Monitoring of water fluxes and tree responses at intensively monitored forest sites - the value of observations at the ecosystem level

Henning Meesenburg[1], Markus Wagner[1], Bernd Ahrends[1],
Stefan Fleck[1], Wendelin Weis[2]

[1]Northwest German Forest Research Institute
[2]The Bavarian State Institute of Forestry

Agenda

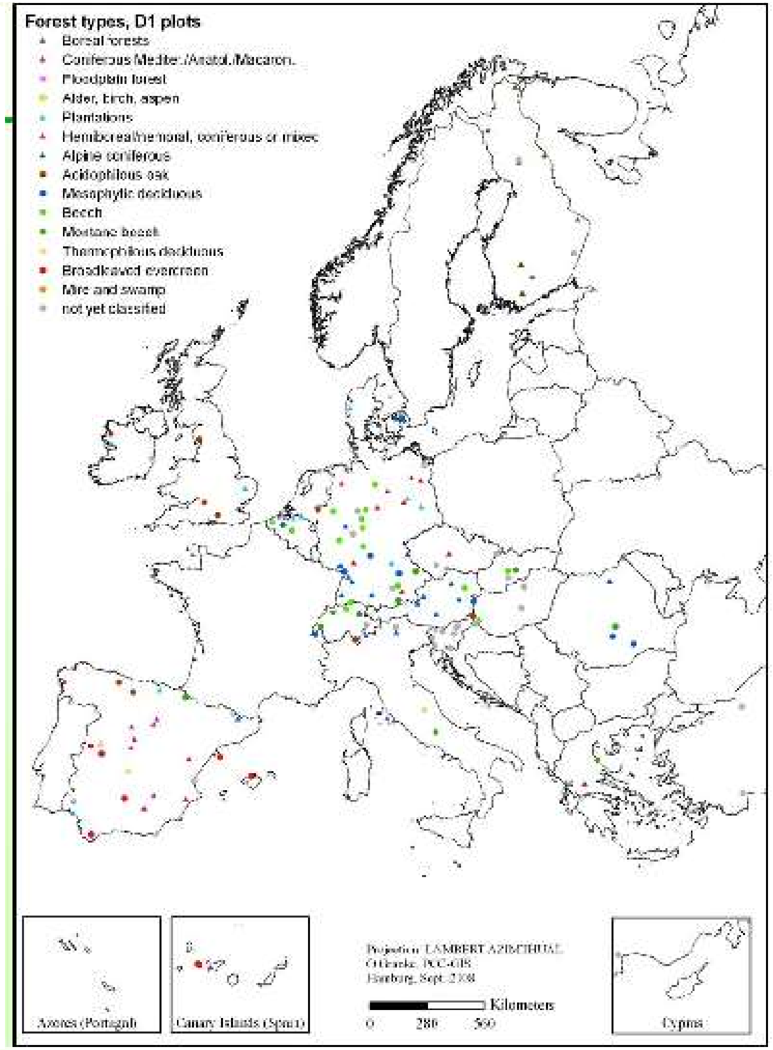
- Forest hydrological monitoring in Europe
- Integration of hydrological and tree response monitoring
- Benefit of hydrological modelling for forest monitoring
  - Case studies
- Conclusions

Hydrological monitoring in forests of Europe

Hydrological monitoring under ICP Forests Level II

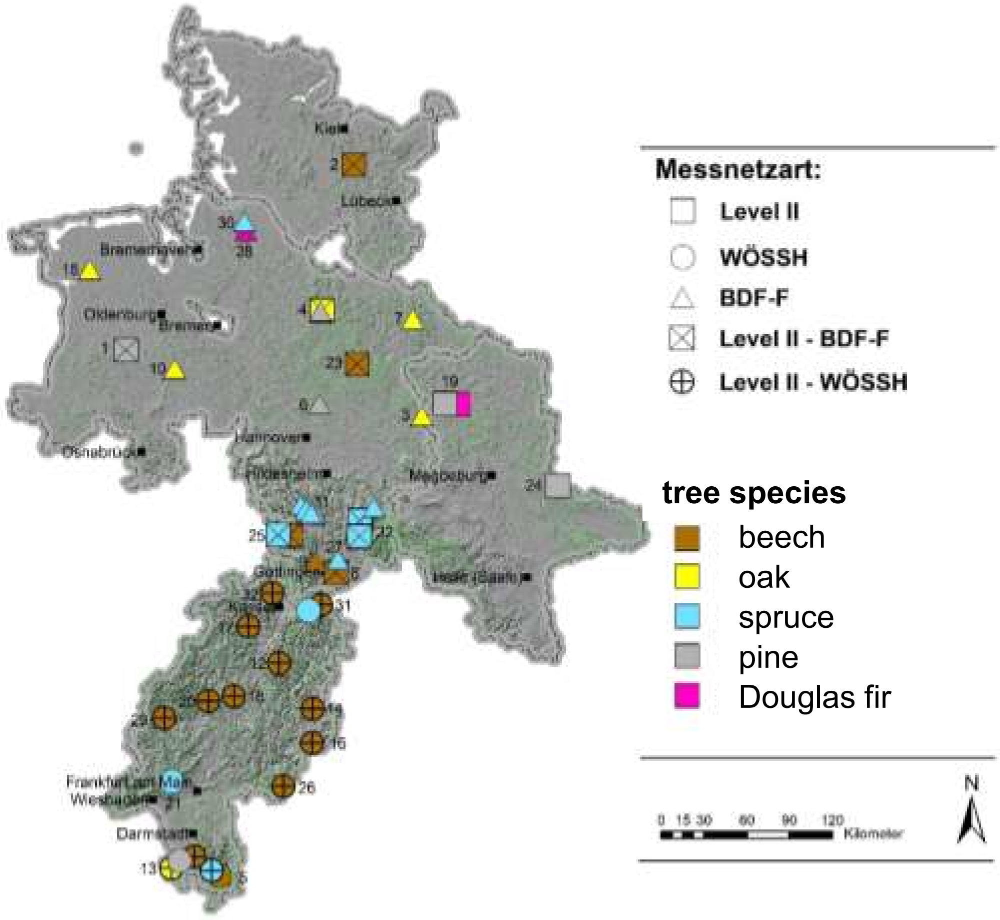
- Soil water content
- Soil water potential
- Soil water retention functions (pF functions)
- Precipitation
- Throughfall (stemflow)
- Soil temperature
- Leaf Area Index LAI
- High resolution radial increment (dendrometers)
- Hydrological modelling

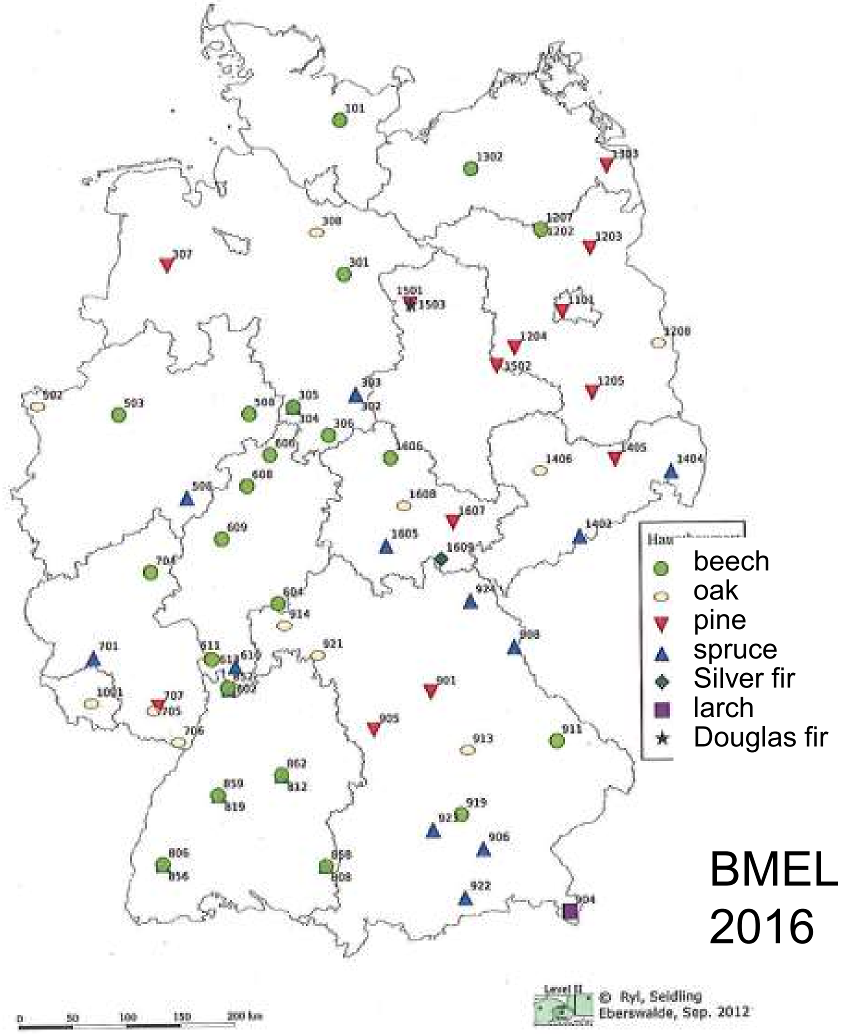
ca. 140 plots



Fischer & Granke 2008

Envrironmental forest monitoring in (Northwest) Germany



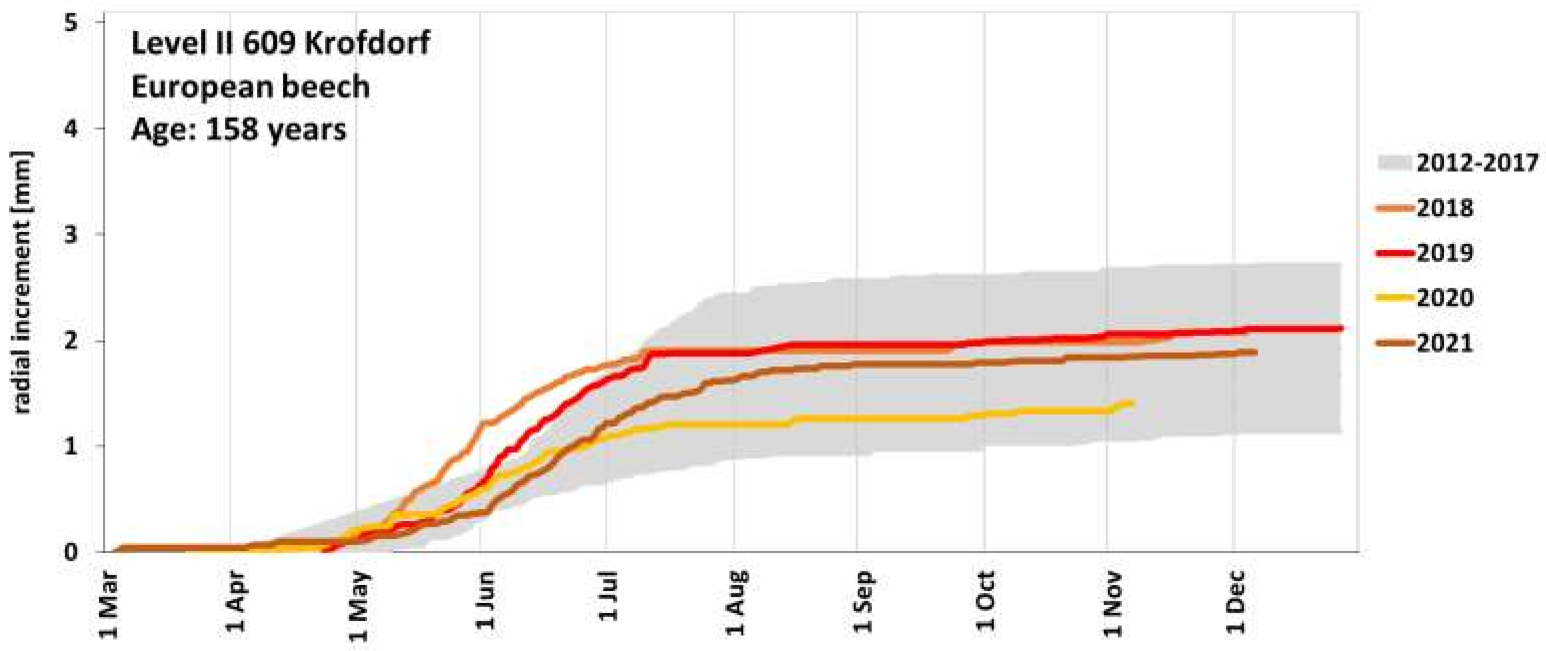


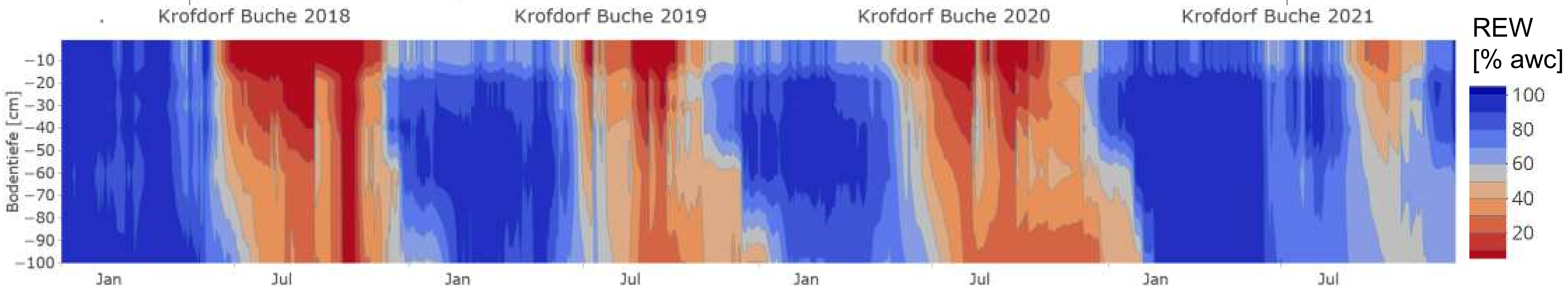
BMEL 2016

Applications of hydrological monitoring

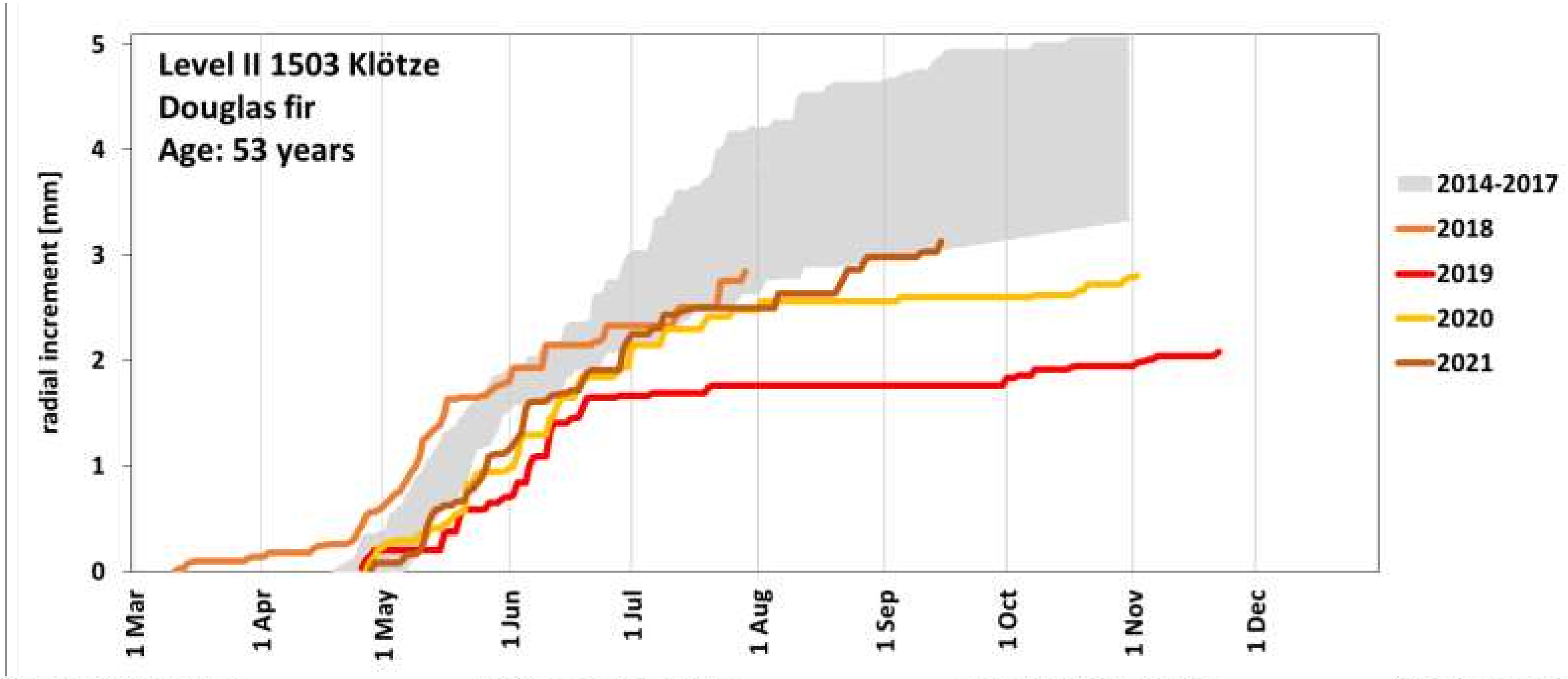
- Soil water availability
  - Soil water content
  - Soil water potential
- Calibration/validation of hydrological models
- Water fluxes
  - Evapotranspiration
    - Interception
    - Transpiration
    - (Soil) Evaporation
  - seepage
  - Groundwater recharge
- Matter fluxes
- water stress and tree response
  - Drought stress
  - oxygen deficiency

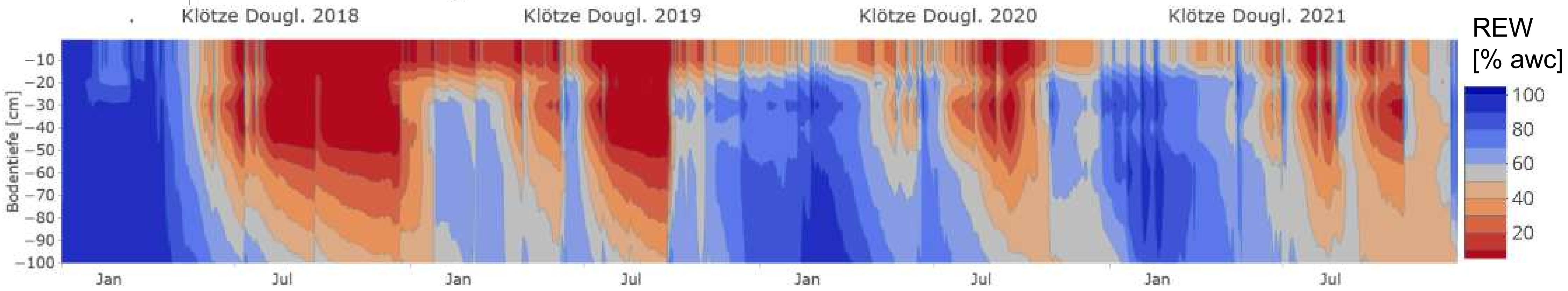
Soil water availability and radial increment



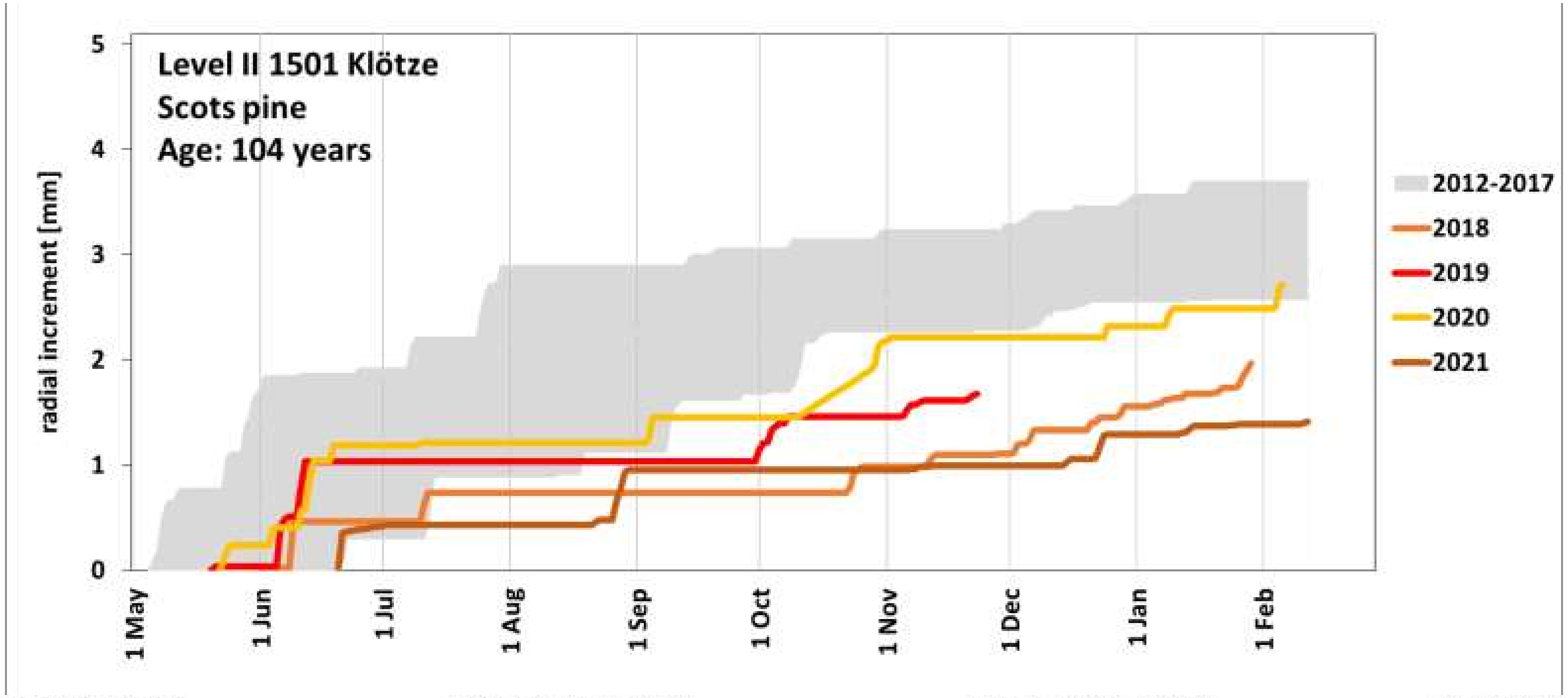


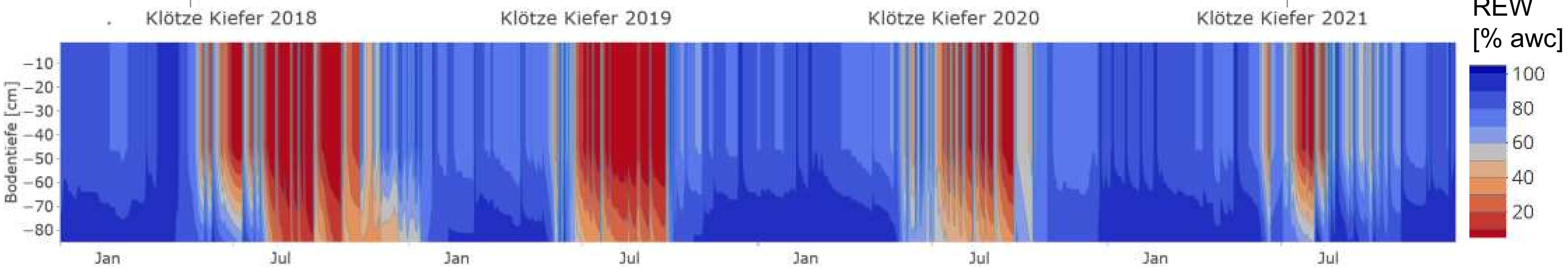
Soil water availability and radial increment



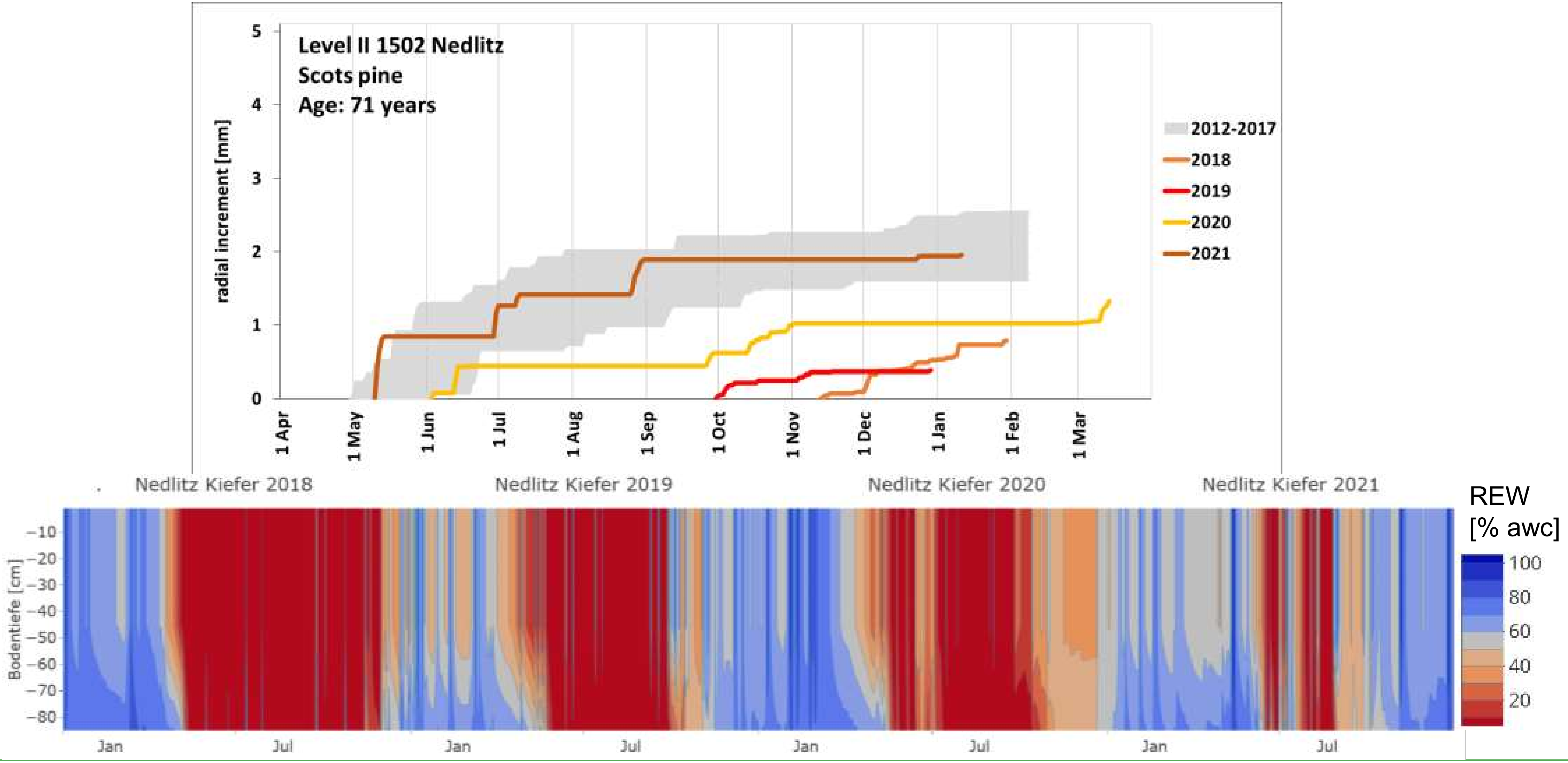


Soil water availability and radial increment

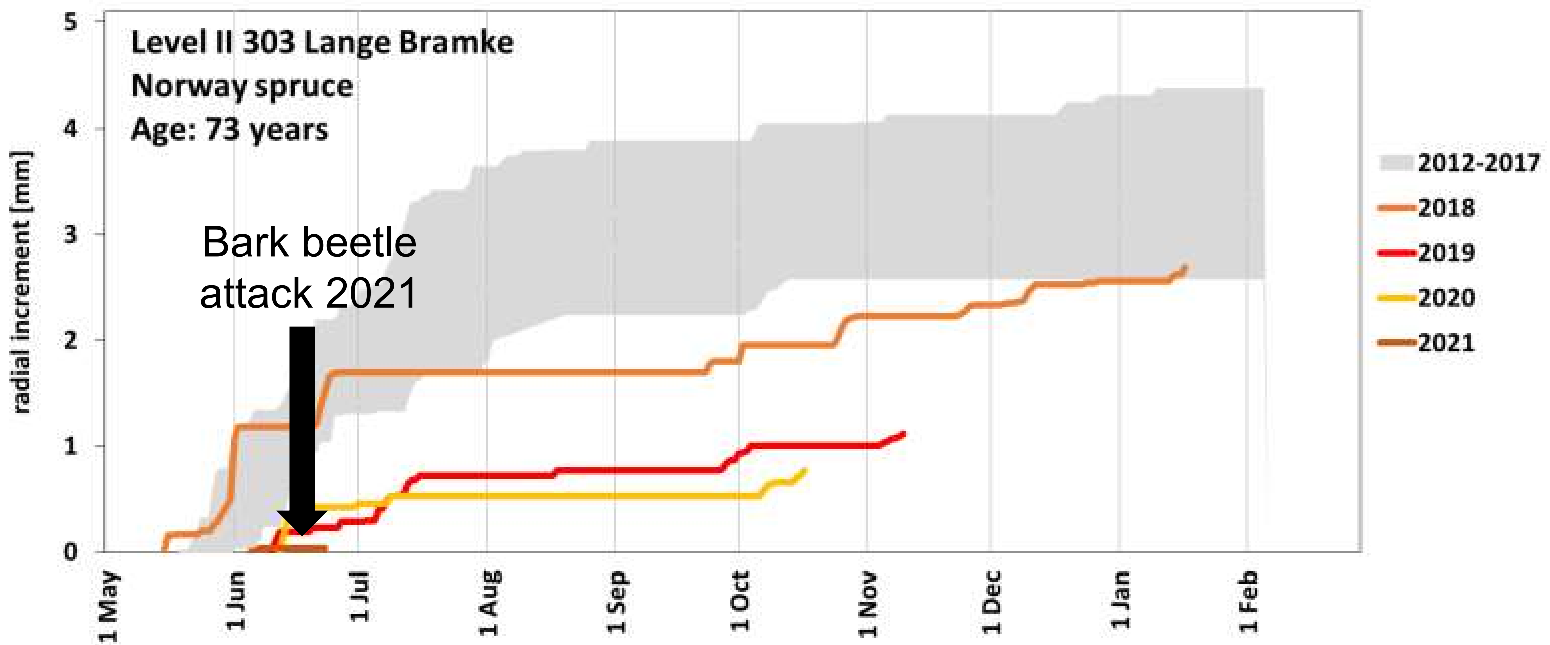


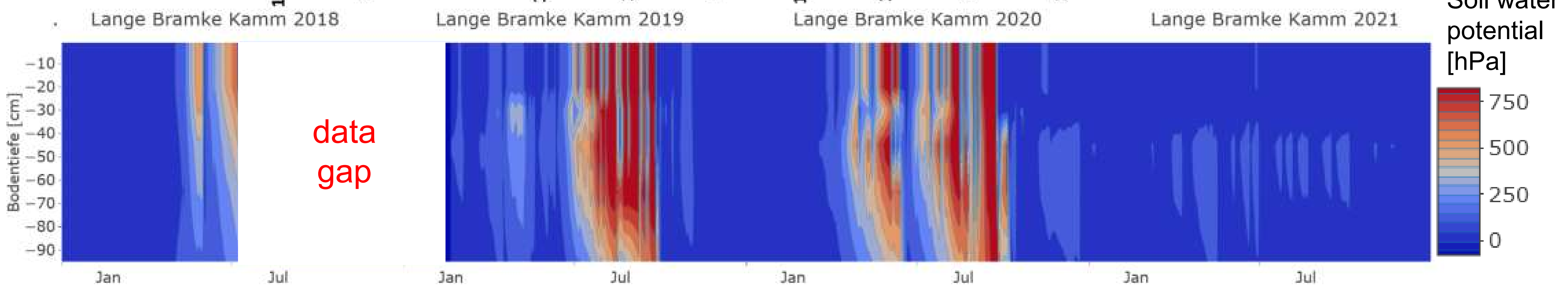


Soil water availability and radial increment



Soil water availability and radial increment





Interim conclusions

- very different pattern of growth response to soil drought
- very different resilience pattern of the observed forest stands
- isohydric vs anisohydric behaviour
- replenishment of soil water storage at begin of growing period appears to be important

Hydrologic modelling

- estimation of water fluxes at monitoring plots
- estimation of stress indicators (drought stress, oxygen deficiency)
- transfer to forest plots/areas without measurements
  - other monitoring plots (e.g. Level I, NFI)
  - forested landscapes
- ‚global' estimation of parameter values

Hydrologic modelling of intensive monitoring sites

Input data

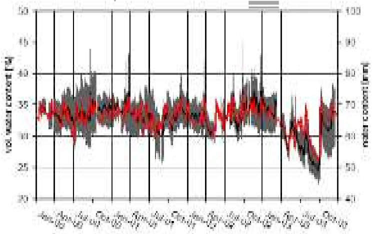
Climate
(daily, observed)

Stand information
(LAI, phenology, growth data, observed)

Soil information
(hydraulic functions, observed)

Methods

Hydrological modelling
(LWF-Brook90)



Calibration
throughfall, soil moisture

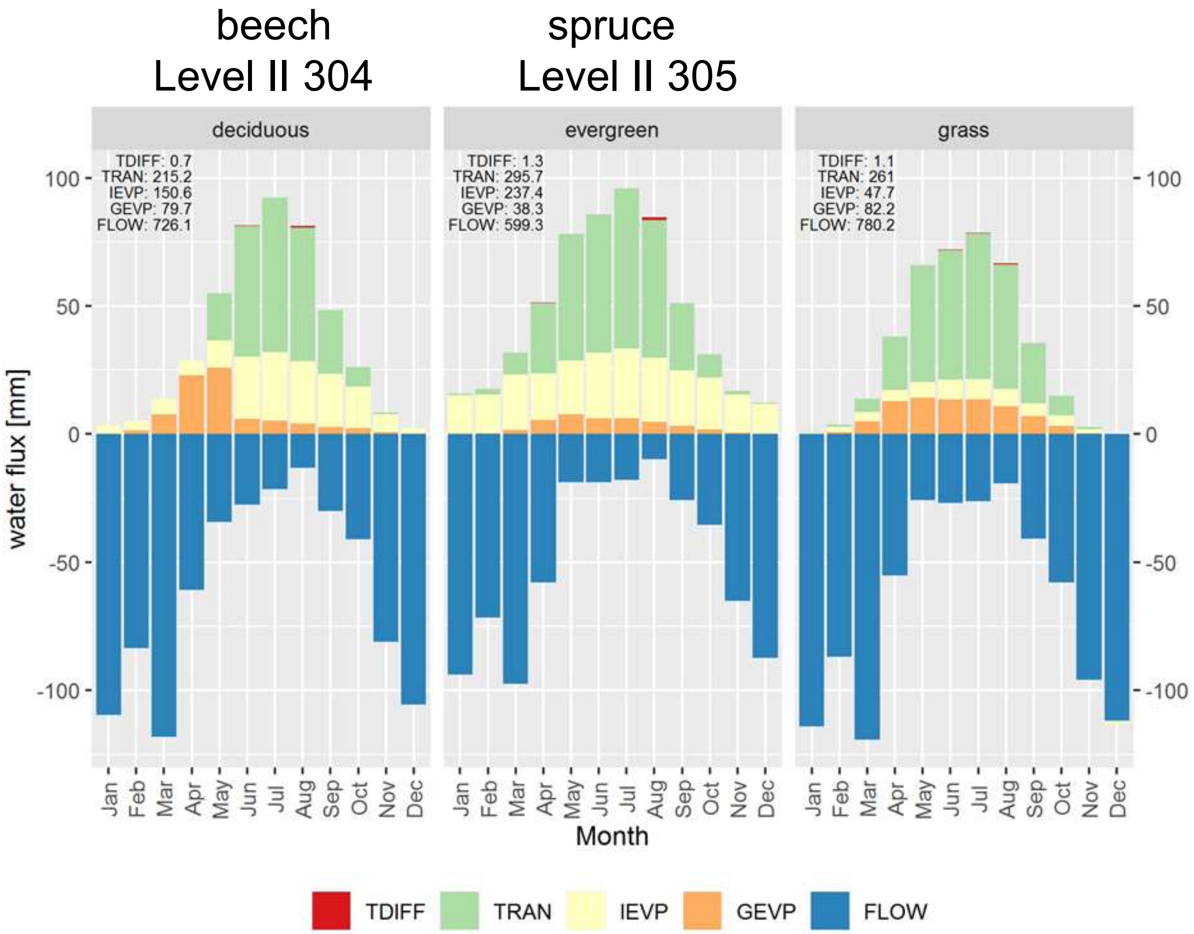
Output

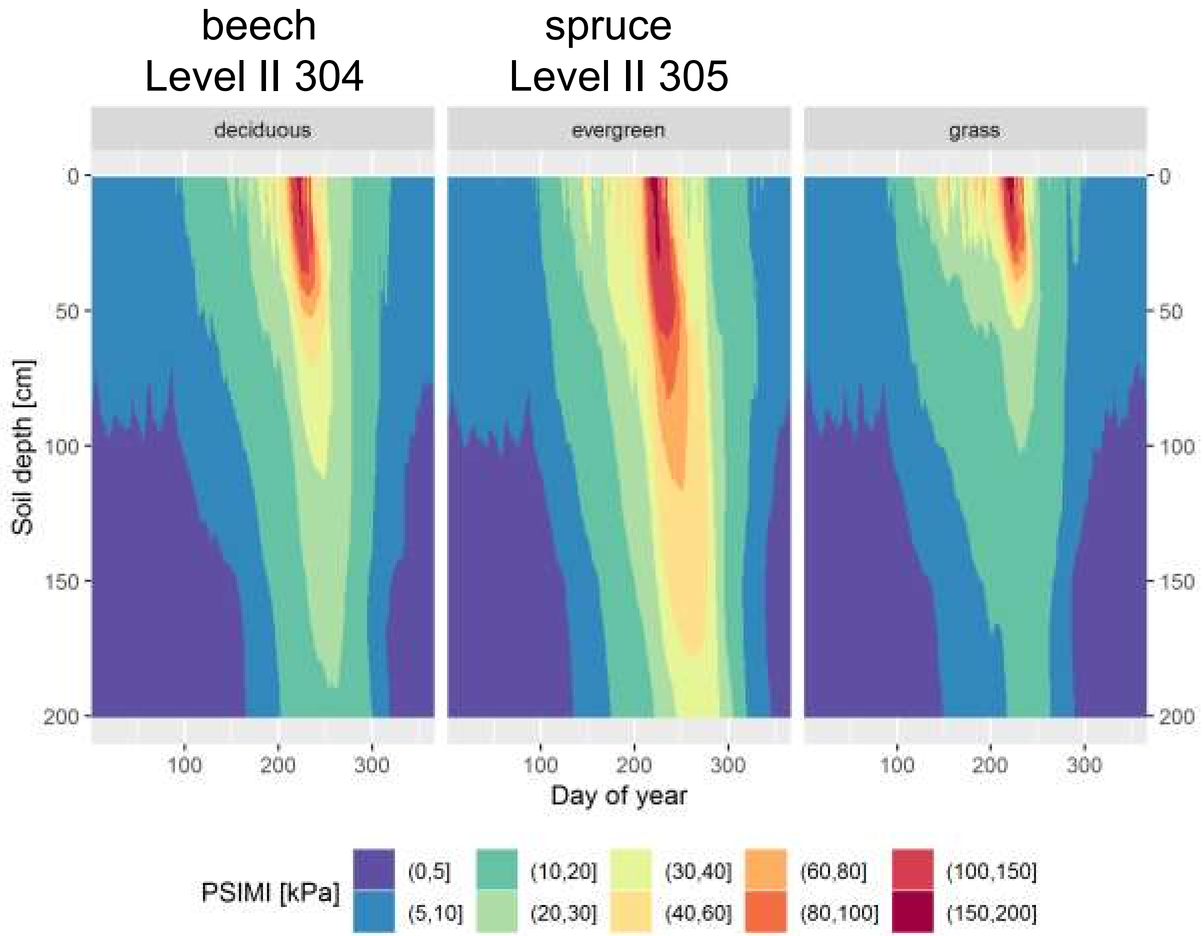
Soil water availability

Drought stress

Oxygen deficiency

estimation of water fluxes and stress indicators for monitoring plots

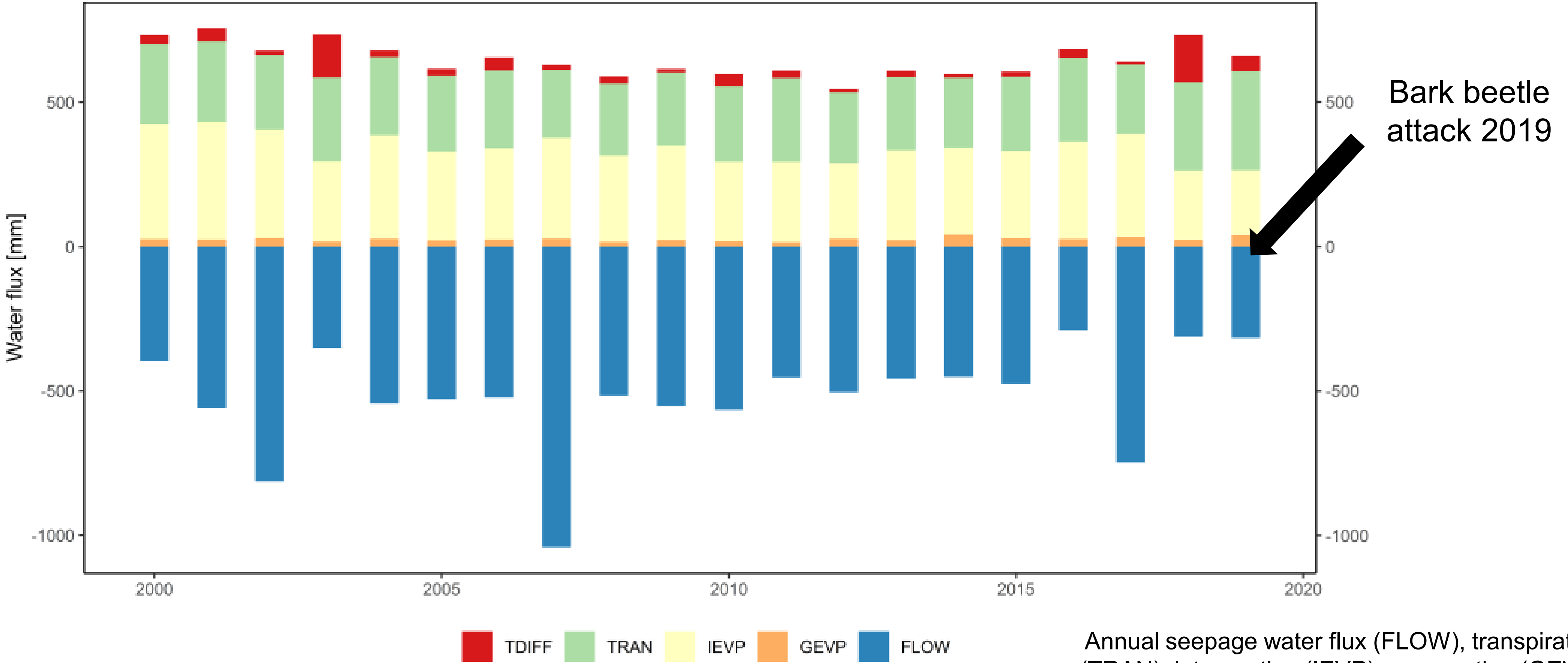




Mean monthly seepage water flux (FLOW), transpiration (TRAN), interception (IEVP), evaporation (GEVP), and transpiration deficit (TDIFF) at Solling for the period 1981-2010 (LWF-Brook90, Schmidt-Walter, pers. comm.)

estimation of water fluxes and stress indicators for monitoring plots

Level II 305 Solling Spruce



PREC	TDIFF	TRAN	IEVP	GEVP	FLOW
1143	38.8	269	314	26	-520

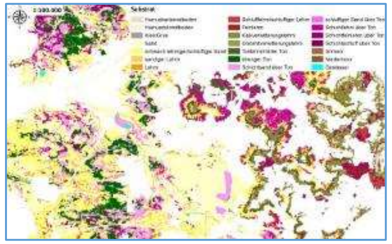
Annual seepage water flux (FLOW), transpiration (TRAN), interception (IEVP), evaporation (GEVP), and transpiration deficit (TDIFF) at Level II 305 Solling Spruce for the period 2000-2019 (LWF-Brook90, Schmidt-Walter, pers. comm.)

Hydrologic modelling of forest plots/areas without measurements

Input data

Climate
(daily, interpolated)

Site information
(regional systems)

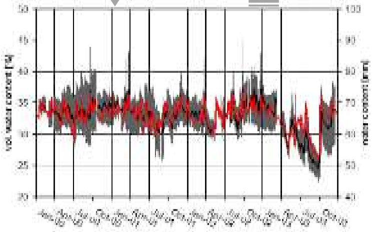


Soil information
(hydraulic functions, PTF)

Methods

Archetype stands
(main tree species, mixed stands)

Hydrological modelling
(LWF-Brook90)



Validation
Level II sites

Output

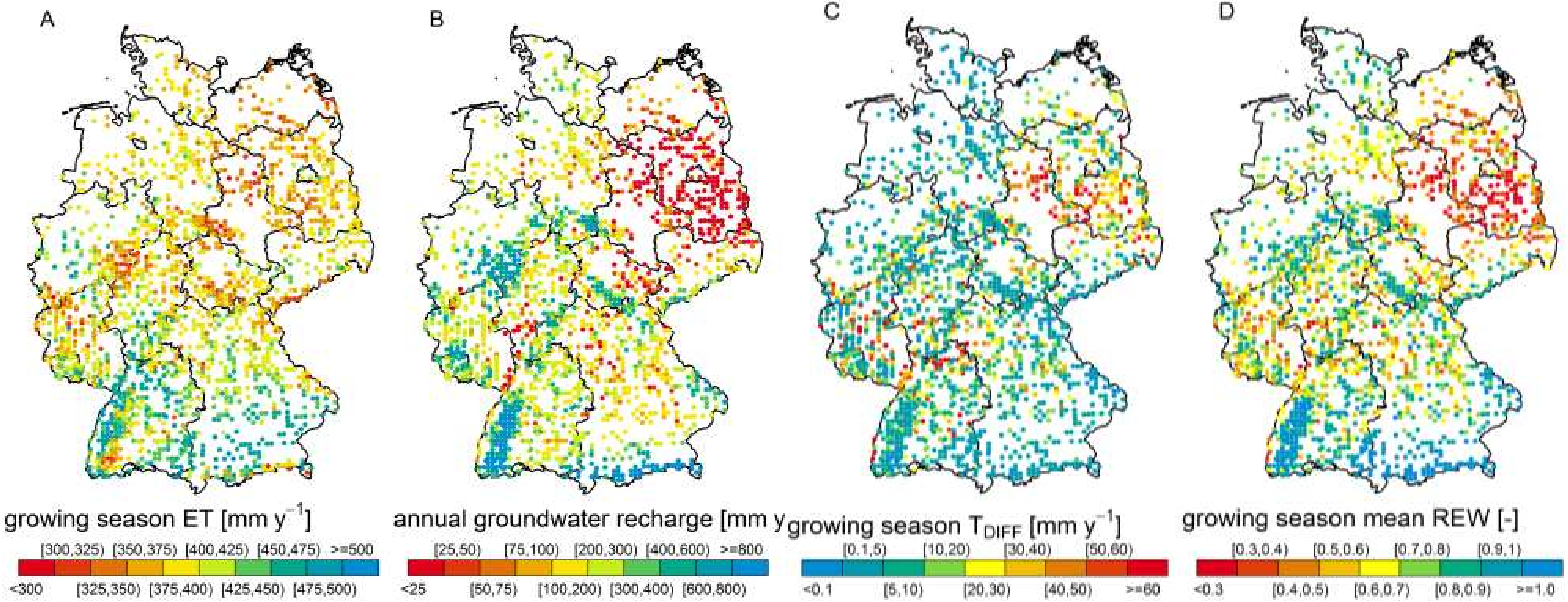
Soil water availability

Drought stress

Oxygen deficiency

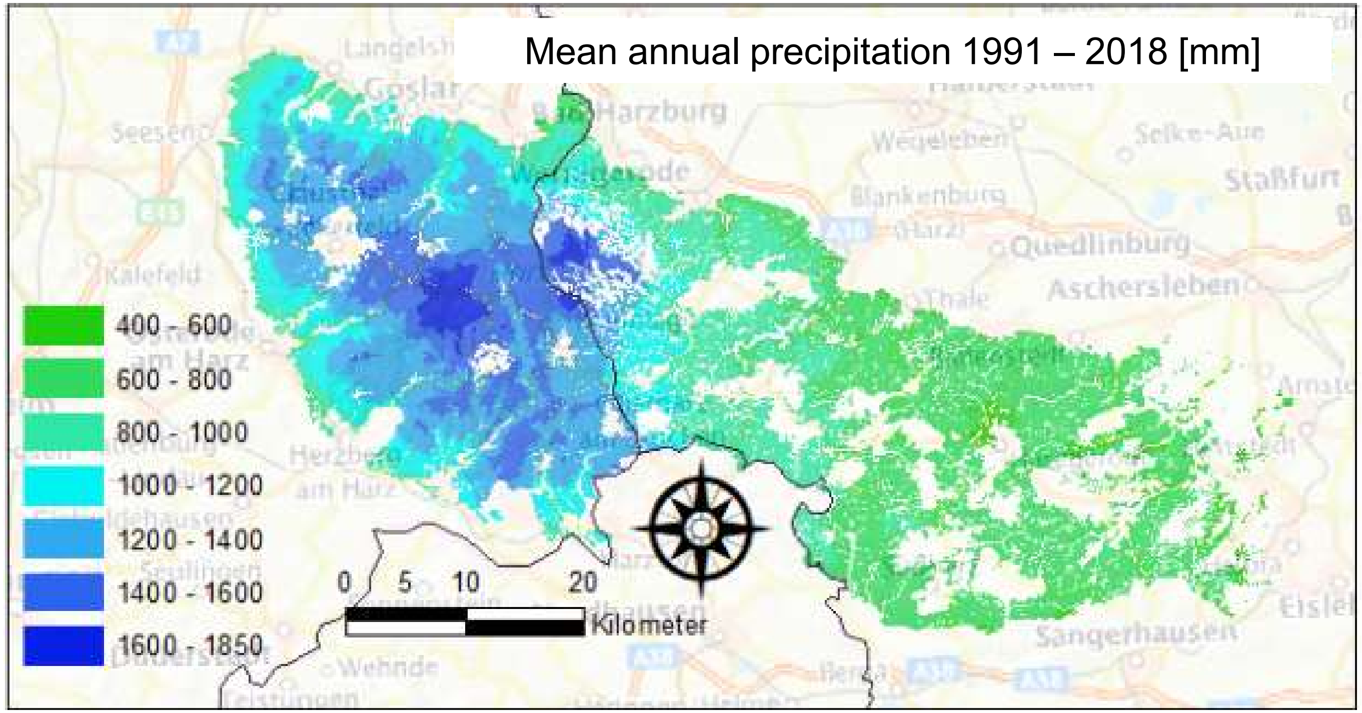
transfer to forest **plots** without measurements

Evapotranspiration | Groundwater recharge | Transpiration difference | Relative extractable water



Water budget components and drought indicators of NFSI plots in Germany
(Puhlmann et al. 2019)

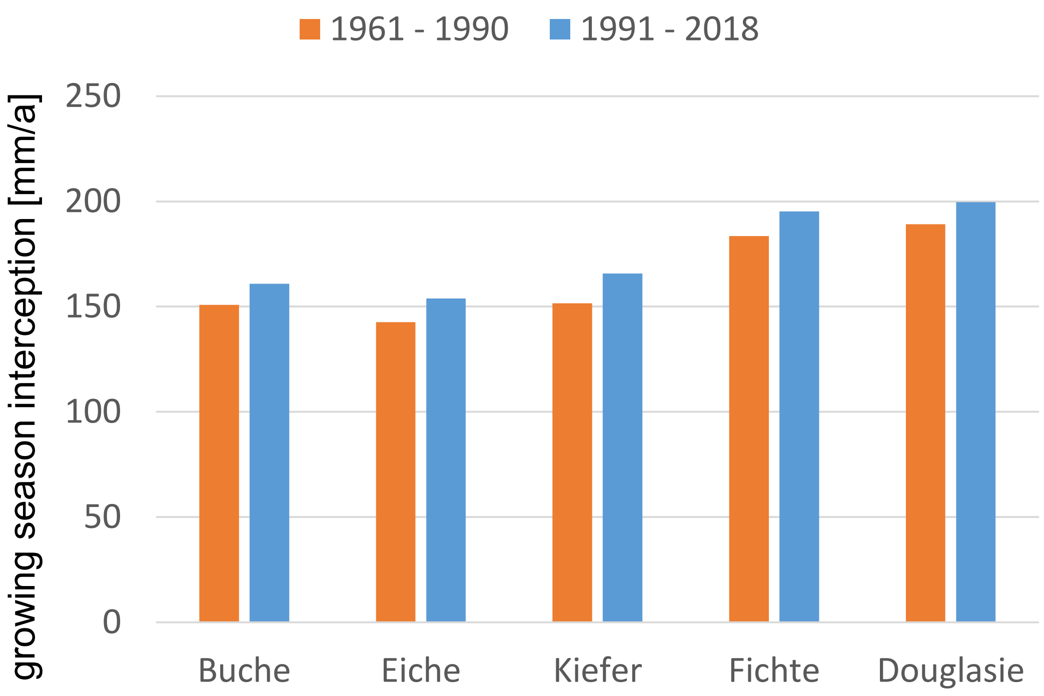
transfer to forest **areas** without measurements
Case study – Harz mountains

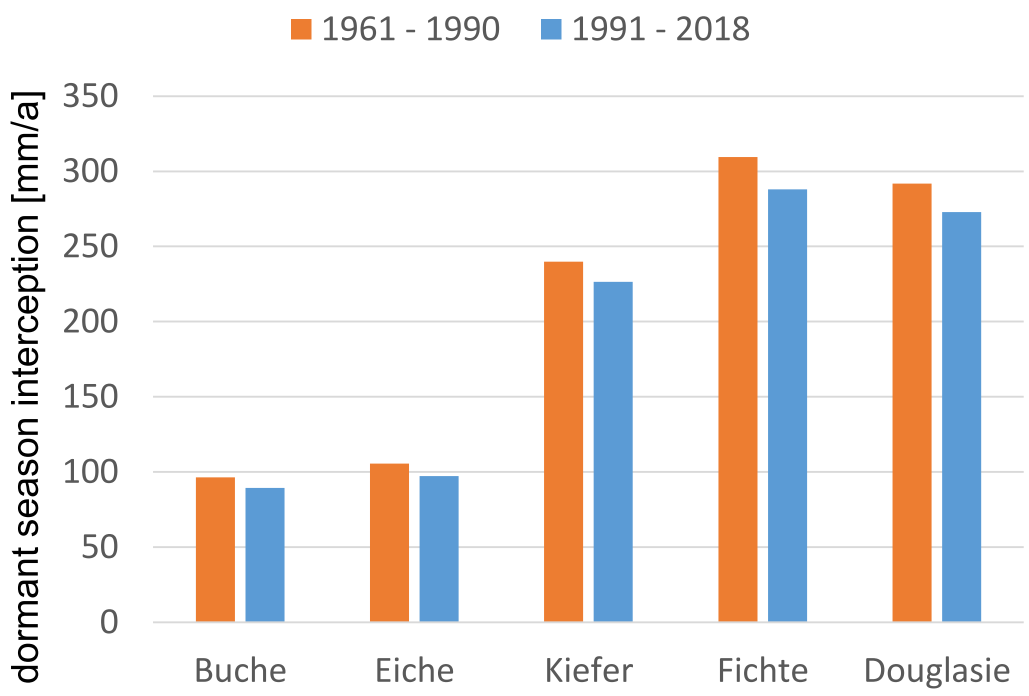


Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages

Gefördert durch:
Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz
aufgrund eines Beschlusses des Deutschen Bundestages

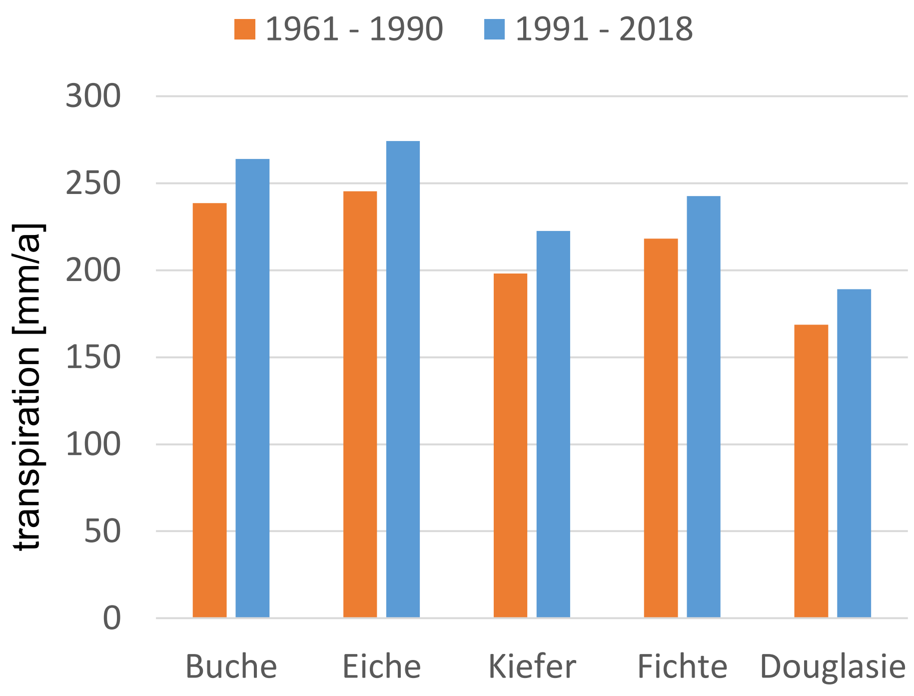
Harz mountains: growing and dormant season interception

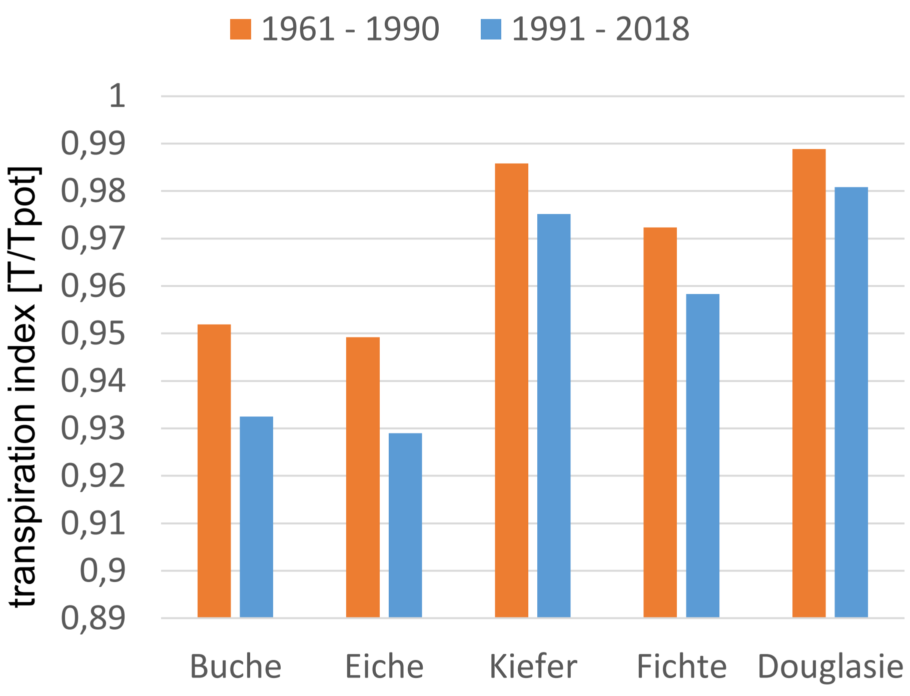




growing season (left) and dormant season (right) interception 1961-1990 and 1991-2020
for major tree species at the Harz mountains

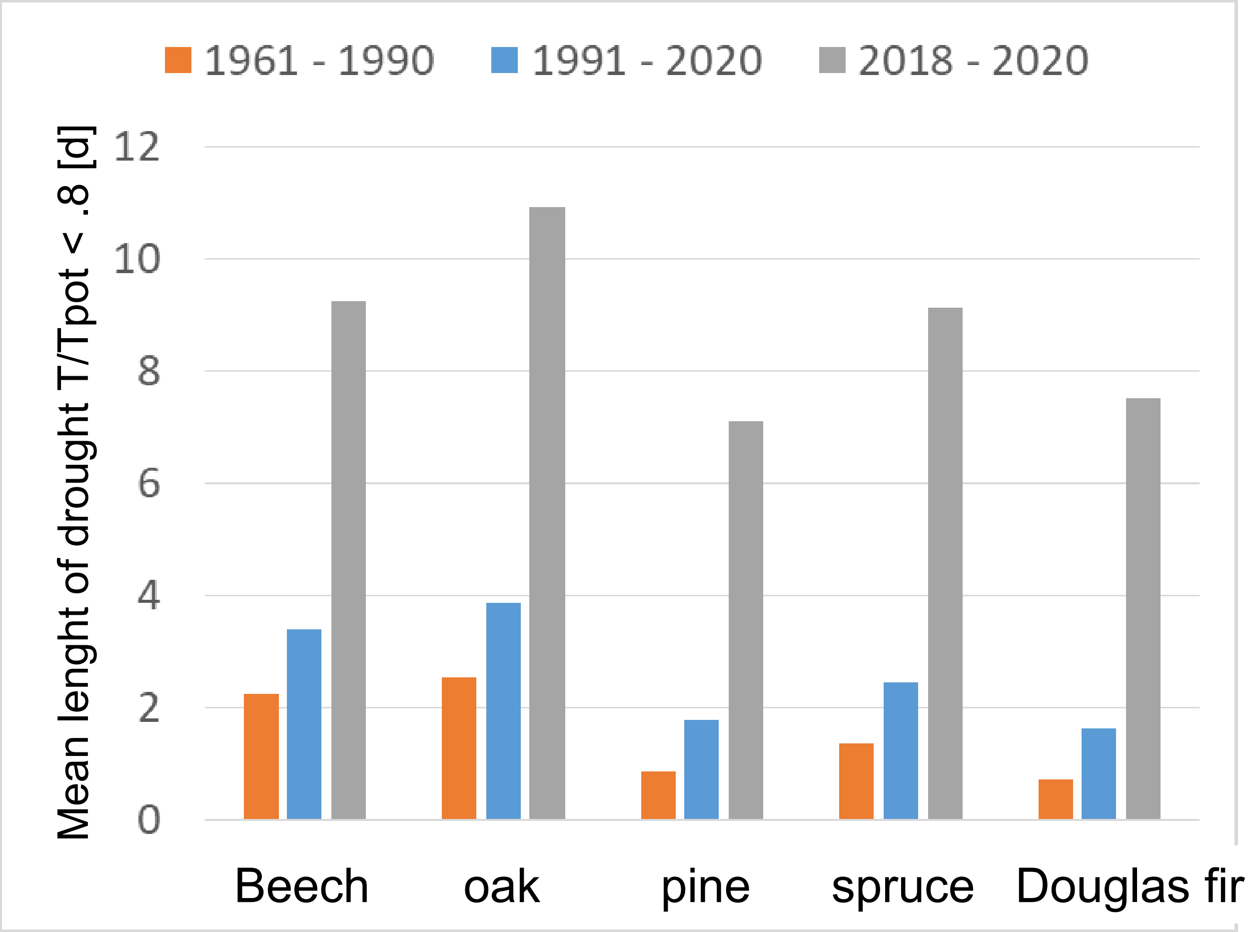
Harz mountains: transpiration and transpiration stress





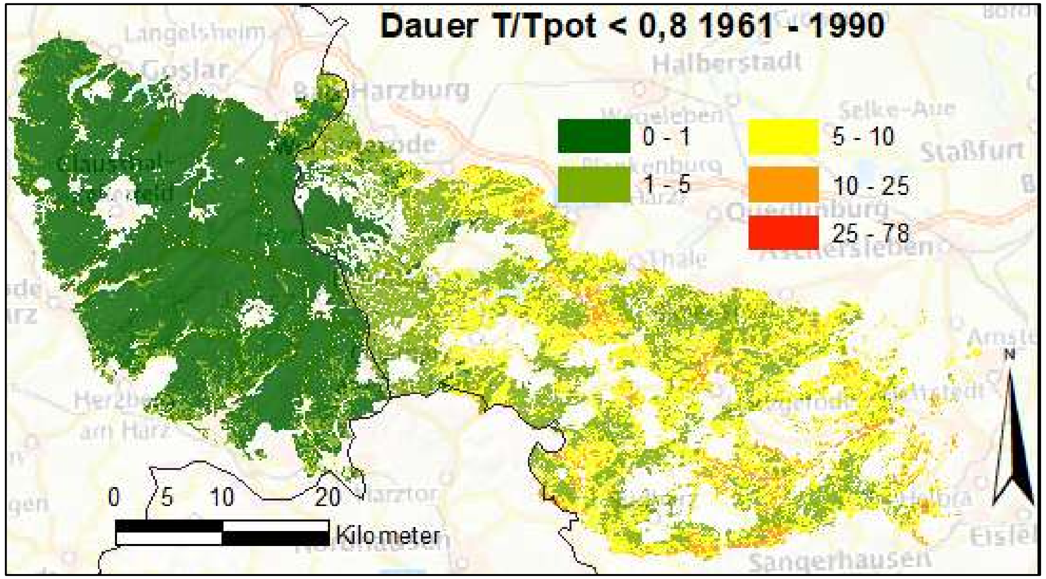
Transpiration (left) and transpiration index (right) 1961-1990 and 1991-2020 for major tree species at the Harz mountains

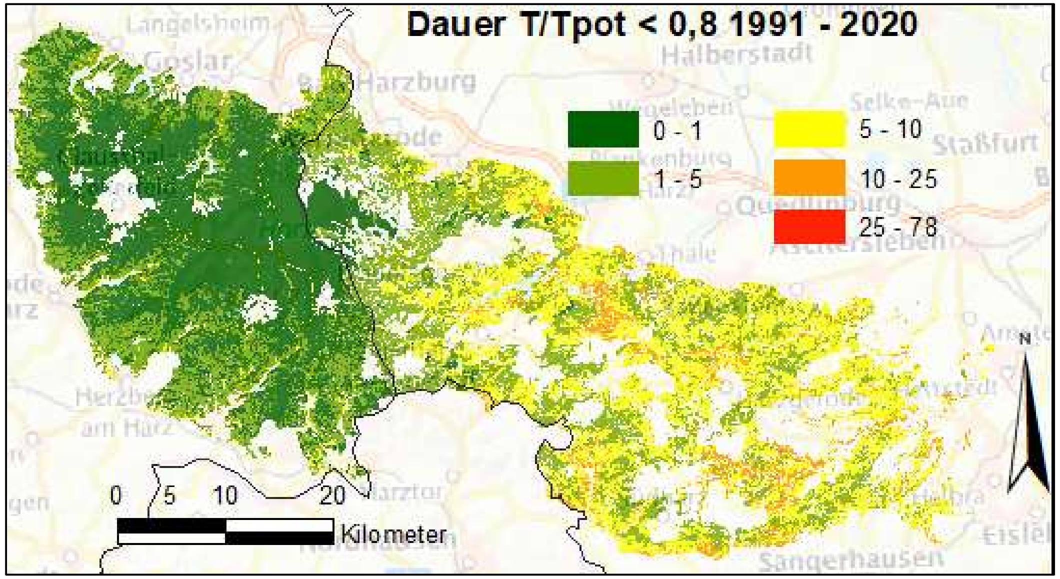
Harz mountains: Length of drought periods

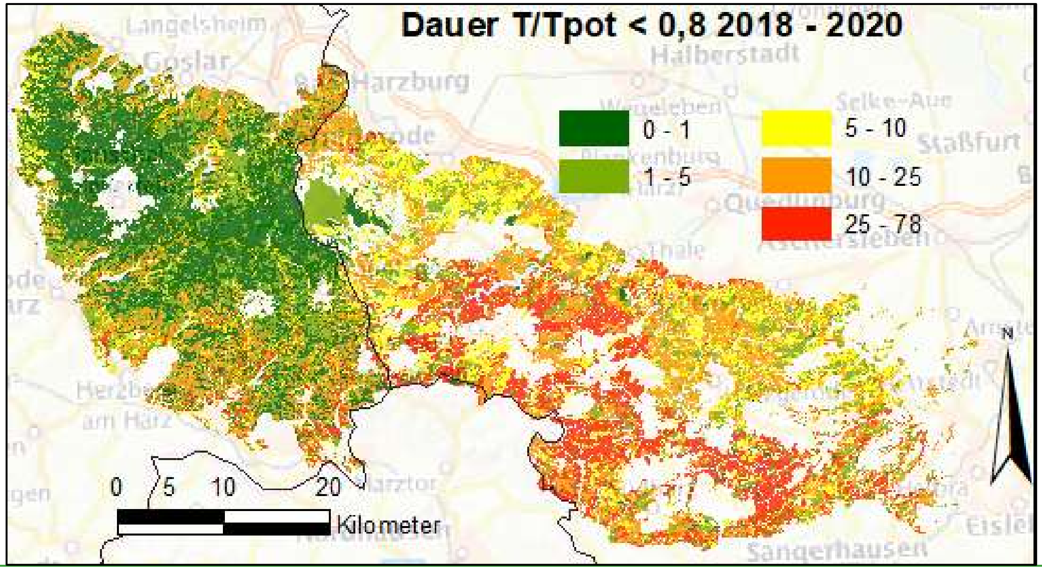


Length of drought periods (transpiration index < 0.8)

Harz mountains: spatial and temporal pattern of drought stress







‚global‘ estimation of parameter values
Parametrisation of interception

species specific interception parameters LWF-Brook90:

FRINTL: rain catchfraction of foliage
FRINTS: rain catchfraction of woody areas
CINTRL: rain storage capacity of foliage
CINTRS: rain storage capacity of woody areas

FSINTL: snow catchfraction of foliage
FSINTS: snow catchfraction of woody areas
CINTSL: snow storage capacity of foliage
CINTSS: snow storage capacity of woody areas

Constraints:
- **no wind during rain event**
- **negligible evapotranspiration during rain event**

372 A. J. RUTTER ET AL.

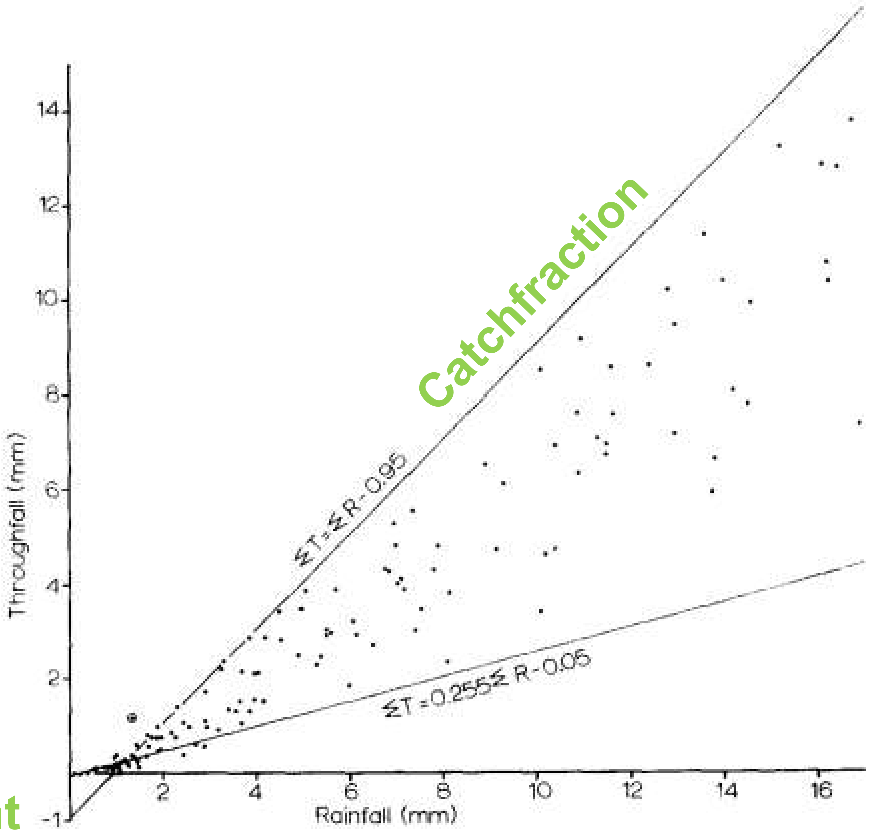


Fig.1. The relation of throughfall to rainfall, for approximate 24 hour periods, in a stand of Corsican pine. The ringed point was neglected.

Parametrisation of interception

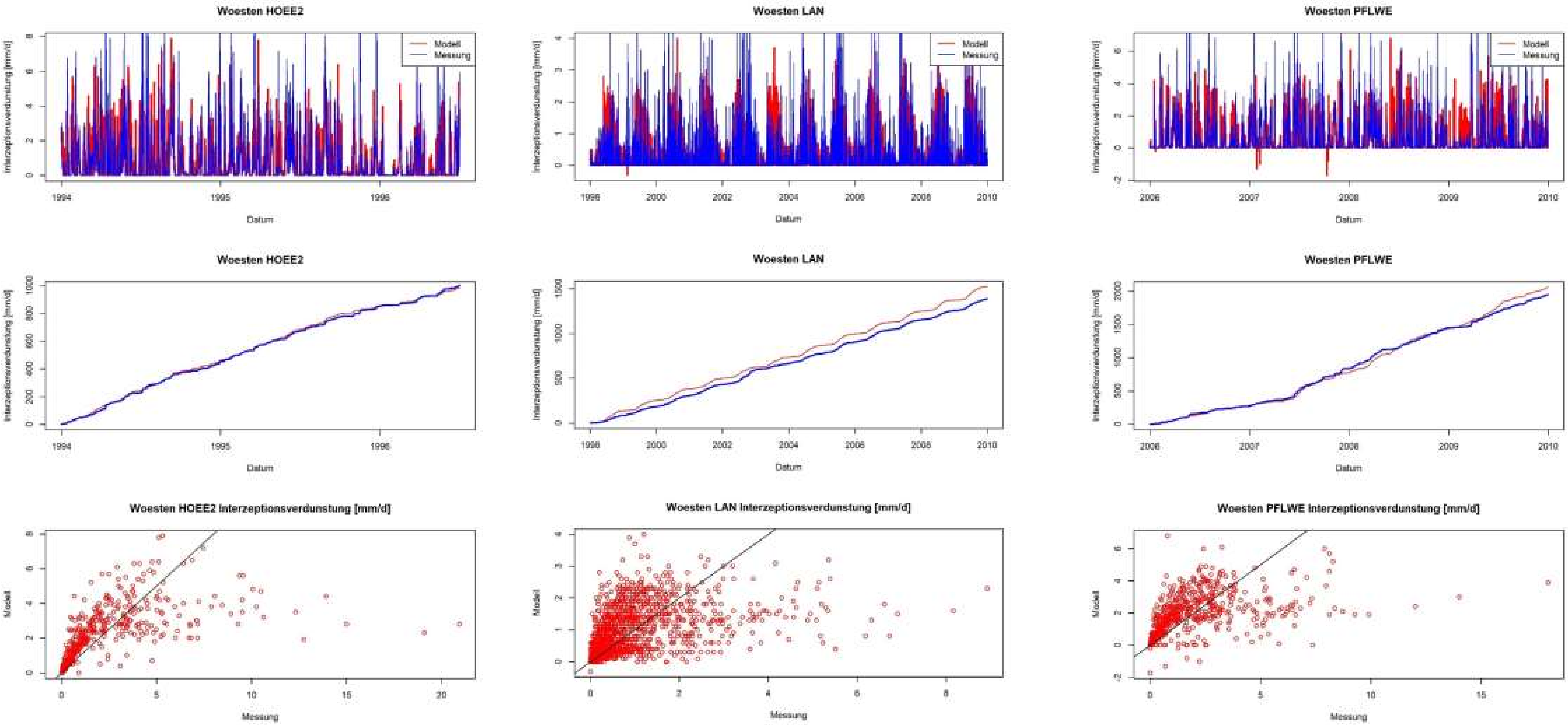
species specific interzeption parameters

Parameter	description	unit	European beech	Ped./Sess. oak	Norway spruce	Scots pine	Douglas fir*
N	Number of data years for parametrization	Data years	118	29	42	66	7
CINTRL	rain storage capacity of foliage	mm	0.6	0.7	0.4	1	0.4
CINTRS	rain storage capacity of woody areas	mm	0.5	1	0.2	1	0.2
CINTSL	snow storage capacity of foliage	mm	2.4	2.8	1.6	4	1.6
CINTSS	snow storage capacity of woody areas	mm	2	4	0.8	4	0.8
FRINTL	rain catchfraction of foliage	-	0.08	0.1	0.08	0.13	0.08
FRINTS	rain catchfraction of woody areas	-	0.08	0.1	0.08	0.13	0.08
FSINTL	snow catchfraction of foliage	-	0.08	0.1	0.08	0.13	0.08
FSINTS	snow catchfraction of woody areas	-	0.4	0.5	0.1	0.3	0.1

*only one stand

Parametrisation of interception

Validation



Conclusions

- Hydrological monitoring at intensive monitoring sites offers valuable information about ecosystem processes and risks to forest ecosystems
- The integration of observations of hydrological drivers and tree responses in monitoring programmes is particular important for the evaluation of ecosystem functioning
- The integration of hydrological modelling should be an essential component of environmental monitoring
- Both long-term changes and extreme events should be captured in monitoring programmes

Thank You for Your attention!

Gefördert durch:

Bundesministerium für Ernährung und Landwirtschaft

aufgrund eines Beschlusses des Deutschen Bundestages

Gefördert durch:

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz

aufgrund eines Beschlusses des Deutschen Bundestages