Forest Management and its Impact upon Hydrological Processes and Water Quality

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Contents of this Presentation

- Brief look at the history of forest hydrology
- Water cycle in forest ecosystems; What is so special? ClimChg
- Forest management and its impact on water quantity and hydrological processes
- Case studies:
  - Species effects – Interception in canopy and litter layer; stemflow, rooting depth & water extraction and recharge
  - Harvesting and forest roads
- Summarizing effects

Contents of this presentation (Continued)

- Effects upon water quality, some general considerations and site and soil relations
- Case studies:
  - Species selection and acidification
  - Fertilizer, inputs, harvesting and clearcutting
  - Insect and pest outbreaks
- Concluding remarks

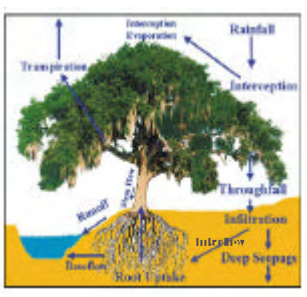
Forest hydrolgy has more than 100 years history

- At the cradle were great names
- like Ebermayer, Hoppe, Schubert
- but the greatest impacthad
- Englers research

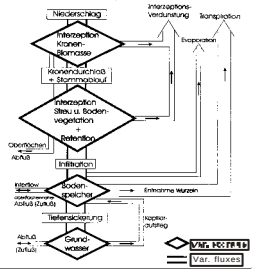
History of Forest Hydrology

- After these pioneer days of research on forest infuences upon the water cycle
- A rich harvest of research results has been produced
  - Look at tree species & treatment effects, paired watersheds
  - Harvesting water from forested watersheds for urban&agric. use, and managment for these goals
  - Enhancing retention effects and mitigating flood risk
  - Modelling the hydrological processes from slope and stand scales to watershed and landscape scales
  - Linking water and nutrient cycles, biogeochemistry & considering environmental change

Water cycle in forest ecosystems



Hydrolgical process model for a forest ecosystem



Water cycle in forest ecosystems (contd.)

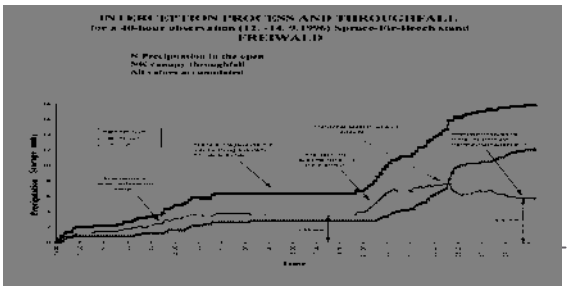
- Global change may influence **Input P** as well as **Output ET** =f(T, u, LAI, WUE)
- From **compartments** of forest ecosystems up to the **whole ecosystem** or farther up in scale to a **forested landscape or watershed** the principle of conservation of matter or **law of continuety** can be applied to calculate **water balance equations**
- **In the simplest form this WATER BALANCE Equation will read:**

  Input = Output +/- ∆ Storage

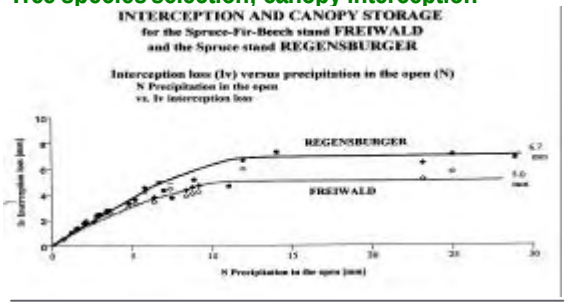
  or P = D +/- ∆S
- Looking at the **hydrological process model** of forest ecosystems one can easily identify that **forest managment** is either **influencing** the **storage capacities** or the **magnitude of flux transfers** → **some case studies**

Case: Tree species selection

- **Canopy interception storage and interception loss**

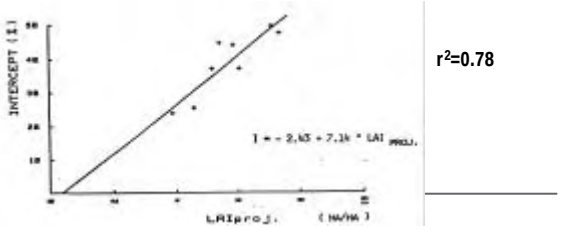


Tree species selection; canopy interception



Tree species selection and canopy interception

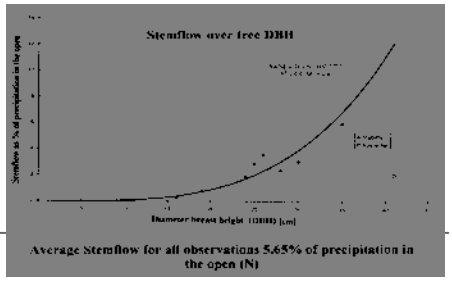
- **Canopy interception loss dependent upon meteorological conditions e.g. precip. rate & kind of precip., temperature, wind but also dependent upon tree species and function of LAI**



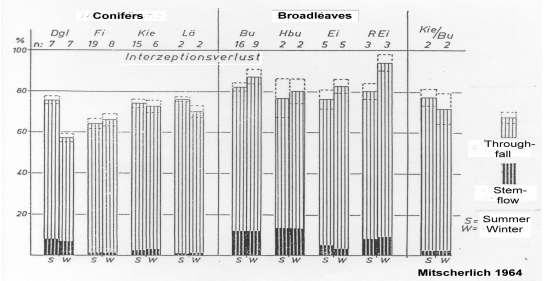
r^2=0.78

Tree species: Stemflow in forest ecosystems

- **Canopy architecture e.g. branching pattern and bark of the bole are decisive for stem flow or not**
- **Beech**
- **Fagus silv.**
- **Stem flow**



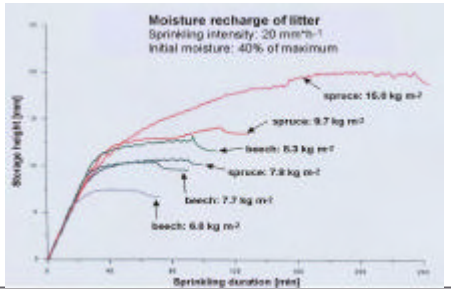
Species effects: Interception, Stemflow Throughfall



Species effects: Interception, Stemflow, Throughfall

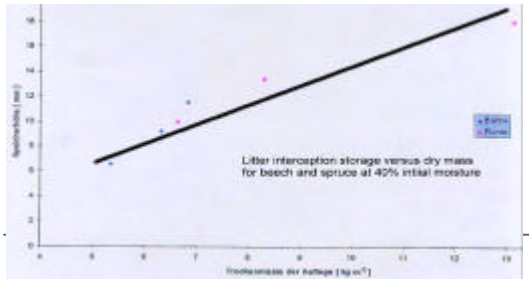
- Interception loss:
  - f(LAI e.g. 0.2mm*LAI; Guo, 2003), summer more than winter; decidous trees
  - conifer (15-40%) more than broadleaves (5-20%);
  - tolerant species more than intolerants
- Stem flow:
  - crown architecture; centripetals vs. centrifugals
  - smooth bark
- Throughfall pattern: spatial variabilty dependent on interception and stem flow

Species effects: litter interception



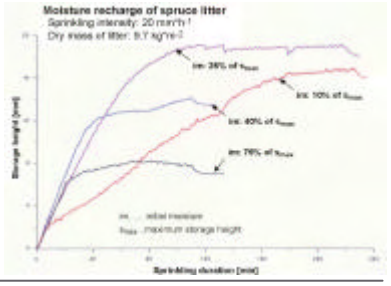
Tree species effects: litter interception

- Tree species produce different quality and amounts of litter and show different turnover rates e.g. humification



Tree species effects: Litter interception

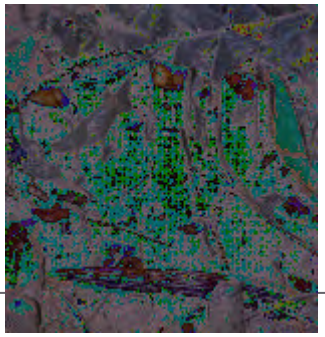
- Moist litter = linear storage
- Extrem dry litter shows hysteresis



Species effects: Litter interception and Infiltration

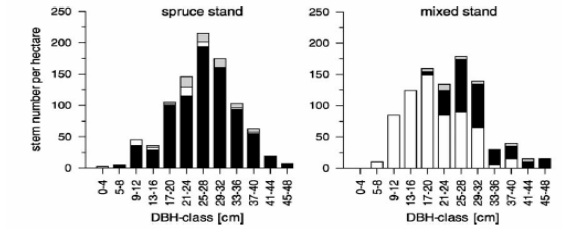
- Litter production and turnover, degradability and humification determine the amount of water held back
- Int_{Litter}= f (DM) e.g. pure spruce 26% P_o vs conifer-broadleave mix 23%P_o
- Periodically extremly dry environments delay humification, induce litter hysteresis against rewetting, may hamper infiltration and induce surface runoff → "straw or reed roof effect"
- BUT also rapid turnover and active humus forms..... may??

Caveat!! Rapid litter turnover in heavy rainfall climate



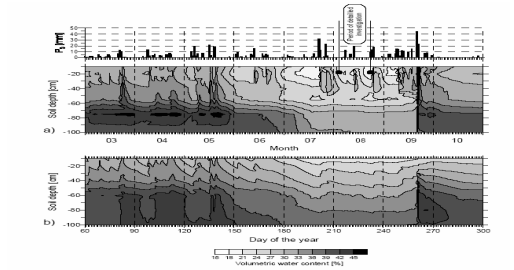
Species effects Water extraction, ET, recharge

Spruce stand 96%, others 4%; LAI =7.1; rooting depth to 60cm
Mixed 78% Fagus; conifers 22% LAI =7.3; rooting depth +90cm
open bar= beech, dark bar =spruce



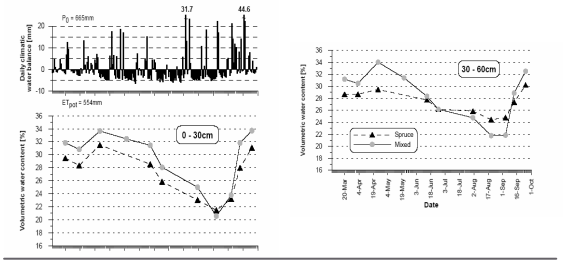
Species effects Water extraction, ET, recharge

mixed stand a) and spruce stand b); year 2001



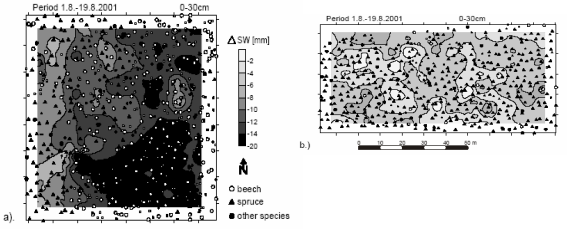
Species effects: Water extraction, ET, & recharge

shallow rooting spruce vs. deeper rooting beech



Species effects: water extraction; ET, recharge

Conifer b) higher WUE than mixed broadleaves a); ETmax=2.9 vs 4.1mm/d for 20 day period spruce used 33.2mm, mixed beech 53.6 mm of SW

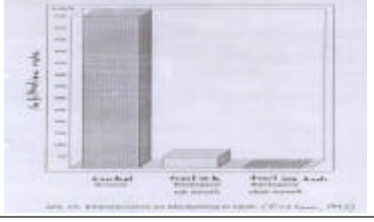


Species effects upon hydrological processes

- **Broadleaves decidous**
  - Less interception loss
  - Lower litter interception, less oDM, better humus
  - Better infiltration
  - Lower WUE, higher T but shorter duration
  - Very often total consumptive water use higher than in conifers
- **Conifers evergreen**
  - Higher interception loss
  - Higher litter interception, higher oDM, humus moder or mor
  - Lower infiltration
  - Higher WUE, less T but longer duration

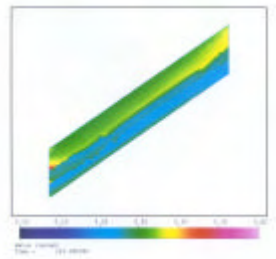
Other forest managment effects: Thinning and harvesting → decrease in interception and water use

- But soil compaction and loss of infiltration capacity (e.g. from 650mm/h to 50 and to 0 mm/h) and increased surface runoff



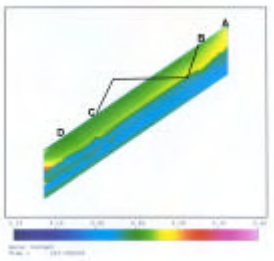
Other forest managment effects: forest roads on slopes

- Slope hydrology after rain

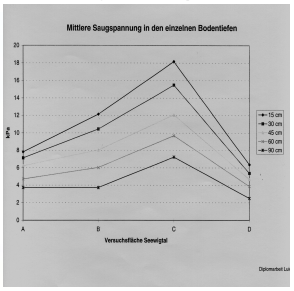


Other forest managment effects: forest roads on slopes

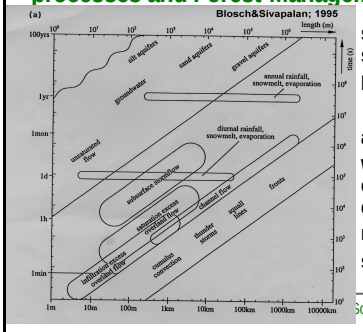
Slope hydrology and a forest road cut



Average Suction potential



Spatial and temporal scale of hydrological processes and Forest Management



surface processes faster than subsurface processes

km/h or m/s vs. m/d or km/yr

all managment measures:

which eliminate storage in the cascade of water through the ecosystem or which

route water to the surface

speed up discharge

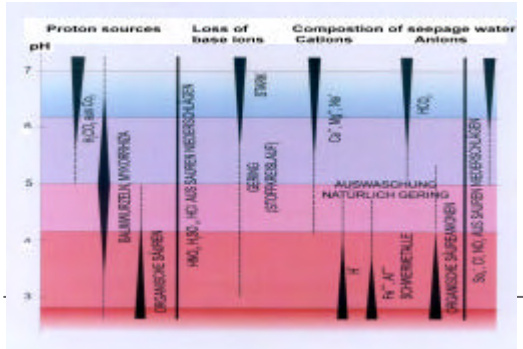
Forest Management and Water Quality

Water Quality: physical, chemical & biological status of H2O

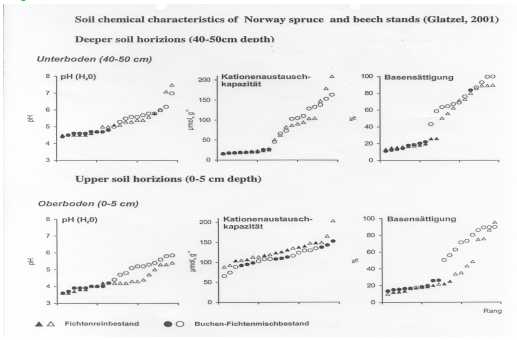
Will not treat: phys&biol WQ: like suspended solids and well known effects of harvesting and roading operations...counter measure BMPs

Main focus: dissolved chemical loads and managmt aspects

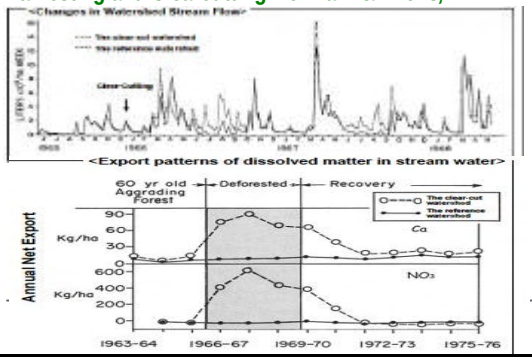
General considerations: Soils and chemical loads



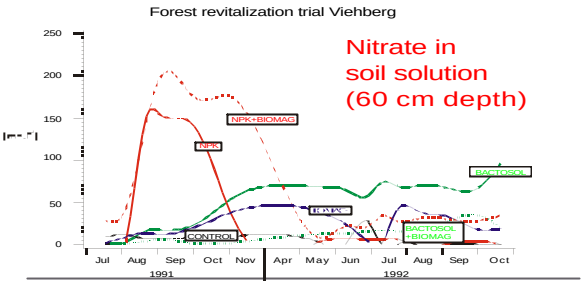
Species selection: conversion to conifers→ acidif.



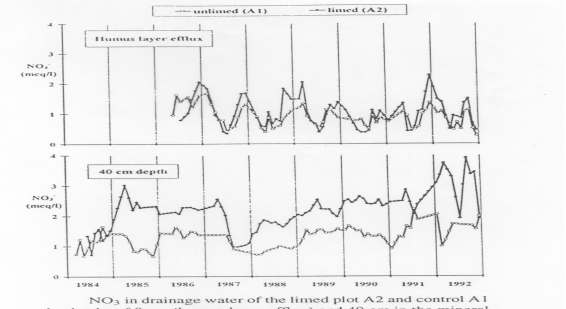
Harvesting and Clearcutting:Bormann&Likens; HBEF



Fertilizer treatments

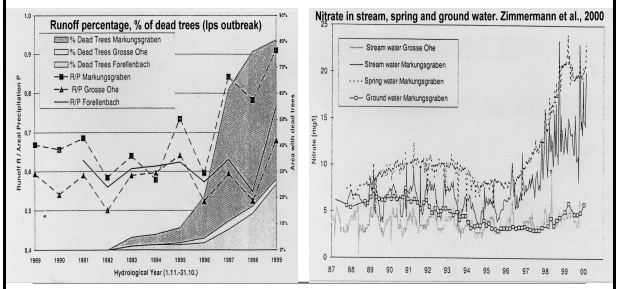


Lime application



NO_3 in drainage water of the limed plot A2 and control A1 at the depths of 0 cm (humus layer efflux) and 40 cm in the mineral soil, below the main root zone in the space between the trees.

Ecosystem processes: pest outbreak



Ecosystem processes: nitrogen fixing tree species

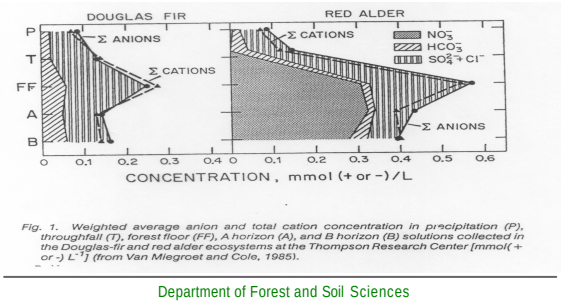
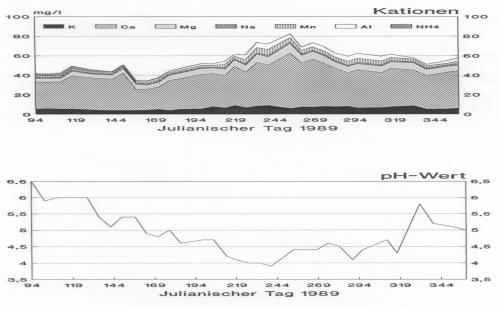


Fig. 1. Weighted average anion and total cation concentration in precipitation (P), throughfall (T), forest floor (FF), A horizon (A), and B horizon (B) solutions collected in the Douglas-fir and red alder ecosystems at the Thompson Research Center [mmol(+ or -) L^{-1}] (from Van Miegroet and Cole, 1985).

Ecosystem processes: Break down of groundvegetation

Allium ursinum dynamic in European beech forest; Jandl,1992



Water quality: chemical load

- Tree species selection, especially conifers → acidification >>load
- Acidogenic atmospheric input >> also chemical loads
- N-fixing tree species similar to N-input from atmosphere
- Mobilizing compartments in the forest ecosystem >>chem. Load
  - e.g. fertilizing, limeing, pest outbreak, die back
  - loosing rooting depth (Kreutzer et al. 1986, conversion)
  - Clearcutting or slash & burn
- Climatic caused nitrification bursts (Matzner, 1993)

Species effects: Water extraction, ET, & recharge