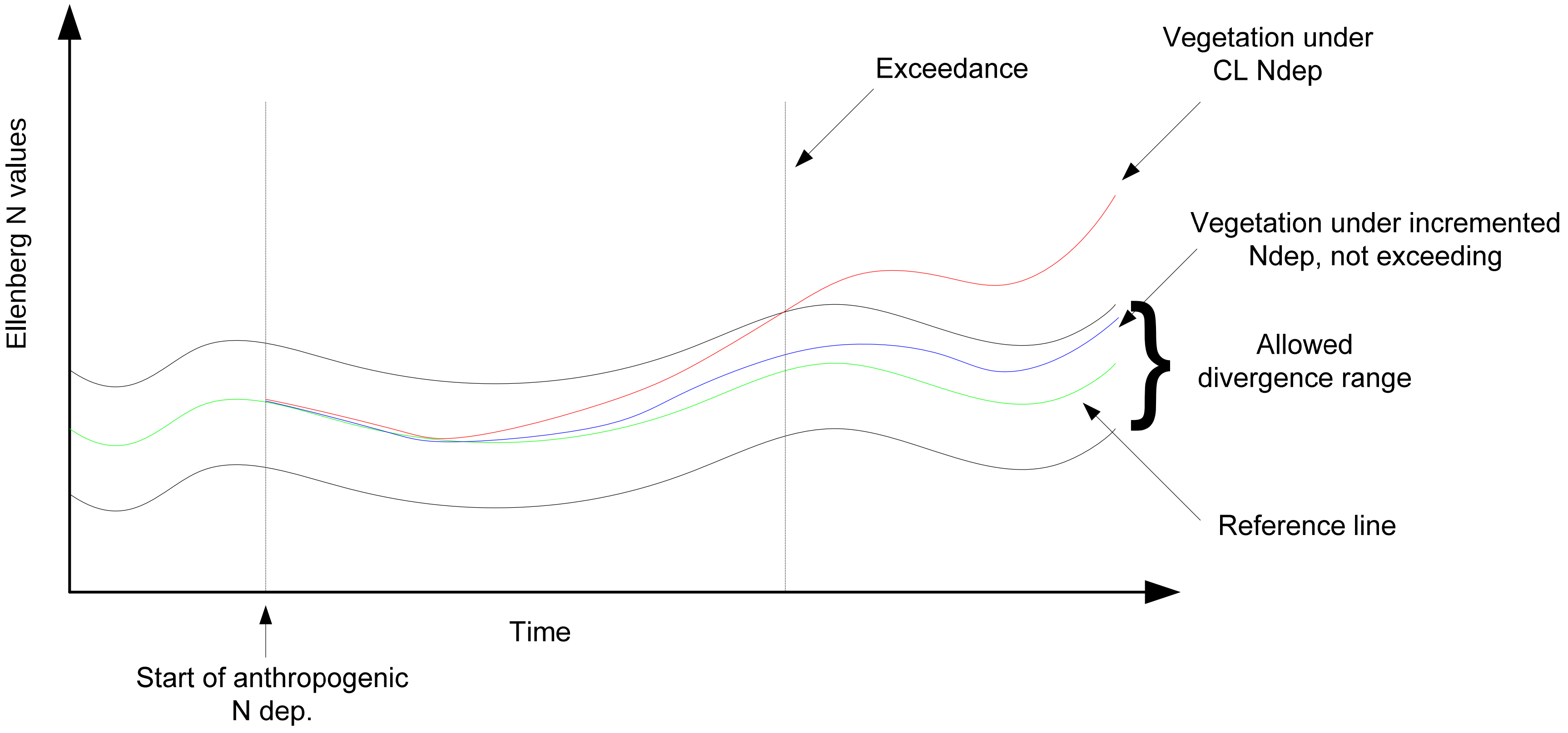
Criteria:
group specific

Vegetation occupancy classes	CL exceedence conditions
Dominant	1- Reduction in cover relative to to other species by: 30% or 50%. Or 2- Shift in dominant species.
Subdominant	1- Increase in cover >= 100% (doubling or more) Or 2- Reduction in cover >= 50% (halving or less)
Marginal	1- Loss of one or more species Or 2- Incursion of one or more species



Stepwise incrementing N deposition until change in the ground vegetation exceeds predefined conditions
Increment atmospheric N dep (N_dep)_i
Simulate vegetation composition
Relative % cover per species type
Classification algorithm
Dominant cover
Subdominant cover
Marginal cover
|Cover - reference| > condition? (1)
|Cover - reference| > condition? (2)
|Cover - reference| > condition? (3)
(1) or (2) or (3)
False
True
(N_dep)_i effects exceed conditions
CLN = (N_dep)_i
Reference vegetation community under background N dep
Simulate vegetation composition under background N depositon
Relative % cover per species type
Classification algorithm
Reference dominant cover
Reference subdominant cover
Reference marginal cover

Dynamic reference level and the steady state concept:



Normalization and comparison