"NATURE-BASED SOLUTIONS (NBS) TO CONFRONT WATER EXTREMES IN EUROPE: DESIGN AND MODELLING TOOLS"

(Within the project TRITON; https://triton.wasser.tum.de/)

# Process-based modeling of naturebased solutions for mitigating floods and droughts

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# Nature based solutions for mitigating floods (and droughts)



areal distributed

point and linear measures

# ТШП

#### **Example: Windach Catchment**



#### **Simulated Events**



#### **Methods**



#### Wasserhaushaltsmodell WaSiM





- temperature
- wind speed
- vapour pressure
  radiation
- · precipitation etc.



- DEM
- land use
- subcatchments
- soil types
- river network
- others

configuration: • control file

Other features:



#### **Conservative Tillage**



**Soil Structure for Different Tillage Methods** density [g/cm<sup>3</sup>] and organic carbon [-]



#### **Conservative Tillage**



**Effects of Measure:** 

Dependent on

- Rainfall event (convective / advective)
- Precondition of the soil (wetness)
- Macropore distribution

Attention: results are heavily model-dependent!

Northern Windach Catchment area: 68 km², HQ<sub>10,</sub> advective land use: 95% arable land

### Reforestation



#### **Hydrological Effects**

- higher evapotranspiration and interception
- higher organic content of soil
- root activity
- higher share of macro-pores





#### Reforestation





Effects of Measure: dependent on



- Discharge volume and peak
- Available area for reforestation

Attention: Using ecological reforestation leads to higher efficiency (factor 1.5).

Windach Catchment area: 128 km<sup>2</sup> land use: 25% forest

#### **Small Decentral Retention Basins**



#### **Hydrological Effects**

Increased Retention Capacity



- Increased Infiltration and Percolation
- Optimization for specific design flood HQ<sub>x</sub> necessary

Design Criteria: $HQ_x$ Retention Volume: $5,000 - 50,000 \text{ m}^3$ Max. Water Level: $h \le 3.0 \text{ m}$ Diameter of Outlet:0.1 - 2.0 m

Fischbach, Windacher Moos Max. Level: 1.85 m Ret. Vol.: 17,700 m<sup>3</sup>

#### **Small Decentral Retention Basins**



#### **Ecological River Restoration**



#### **Hydrological Effects**

- Increased retention volume in river segments and riparian forests
- Longer travelling time of water
- Increased infiltration and percolation
- Reduction of river bed erosion

Schweinach, Windacher Moos, HQ100 Uplift of Riverbed: 50% Widening of Riparian Strips: 50% Additional Restoration of Riparian Forest



#### **Ecological River Restoration**



#### **Effects of Measure:**

- Specific retention volume
- Shape of flood wave
- Kind of vegetation

#### **Decrease of Flood Peak [%]:**

event type		advective		convective	
return period [a]		10	100	50	60
alluvial forest	without	5.9	0.9	3.5	2.4
	included	6.4	5.0	11.1	11.0

Schweinach, Windacher Moos Uplift of Riverbed: 50% HQ<sub>100</sub>, advective Widening of Riparian Strips: 50% Additional Restoration of Riparian Forest



#### Integration – Concept of Measures



- Feasibility
- Costs ۲

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#### **Concept Windach Catchment**





#### **Effectiveness of Decentral Flood Protection**



#### Sources:

Rieger, W. & M. Disse (2013): Physikalisch basierter Modellansatz zur Beurteilung der Wirksamkeit einzelner und kombinierter dezentraler Hochwasserschutzmaßnahmen (A physically-based model approach to assess the effectiveness of single and combined measures of decentralized flood protection). In: Hydrologie und Wasserbewirtschaftung, HW 57.2013, H.1, S. 14 – 25.

Rieger, W. (2012): Prozessorientierte Modellierung dezentraler Hochwasserschutzmaßnahmen. Dissertation, Mitteilungen des Instituts für Wasserwesen der Universität der Bundeswehr München, number 116, ISBN 978-3 8440-1209-5

## Summary



Small and medium Chances flood events If central measures not possible

No regret measures

Generally minor effect in large catchments Not effective for low .imits probability floods Soil has more influence than land use

**Synergy Effects:** Reducing washout of pesticides Reducing export of nutrients **Tackling erosion** Mitigation of droughts Supporting groundwater recharge Barrier for protection goods Interconnecting ecosystems Supporting biodiversity Enhancing local recreation Support beauty of landscape EU-WFD

#### Nature based solutions for mitigating droughts (and floods)

- » Drought have increased tree mortality in Germany, especially "drought year" 2018 (Lüttger et al., 2018, Schuldt et al., 2020)
   » IPCC, 2021:
  - » Reduction of precipitation in summer months
  - » Increased risk of drought
  - » Increased risk of heavy torrential rainstorms

New water management strategies for increased resilience of forests with regard to droughts needed!



Foto: Ralf Straußberger

Sources:

- Schuldt, B., Buras, A., Arend, M., Vitasse, Y., Beierkuhnlein, C., Damm, A., Gharun, M., Grams, T.E., Hauck, M., Hajek, P. and Hartmann, H., 2020. A first assessment of the impact of the extreme 2018 summer drought on Central European forests. Basic and Applied Ecology, 45, pp.86-103.
- Lüttger, A.B., Feike, T. Development of heat and drought related extreme weather events and their effect on winter wheat yields in Germany. Theor Appl Climatol 132, 15–29 (2018).
- IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

# 1. Project STUDIO: Nature-based solutions for drought resilient forests: a study in Franconia, Germany

- » Decentralized, nature-based measures used to:
  - a) Increase infiltration of precipitation runoff into the soil
  - b) Store water in the unsaturated soil zone

Thereby increasing the water availability for trees drought events; increase drought resilience of forests

- » Water retention successfully tested in pilot study ("LIFE 11")
  - » Reduction of discharge of forests during heavy torrential rainstorms
  - » Reducing the risk of flash-floods



#### **Concept: Measures of Water Retention**



Adaptation in forest road construction with e.g. gutters



#### Study Area

- » Forested slope (6 ha) in the "Steigerwald" in Northern Bavaria, Germany
- » Predominant tree species are beeches and oak trees
- » Region heavily impacted by tree mortality (according to local forest management)
- » Climate diagram of DWD climate station in Gollhofen





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# Study Area: LiDAR Survey

- » High resolution topography survey performed
- » Executed by company (Cloud-Vermessung + Planung GmbH)
- » High resolution DEM (10 cm grid)
  delivered











# ТШП

#### **Measurement Sites**

» **60** soil moisture measurements at 13 sites



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- » Continuous soil moisture measurements at 2 sites in 9 depths









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- Manual soil moisture measurements at 11 sites and 3 4 depths





#### **Measurement Sites**

- » **60** soil moisture measurements at 13 sites
- » Continuous soil moisture measurements at 2 sites in 9 depths
- Manual soil moisture measurements at 11 sites and 3 4 depths
- » Climatic measurements at 2 locations
- » Precipitation measurements at 10 locations









## **Measurement Results**

- » Comparison of precipitation, temperature and soil moisture at the hill-top location
- » Soil moisture is decreasing with increasing temperature (start of summer)
- » How much will deeper soil layers dry out?





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### **Measurement Results**

- » Soil moisture profile
  over time (November
  2021 March 2022)
- » Rewetting can be observed
- » Soil moisture highly dependent on soil type





#### Next steps

#### Implementation of a measure

- Alignment of deadwood along slopes easily implemented
- » High potential to be implemented in forest management practice
- Reduces flow velocity of overland discharge therefore increasing the infiltration into soil
- » Efficiency can be studied in detail by implementing this measure at a measurement site



# ТЛП

## 2. Green Ditches (Project of Bavarian Water Authority)



## **Green Ditches (Project of Bavarian Water Authority)**



Weihten das Stauwehr ein: (v. l.) Landrat Helmut Weiß, die Landtagsabgeordneten Hans Herold, Walter Nussel und Gabi Schmidt, Bürgermeister Jürgen Heckel, BBV-Bezirkspräsident Günther Felßner, Umweltminister Thorsten Glauber, Volker Goller und Thomas Keller vom Wasserwirtschaftsamt.



## Outlook

#### Modelling

- Further measures evaluated by the hydrological model HydroGeoSphere (HGS)
- Model comparison with the hydraulic model
  TELEMAC will potentially deliver insights into the relevant infiltration processes
- » Coupling HGS with the forest growth model BALANCE (Project STUDIO)
- » Upscaling the measures in forest and field for evaluating the retention efficiency in the catchment



#### Sources:

- Taccone, F., Antoine, G., Goutal, N. and Delestre, O., 2017. A new gravity-driven runoff and erosion model for TELEMAC. In Proceedings of the XXIVth TELEMAC-MASCARET User Conference, 17 to 20 October 2017, Graz University of Technology, Austria (pp. 147-152).
- Brunner, P. and Simmons, C.T., 2012. HydroGeoSphere: a fully integrated, physically based hydrological model. Ground Water, 50(2), pp.170-176.
- Thomas Rötzer Lehrstuhl für Waldwachstumskunde, TU München April, 2015. BALANCE ein prozessbasiertes, räumlich hoch aufgelöstes Waldwachstumsmodell

# Thank you for your Attention! Questions?