Increasing Importance of Forest Hydrology in a Changing Climate for Forest and Water Management

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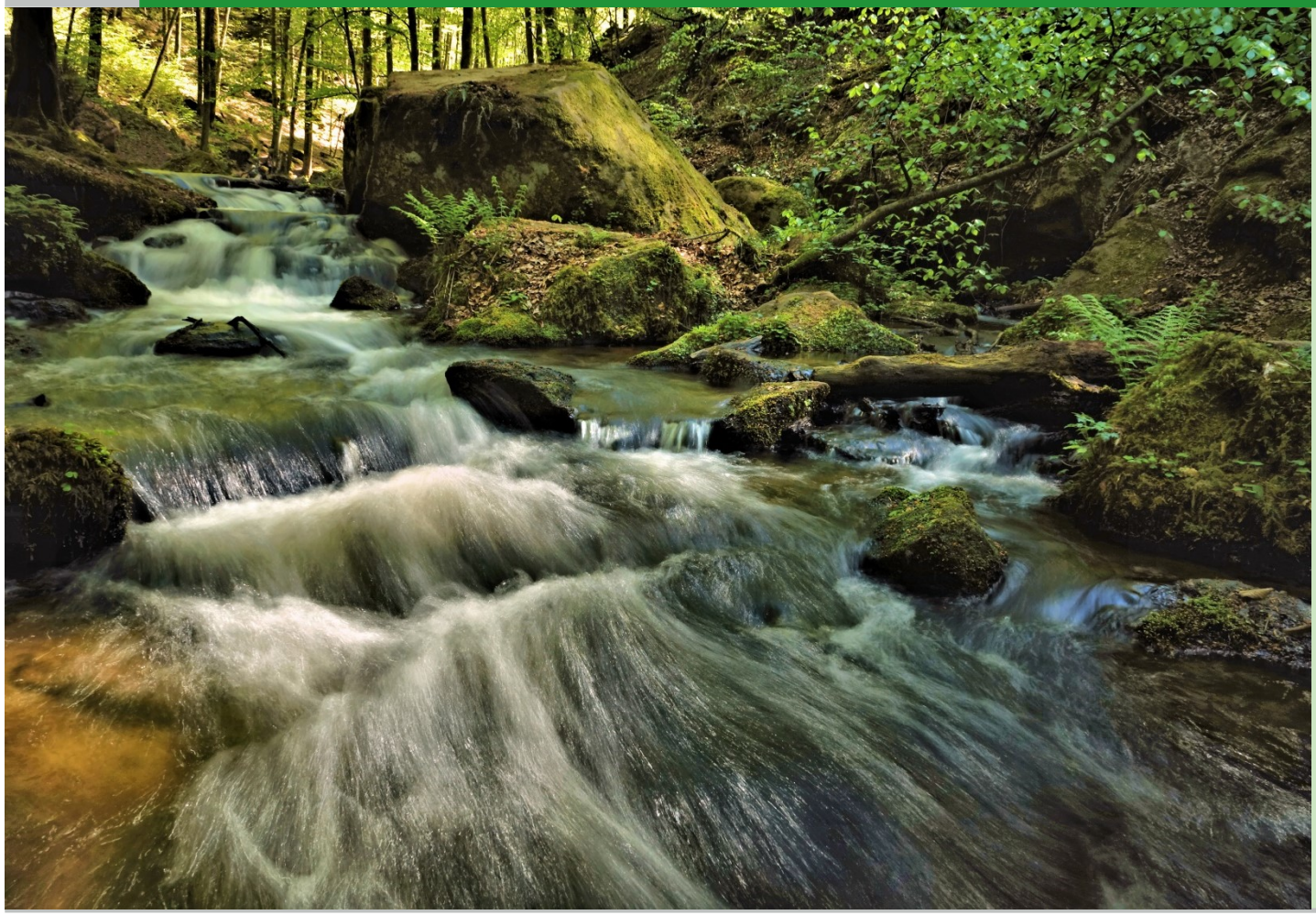

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Capacity Building Workshop Forest Management and Water Regulation
Global Water Partnership – Mediterranean (GWP-Med)
16th – 17th December 2020

Landesforsten
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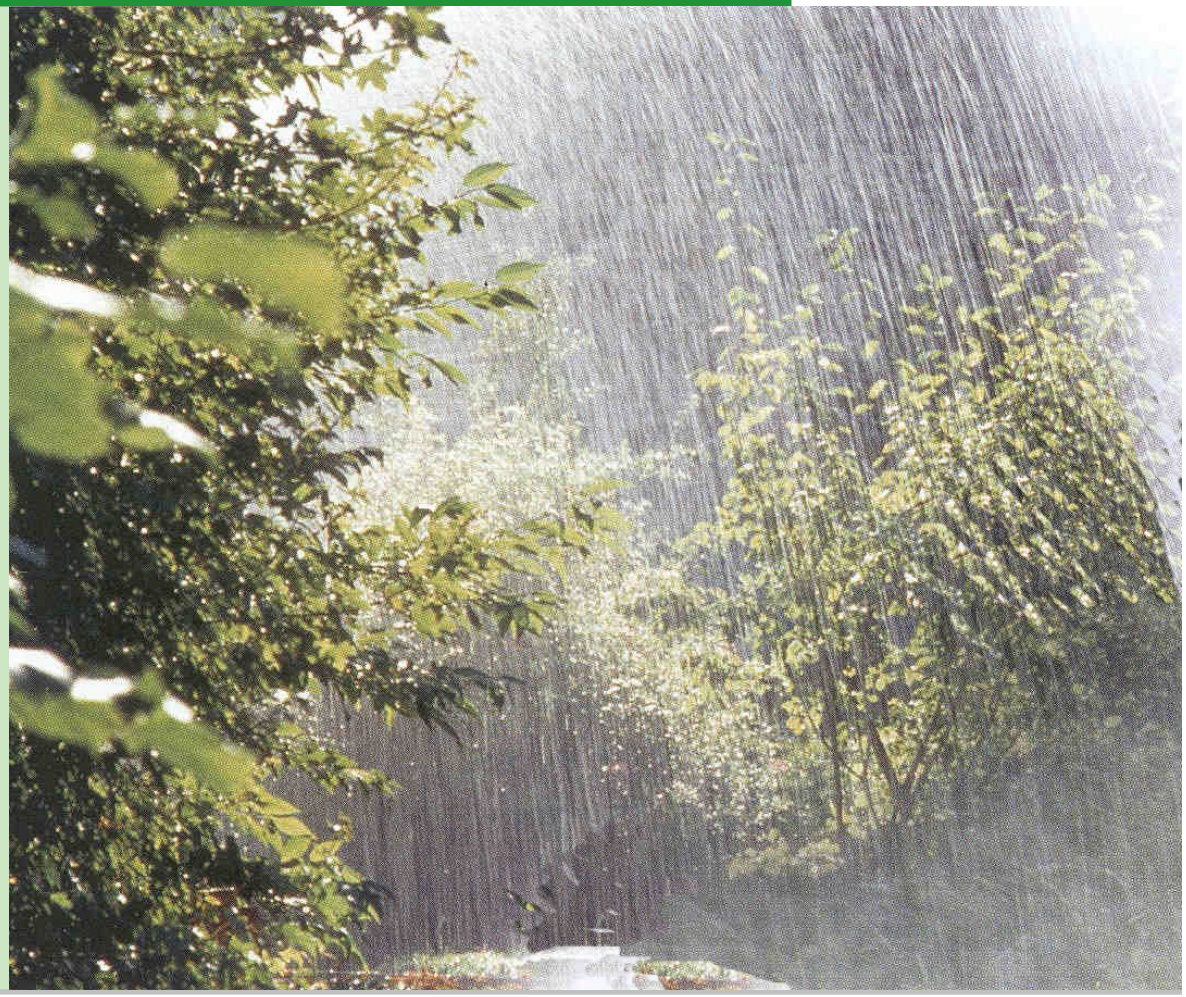
Outline

- Forest Hydrology
- Landuse Management
- Ecosystem Services
- Climate Change
- Providing Drinking and Process Water
- Drought – Risk of Forest Health and Vitality
- Risk Mitigation for Flood and Flashflood Generation and Precautionary Water Retention

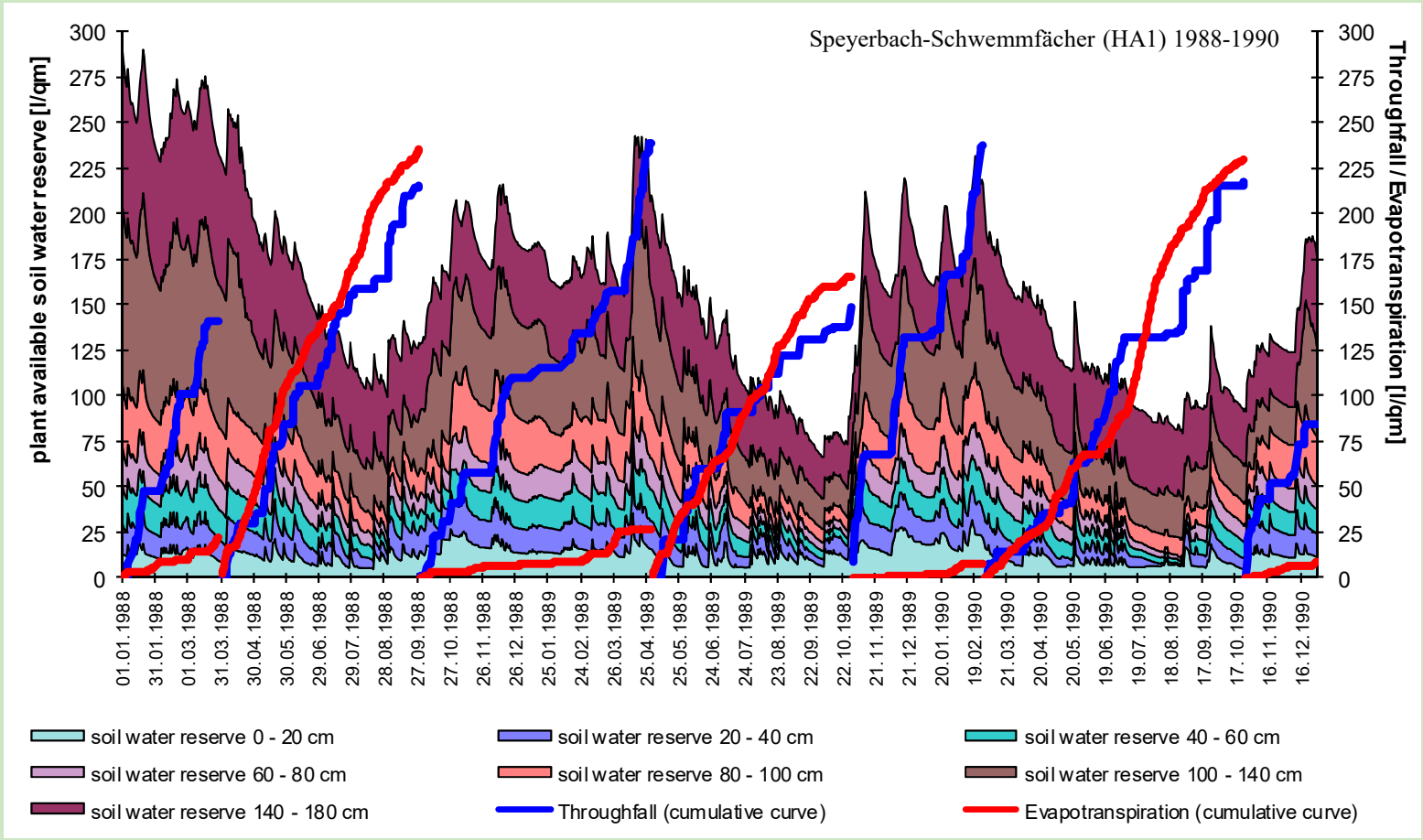
Forest Hydrology

Forest hydrology deals with the water balance of forests and natural woodlands (landscape water balance), in particular, precipitation in and outside of forests (rainfall, snow, mist, interception, throughfall) evapotranspiration, groundwater recharge, runoff behavior (runoff, runoff process) in dependency on forest types (tree species composition, stand type, stand age) and forest management measures. The investigation of the effects of recent forest damage on the water balance has gained special

http://www.geodz.com/deu/d/Forsthydrologie



Soil Water Reserve in Forests depends upon Precipitation and Evapotranspiration



Schüler 1999

Groundwater Recharge depends upon Precipitation and Evapotranspiration

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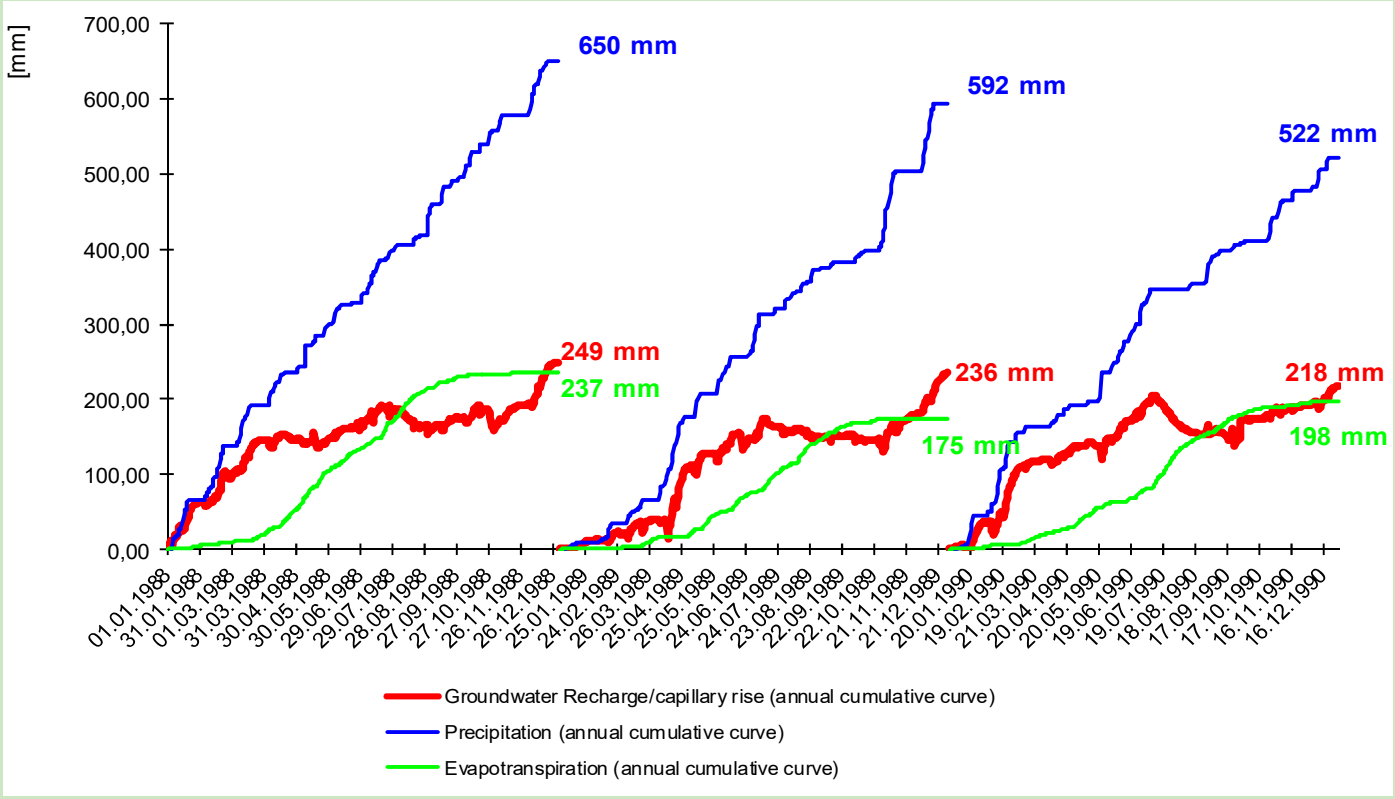
Speyerbach-Schwemmfächer (HA1)



GW	=	Groundwater Recharge
Of	=	Outflow
kA	=	capillary Rise
If	=	Inflow
N_F	=	Precipitation
I	=	Interception
E	=	Evaporation
T	=	Transpiration
$\delta\ \Theta$	=	Soil Moisture

$$GW = P - I - E - T - Of + If - cR - \delta\ \Theta$$

Schüler 1999

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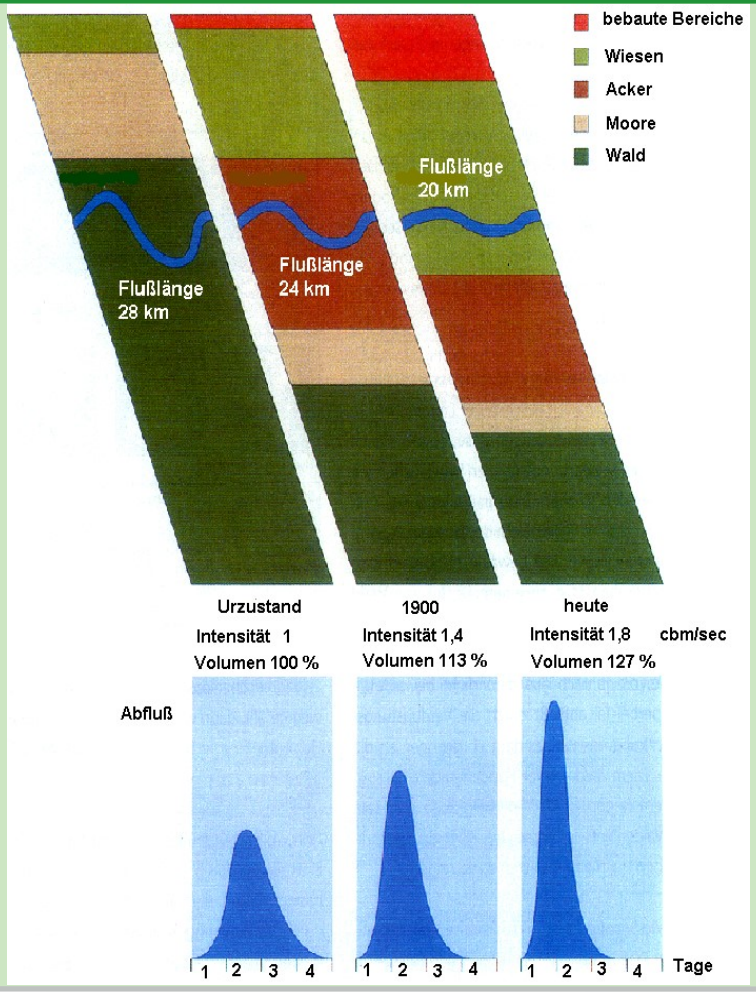
People subdue the earth

In the past Land-Use changed considerably from vaste woodland with meandering rivers flowing in extended natural Flood Plains.

But then people subjugated the land with agriculture, settlement areas and traffic infrastructure.



Close-to-Nature Management versus Exploitative Management

People‘s Activities endanger

- Nature
- Biodiversity
- Forests
- Water
- Climate
- …

Water + Forest Management
= Landuse Management

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Water Management is more than Water Engineering, it is (also) adapted Land-Use Management and it is related to Forest Management …

Respect the Power of Water

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Power of Water

Consequences ?

Land-use in forested headwater catchments increase the risk of disturbances in forest hydrological cycles, but adjusted precautionary land-use can also support beneficial natural processes.
Forestry, agriculture and measures in settlement areas and traffic infrastructure as well as handicraft, trade and industry must adequately respect nature, so that people can continue to benefit from ecosystem services.

Landnutzung im Wasgau 1950 (oben) und 1987 (unten) – Blick von der Burgruine Lindelbrunn zum Haselstein bei Oberschlettenbach

Ecosystem Services

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ZENTRALSTELLE DER FORSTVERWALTUNG

Human well-being is highly dependent on sustainably providing ecosystem services

Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber, timber
- Biochemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination
- Soil protection

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting Services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

Daily 1997, MA 2003

Forest Ecosystem Services

(Malberg – historical place of worship and place of myths and narrations)

Forest is more than a producer of wood. The forest as an ecosystem produces a variety of important services for mankind:

1. Provisioning Services (timber, fuelwood, water, medical plants, …)
2. Regulating Services (CO_2-sequestration, protection against flood, erosion and landslides, preventing land degradation, …)
3. Supporting Services (biodiversity, soil formation, nutrient cycling, climate, …)
4. Cultural Services (recreation, spiritual heritage, myths and narratives, …)

MEA 2005

Cascade relationship between forest ecosystems and people

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Ecosystem Forest

Providing Services

Human Well-Being

Political Decision making → Management Strategies → Management Plans Implementation

Haines-Young & Potschin 2010; De Groot et al. 2010; Van Oudenhoven et al. 2012

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Payments for Ecosystem Services

Payments for Ecosystem Services (Forest for water)

Summary

The aim of the PESFOR-W COST Action is to synthesize knowledge, provide guidance and encourage collaborative research to improve Europe's capacity to use Payments for Ecosystem Services (PES) to achieve Water Framework Directive (WFD) targets & other policy objectives through incentives for planting woodlands to reduce agricultural diffuse pollution to watercourses.

PESFOR Flyer 2019

Objectives of this EU COST-Action are

1. to characterize and critically evaluate the governance models and design structure of existing Payment schemes in the EU, with regard to
   - service provision (supply);
   - policy drivers;
   - **payments/markets** (demand);
   - types of governance (organizational arrangements)
2. To develop a European Payment for Ecosystem Services repository of Case Studies that investigate lessons from existing PES schemes, to share with practitioners, policy makers and stakeholders to promote best practice.

https://www.forestresearch.gov.uk/research/pesforw/

Climate Change – a challenge for forests and people

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Depending on how global greenhouse gas emissions develop, climate models predict an increase in mean annual temperatures of around 2-6° C by the end of the 21st century. Extreme weather events such as heat, drought and torrential rain will continue to increase. There will be more precipitation in the winter months and less in the summer months.

Less precipitation, rising temperatures and evapotranspiration as well as extended periods of drought put forest ecosystems under stress and endanger the supply of drinking and process water from forests to the population.

http://www.kwis-rlp.de/en/daten-und-fakten/klimawandel-zukunft

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The ambivalence of forests in view of decreasing water resources

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Forests and woodlands should provide **protective services** for water resources, but the vitality of forests and woodlands themselves is affected by decreasing water availability.

In view of climate change projections, the water cycle of forests must be reassessed, and forest and water management must be adapted to the tremendous risks which are still uncertain in their factual future extent.

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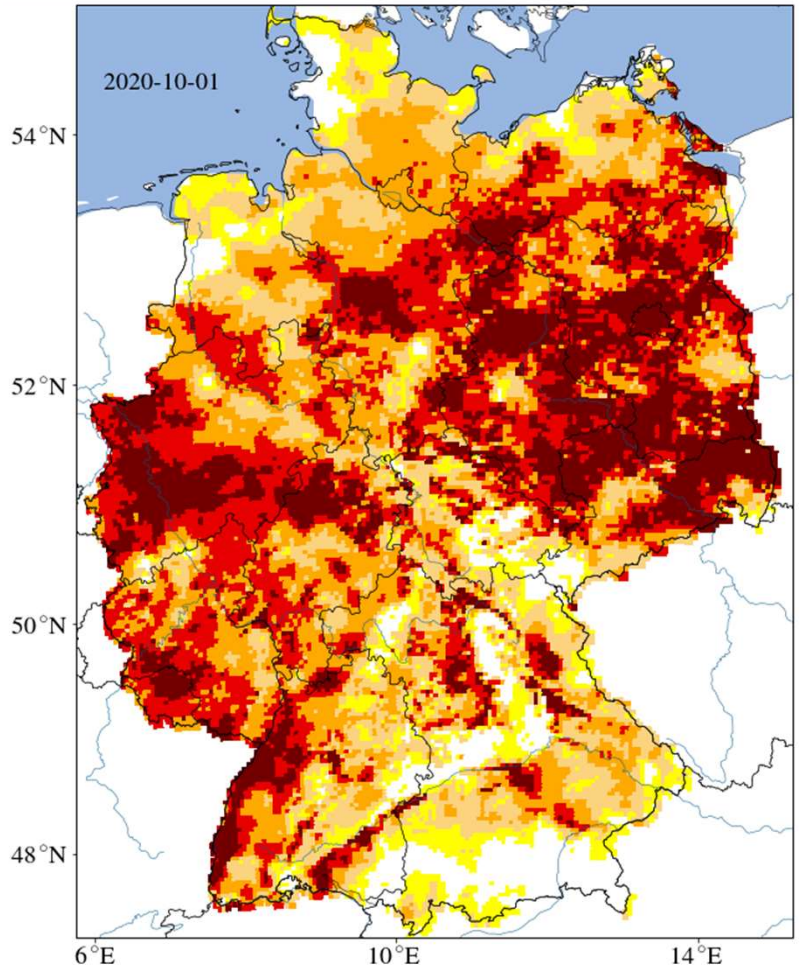
Impacts of the last three dry years



Extreme weather from 2018 – 2020 and drought

The last three years in Germany have been characterized by significantly warmer summers with dry periods. As a result, severe soil drought developed in some German regions.

Winter precipitation has not been sufficient to compensate for the respective water deficit of previous years. Rainfall events in the summer months increasingly turn out to be extreme events, with water running off the surface rather than penetrating the soil.

- Not enough water to fill up the plant available field capacity of the soils !
- Not enough water for groundwater recharge !
- Too much water for infiltration cause flash floods, erosions and even landslides after torrential rain !

MUEEF RLP 2019

Competition for Water

Forests take their needed water from the upper unconfined aquifers.
But in forest areas agriculture also takes water for irrigation crops from wells in the upper or middle confined aquifers.
These aquifers are connected via hydraulic windows with the unconfined upper aquifers, and they run dry.
Thus, the trees suffer or even die due to lack of water.

It is an ethic question to take water for agriculture and let the forests die of thirst!

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An alarming battle for groundwater (GW)

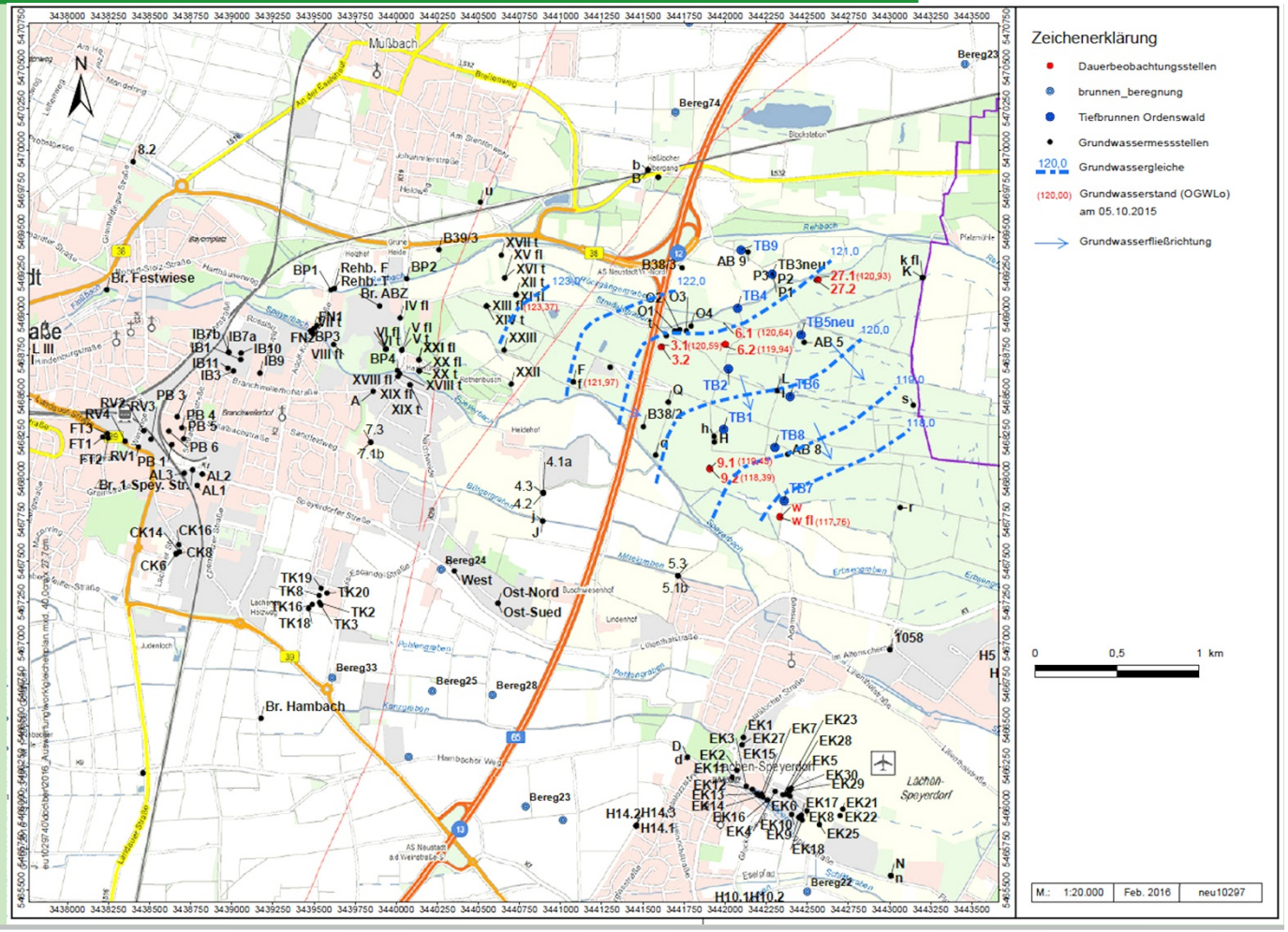
Forest as land-use still ensures GW of a high quality. Decreasing GW recharge and high nitrate pollution under intensively farmed areas is the reason that drinking water suppliers install a big number of wells in forests.

But, if too much GW is extracted from deep wells, the upper aquifers run dry via hydraulic windows.

Firstly the forests lack water, secondly agriculture lacks it.

The number of wells is a question of existence!

Schueler 2020



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If trees lack water, ….

…

how long will it take before there is no longer enough water for people ???

Schueler 2020

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Drought and Forest Stress

Reactions of Trees 2018 - 2020

Drought and heat lead to a reduced vitality of trees. Deteriorated trees are more susceptible to pests, at the same time the higher temperatures and the longer duration of the warm season favor the development of insects and the migration of new pest populations

Schueler 2020

E.G.: Forest hydrology and the suffering of beech trees in their natural range

Heavily cleared older beech trees showed severe drought stress symptoms in the summer 2020. Due to the intensive thinning operations, either a dense beech regeneration has established under the canopy of the old beech trees, or a succession of companion tree species, shrub species or a dense grass root felt.

Although the beech regeneration under these highly stressed old beech trees showed some individual yellow leaves, the young trees were still largely vital.

Schüler 2020

Hydrological explanation.: The suffering of beech trees in their natural range

Evapotranspiration of beech stands initially decreases with increased thinning. But when thinning exceeds a tipping point, evapotranspiration increases again because transpiration in the forest floor vegetation and evaporation on the forest floor increase due to higher radiant energy and greater wind movement.

When water cannot be replenished from the soil into the root after the soil matrix potential has exceeded the critical value of pF = 4.2, the tension in the xylem conducting vessels increases, and **emboli** interrupt the xylem flow into the beech leaves.

Silvicultural consequences from hydrolocial recognitions:

Because beech trees are sensitive to drought stress when thinning strategies are too strongly oriented towards increment, silvicultural strategies fail when beech growth is forced too strongly.

Therefore, - due to climate change - close-to-nature silviculture in the dimensioning phase must be oriented towards the stand dynamics of natural beech stands with a closed canopy, thus smaller individual crowns and less forced diameter increment.

Hacke & Sauter 1995, Nardini et al. (2001), Tyree & Zimmermann (2002), Cochard et al. (2004), McDowell et al. 2008, Johnson et al. 2012,Tomasella et al. 2019

Shift in natural distribution of tree species within xeric boundaries

Example for ecosystem shifts explained by Forest Hydrology:

If in future midsummers a xeric stand climate occurs with significantly higher temperatures, previous beech sites will be increasingly dominated by oak, as the comparative *NemKlim* studies in the Romanian Carpathians suggest.

The increase in temperature caused by climate change and the resulting increase in evapotranspiration will shift the boundary line of forest vegetation associations with dominant beeches to higher elevations and to regions with higher precipitation.

More thermophilic oak forests will take over the previous natural ranges of beech forest communities.

Hohnwald et al. 2020, Soudzilovskaia et al. 2013

How to deal with too much water?

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To delay discharge as long as possible, forest and water management must focus on water retention in headwater catchments.
Forests and trees need water for growing and surviving during drought periods.

Schueler et al. 2007

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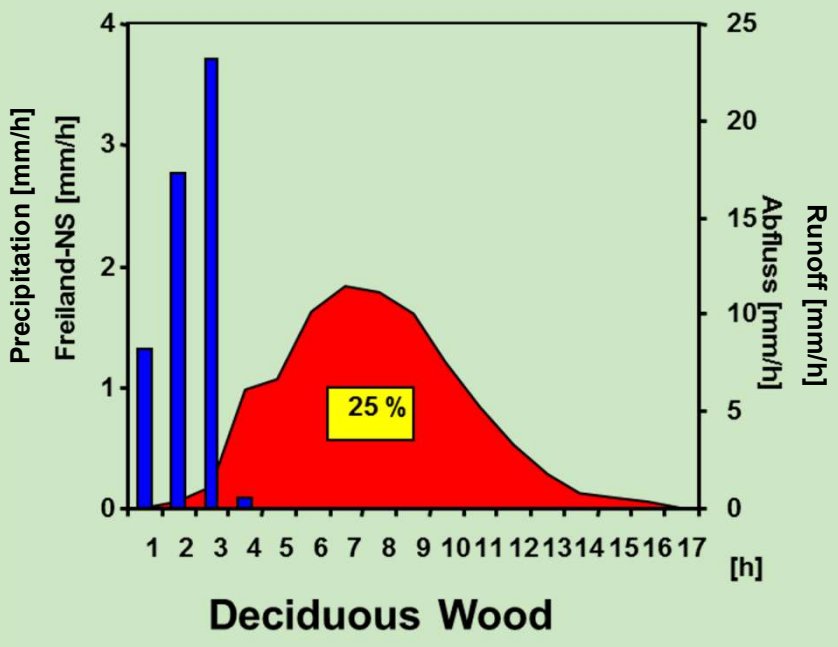
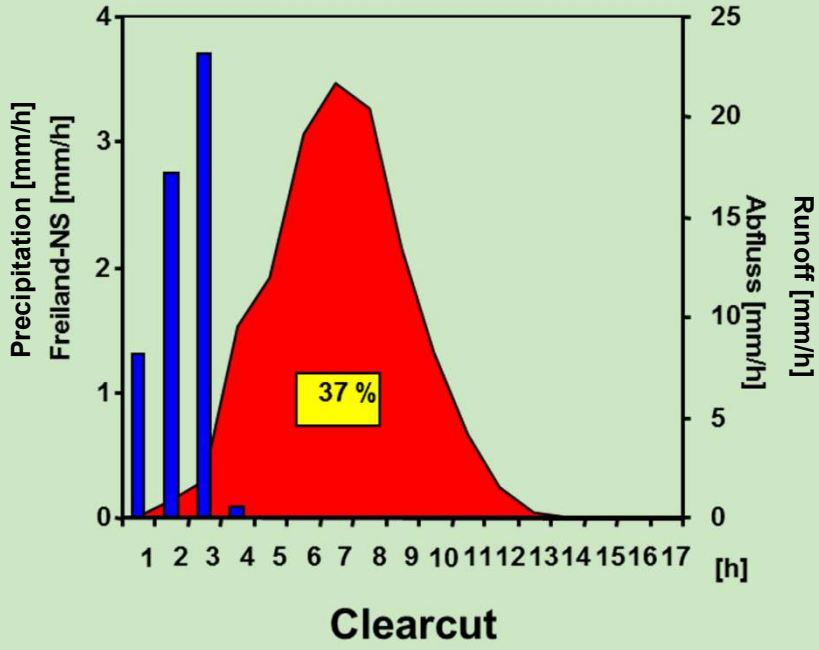
Flashfloods

Flashfloods of small rivers can cause considerable damages in settlement area … and they will happen more often in future. They have an extremely short advance warning time – and technical protection measures (water engineering) are lacking or not sufficient.
That underlines to delay also this very fast runoff as much as possible.

Schueler et al. 2007

Forest Management and Water Retention



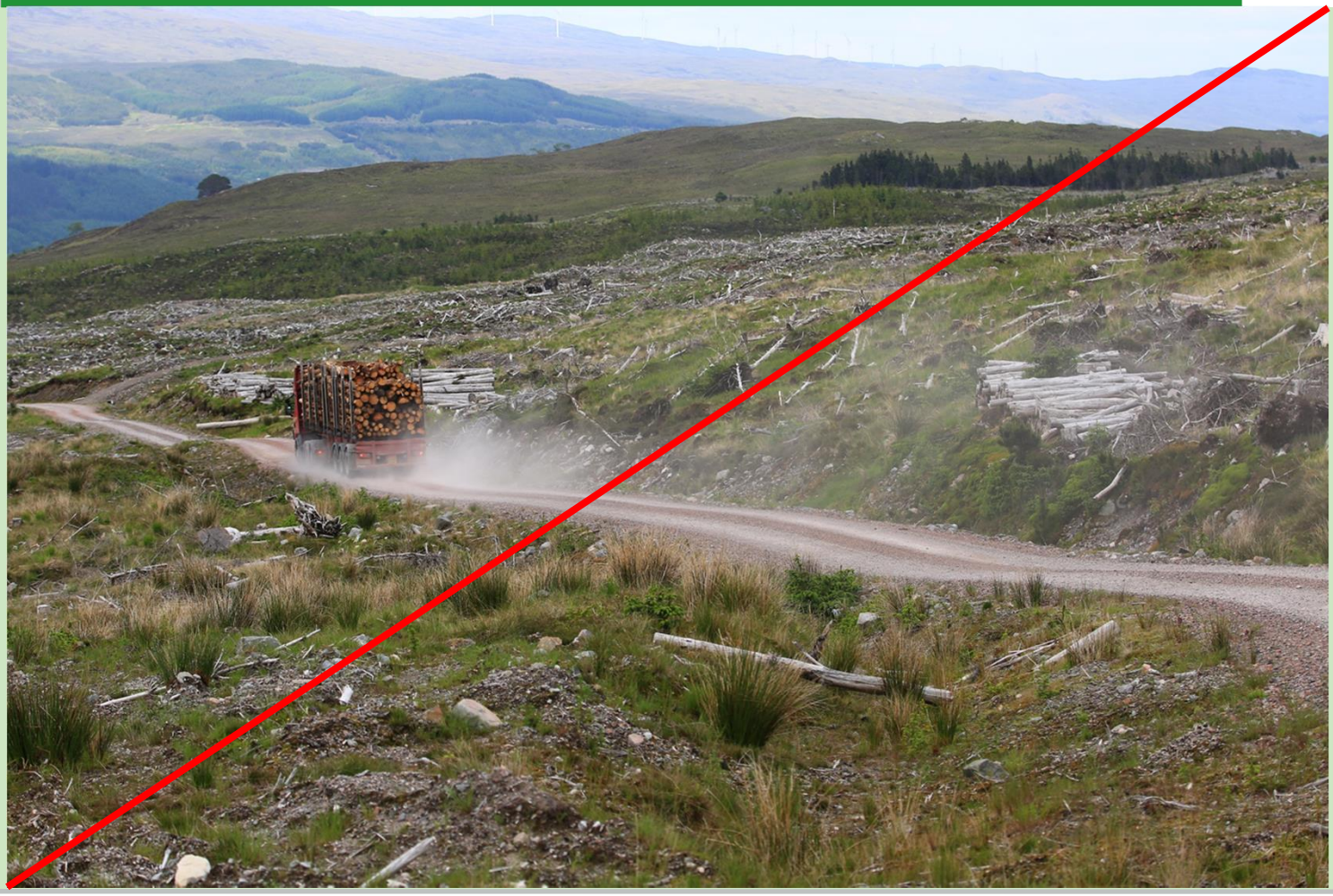


Runoff increases in a clearcut area in a shorter peak.
here: artificial heavy precipitation event during vegetation period on a sensitive Gleysol

Responsible forest management has to develop horizontally and vertically structured, ecologically stable, close-to-nature mixed forests, managed without clearcuts.

Bott 2002, Schueler et al. 2007

No clearcuts



Driving with Vehicles in Forests

Don‘t drive with heavy machinery **uncontrolled** on forest soils

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Some Statements …

1. There is an almost unshakable opinion that forest **interception** can reduce or avoid floods.
BUT … interception with a saturation capacity of 10 mm is almost meaningless compared to the amount and intensity of rain of torrential rainfall events (> 40 mm/event).

2. The water consumption of forests with approx. 1-10 mm/day empties the soil water reservoir, and thus increases the storage capacity for newly arriving precipitation water.

BUT … the evapotranspiration of a grass cover (with up to 8 mm/day) is as high as that of forests, and if the gras is matted water cannot infiltrate.

3. The recent soil physical conditions determine the runoff behaviour of water from forests.

BUT … Land use history teaches that forests often remained on "bad" soils with low water storage capacity or on stagnant soils with natural rapid runoff.

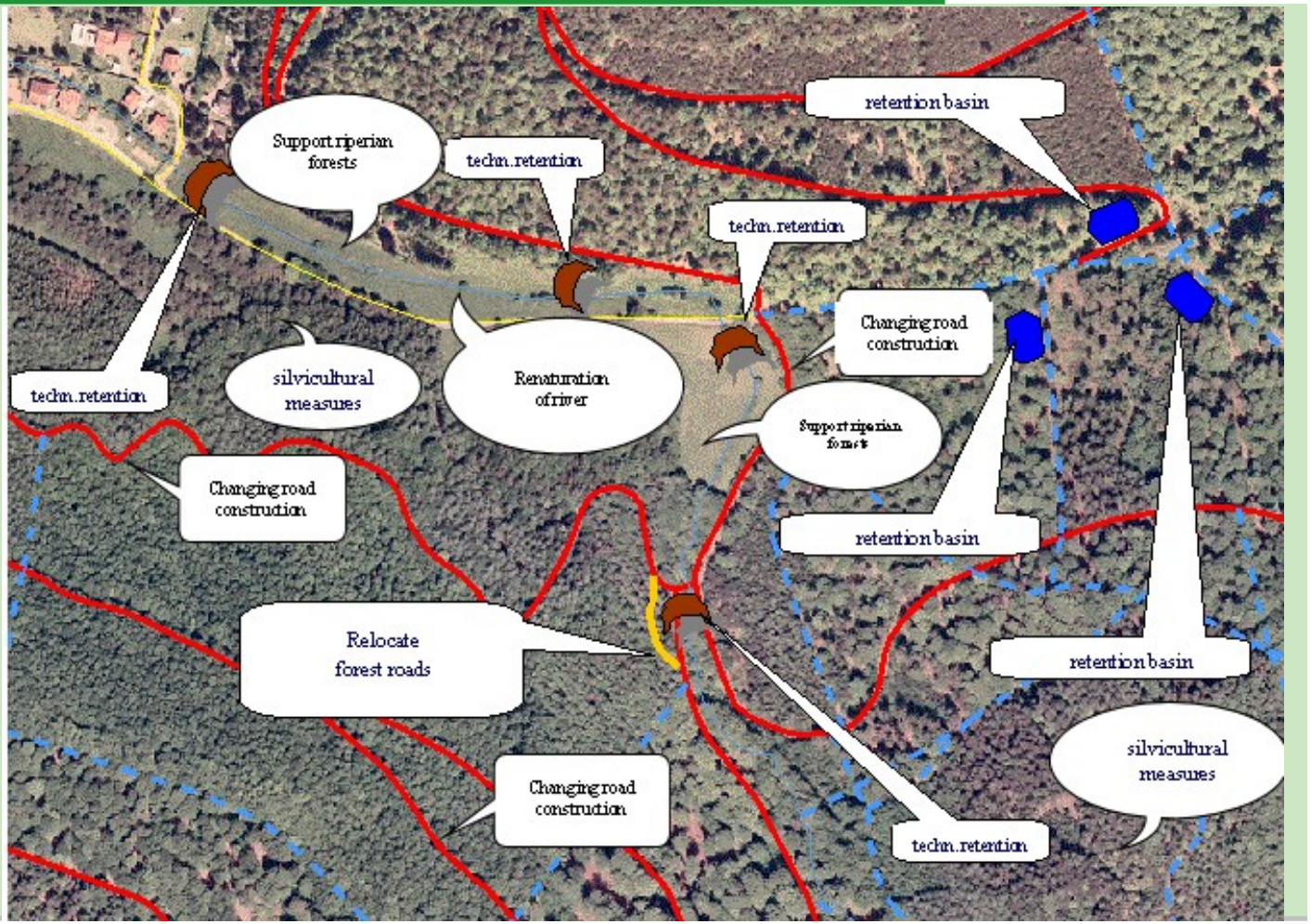
4. As driving in forests was rather restricted, forest soils have a well draining pore system with a high infiltration rate, with good water conductivity and therefore with a low tendency to surface runoff and with slow interflow.

But …, soils under afforestations after agricultural use or intensively managed forests with heavy forest machines have unfavourable soil physical conditions, and it takes centuries to regenerate a destroyed pore system.

Penman 1948, Salihi 1984, Elling et al. 1990, Benecke 1990, Peck & Mayer 1996, Schueler 1999, Schobel 2008, Huemann et al. 2011, Klaes et al. 2016

Decentralized water retention measures in forests

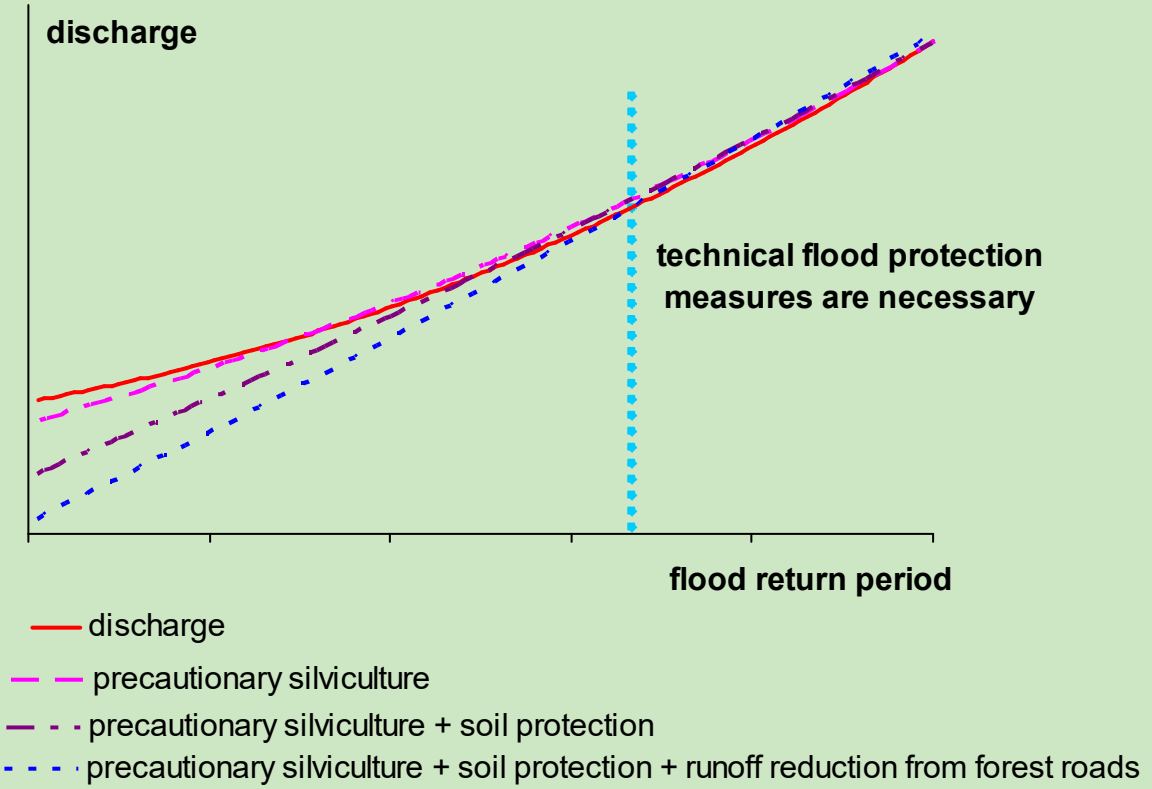
Decentralized retention measures have only a chance to be efficient, if all possibilites in catchment areas are achieved, always beginning nearest to the places of run-off generation .



Schueler 2006

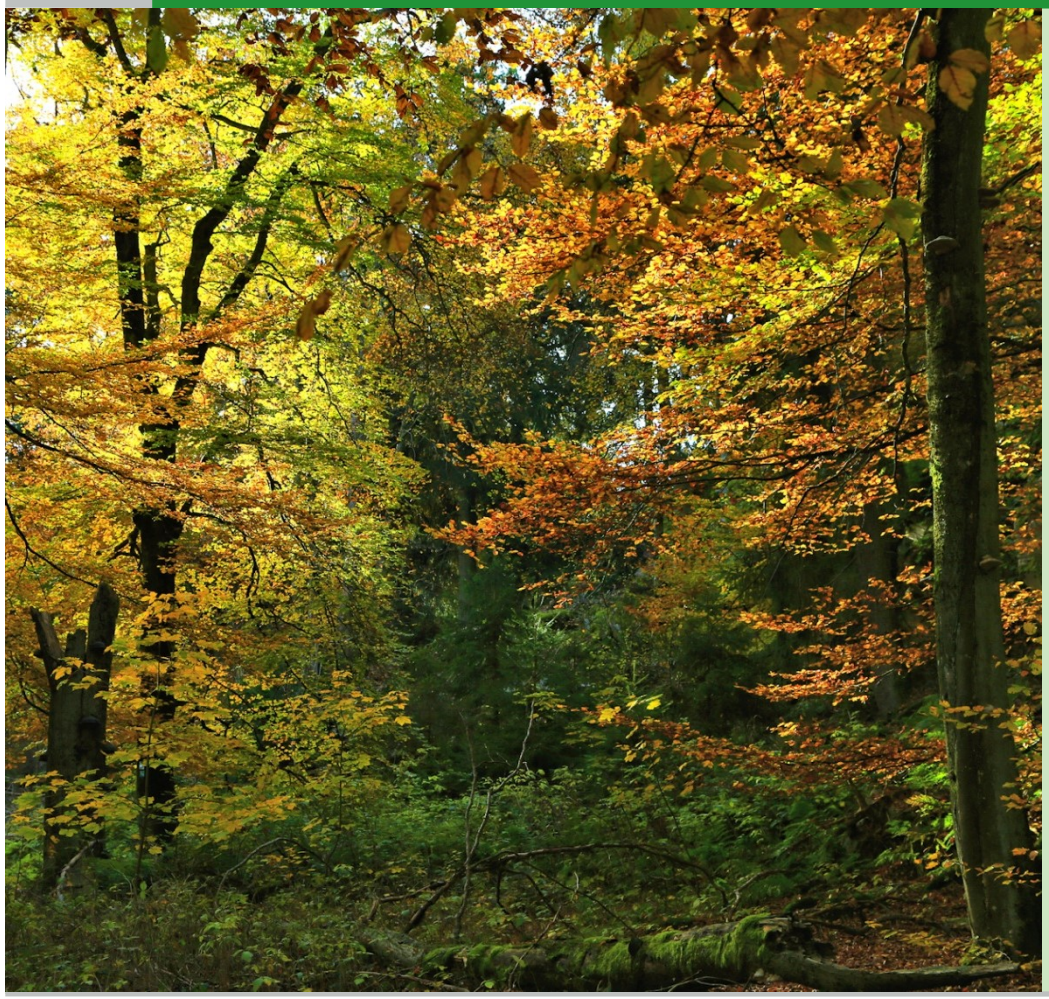
Efficiency of precautionary water retention measures in forests of headwater catchments

- In the microscale each additional flood precautionary measure makes the discharge curves diverge from their starting points and meet on the flood frequency curve at a higher flood return period
- Above a point of intersection, technical flood-protection measures are necessary
- This depends strongly on the climatic situation's scale and on the site, soil, geology, land-use and landscape characteristics.



Schueler 2006

Forest Management due to Climate Change Impacts



Principles of forest management in climate change should be based on **"no-regret" decisions with broad risk diversification** considering:

- climate resilient, vital, and site-adapted mixed forests with native main and associated tree species
- as well as complementary tree species which are already adapted to expected climate development in neighbouring growing areas,
- a wide age range and
- a wide range of possible climate projections

depending on **ecosystem services** to be provided.

Forest hydrology is a key element of silviculture in a changing climate.

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Thank you for your attention

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