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Vegetation response to critical limits exceedances

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a Life+ co-financed project for the "Further Development and Implementation of an EU-level Forest Monitoring System".

The project coordination centre is situated at the Institute for World Forestry, Hamburg, Germany.

Hypothesis

Human made emissions → SO_x, NO_x, NH_3, ...

Eutrophication

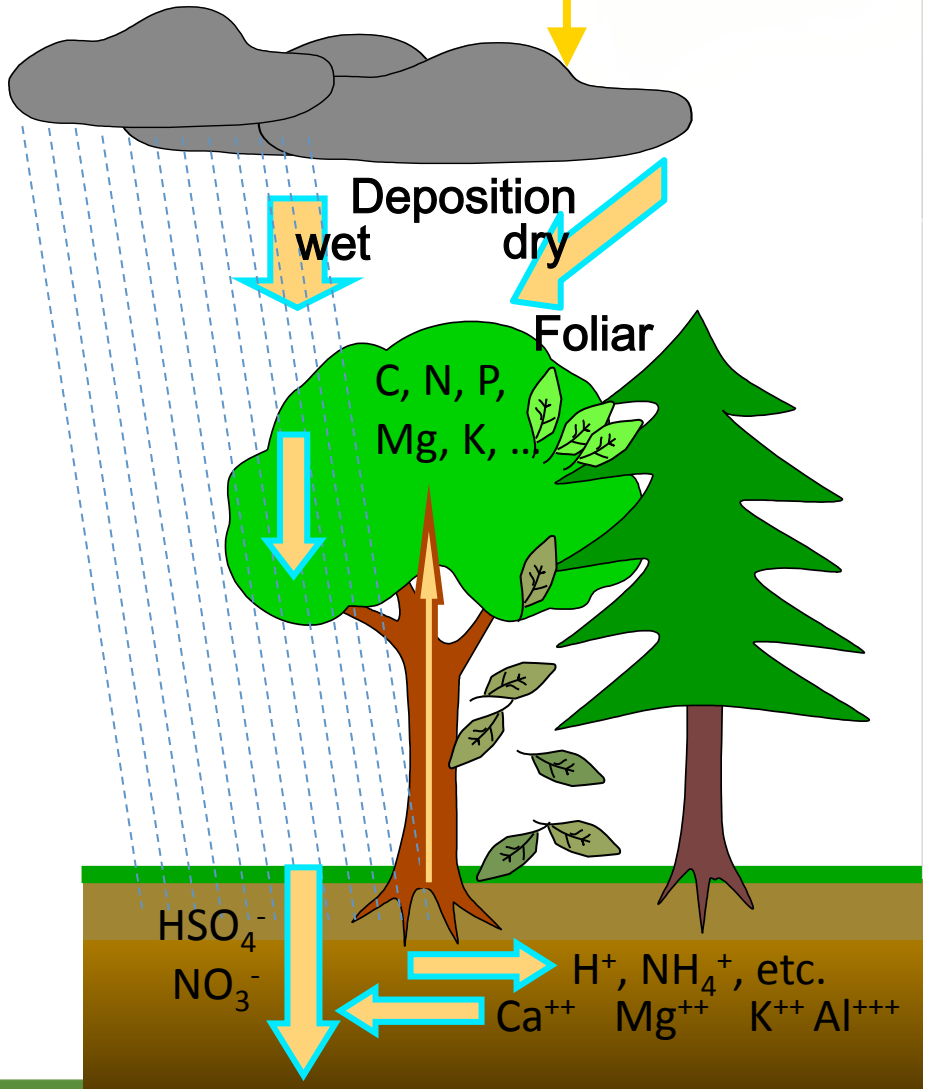
(Aber et al. 1989 and others)

(+) Growth increase in N limited forests

(-) Imbalanced foliar nutrition

(-) Nitrate Leaching (Le) into ground water

(-) Vulnerability against frost, defoliators and disease may increase



Human made emissions → SO_x, NO_x, NH_3, ...

Eutrophication

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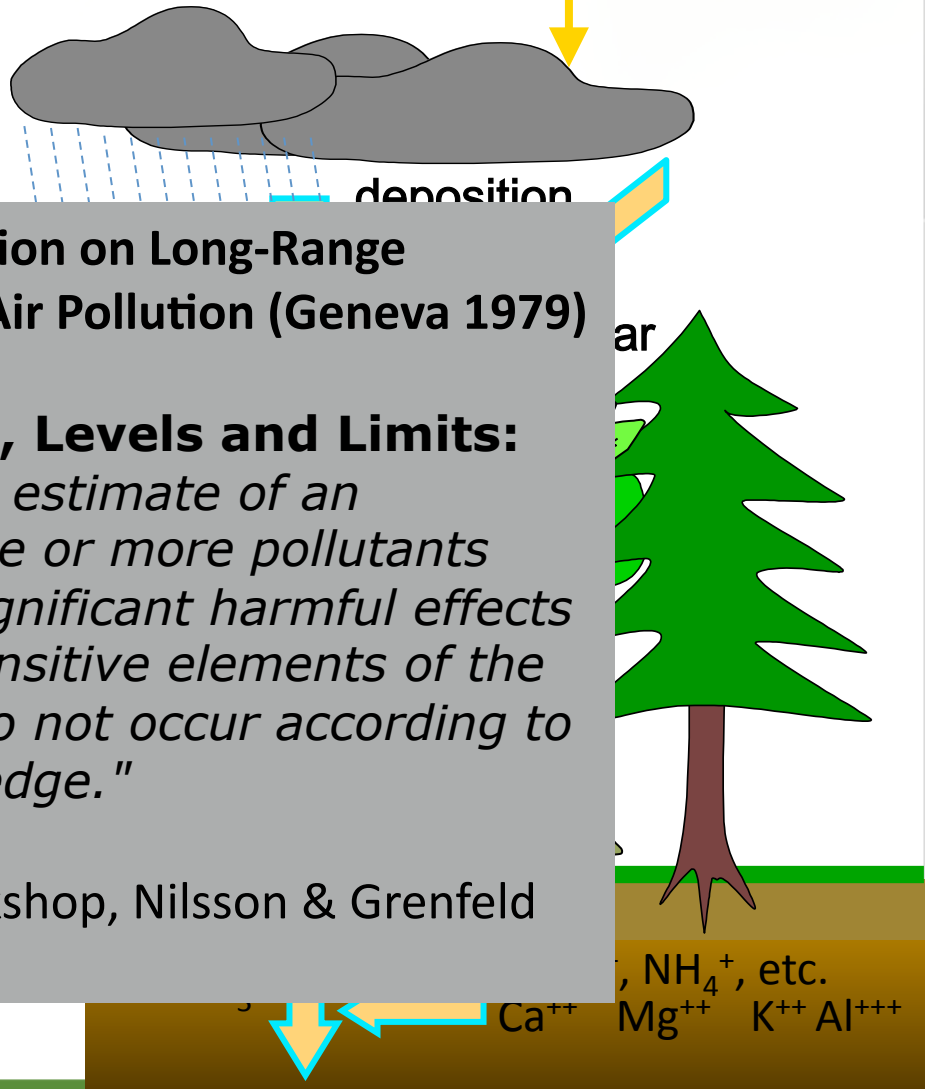
and disease may increa

UN-ECE Convention on Long-Range Transboundary Air Pollution (Geneva 1979)

Critical Loads, Levels and Limits:
"A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge."

(Skokloster Workshop, Nilsson & Grenfeld 1988)



Human made emissions → SO_x, NO_x, NH_3, ...

Eutrophication

(Aber et al. 1989 and others)

(+) Growth increase in N limited forests

(cf. presentation M. Dobbertin)

(-) Imbalanced foliar nutrition

CL N Deposition: 10-20 kg N $ha^{-1}a^{-1}$ (Empiric)

(e.g. Achermann 2003)

Nitrate in soil solution $NO_3^- < c_{crit}$ (limits)

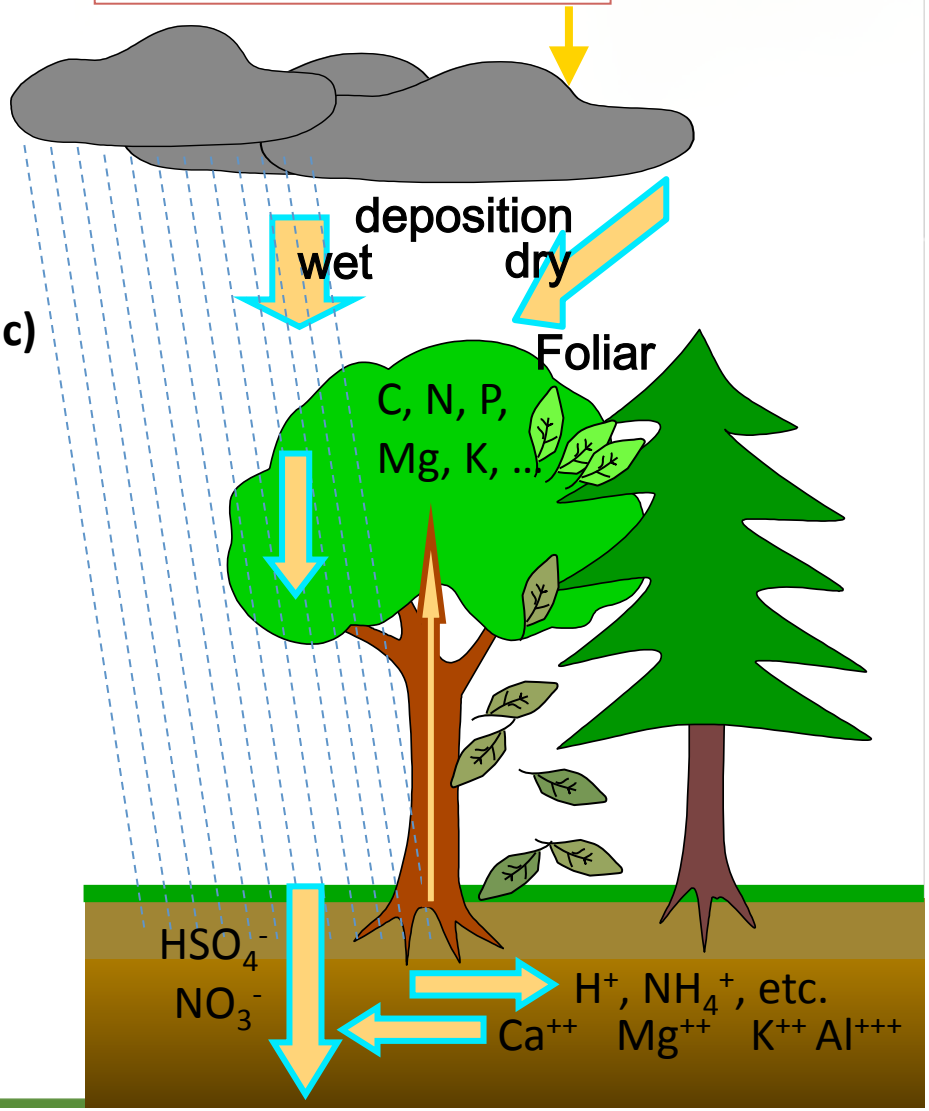
(cf. presentation P. Rautio)

(-) Nitrate Leaching (Le) into ground water

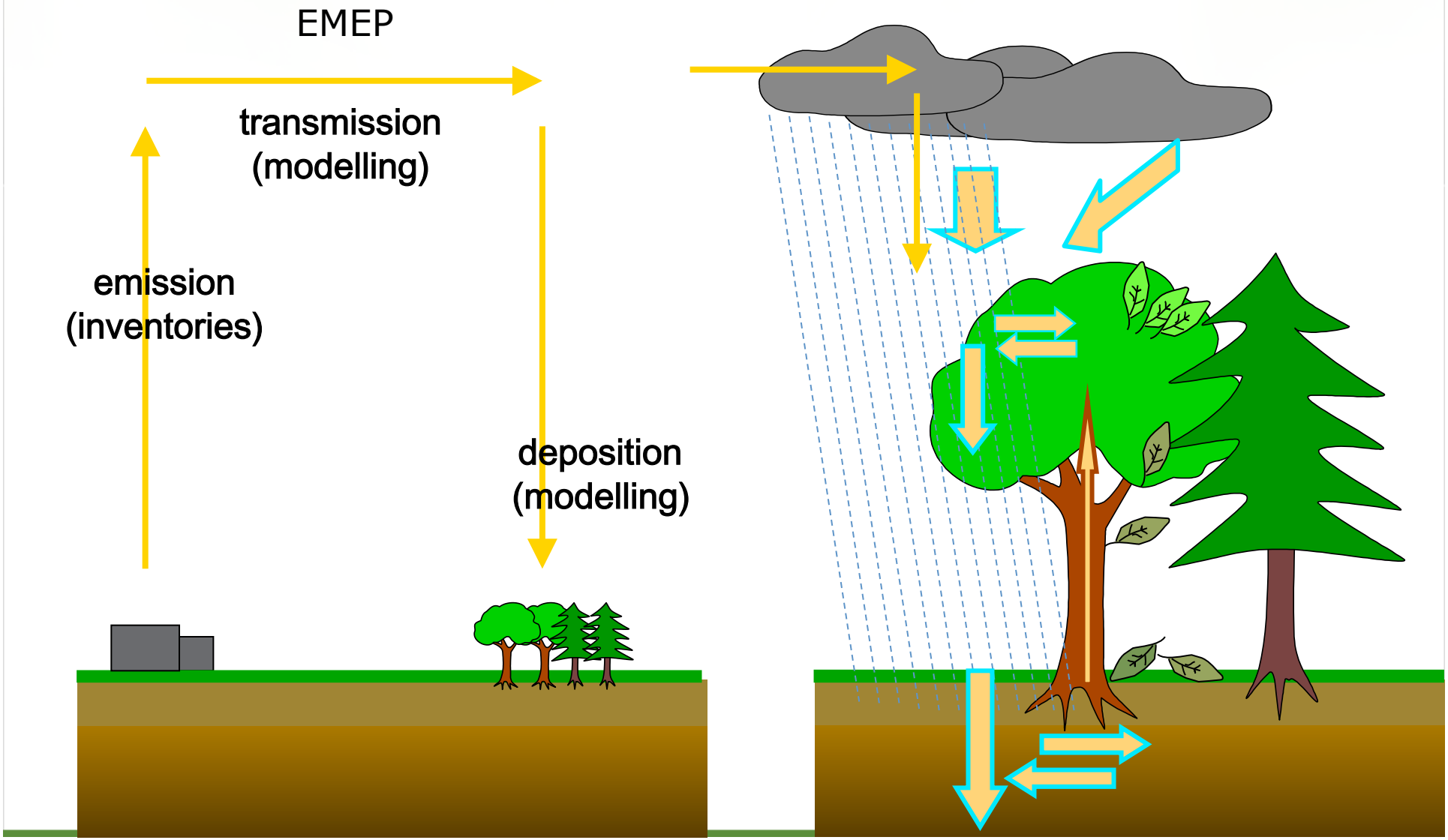
Leaching < $Le_{acceptable}$ (SMB)

(cf. presentation H.-D. Nagel)

(-) Vulnerability against frost, defoliators and disease may increase



Critical Loads and exceedances



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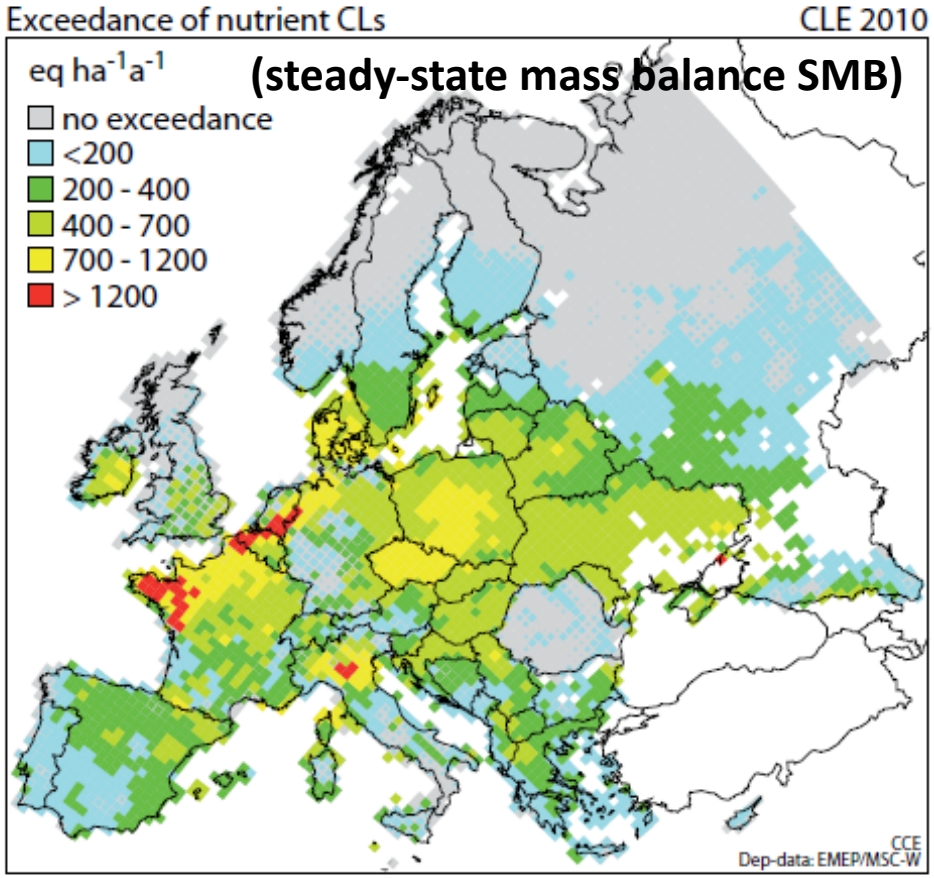
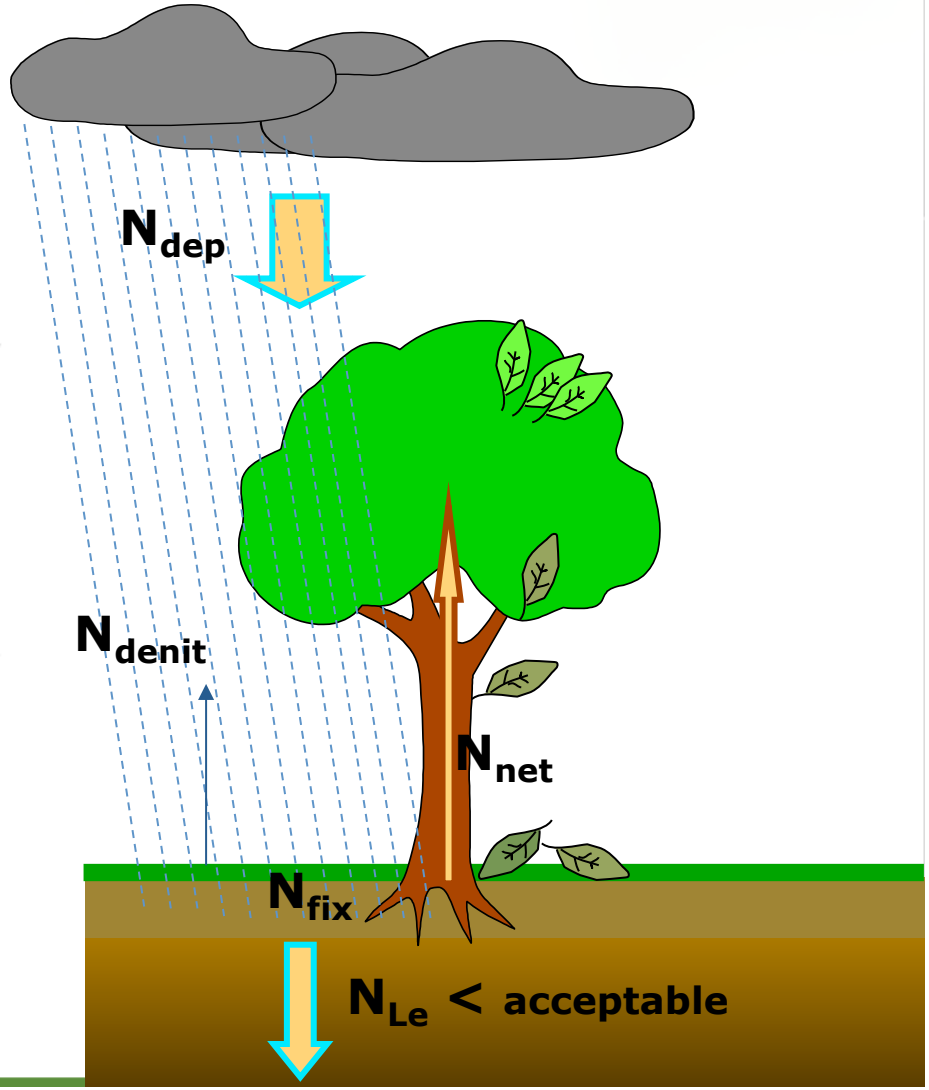
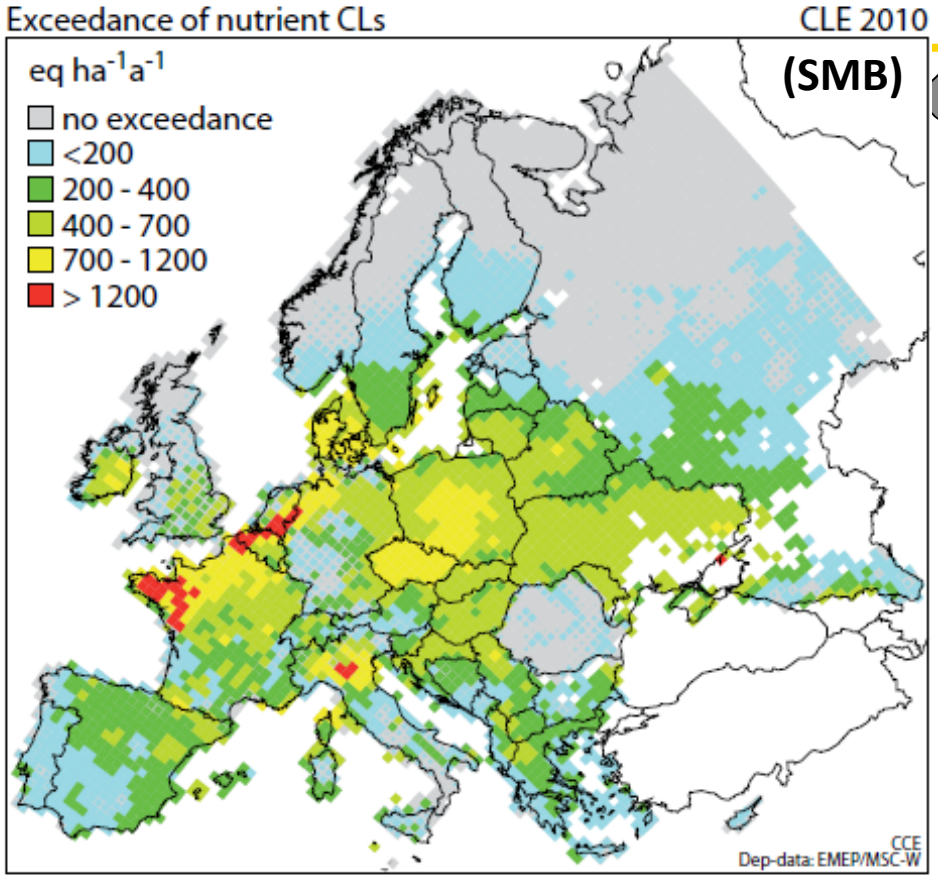
Critical loads and exceedances

ICP Modelling & Mapping

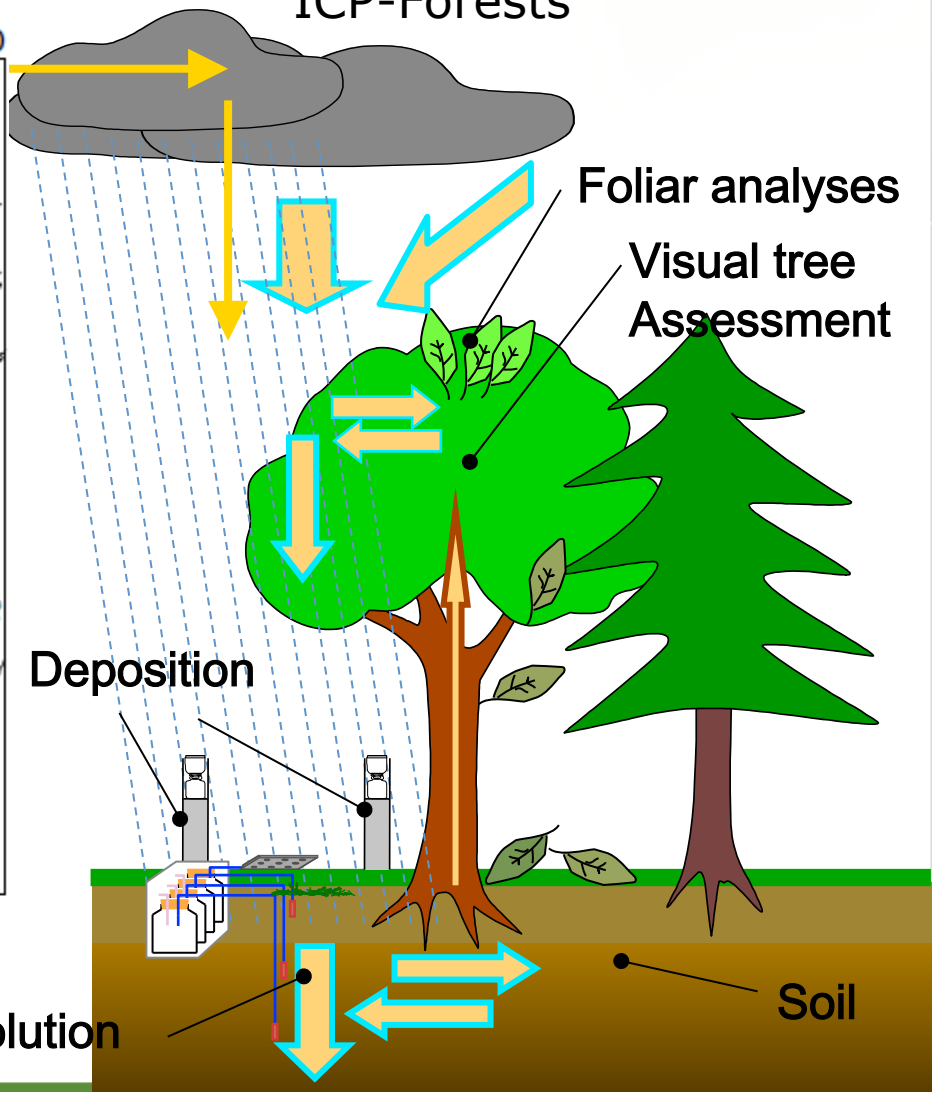




ICP Modelling & Mapping



ICP-Forests



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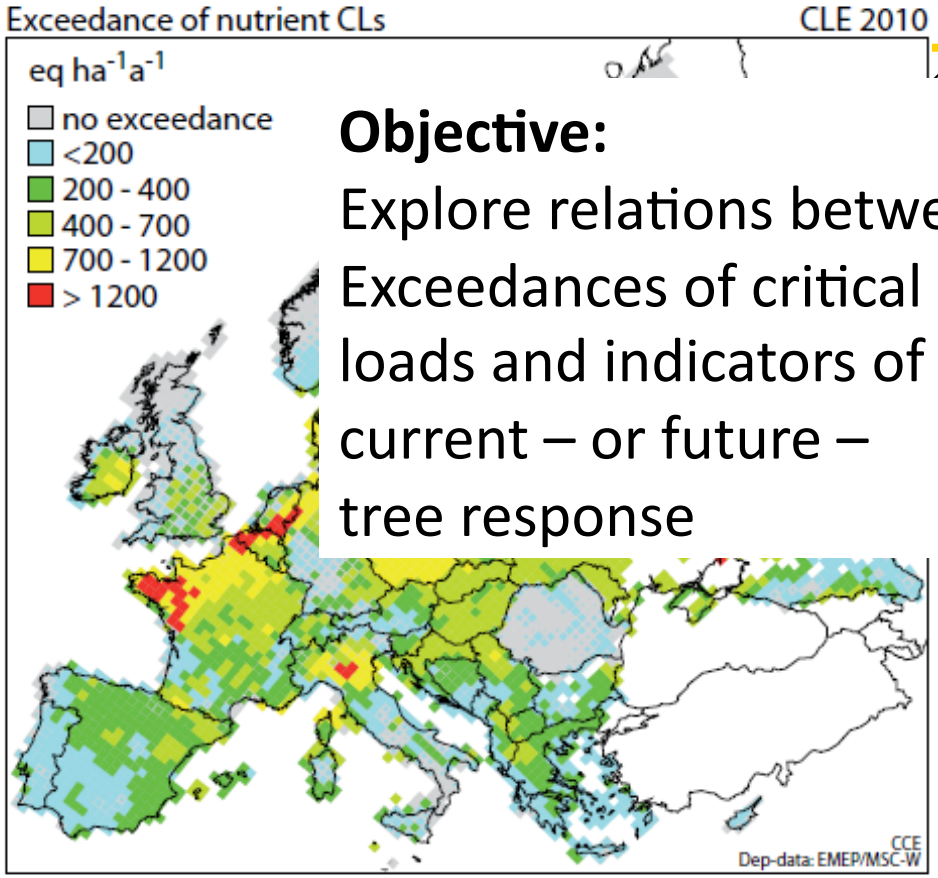
Objectives and methods

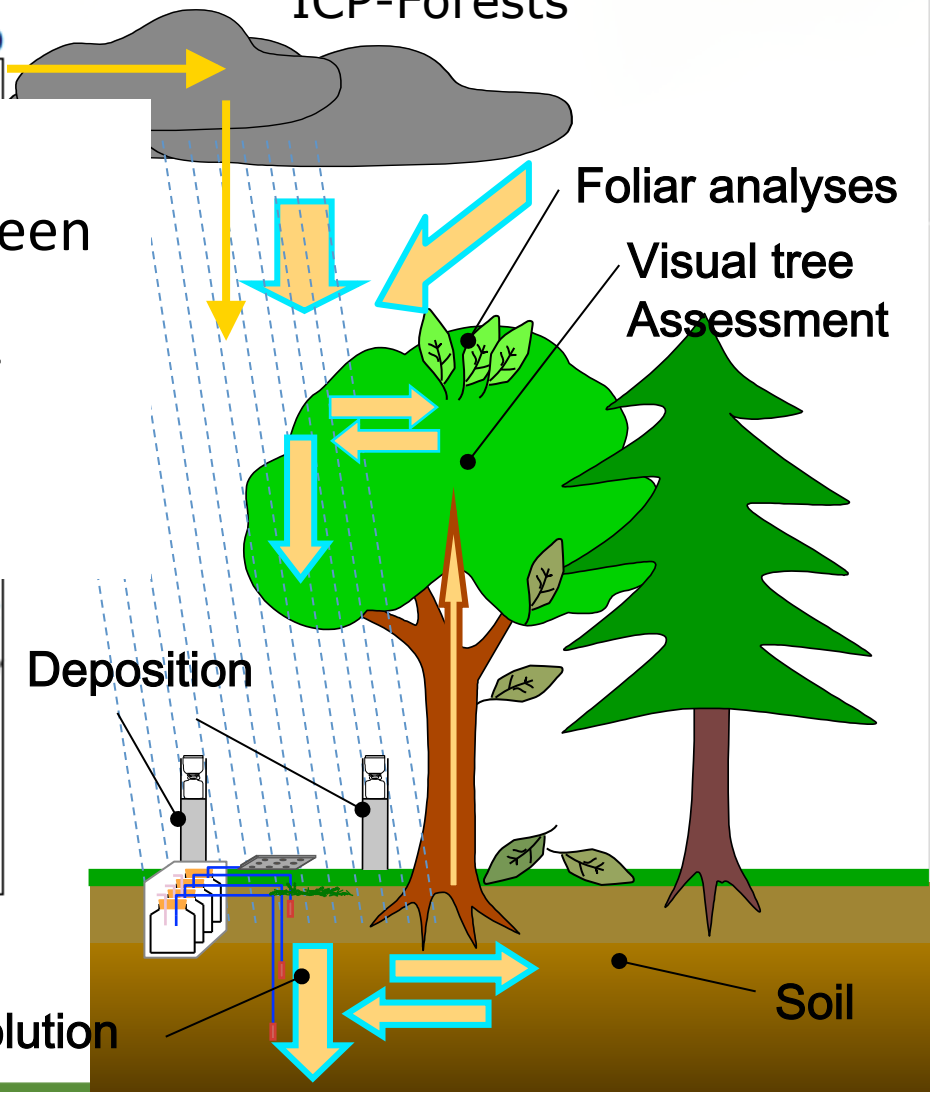
ICP Modelling & Mapping



Objective:

Explore relations between Exceedances of critical loads and indicators of current – or future – tree response

ICP-Forests



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Objectives and methods

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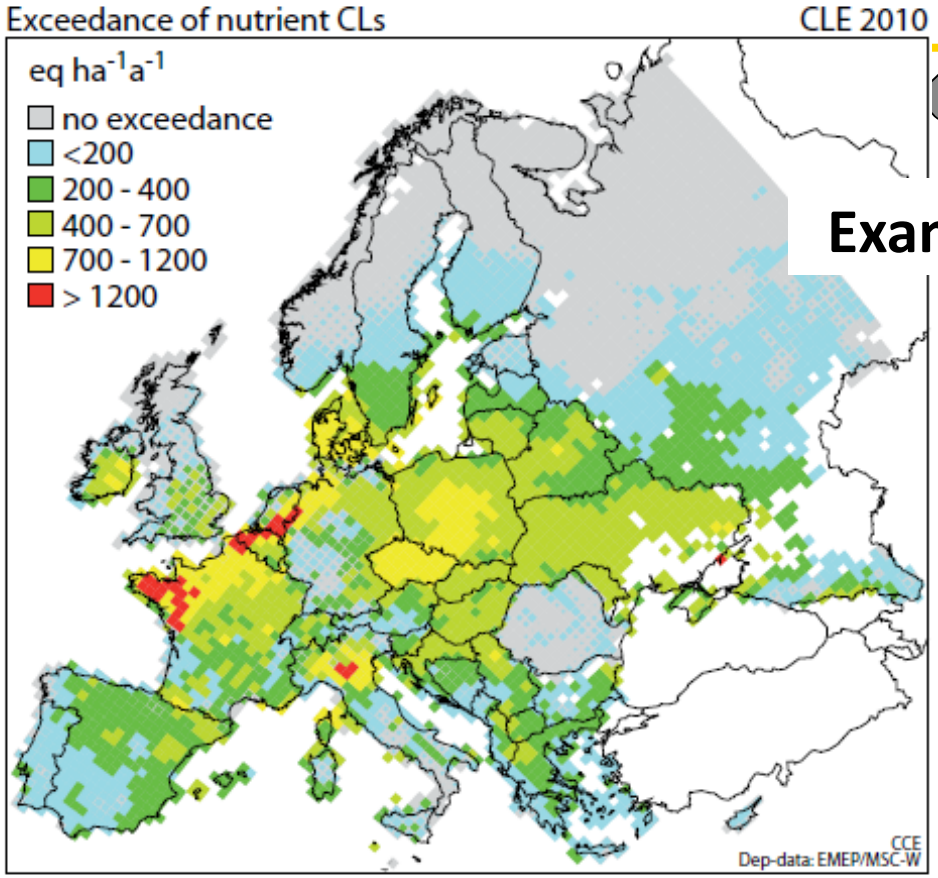
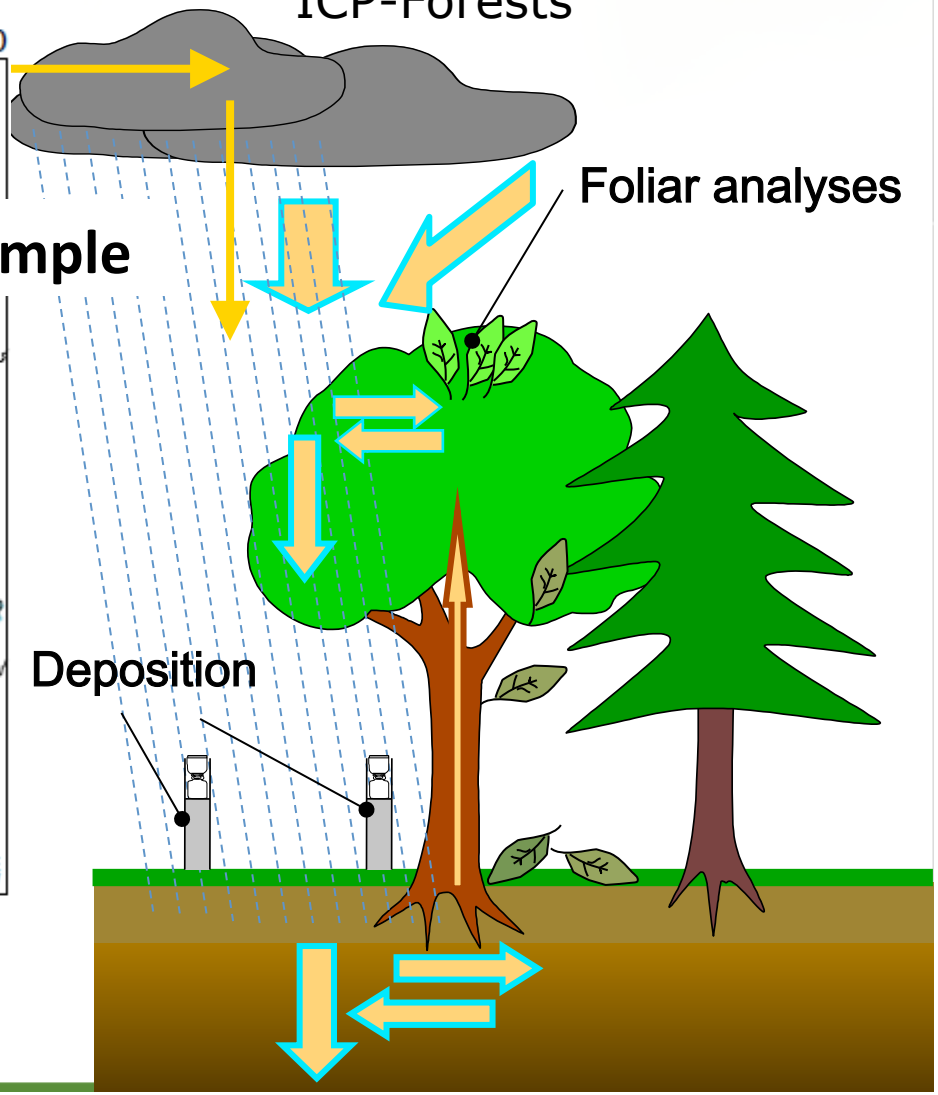


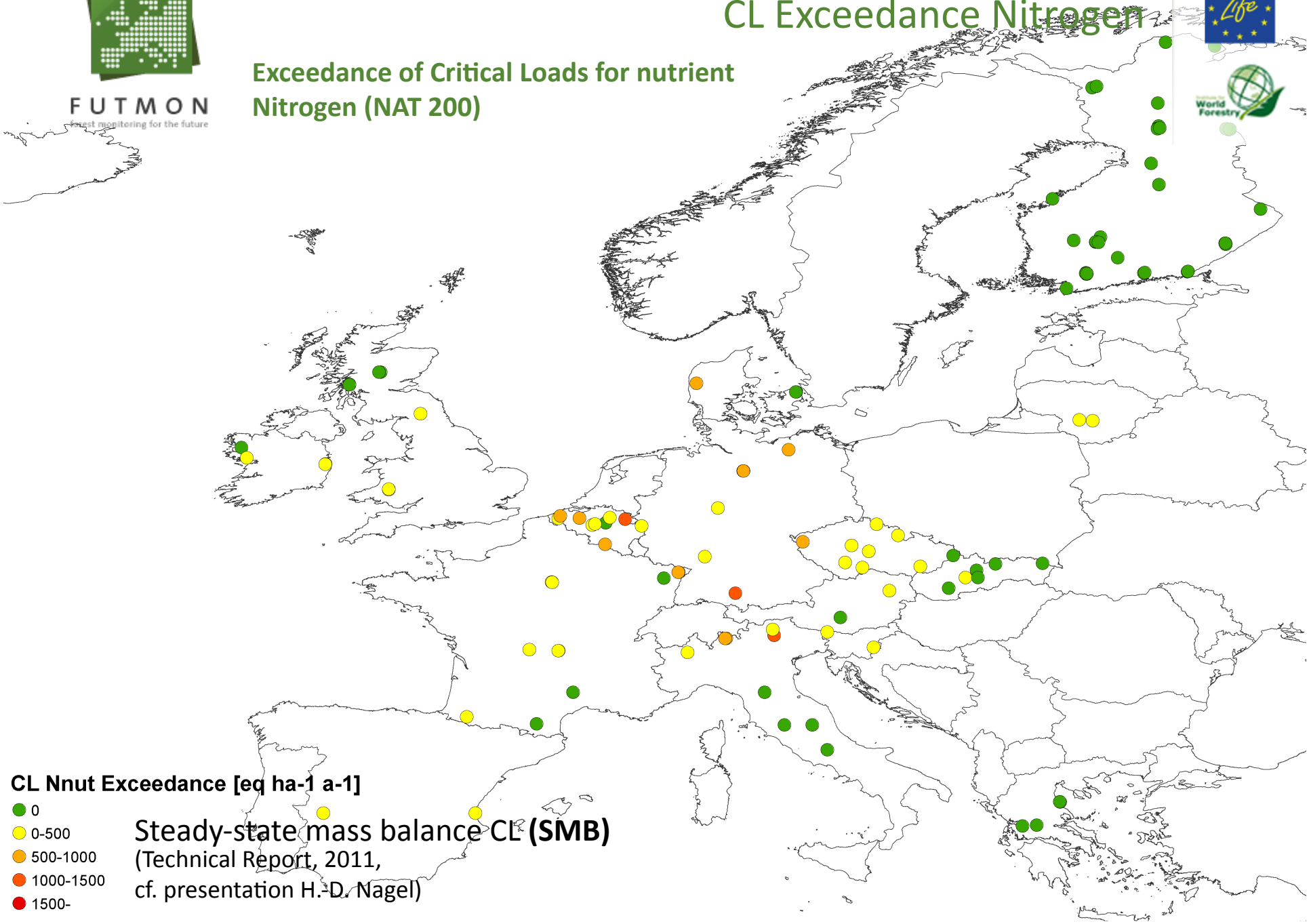
ICP-Forests

Example



CL Exceedance Nitrogen

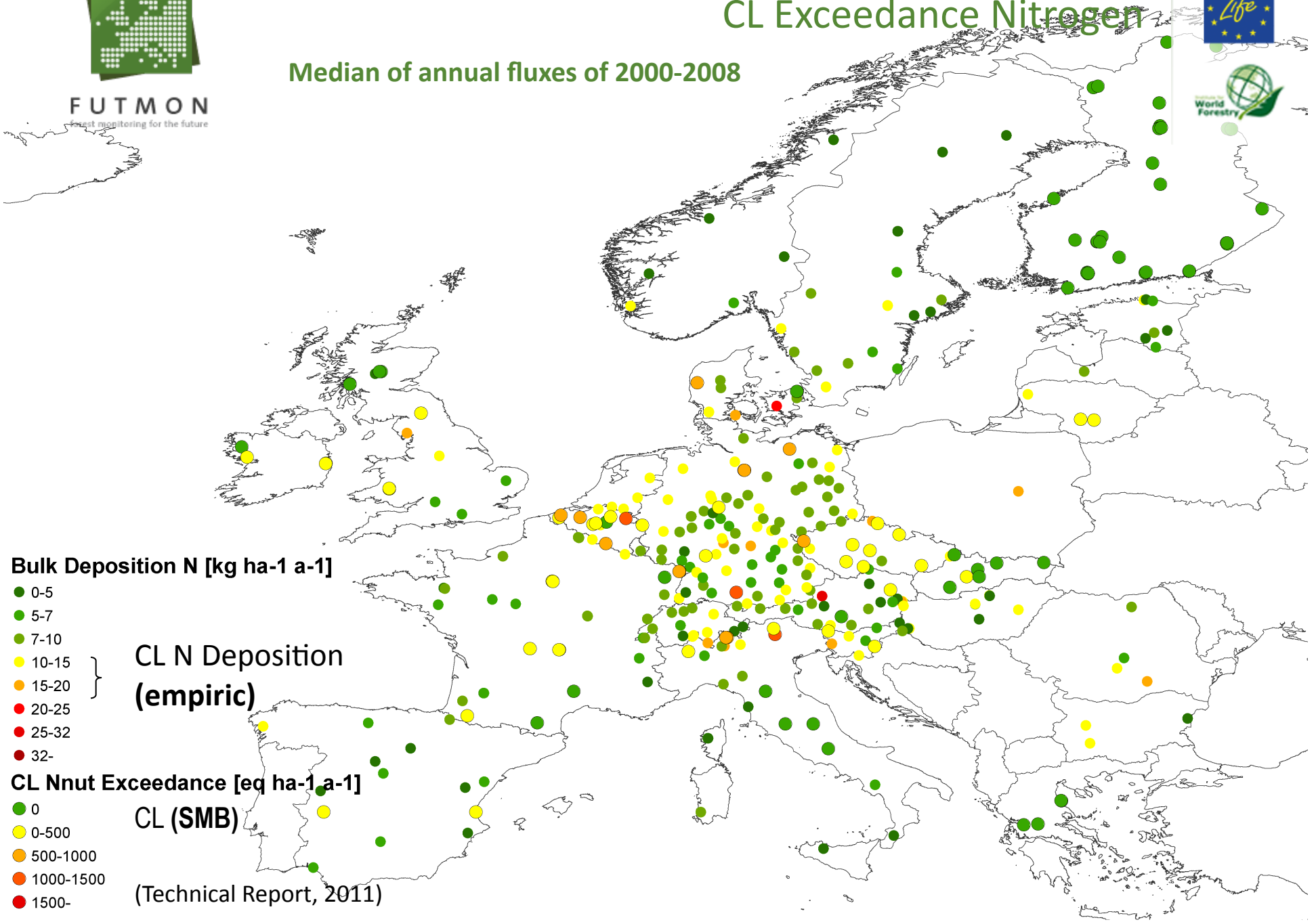
Exceedance of Critical Loads for nutrient Nitrogen (NAT 200)



Steady-state mass balance CL **(SMB)**
(Technical Report, 2011,
cf. presentation H.-D. Nagel)

CL Exceedance Nitrogen

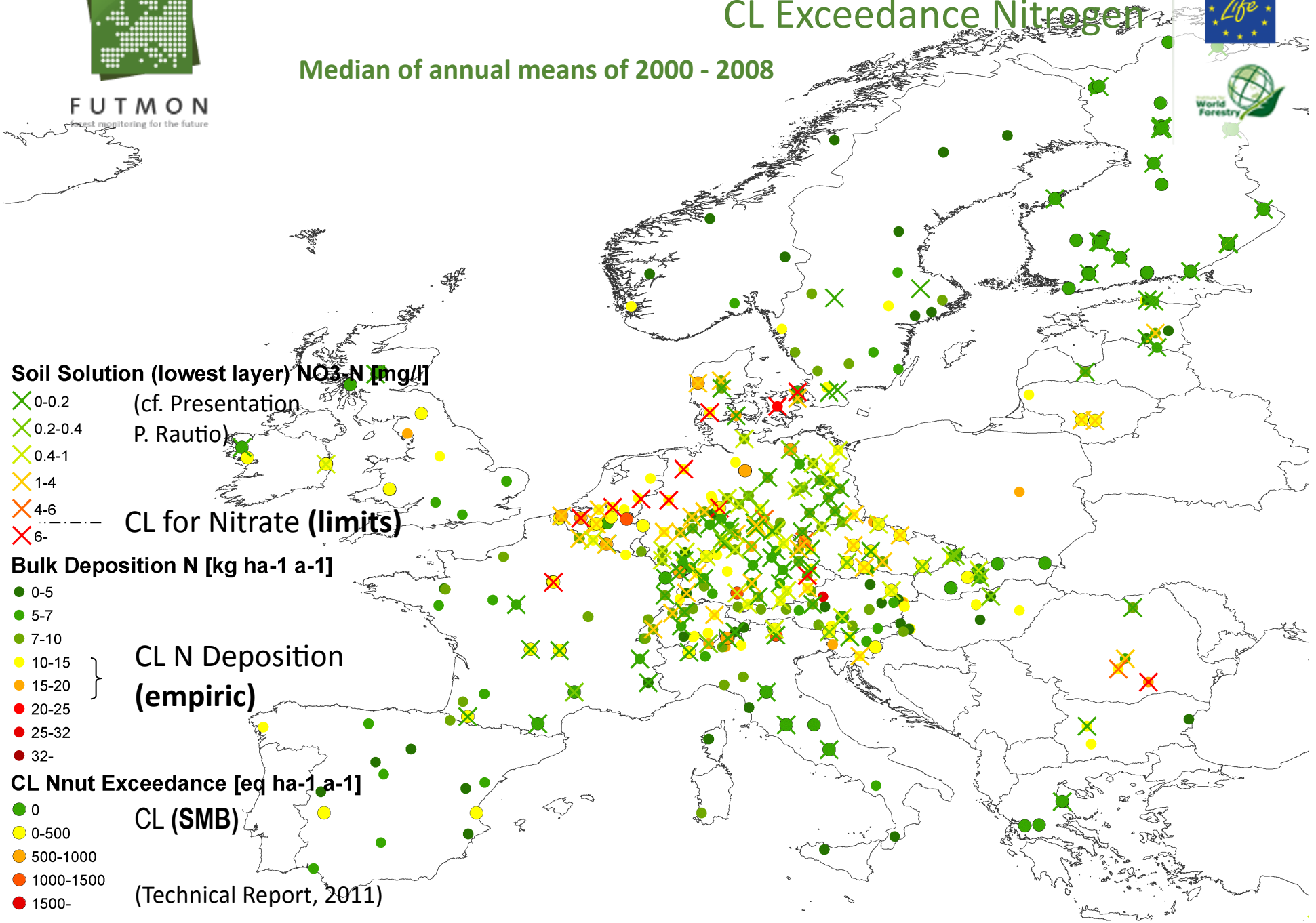
Median of annual fluxes of 2000-2008



(Technical Report, 2011)

CL Exceedance Nitrogen

Median of annual means of 2000 - 2008



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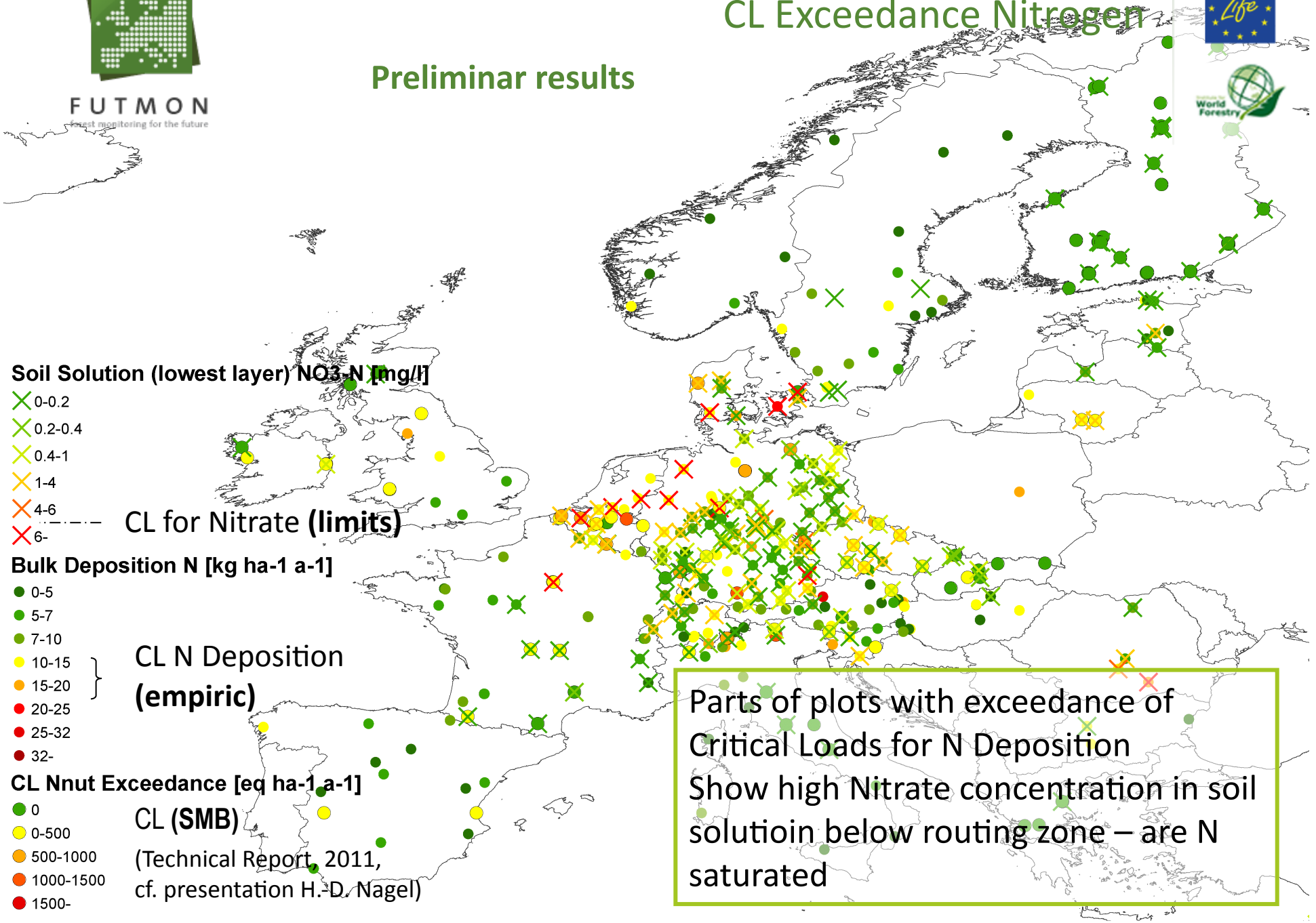
CL Exceedance Nitrogen

Preliminar results



Parts of plots with exceedance of Critical Loads for N Deposition Show high Nitrate concentration in soil solutioin below routing zone – are N saturated

Foliar Nutrition

Literature values

Literature values of ‚**optimal' foliar nutrition**

Tree species	N (mg/g)	Mg (mg/g)	K (mg/g)	Mn (mg/kg)
broadleaves				
Beech	19-25	**1.0-**	**5-**	**-1500**
Oak	20-30	**1.5-**	6-	
conifers				
Spruce	**13.5-17**	0.6-	3.5-	-5000
Silver Fir	13-18	**1.5-**	5-	
Pine	**14-17**	0.6-	3.8-	

(Compiled from Bergmann 1993, Bonneau 1988, Van den Burg 1985 and others)

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Foliar Nutrition

Foliar N [mg/g]

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Foliar Nutrition

Foliar Mg [mg/g]

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Foliar Mg [mg/g]

Exceedance of CL:
Tendency to better or superoptimal N nutrition?
Tendency to less optmal balanced foliar nutrition?

Cause-Effect relationship or simply coincidence?

Driver → Response

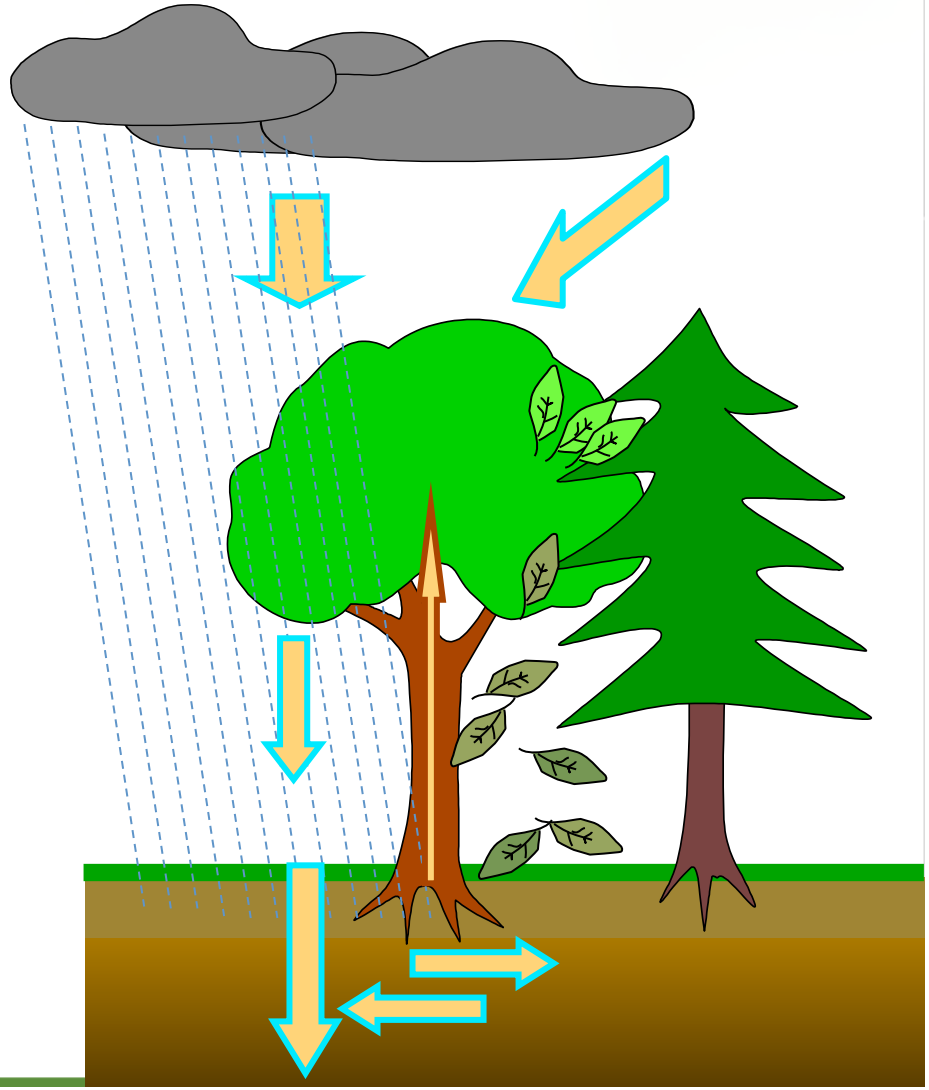
Deposition → **Foliar content**

Confounding factors

- Light
- Precipitation
- Altitude
- Latitude
- Stand age
- Soil solution
- Soil

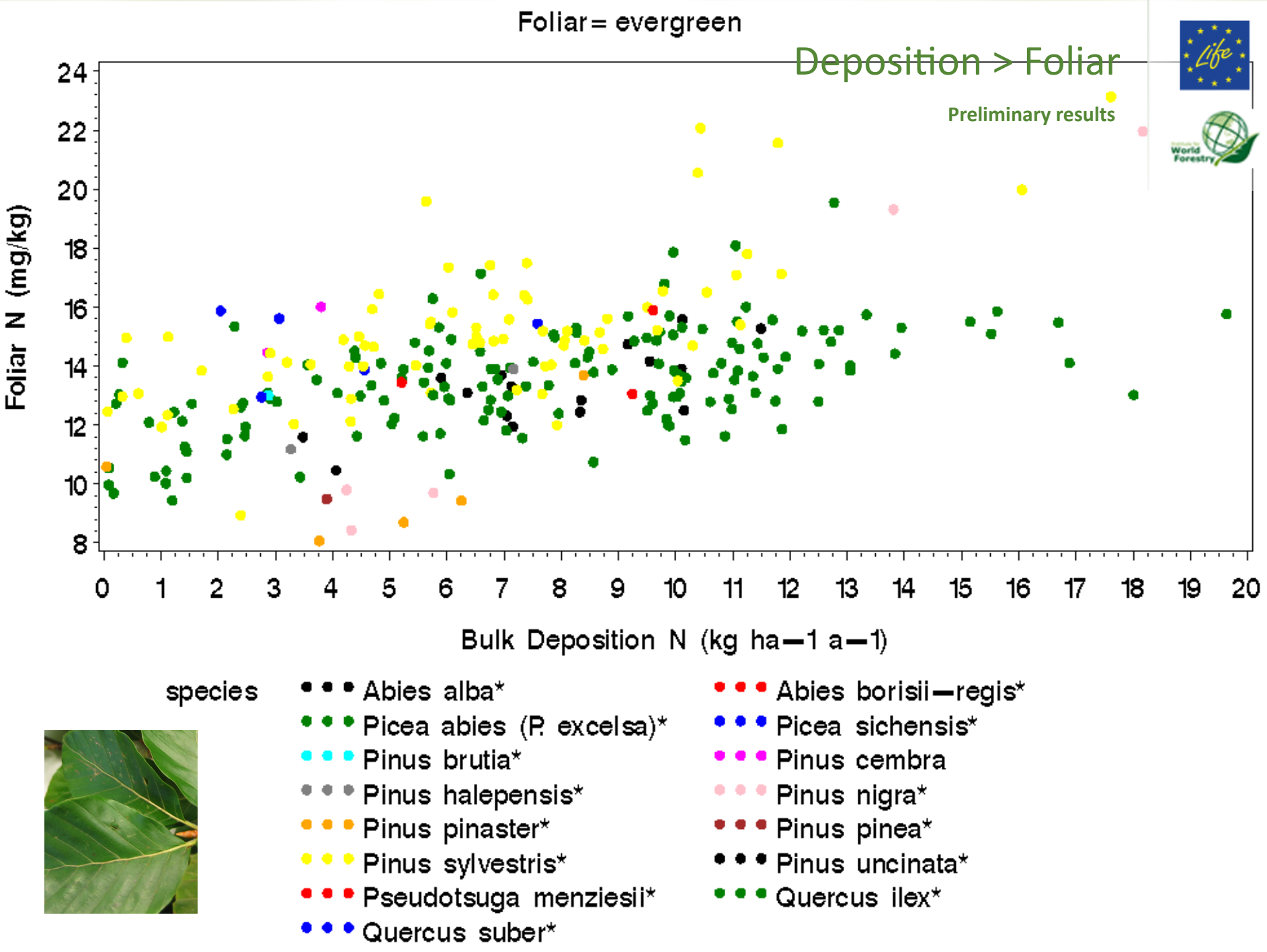
Stratification

Tree species



Deposition > Foliar

Preliminary results



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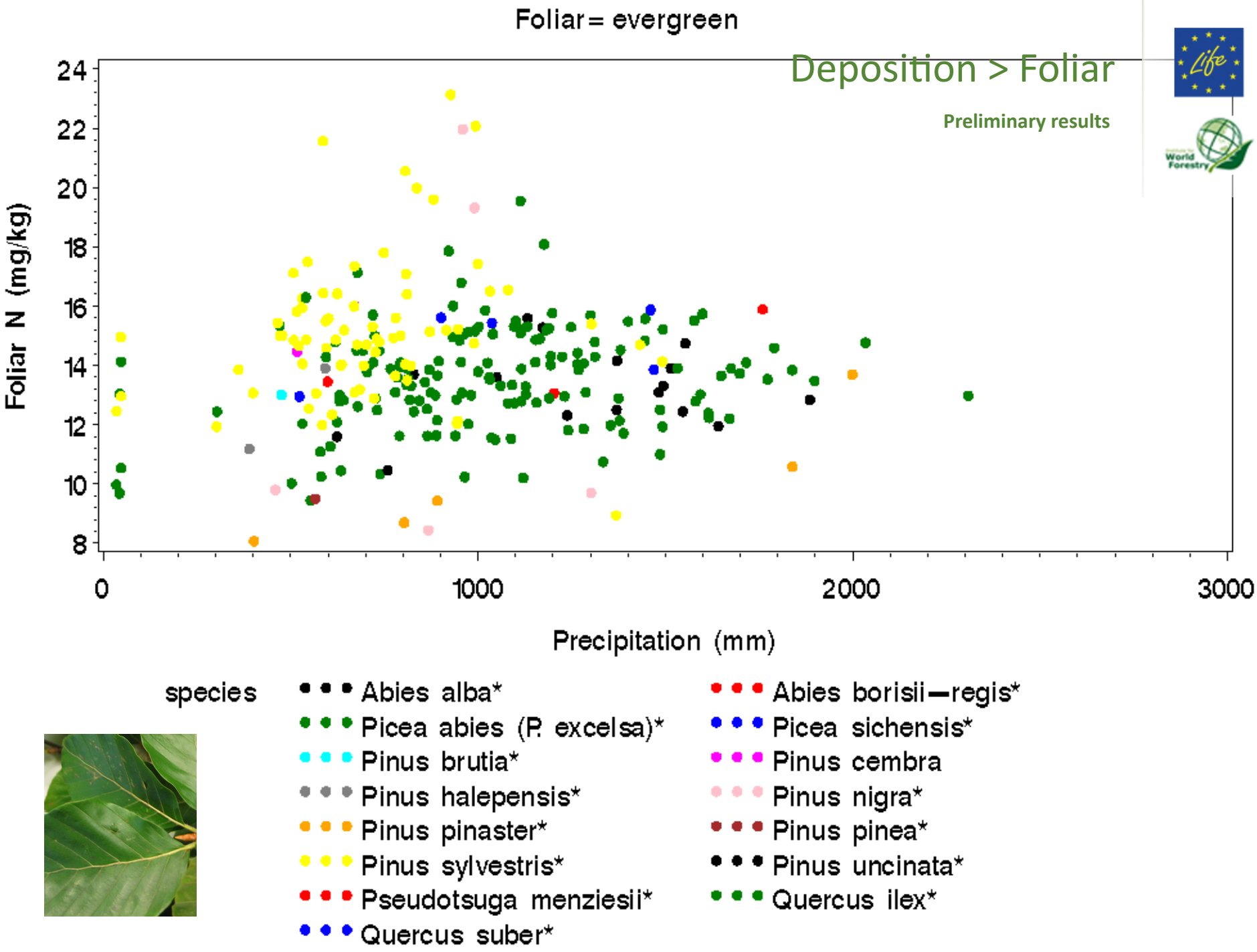
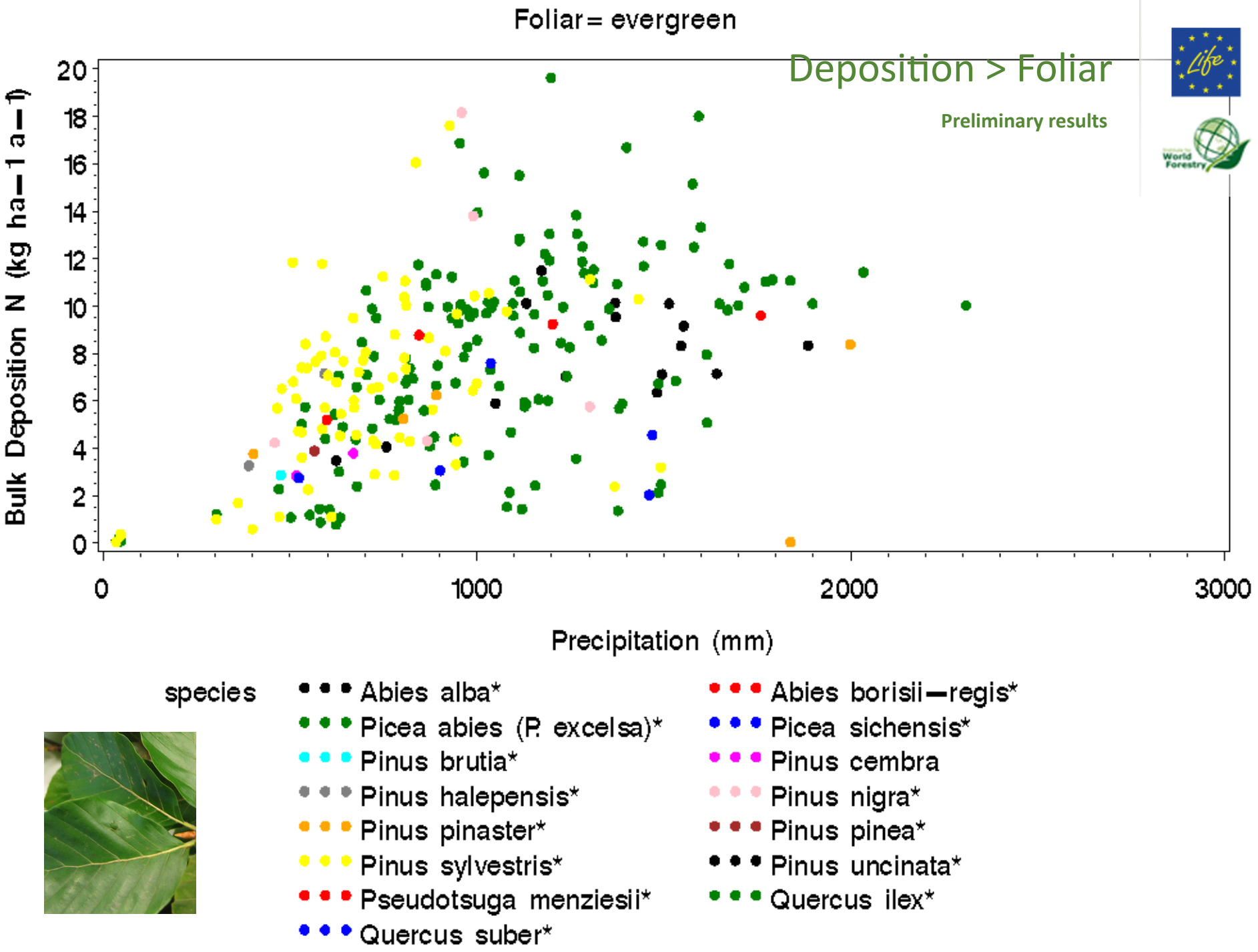


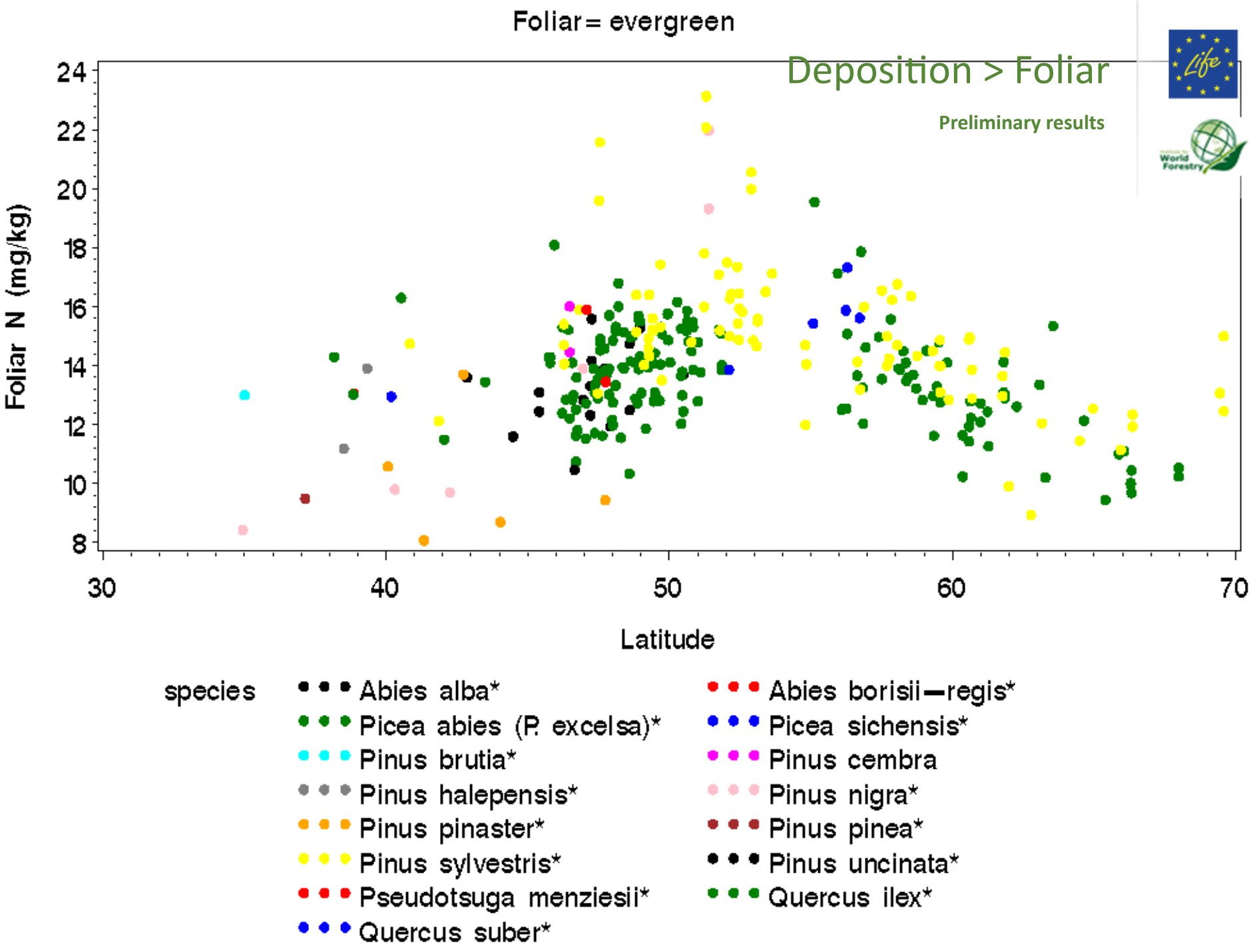
Deposition > Foliar

Preliminary results



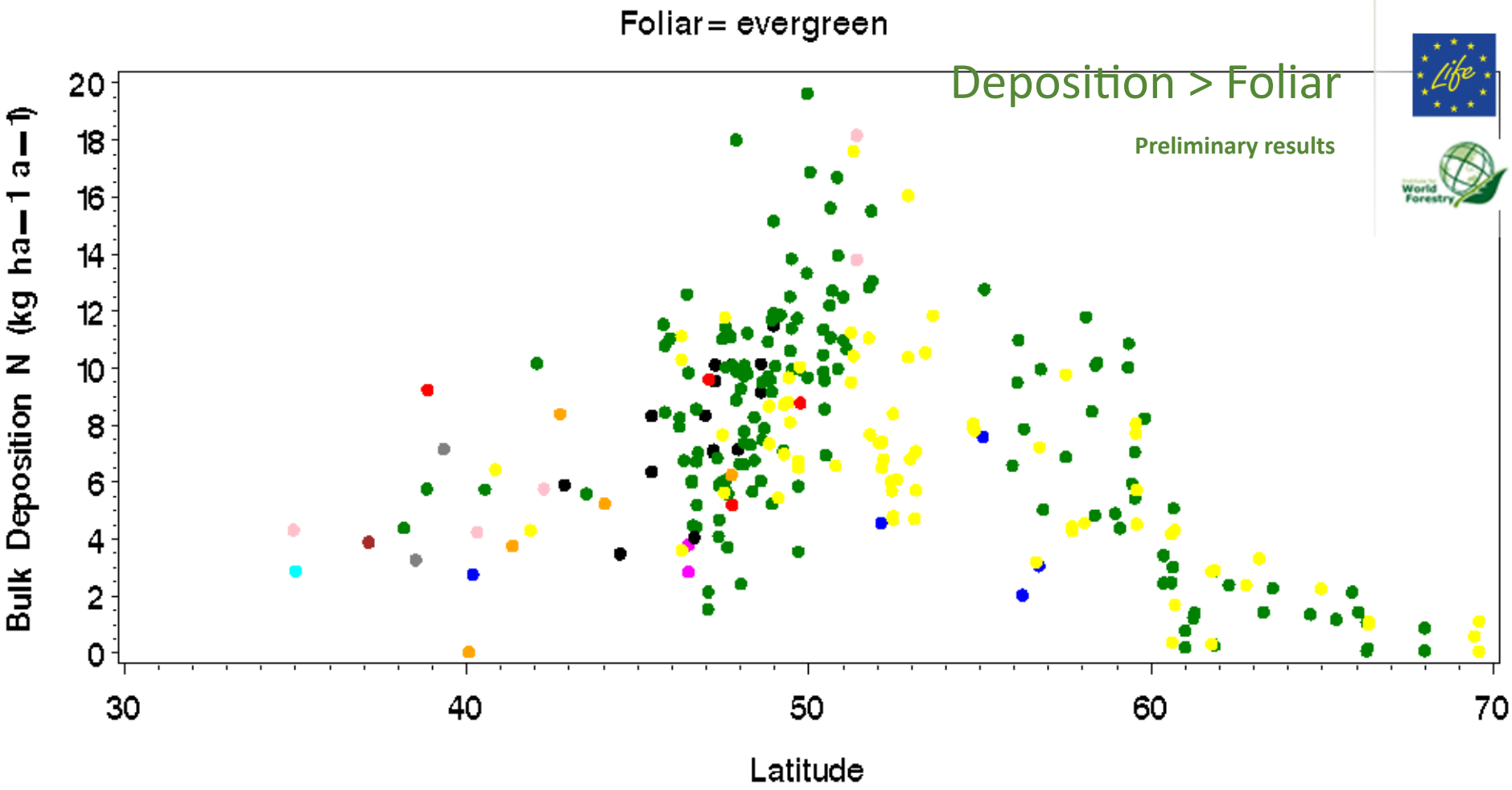
Deposition > Foliar

Preliminary results

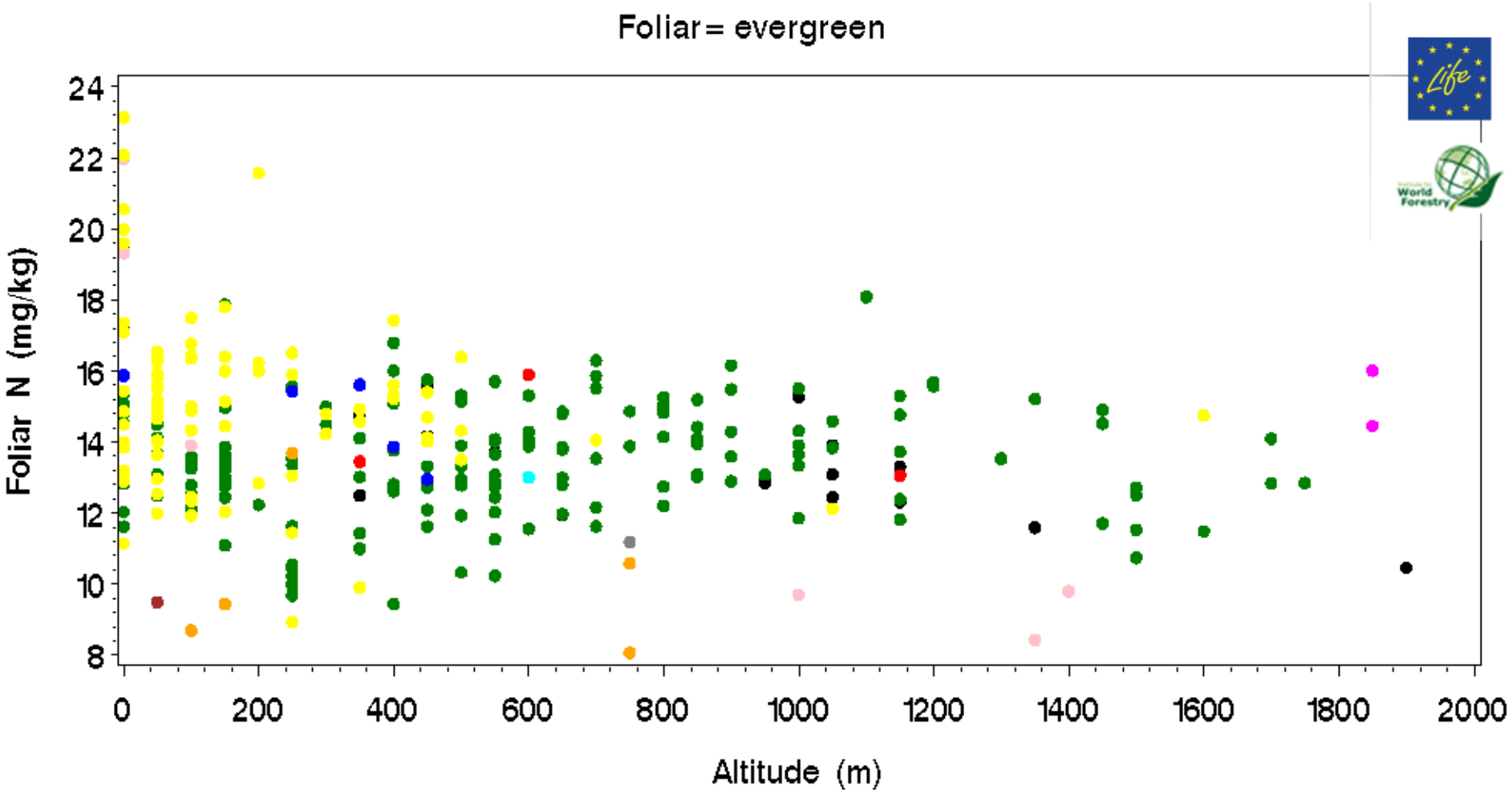


Deposition > Foliar

Preliminary results



- Abies alba*
- Picea abies (P. excelsa)*
- Pinus brutia*
- Pinus halepensis*
- Pinus pinaster*
- Pinus sylvestris*
- Pseudotsuga menziesii*
- Quercus suber*
- Abies borisii−regis*
- Picea sichensis*
- Pinus cembra
- Pinus nigra*
- Pinus pinea*
- Pinus uncinata*
- Quercus ilex*



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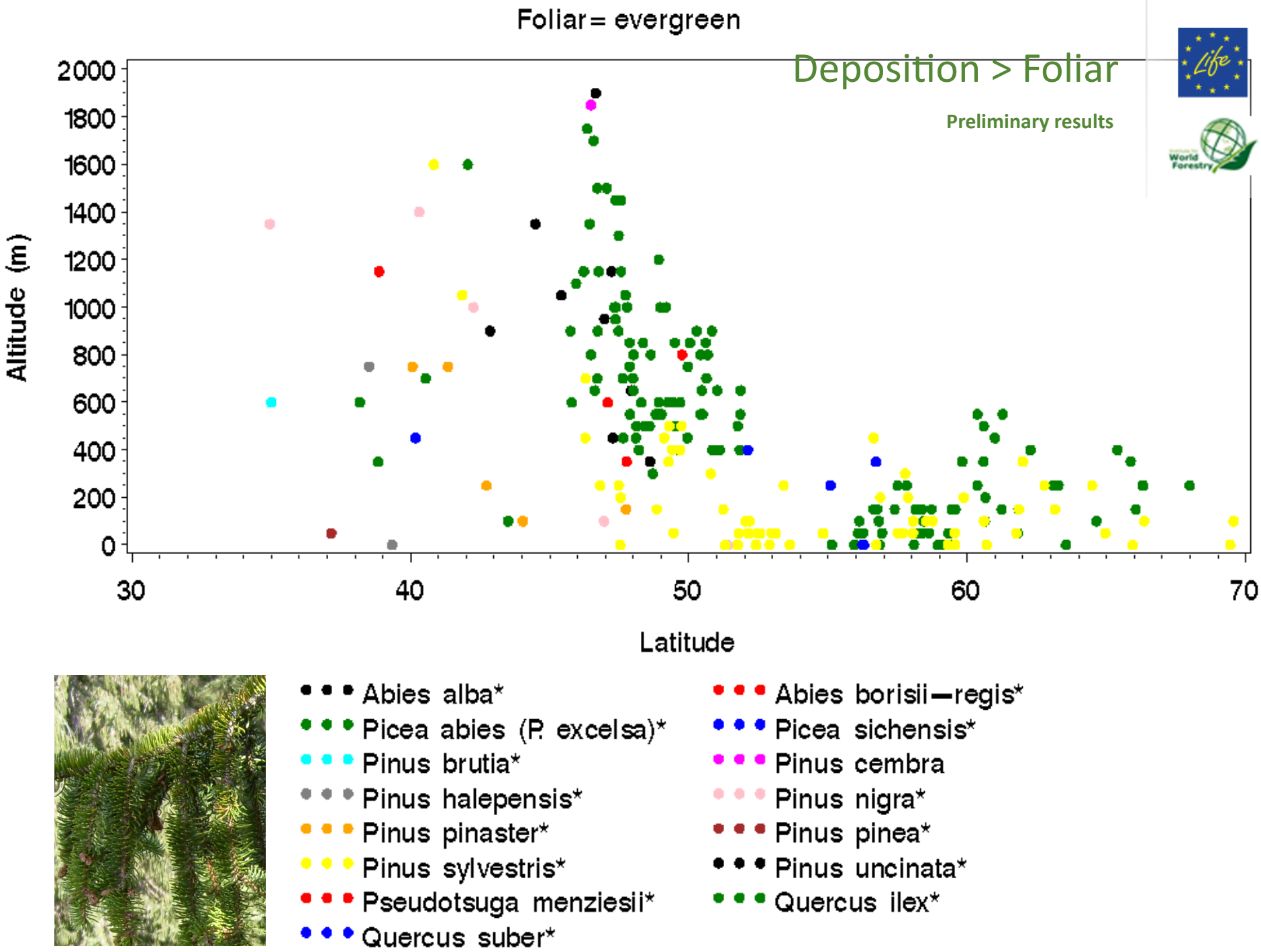
Deposition > Foliar

Preliminary results



Correlation - Deposition>Foliar

Preliminary results

Correlation Coefficient (Spearman) and Significance level

Tree species	Parameter	N	Ca	Mg	K	n
Picea abies	N Deposition	0.57***	-0.20*	-0.23*	-0.31*	148
Spruce	Precipitation	0.23*	-0.25*	-0.26*	-0.11	147
	Latitude	-0.24*	-0.15	-0.02	0.09	149
	Altitude	0.13	0.04	-0.13	0.00	149
Pinus sylvestris*	N Deposition	0.54***	0.46***	-0.27*	0.03	72
Pine	Precipitation	0.13	0.04	-0.01	0.44*	72
	Latitude	-0.48***	-0.47***	0.21*	-0.09	72
	Altitude	-0.12	-0.04	0.07	0.01	72
Fagus sylvatica*	N Deposition	0.22*	-0.06	-0.15	-0.02	92
Beech	Precipitation	0.18	0.03	-0.15	0.01	92
	Latitude	-0.20*	-0.51***	-0.22*	-0.25*	93
	Altitude	0.18	0.38*	0.22*	0.07	93
Quercus robur	N Deposition	0.14	-0.35	-0.27	0.20	26
Oak	Precipitation	-0.35	-0.31	-0.46*	-0.08	26
	Latitude	0.02	-0.43*	-0.53*	-0.02	26
	Altitude	0.02	0.01	-0.11	-0.04	26

Foliar = seasonal

Betula pendula*
Fagus moesiaca*
Fraxinus excelsior*
Populus canescens
Prunus serotina
Quercus frainetto (Q. conferta)*
Quercus petrea_or_robur
Carpinus betulus*
Fagus sylvatica*
Larix decidua*
Prunus avium*
Quercus cerris*
Quercus petraea*
Quercus robur (Q. pedunculata)*

Cause-Effect relation? or simply coincidence?

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Driver

Deposition

Response

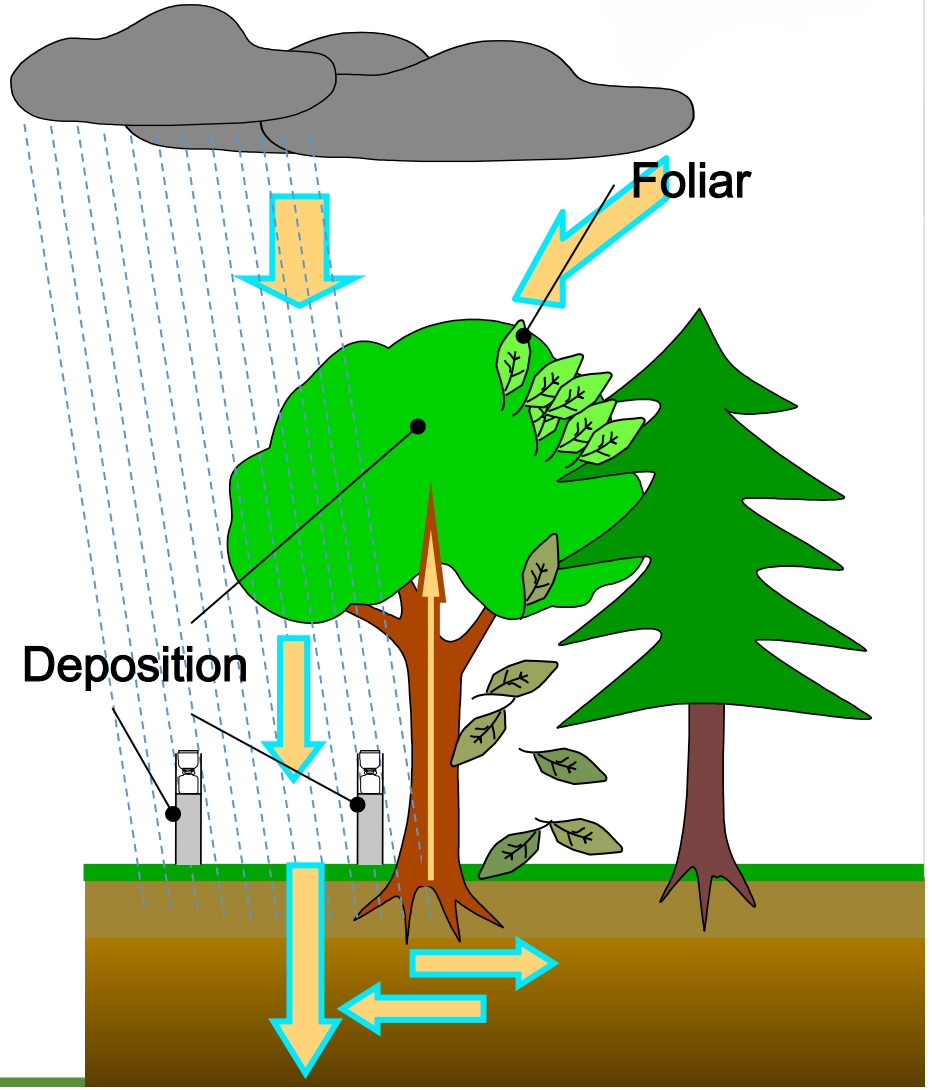
Foliar content

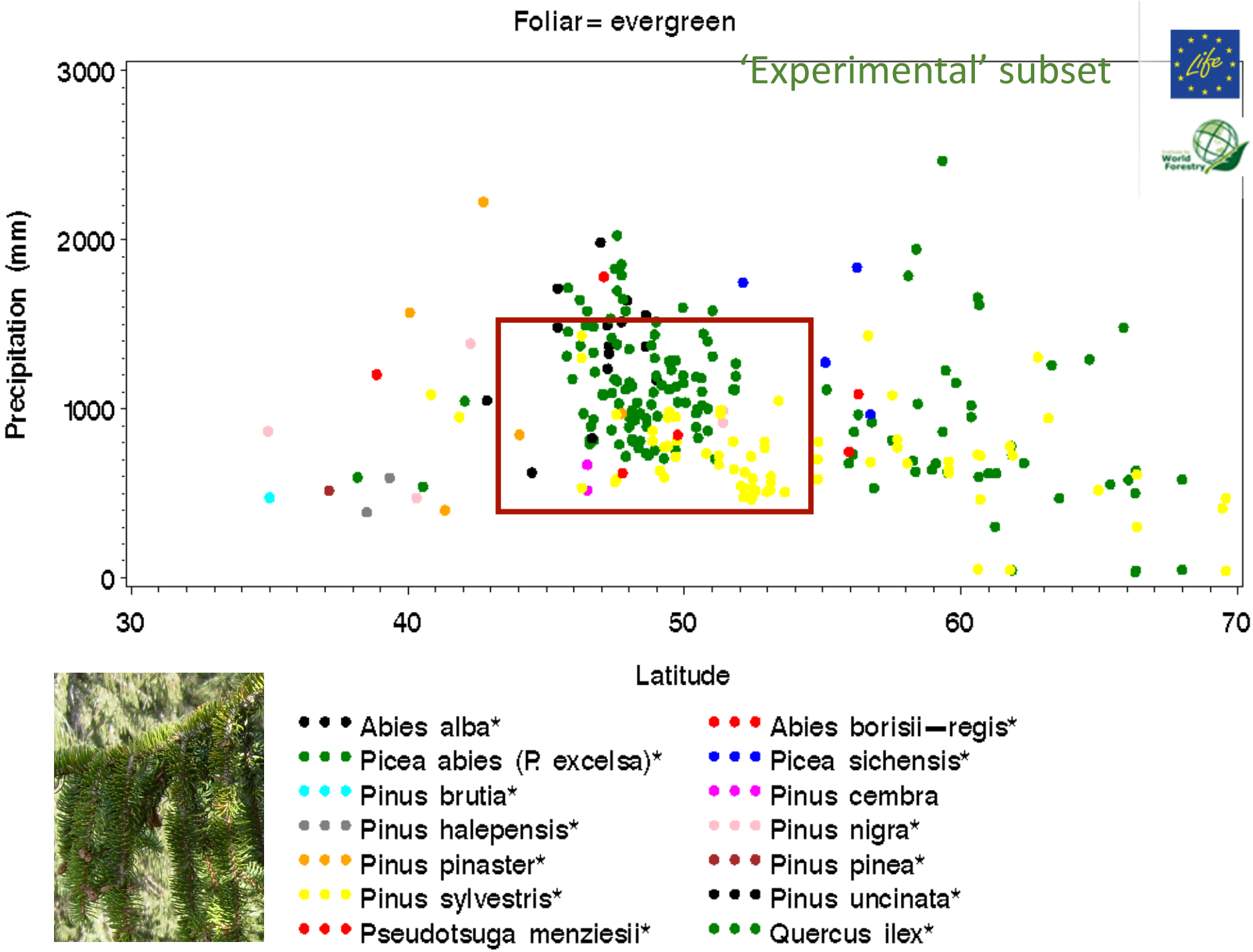
Confounding factors

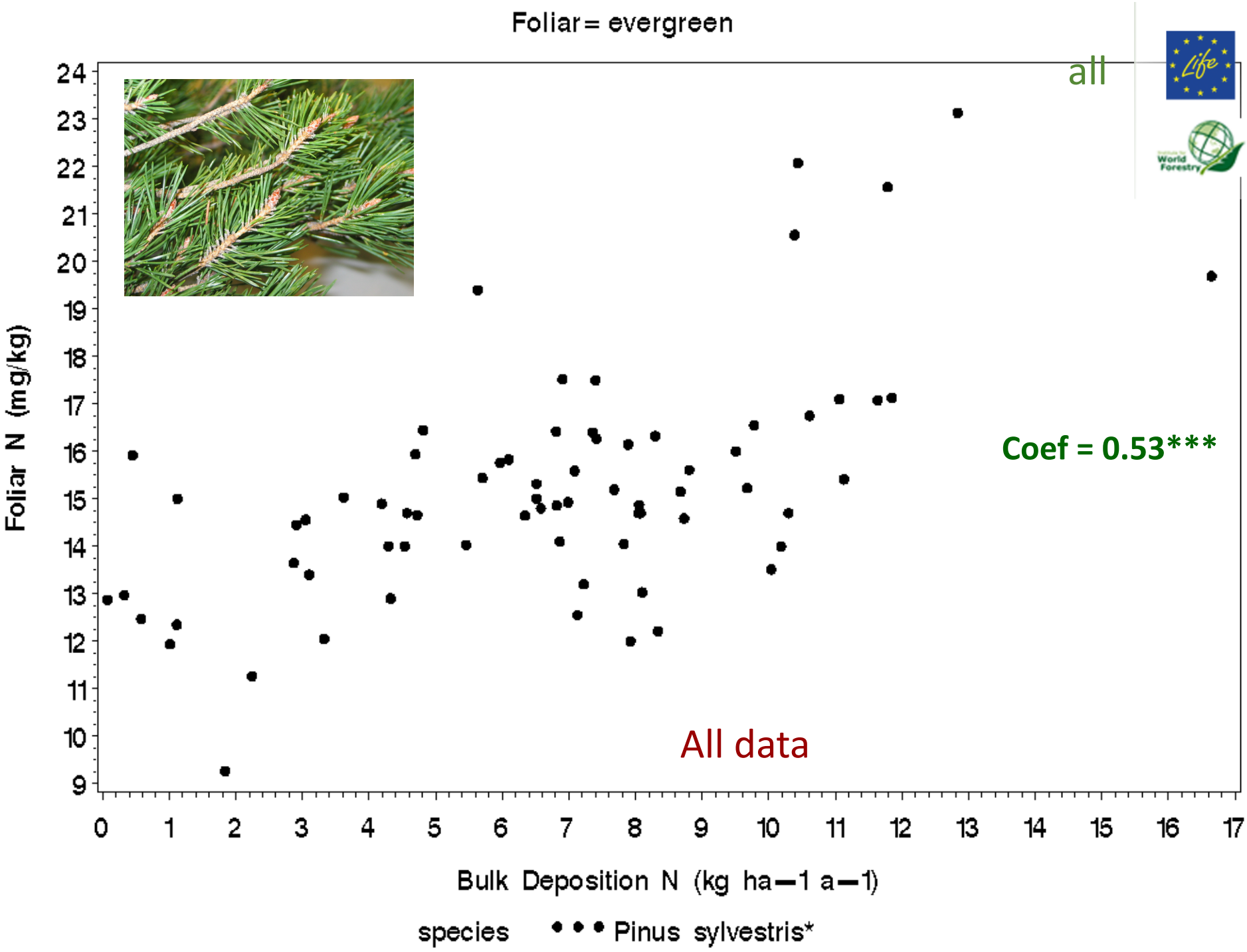
Light, T ?
Precipitation
Altitude
Latitude
Stand age ?
Soil solution ?
Soil ?

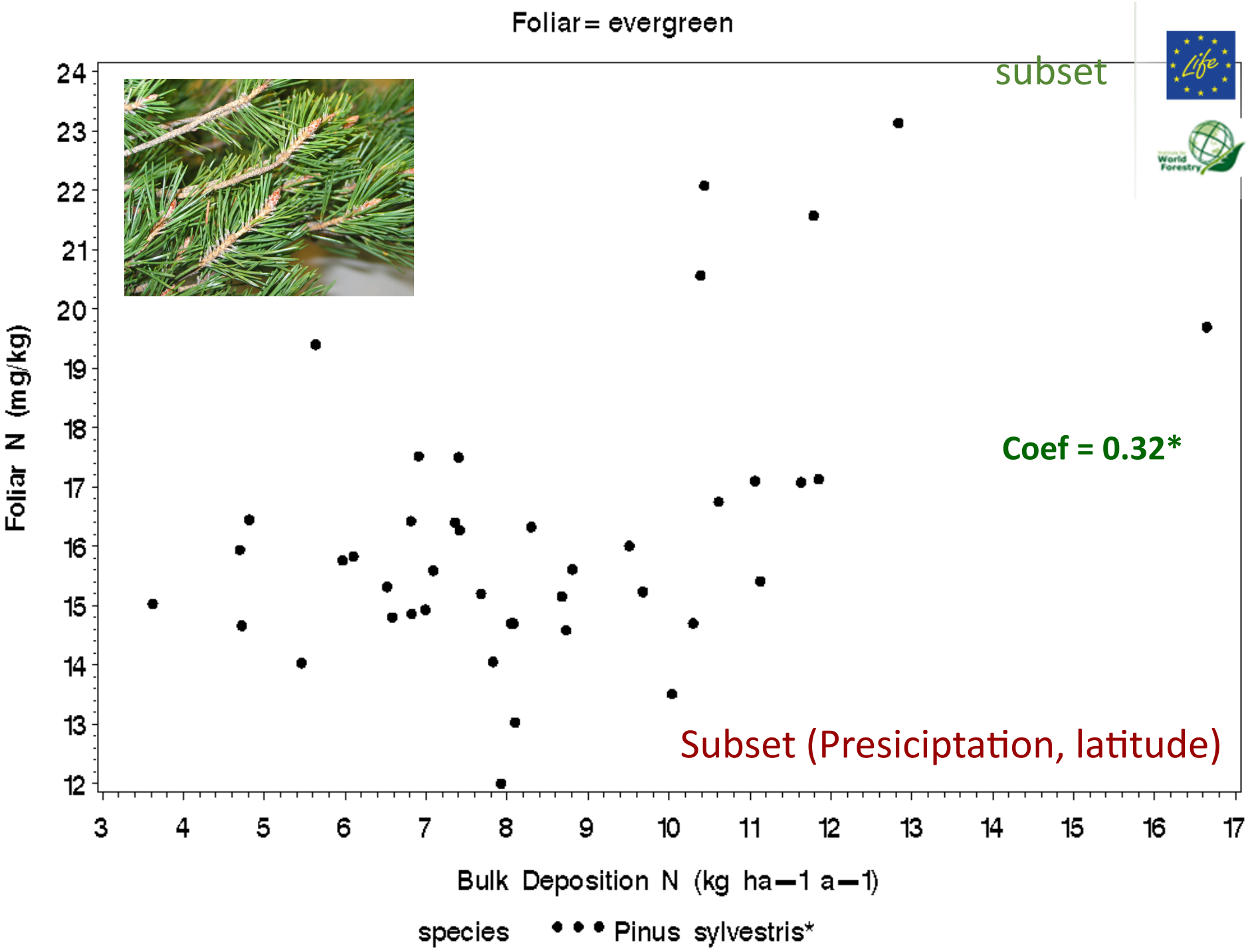
Stratification

Tree species




Foliar = evergreen
'Experimental' subset
Precipitation (mm)
3000
2000
1000
0
30
40
50
60
70
Latitude
Abies alba*
Picea abies (P. excelsa)*
Pinus brutia*
Pinus halepensis*
Pinus pinaster*
Pinus sylvestris*
Pseudotsuga menziesii*
Abies borisii-regis*
Picea sichensis*
Pinus cembra
Pinus nigra*
Pinus pinea*
Pinus uncinata*
Quercus ilex*

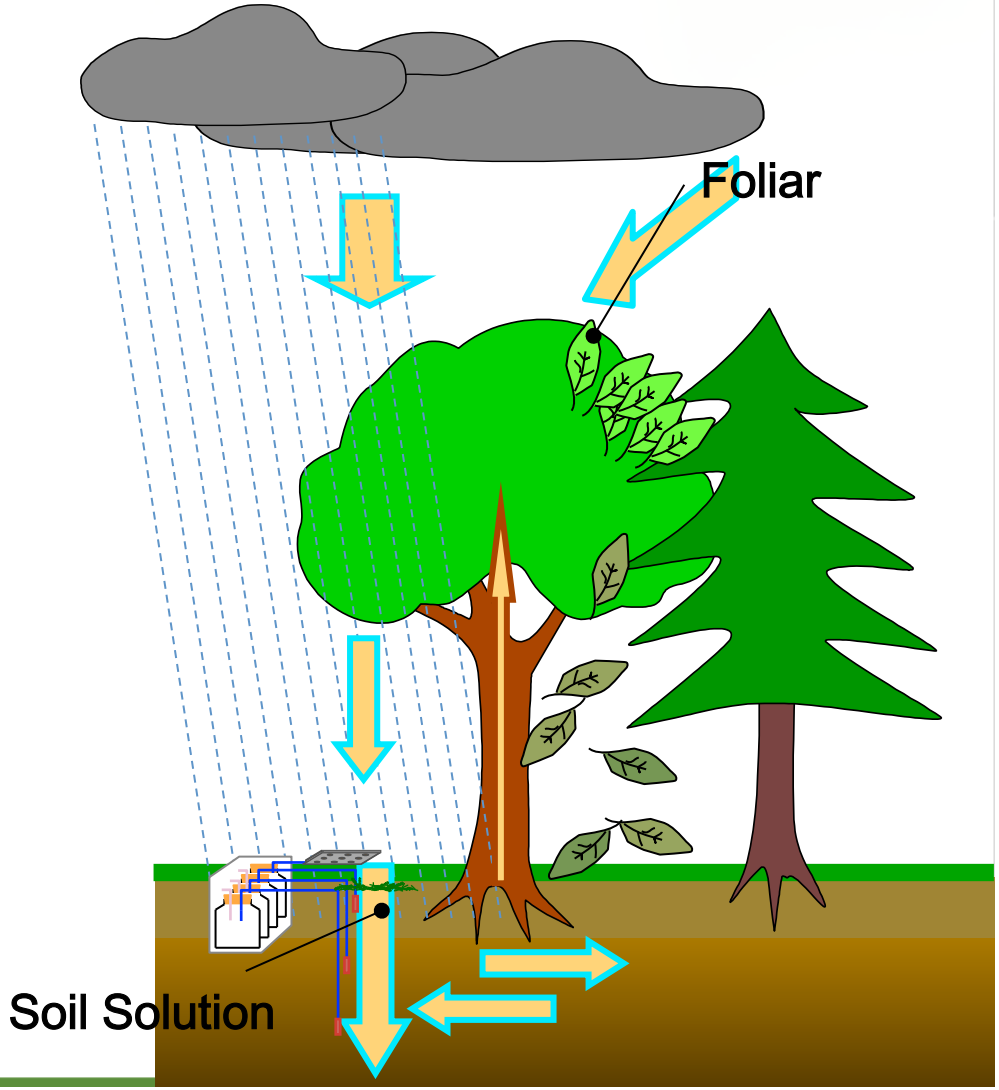

Foliar= evergreen
all
Coef = 0.53***
All data
Foliar N (mg/kg)
Bulk Deposition N (kg ha−1 a−1)
species
Pinus sylvestris*


Foliar= evergreen
subset
Coef = 0.32*
Subset (Presiciptation, latitude)
Foliar N (mg/kg)
Bulk Deposition N (kg ha—1 a—1)
species Pinus sylvestris*

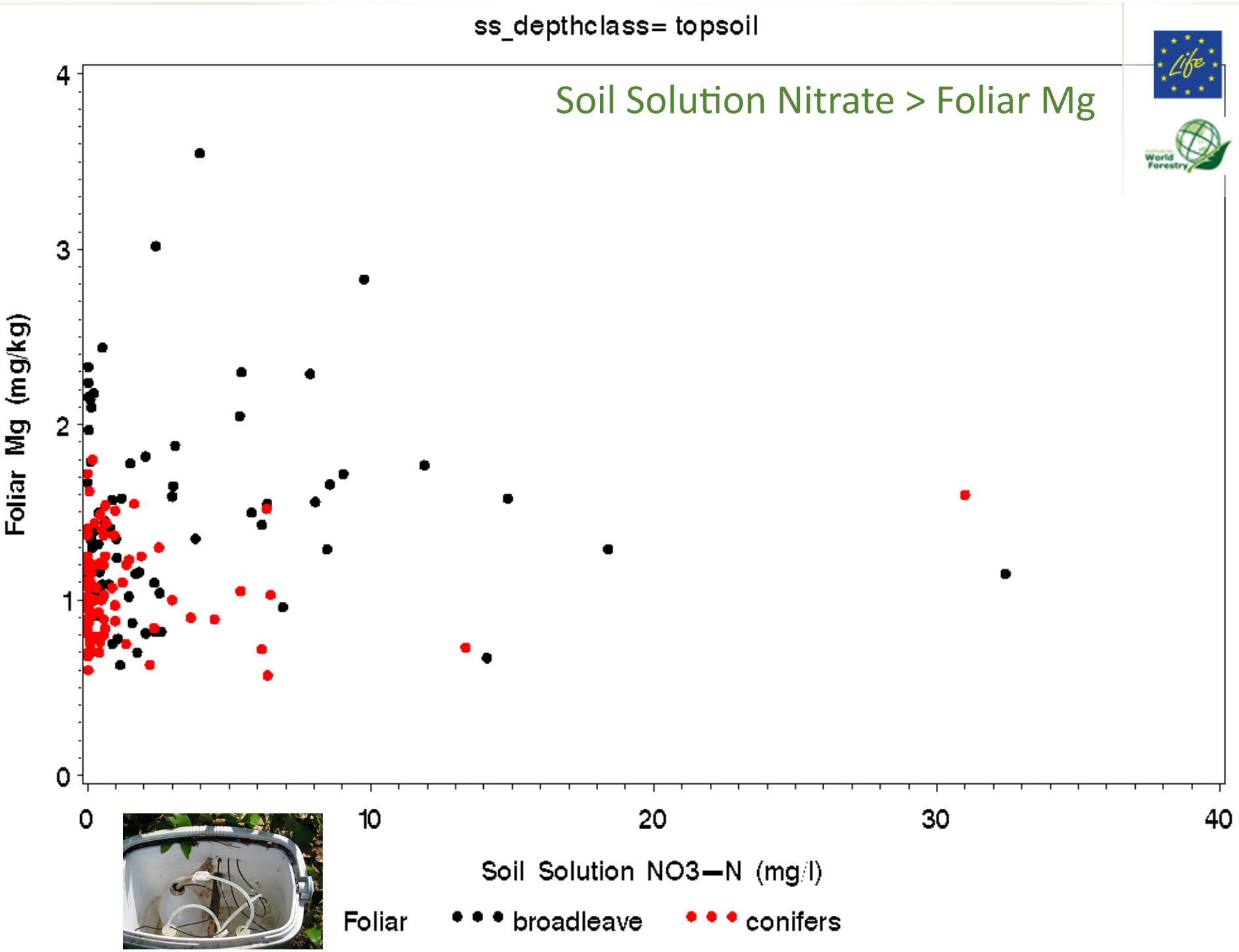
Cause-Effect relation? or simply coincidence?

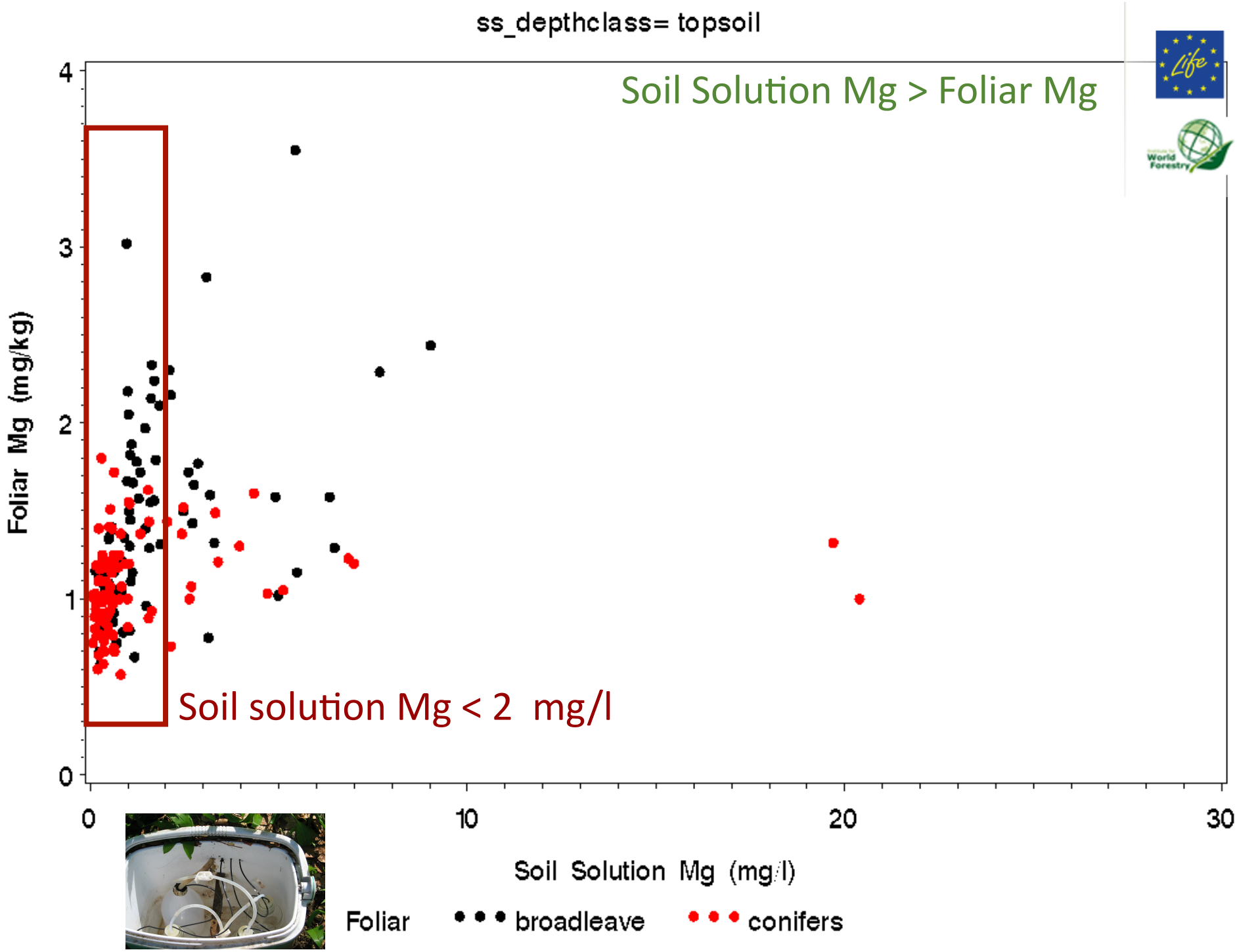
Driver		Response
Soil solution	→	**Foliar content**

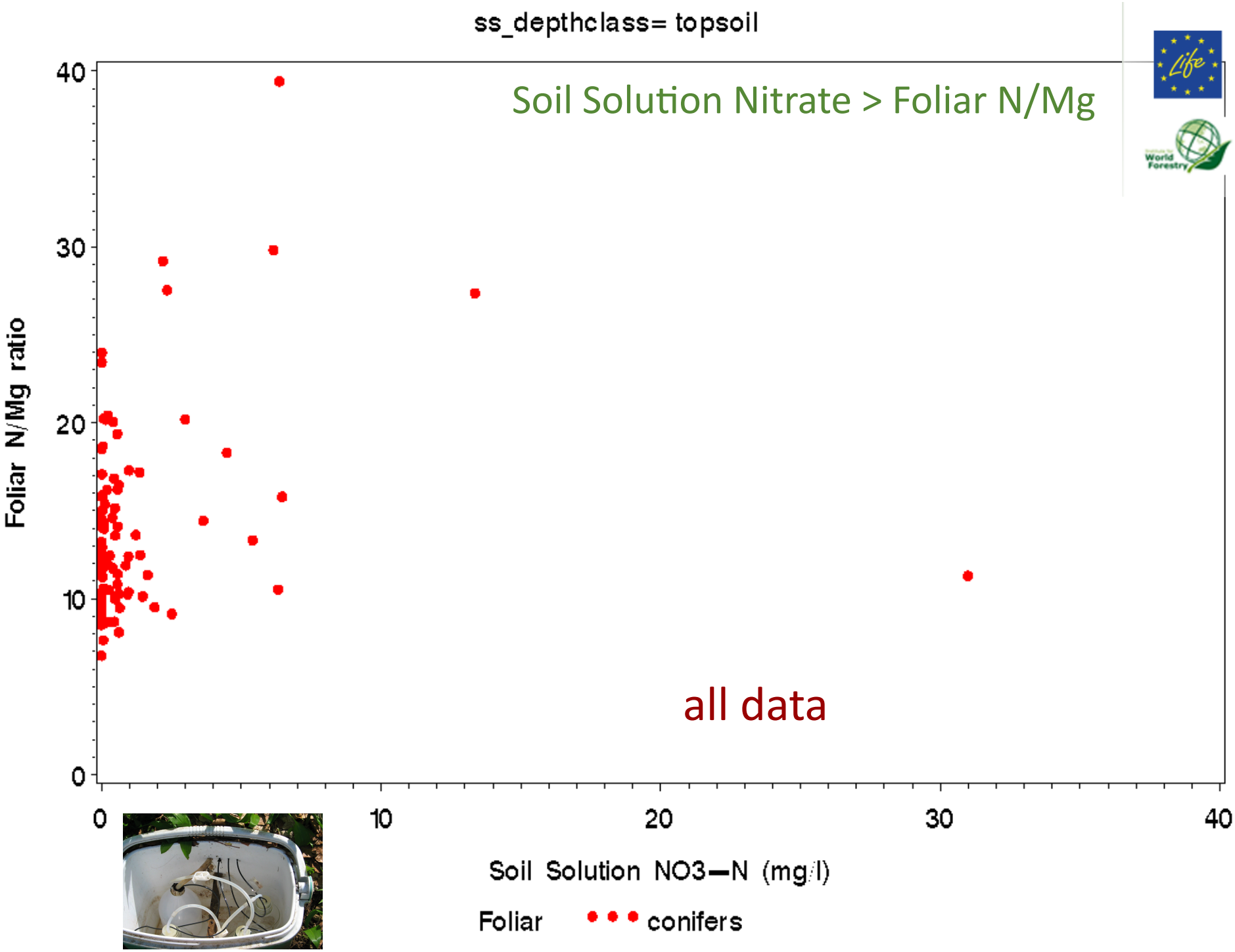
(cf. Presentation P .Rautio)



Soil Solution Nitrate > Foliar Mg

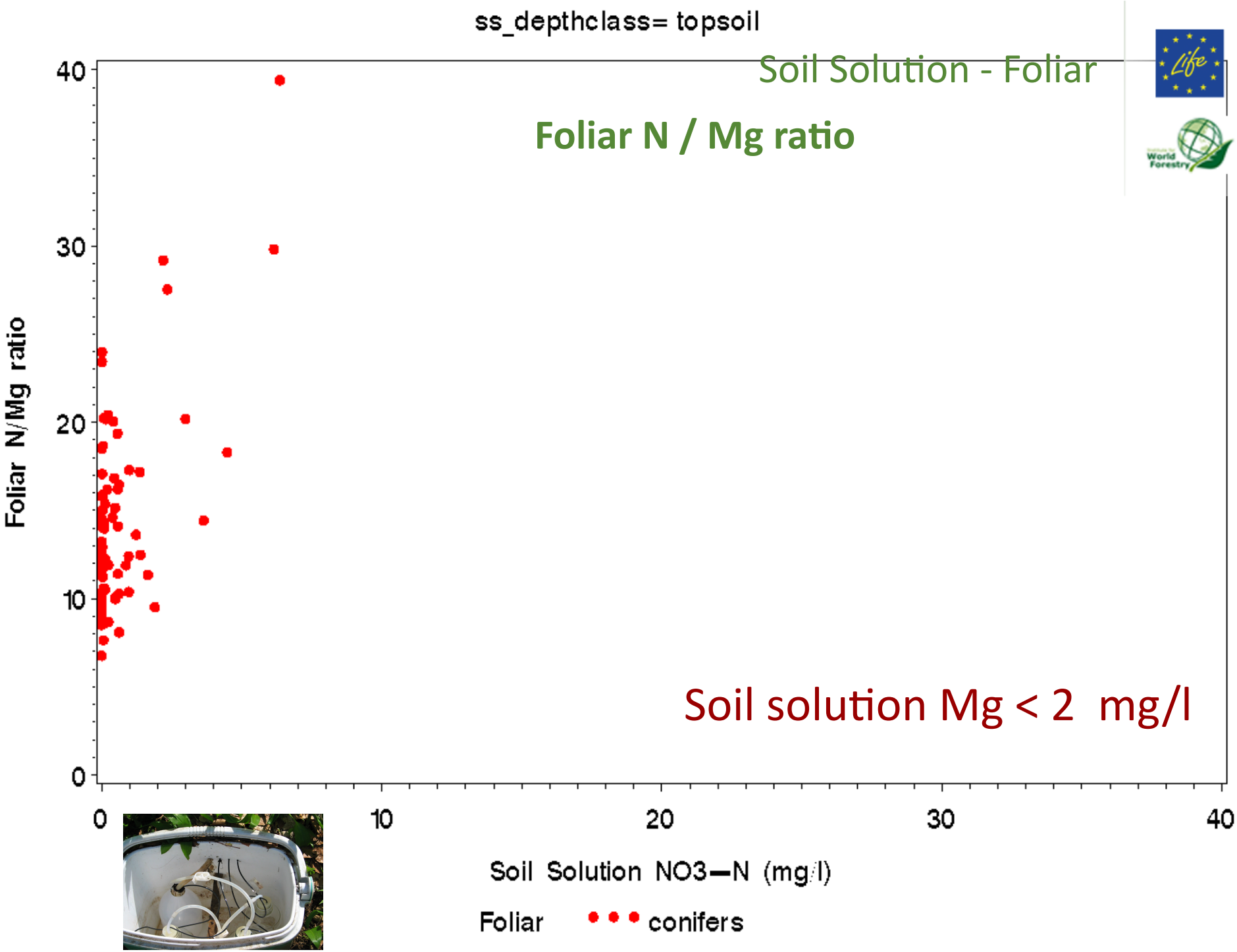



ss_depthclass= topsoil
Soil Solution Mg > Foliar Mg
Foliar Mg (mg/kg)
4
3
2
1
0
Soil solution Mg < 2 mg/l
0
10
20
30
Soil Solution Mg (mg/l)
Foliar
broadleave
conifers


ss_depthclass= topsoil
Soil Solution Nitrate > Foliar N/Mg
Foliar N/Mg ratio
0
10
20
30
40
all data
0
10
20
30
40
Soil Solution NO3—N (mg/l)
Foliar
conifers

Soil Solution - Foliar

Foliar N / Mg ratio



Soil solution Mg < 2 mg/l

Outlook for 2011:

.. explore CL exceedance > further tree response:

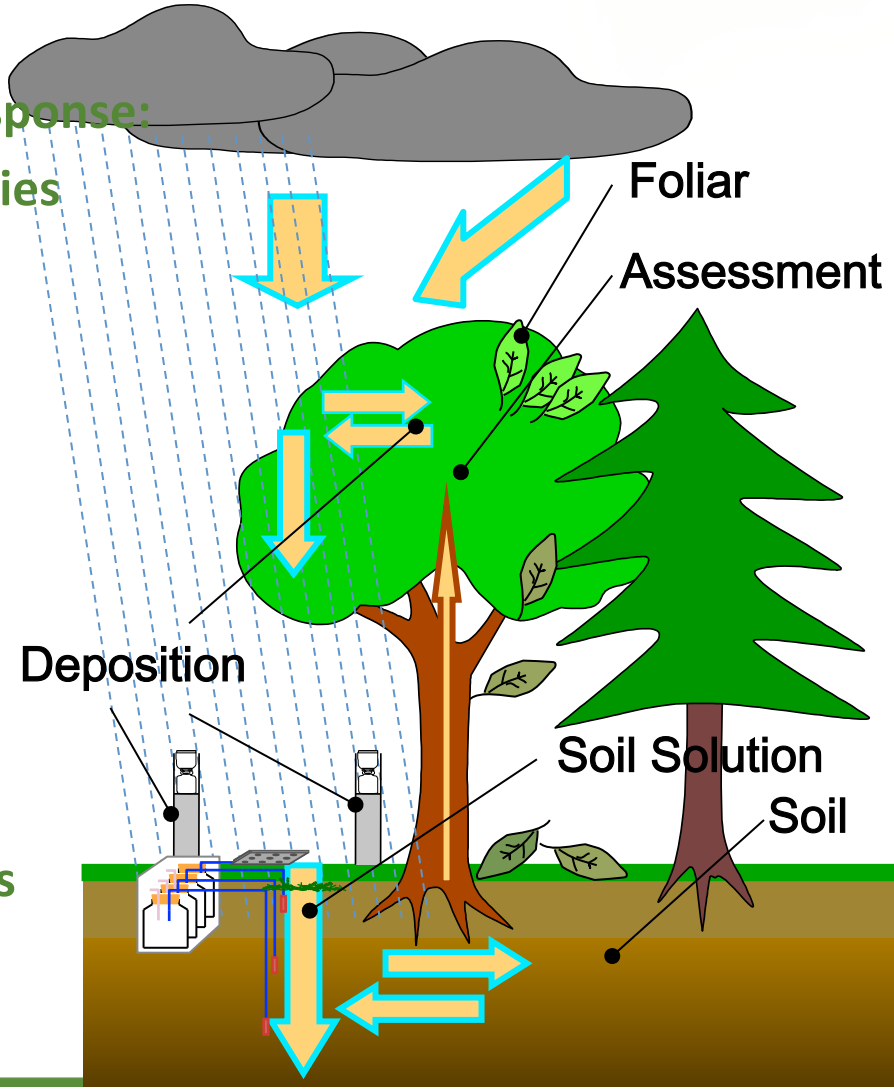
- Visible symptoms of nutrient deficiencies
- Crown Condition

.. consider further ‚confounding factors‘:

- Soil contents
- Stand age

… using:

- cooperation with national experts
- Quality Assurance informations
- Multivariate statistical approaches
- Spatial variation and Temporal changes



Preliminary Conclusions

Ecological Effects Study 2011 (-2012)

Conclusions

- Parts of plots with CL exceedance seem to be N saturated (high Nitrate below rooting zones) and effects are expected to already take place there.
- High N deposition tend to be related to
  … higher foliar N nutrition,
  (N nutrition is partly still below optimal values, partly exceeds them)
  .. and to lower Mg and K nutrients (partly below optimum)
- Similar relations between soil solution and foliar nutrition

- These first results are not in contradiction to the hypothesis of Acidification and Eutrophication.
- ICP-Forests data is suited to cross-check modelling and mapping with real data.
- The Long-term data series will enable to establish cause-effect relationships not only on spatial variability but also on temporal changes.