ForeStClim

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Transnational Forestry Management Strategies in Response to Regional Climate Change Impacts

The Impact of Forests on Water Supply and Flood Prevention in a Changing Climate

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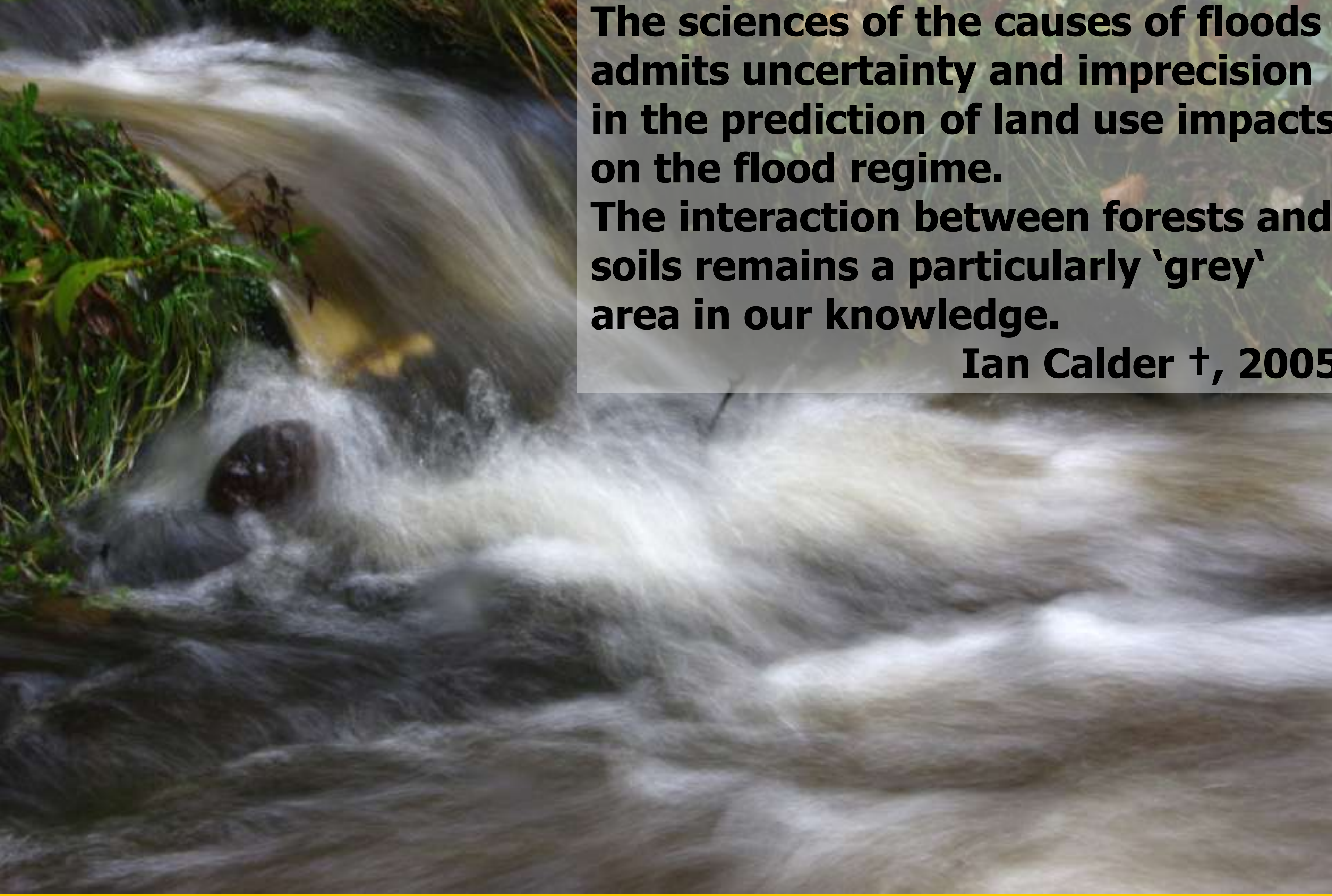
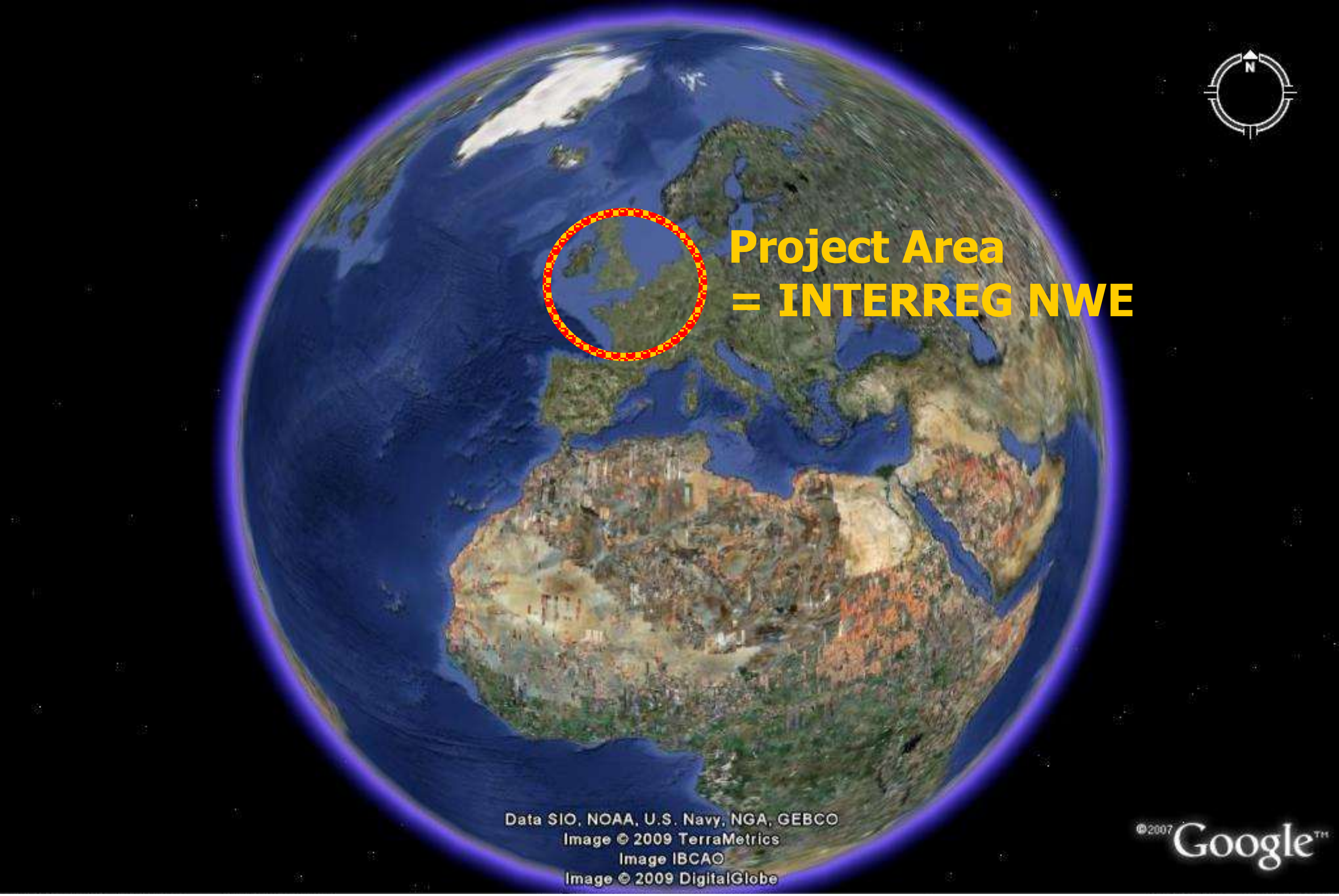


The sciences of the causes of floods admits uncertainty and imprecision in the prediction of land use impacts on the flood regime.
The interaction between forests and soils remains a particularly ‛grey‛ area in our knowledge.

Ian Calder †, 2005


Project Area
= INTERREG NWE
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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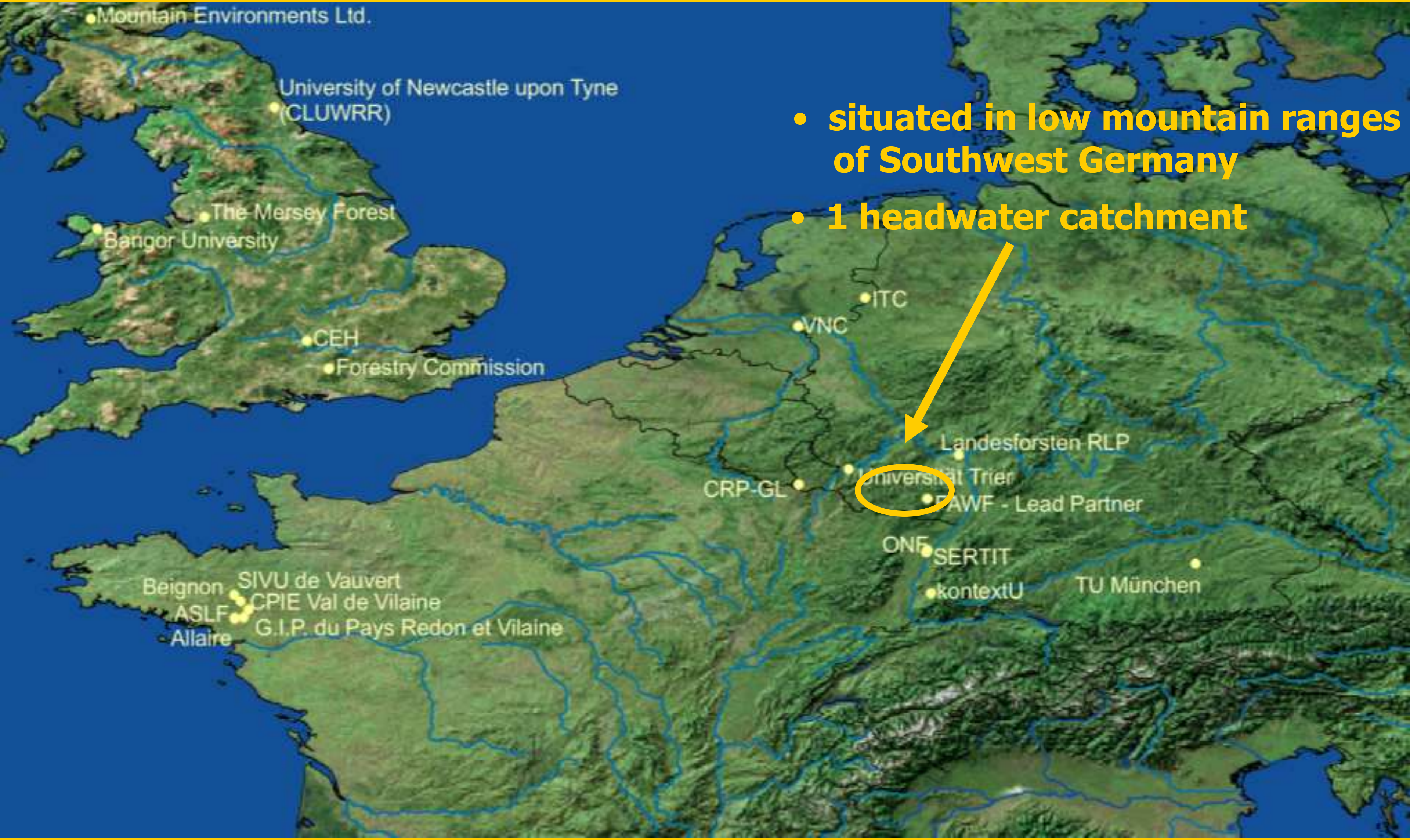
Study Area: Catchment of Frankelbach, SW-Germany



- situated in low mountain ranges of Southwest Germany
- 1 headwater catchment

Site Conditions in the Frankelbach headwater catchment

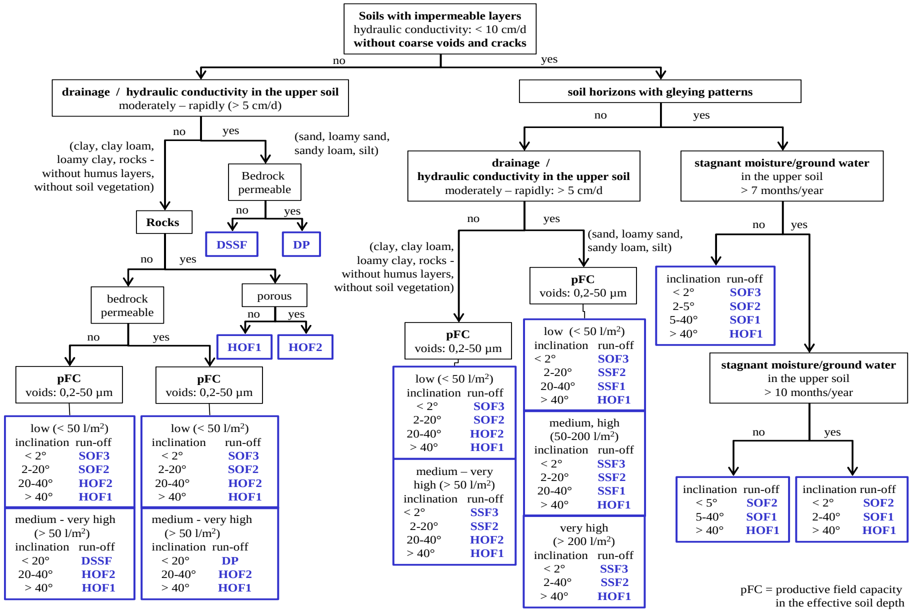
The headwater catchment **area** of the Frankelbach is about 8 km^2 large.
The **height** above sea level is 210m to 430m.

Precipitation: 700 - 800 mm/year with a cumulation of storm rainfalls during summertime in the last decade.
Average temperature: 9° Celsius
Average temperature during vegetation period: 14° Celsius

Geology: Permian era (296 – 258 Mio years); New Red, so-called "Rotliegendes"
Sediments were deposited during semiarid and subtropical conditions and later bulged by volcanism
Soils: Brown earth / colluvia from sand-loam, silt-loam, partly relocated, (in the valleys loamy floodplains)

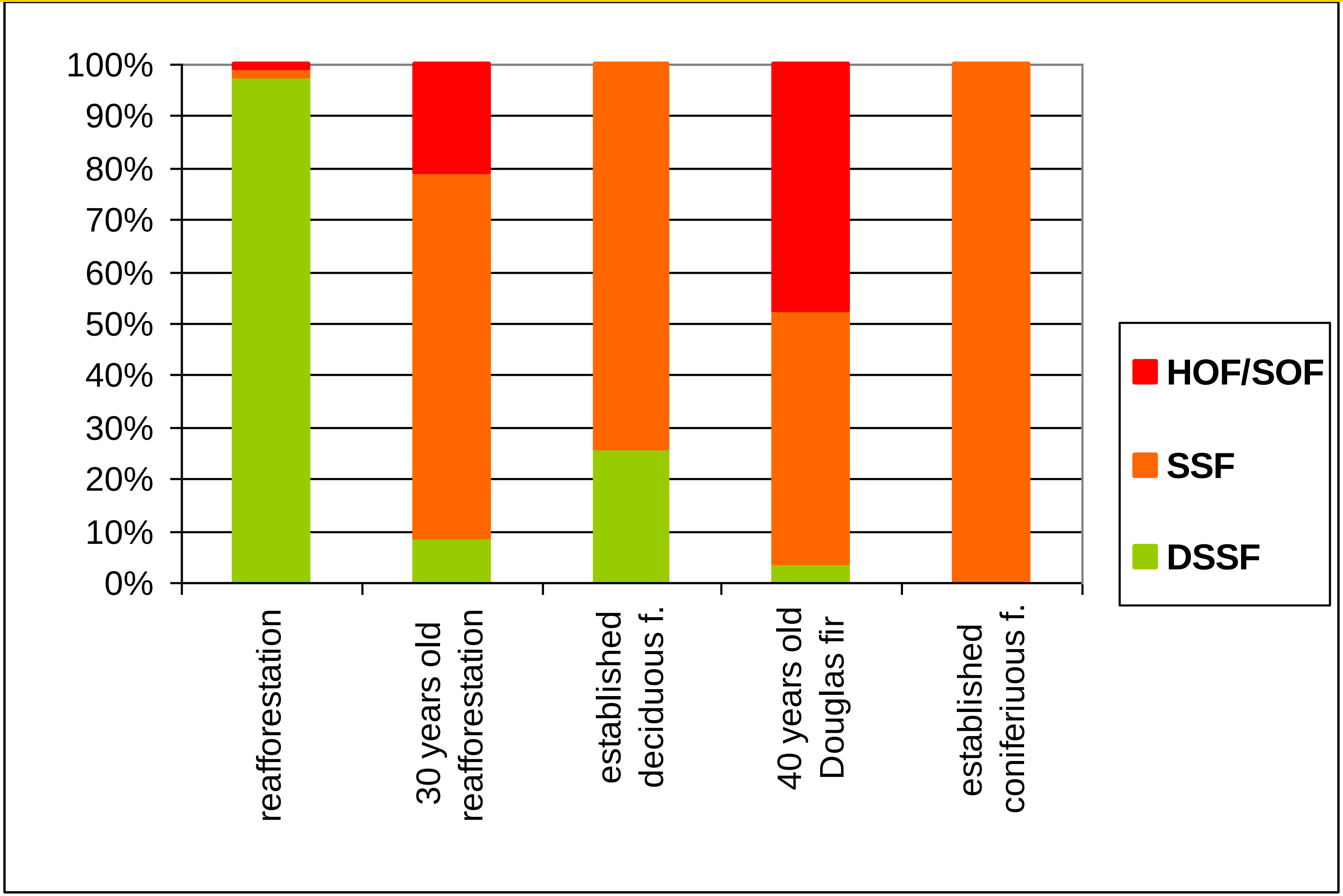
Assessment of Runoff Processes

An **expert system** bases on slope, land-use, parent rock material (geology), measured soil physics, and on **infiltration and sprinkling experiments**.

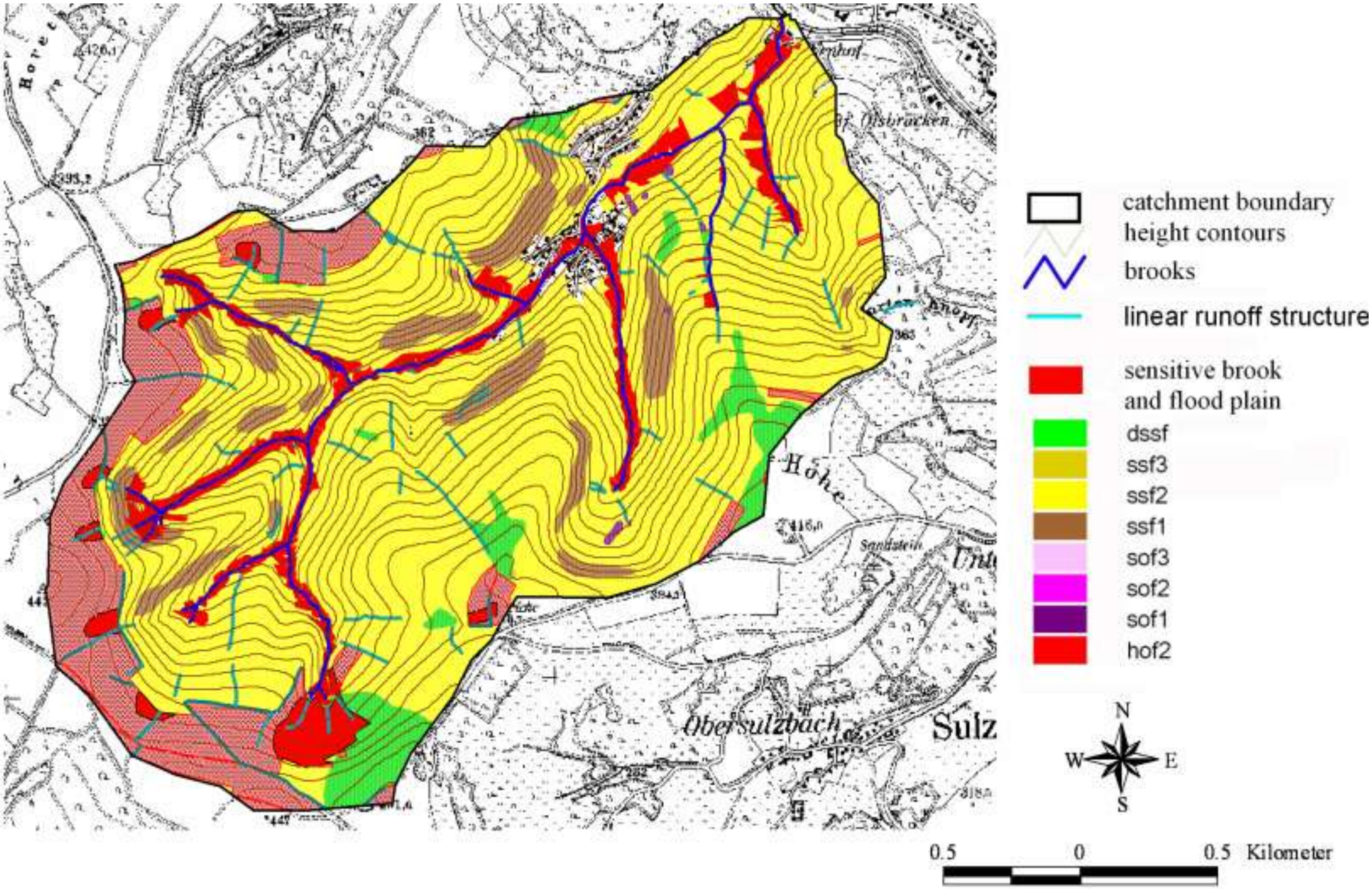


Slope scale simulations were carried out on moderately sloped test areas of 5 x 10 m (effective 3 x 10 m). Per day an amount of 40 mm rainfall was applied during a period of 3 days in 4 intervals of 15 min duration, resulting in rainfall intensities of approx. 10 mm per 15 min. Surface and subsurface water flow were collected and measured for the middle 3 x 10 m to exclude lateral losses of water.

Runoff types in the Frankelbach catchment



Digital map with the run-off sensitivity in the Frankelbach catchment

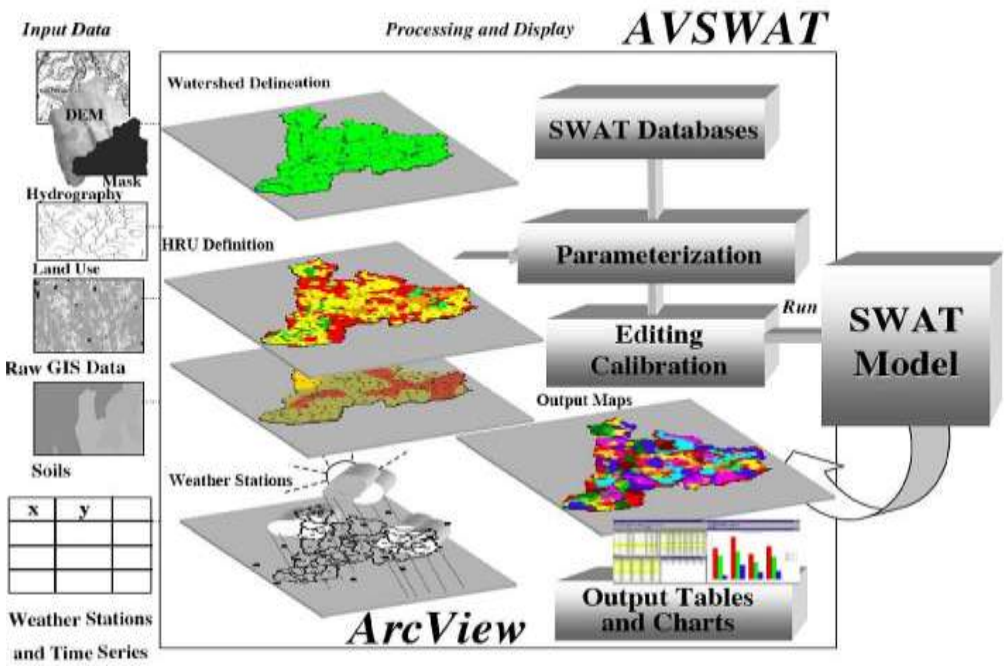


Modelling - What will happen if…?

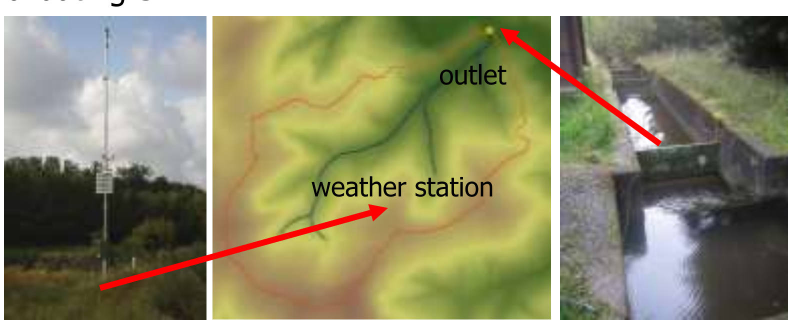
Modelling is always an approach to reality ranging from a black-box-system to a more or less process-related procedure. The degree of abstraction and simplification of real hydrological processes varies between different models. The goal to be achieved is to trace the measured discharge hydrograph of an outlet as good as possible. This rarely gains new insights, but a well validated model enables scenario studies by varying the input parameters according to specific changes in climate or/and land use distribution for example.

ForeStClim-Task Force Water and Forests:
Assessment of the water balance of differently structured study areas in response to a changing climate in the recent period 2005 – 2010 and two future projections 2021-2050 and 2071 – 2100 with two climate change signals HC3Q0 – „dry and warm", and DMI-ECHAM5 – „humid and cold"

Overview: Watershed modelling with the SWAT and APEX model

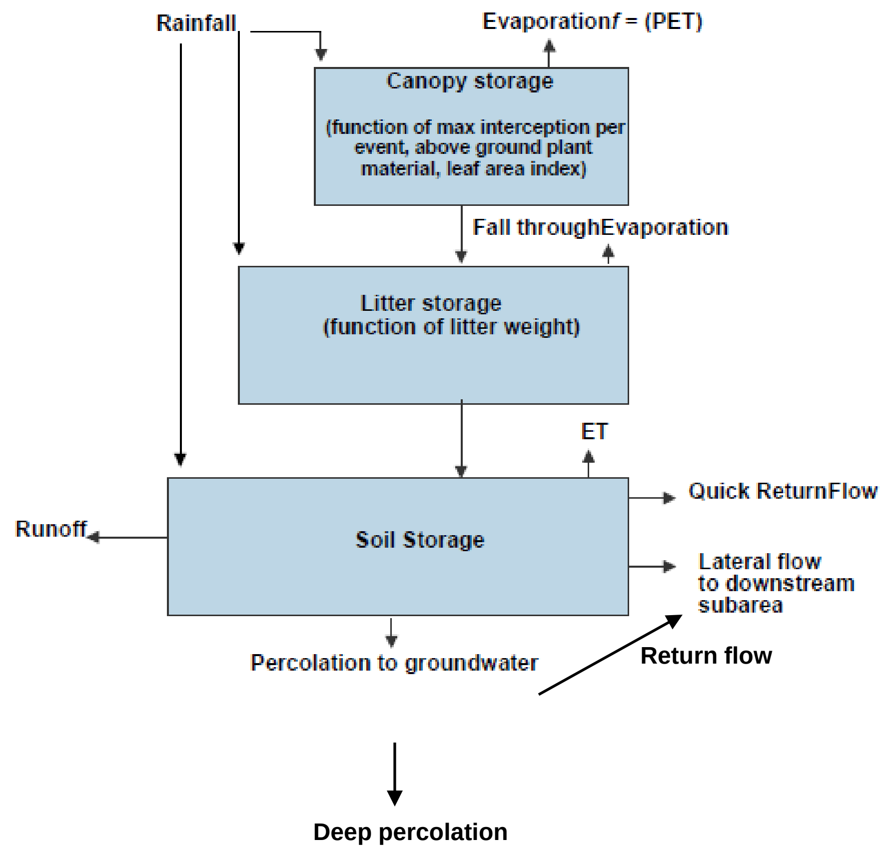


The direct relationship between weather data and the discharge response is one of the most important prerequisite for validating SWAT



APEX

Program Modules and Processes



APEX Model background

Agricultural **P**olicy / **E**nvironmental e**X**tender Model

→ compatible with SWAT (Soil & Water Assessment Tool)

→ developped at Blackland Texas A&M AgriLife Research & Extension Center

APEX

Parameter variations

Database adjustments

Input

DEM

Land use data

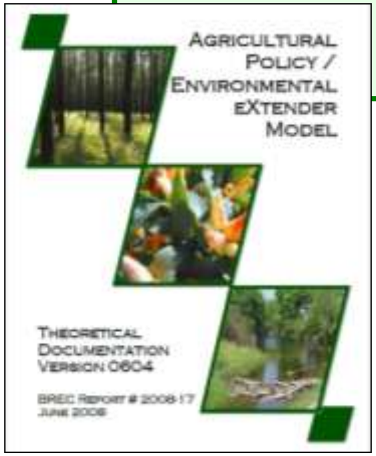
Soil data

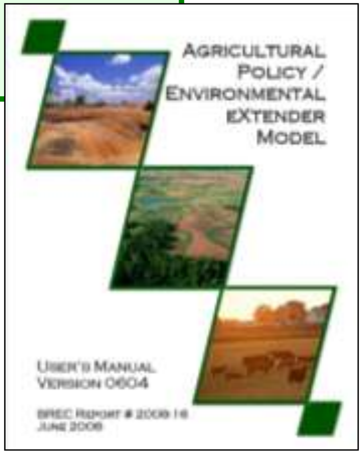
Climate Data

ArcAPEX

Output

Selected files





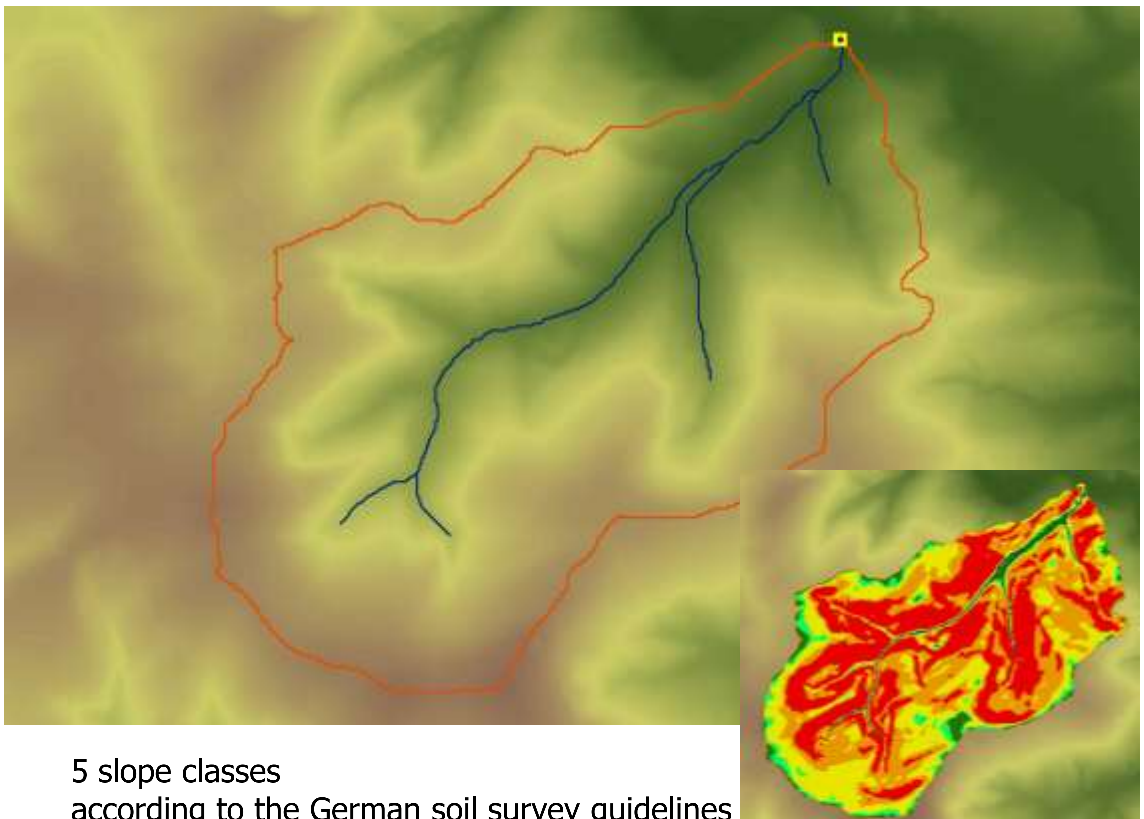
Parameterization: Water Delineation by Digital Elevation Model (DEM)

DEM = requirement for water delineation step and HRU analysis

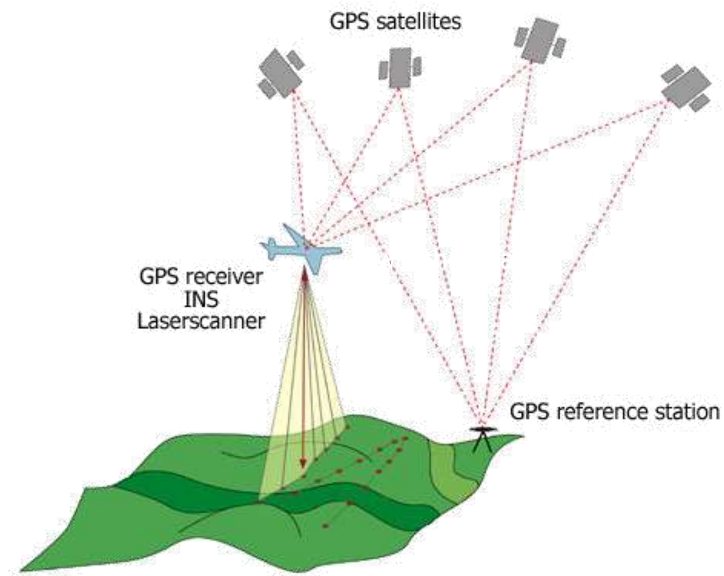
Available:

a) Regular available resolution in Germany: 20x20 m

b) Airborne laser-scanning resolution: 10x10 m

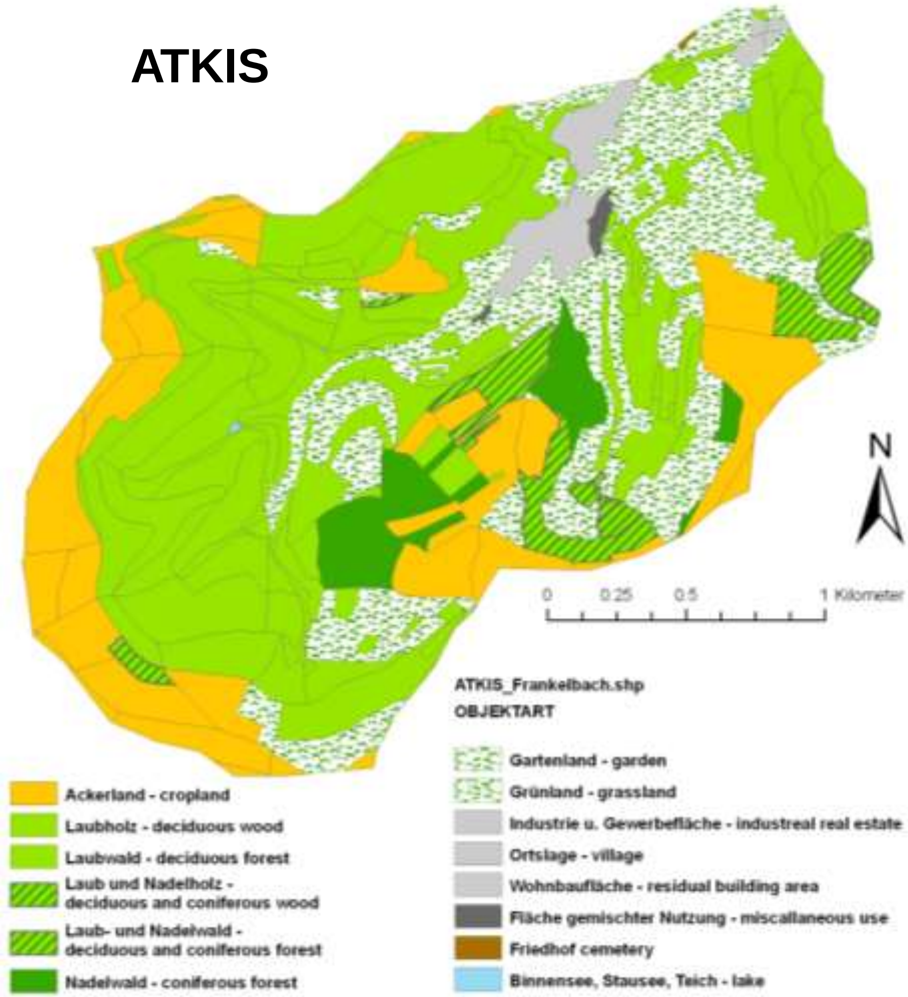


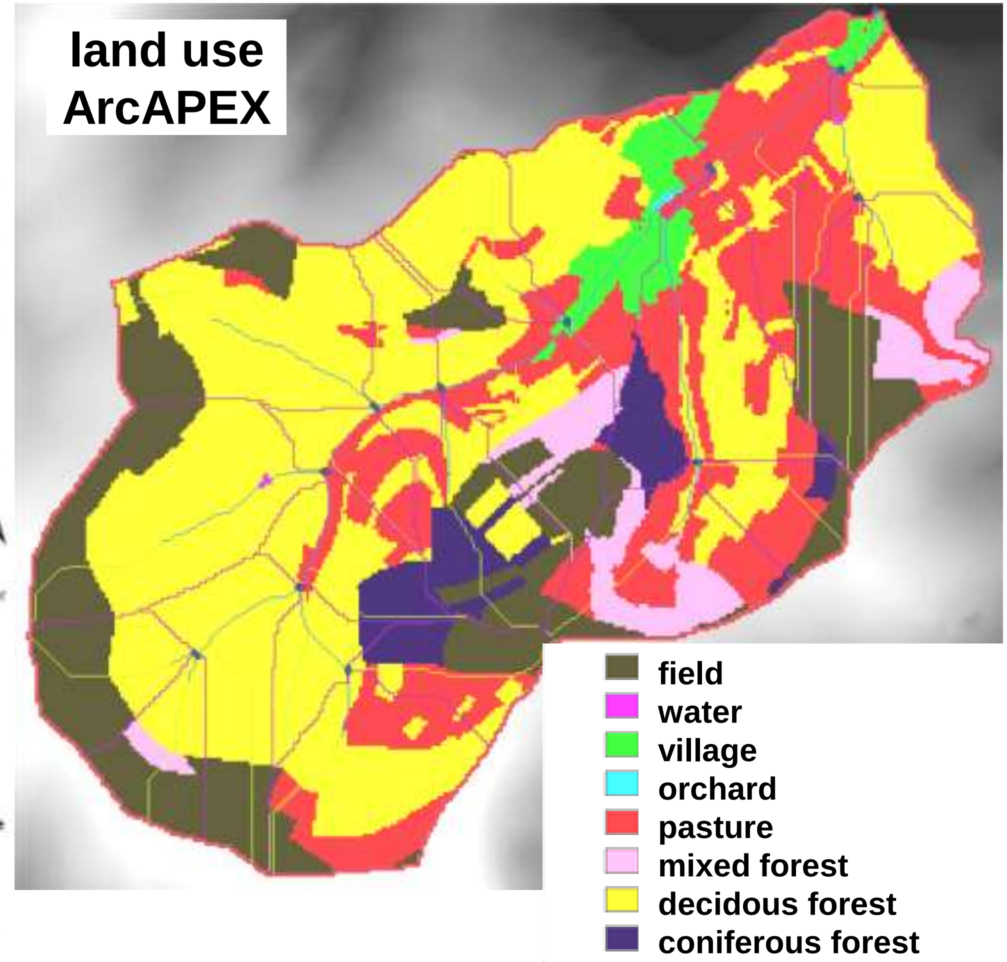
5 slope classes
according to the German soil survey guidelines



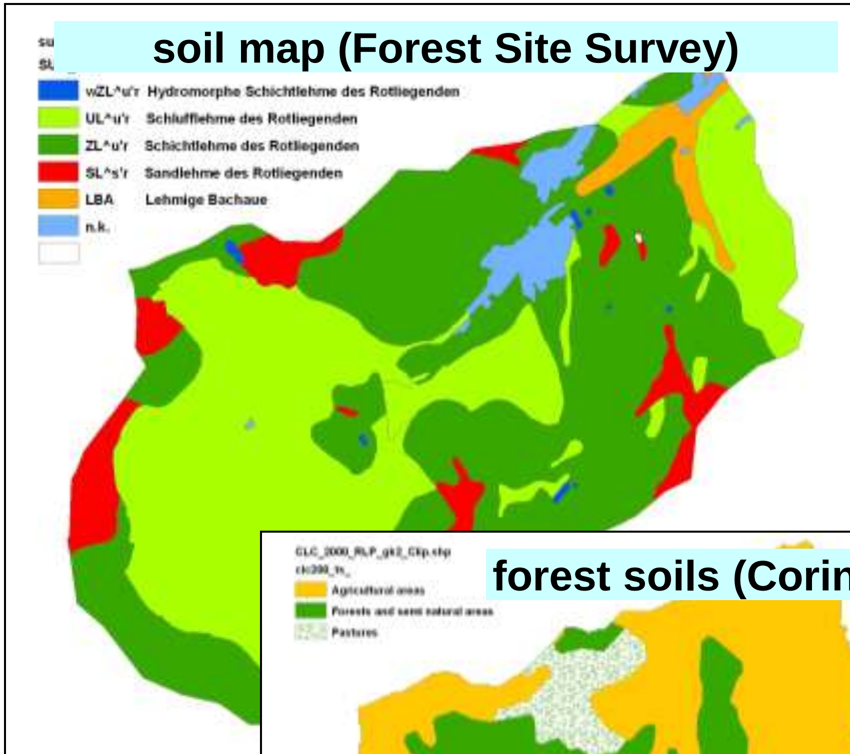
www.terraimaging.de

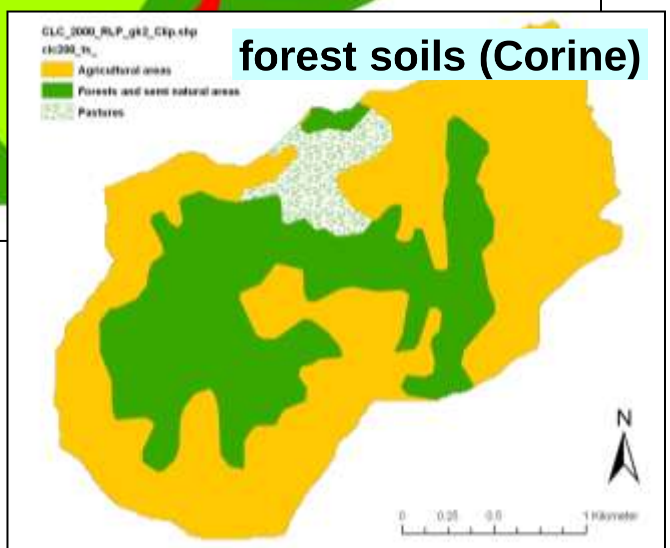
study areas: Landuse (Frankelbach)

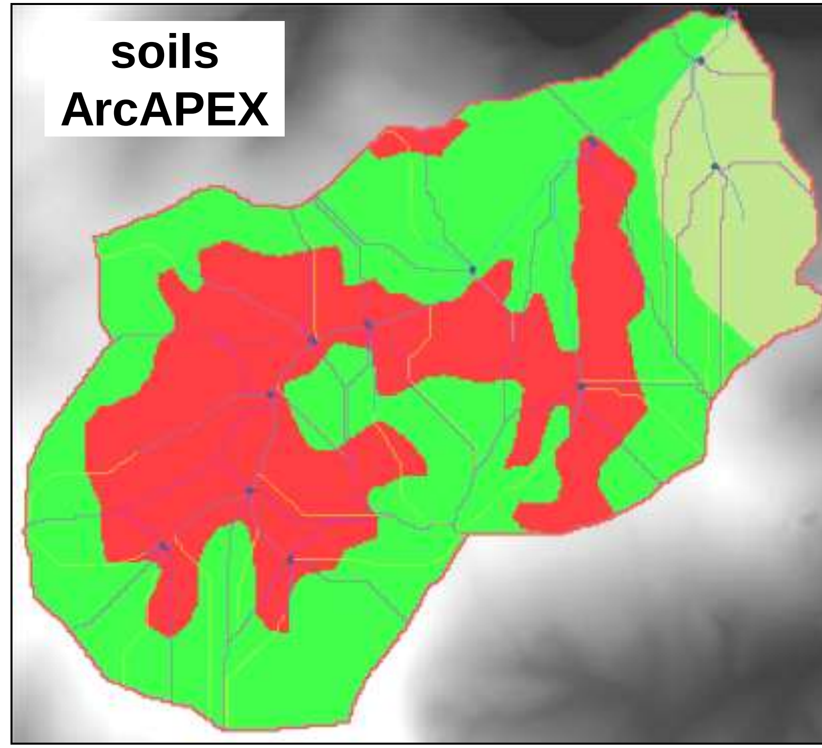




study area: Soils (Frankelbach)







study area: Measured Climate and Discharge Data (Frankelbach)

	temp (°C)	prec (mm)	discharge [1] (mm)	prec - discharge (mm), estimated
2005			152.2	
2006			207.5	
2007	9.7	749.5	293.8	
2008	9.0	692.3	267.8	
2009	8.5	780.0		
2010	7.9	714.7		
mean value	8.8	734.1	230.3	≈ 500

[1] ca. 10% missing values replaced by estimation

study areas: Climate Change Impact (Frankelbach)

ECHAM5 → „wet and cool“

Temp	annual mean	change (K)	min	max
1961-1990	8.0		6.6	9.6
2021-2050	8.8	0.7	7.3	10.3
2071-2100	10.1	2.1	9.1	11.0

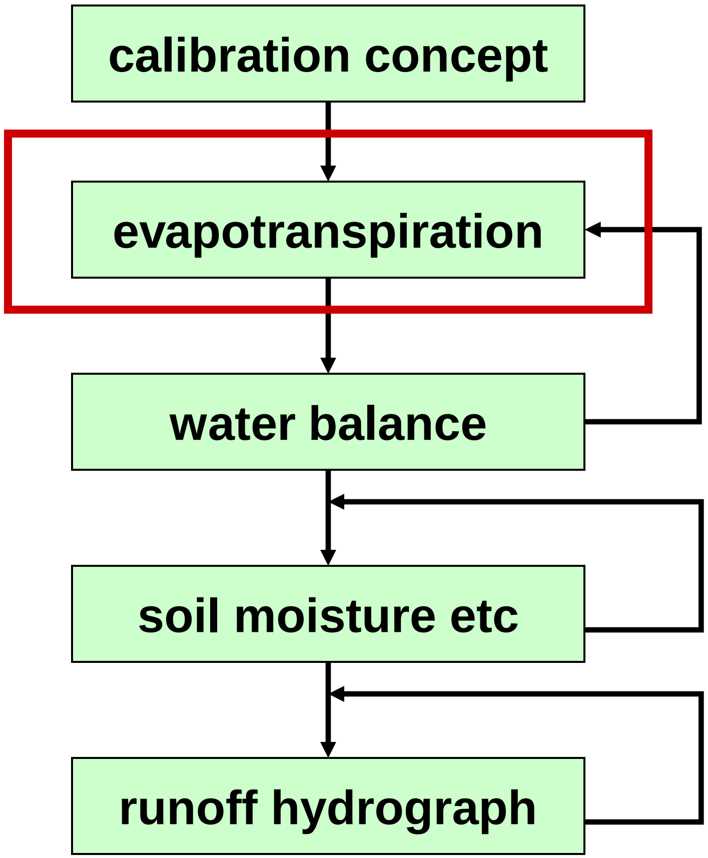
Precipitation	mean annual sum	change (mm)	change (%)	min	max
1961-1990	748			631	984
2021-2050	799	51	6.8	610	1014
2071-2100	899	151	20.1	741	1051

HC3Q0 → „dry and warm“

Temp	annual mean	change (K)	min	max
1961-1990	8.0		6.5	9.7
2021-2050	10.3	2.2	8.2	12.3
2071-2100	12.2	4.2	10.1	14.0

Precipitation	mean annual sum	change (mm)	change (%)	min	max
1961-1990	748			537	957
2021-2050	728	-20	-2.6	506	883
2071-2100	744	-4	-0.6	593	173

study areas: Evapotranspiration



$$ETa = \frac{1}{L^*} \cdot \frac{s \cdot (R_n - G) + \frac{\rho \cdot c_p}{r_a} \cdot (e_s(T) - e)}{s + \gamma \cdot \left(1 + \frac{r_s}{r_a}\right)}$$

Penman-Monteith

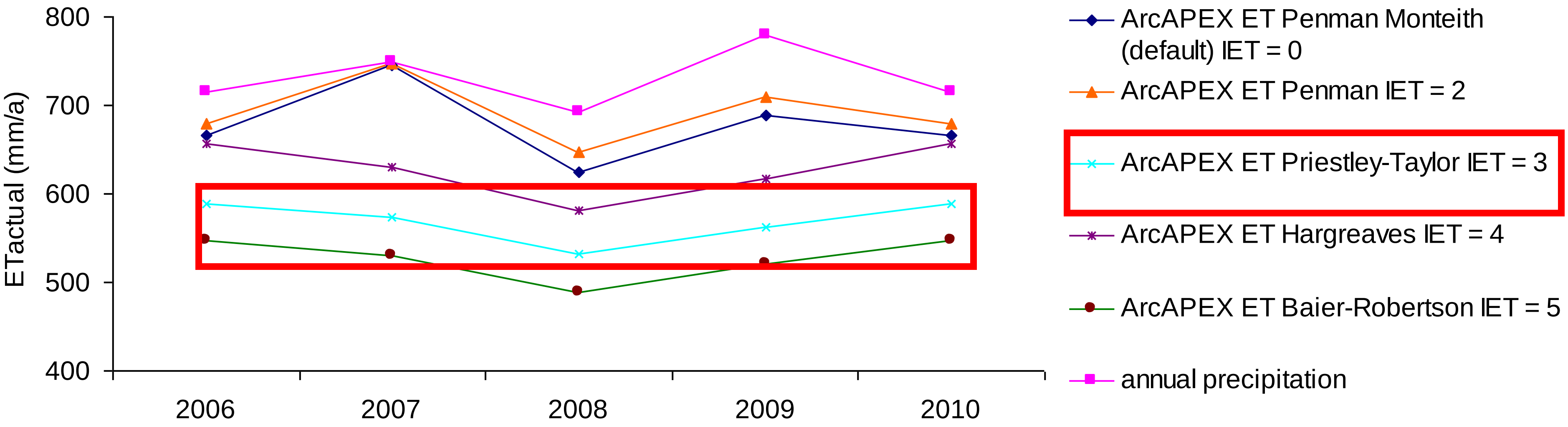
$$ET_0 = \frac{1}{\lambda} \cdot \frac{s \cdot (R_n - G)}{s + \gamma} \cdot \alpha$$

Priestley-Taylor

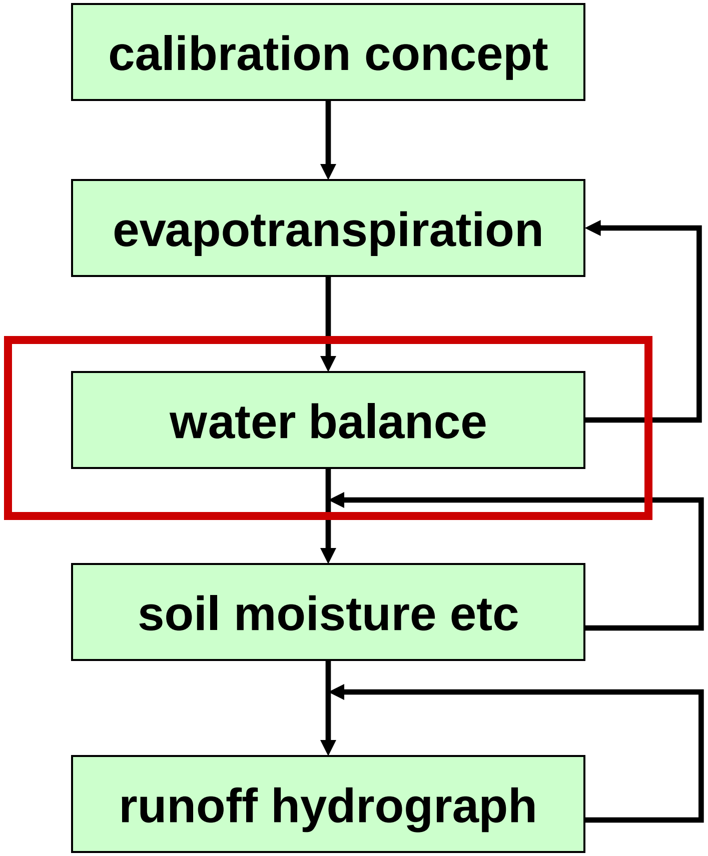
$$PET = 0.0075 \cdot R_a \cdot C_t \cdot \delta_t^{1/2} \cdot T_{avg.d}$$

Hargreaves

study area: Actual Evapotranspiration depending upon Calibration Results (Frankelbach)



study areas: Water Balance



study areas: Water Balance depending upon Calibration Results

water balance modelled

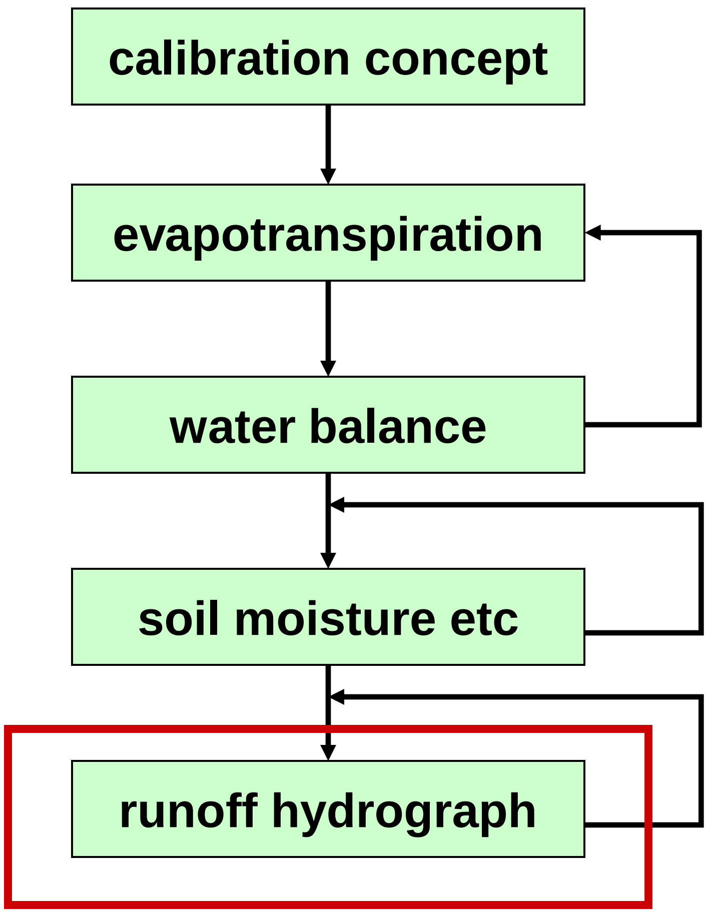
	Prec (mm)	discharge (mm)	ETa (mm)	change of storage (mm)
2006	726	240	532	-46
2007	750	188	533	29
2008	692	194	491	7
2009	780	181	515	84
2010	715	184	536	-5
Mean value	733	197	521	14

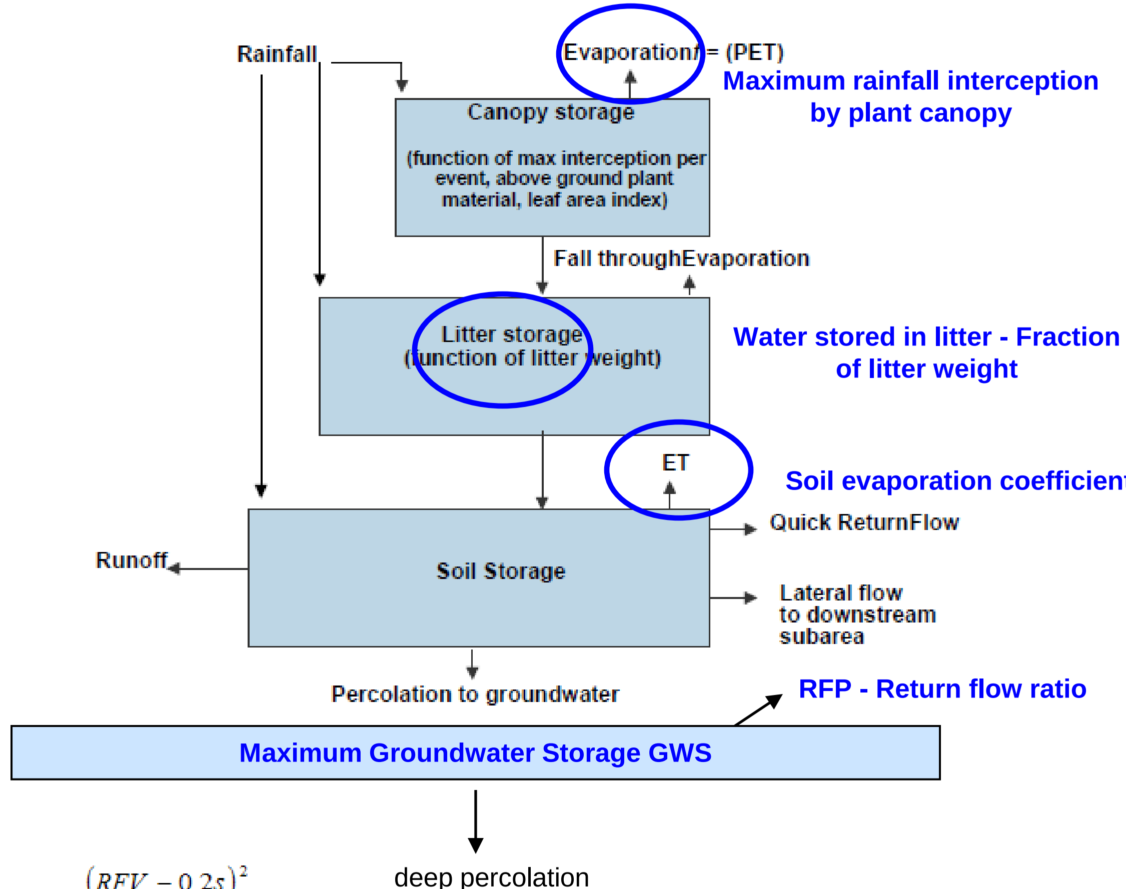
Frankelbach

comparison modelled / measured

	discharge modelled (mm)	discharge measured (mm)	difference (mm)
2006	240	207	33
2007	188	294	-105
2008	194	268	-74
2009	181		
2010	184		
mean value	197	256	-49

study areas: Runoff Hydrograph





$$Q = \frac{(RFV - 0.2s)^2}{(RFV + 0.8s)}$$

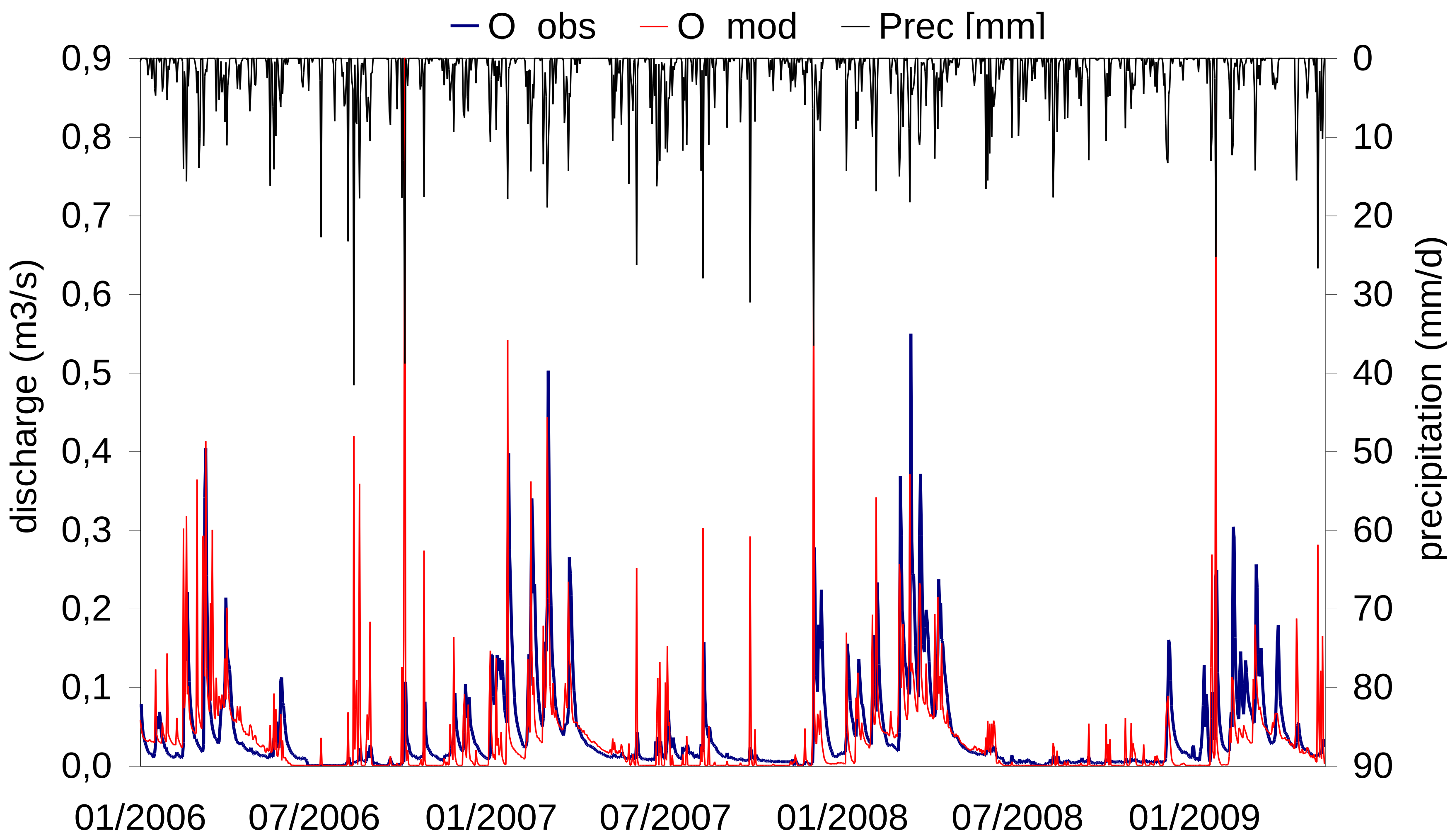
SCS* Curve Number Method

$$s = 254 * \frac{100}{CN - 1}$$

CN = f (land use, soil type, slope, soil moisture)

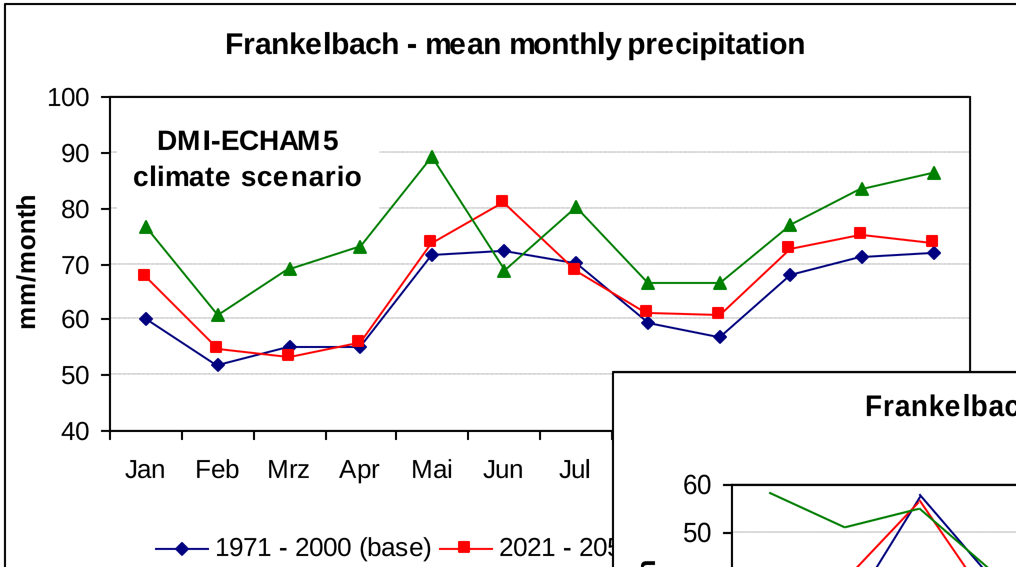
** Soil Conservation Service*

study areas: Runoff Hydrograph (Frankelbach)



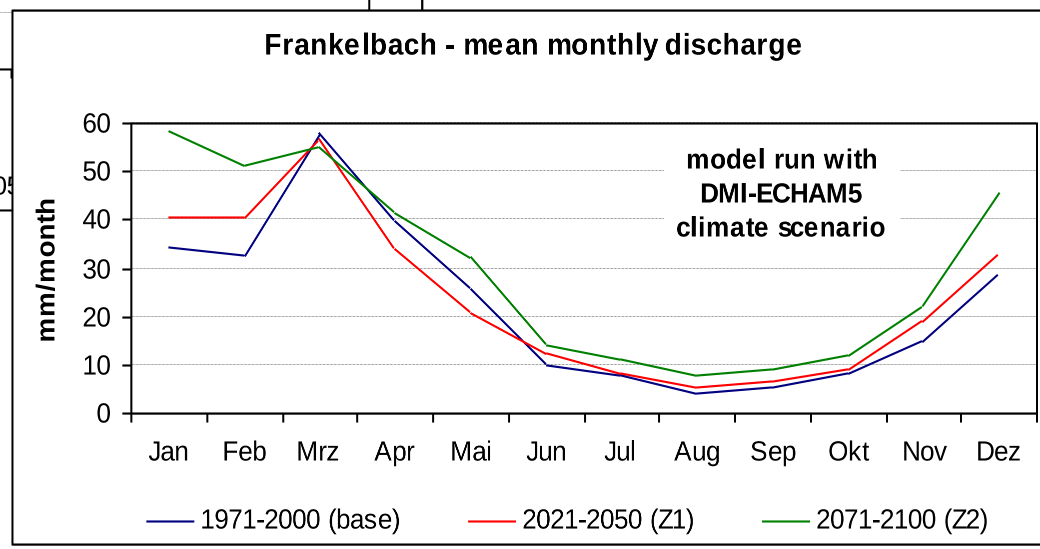
study areas: Climate Change Impact (DMI-ECHAM5)

Climate change signal → „wet and cool“



→ summer events (convective storms) don‘t have a major impact on runoff scheme

→ increased winter precipitation (rain and snow) leads to increased winter runoff and longer high flow periods



study areas: Climate Change Impact (DMI-ECHAM5)

Climate change signal → „wet and cool“

DMI - ECHAM5	**mean annual prec**		**mean annual runoff**		**mean annual PET**		**mean annual AET**		**AET/PET (%)**
	sum (mm)	change (%)	sum (mm)	change (%)	sum (mm)	change (%)	sum (mm)	change (%)	
1971 - 2000	764		270		763		480		62,9
2021 - 2050	799	4,6	287	6,3	765	0,3	496	3,3	64,8
2071 - 2100	899	17,6	362	33,9	764	0,1	520	8,3	68,1

→ increased runoff and more AET because of higher water availability!

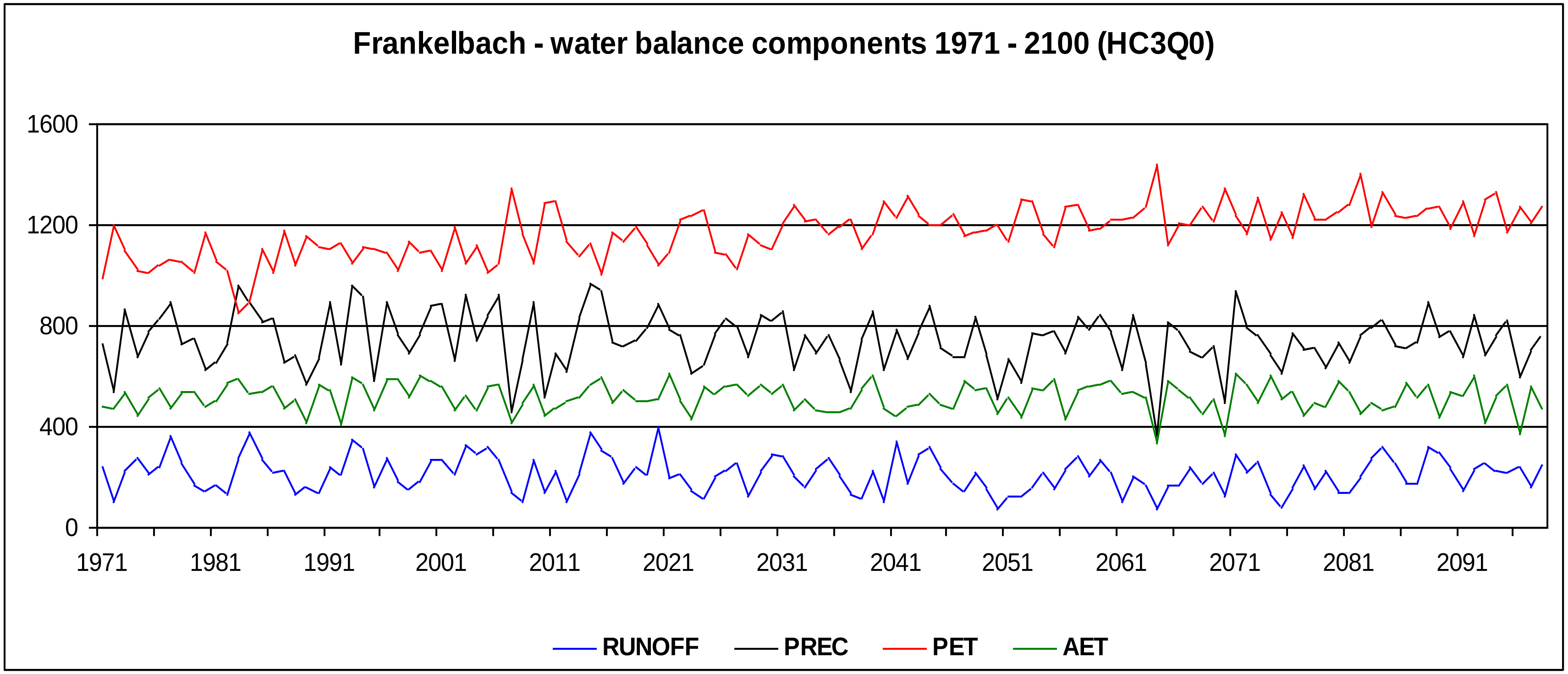
Average number of stress days for **forested** subareas

Statistics	mean annual nr of days with		mean annual nr of days with	
	water stress	**change (%)**	**temperature stress**	**change (%)**
1971 - 2000	50		179	
2021 - 2050	53	5,0	170	-5,0
2071 - 2100	49	-2,8	149	-16,4

APEX definition of water stress! (based on plant specific optimum temperatures and water requirements)

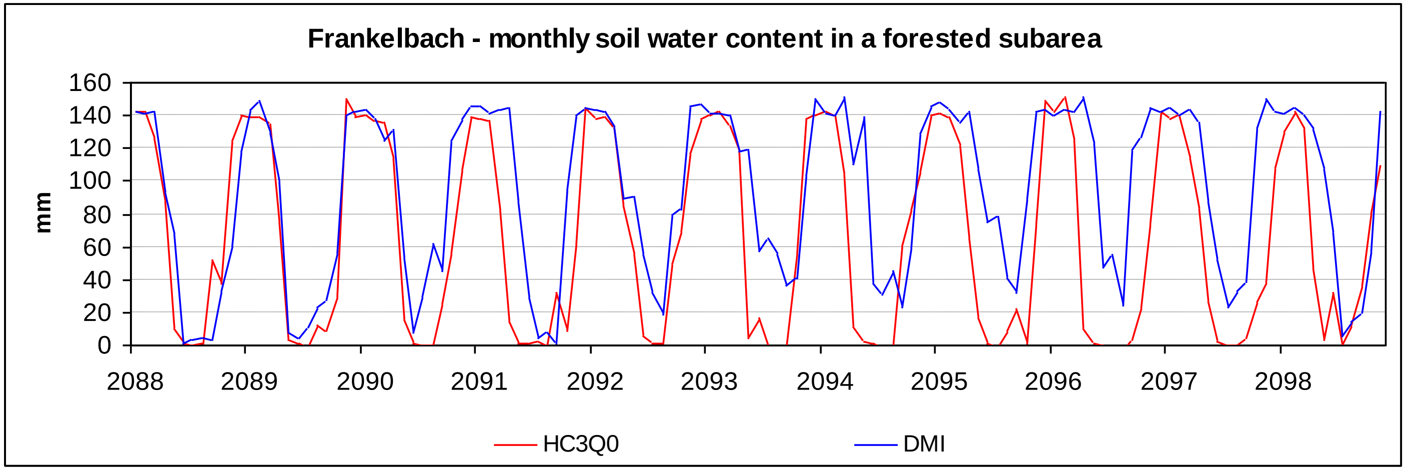
study areas: Climate Change Impact (HC3Q0)

Climate change signal → „dry and warm"



study areas: Climate Change Impact (Frankelbach)

Example:



- good representation of seasonal dynamics (soil moisture high in winter, low in summer)
- maximum value is fixed by soil characteristics
- DMI -> soils dry out in summer (modelled soil water content drops to zero)
- ECHAM -> soils dry out but not to the same extent (soil water content > zero)

study areas: Climate Change Impact (HC3Q0)

Climate change signal → „dry and warm“

HC3Q0	mean annual prec		mean annual runoff		mean annual PET		mean annual AET		AET/PET (%)
	sum (mm)	change (%)	sum (mm)	change (%)	sum (mm)	change (%)	sum (mm)	change (%)	
1971 - 2000	763		222		1067		525		49,2
2021 - 2050	728	-4,5	202	-9,2	1186	11,2	515	-1,9	43,4
2071 - 2100	744	-2,5	215	-3,2	1247	16,9	515	-1,9	41,3

Average number of stress days for forested subareas

Statistics	mean annual nr of days with		mean annual nr of days with	
	water stress	change (%)	**temperature stress**	change (%)
1971 - 2000	80		172	
2021 - 2050	113	41,3	144	-16,3
2071 - 2100	121	51,5	119	-30,9

APEX definition of water stress! (based on plant specific optimum temperatures and water requirements)

Increased temperatures are positive for plant growth but water is still the limiting factor!

Conclusions

1. The **recent physical soil conditions** seem to be the crucial factor for the plant-available soil water content, for mitigating fast runoff and reducing flow peaks

   – **not so much the real type of land-use**.

   The **history of land-use** often teaches us that forests were left on soils with bad soil conditions, e.g. shallow or hydromorphic soils with less field capacity, whereas the better soils were allocated by agricultural land-use.Thus, the less benefiting soil conditions under forests may have detrimental effects on the productivity, and on the runoff behaviour, at least as SSF / DSSF.

2. **APEX** makes it possible to quantify the plant-available water, and the runoff from catchment areas in a daily resolution. There are still difficulties to modell a delayed runoff, eg in areas with a high litter storage capacity (eg. peatland).

3. **Outlook:** Integrating a bandwith of regional climate projections makes it possible to derive recommendations for prospective best land-use practices with regard to future productivity, flood mitigation, a forward-looking sustainable forest management, and a considerate stewardship of water ressources having regard to forest and water interactions

Getting better understanding of the interactions between landscapes, forest, soil and water as well as of impacts of different land-uses on floods remains an important scientific task.

Living with Water in Forests

by Vu Thi Bich Hong

Water is Challenge and Threat

by Vu Thi Bich Hong

Challenges for Forest and Water Management

by Vu Thi Bich Hong

Suffering of Trees in Water

by Vu Thi Bich Hong

Suffering of Trees in Drought

by Nick Ut


Thank you for your attention !
And let me express my gratitude to my co-authors
- and of course to the European Union for funding our project.
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