HydroEco´2011

Consideration of the Vegetation Layer in Hydrological Modelling

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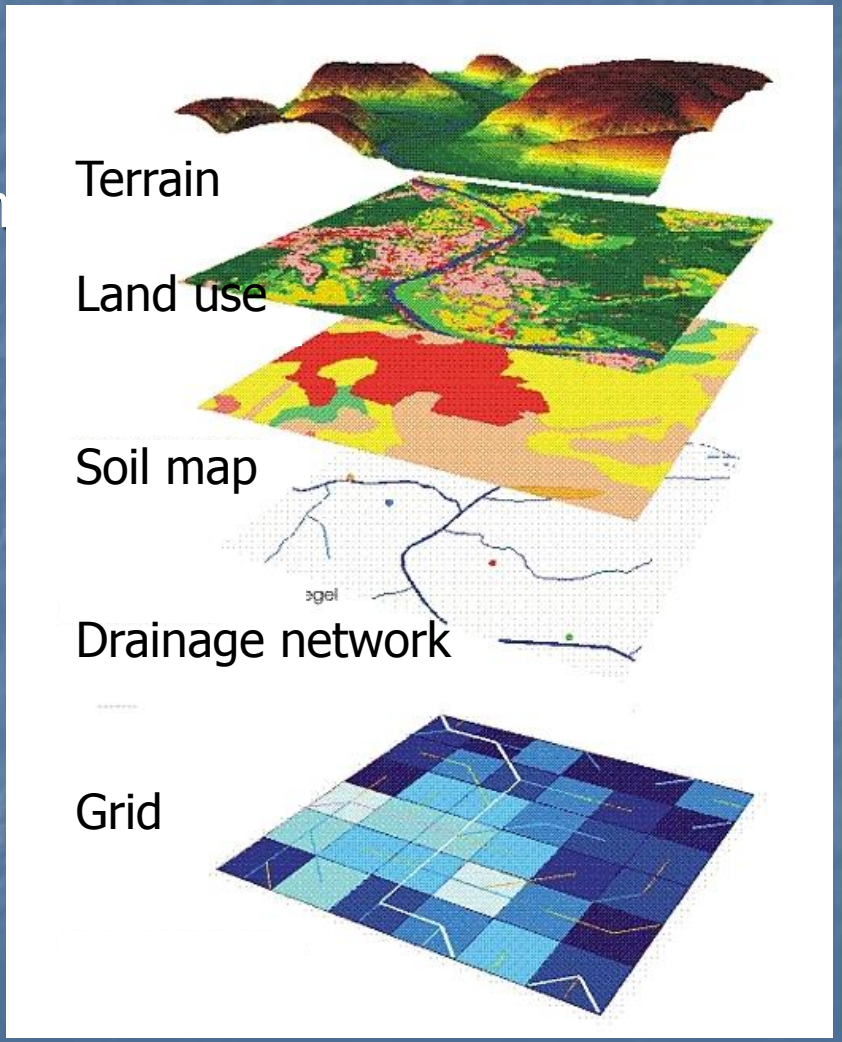
Structure of the presentation

- How is the vegetation layer represented in hydrological catchment models ?
- What is the role of the vegetation layer in hydrological processes ?
- What are the consequences for modelling and applications ?

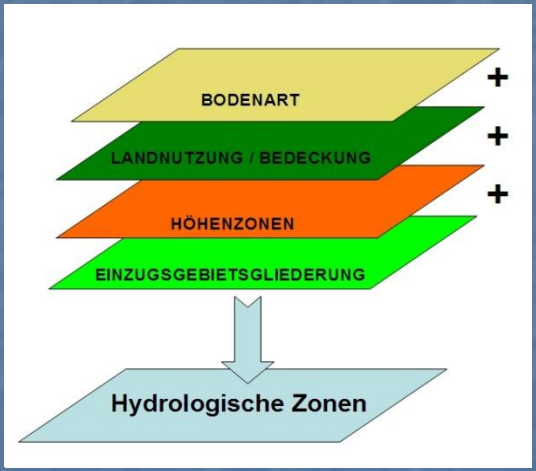
Hydrological catchment models

- Models from n km^2 to n*10^3 km
- Grid based



Hydrological catchment models

- Models from n km² to n*10³ km²
- Grid based
- Hydrological response units (HRU)



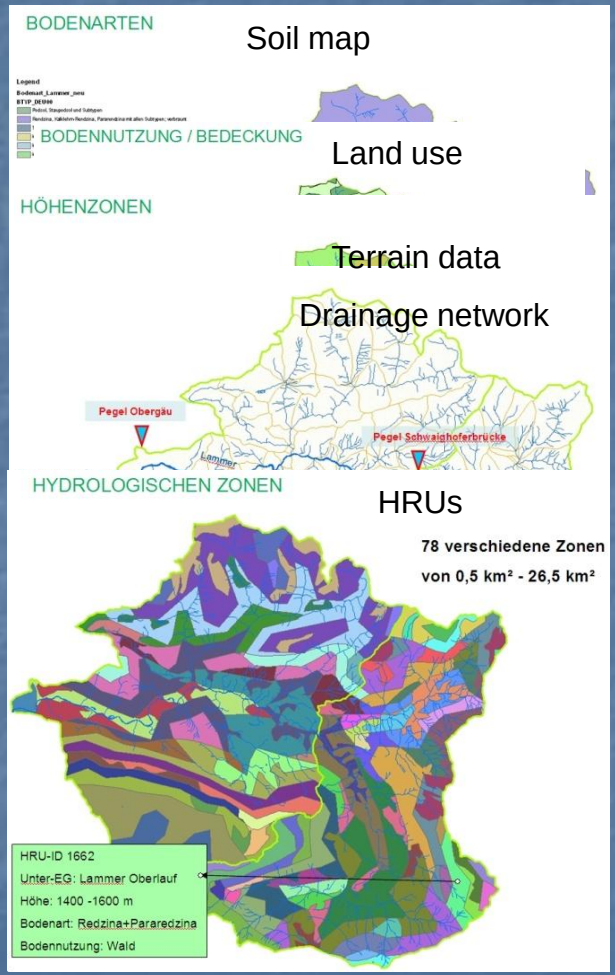
Soil map

Land use

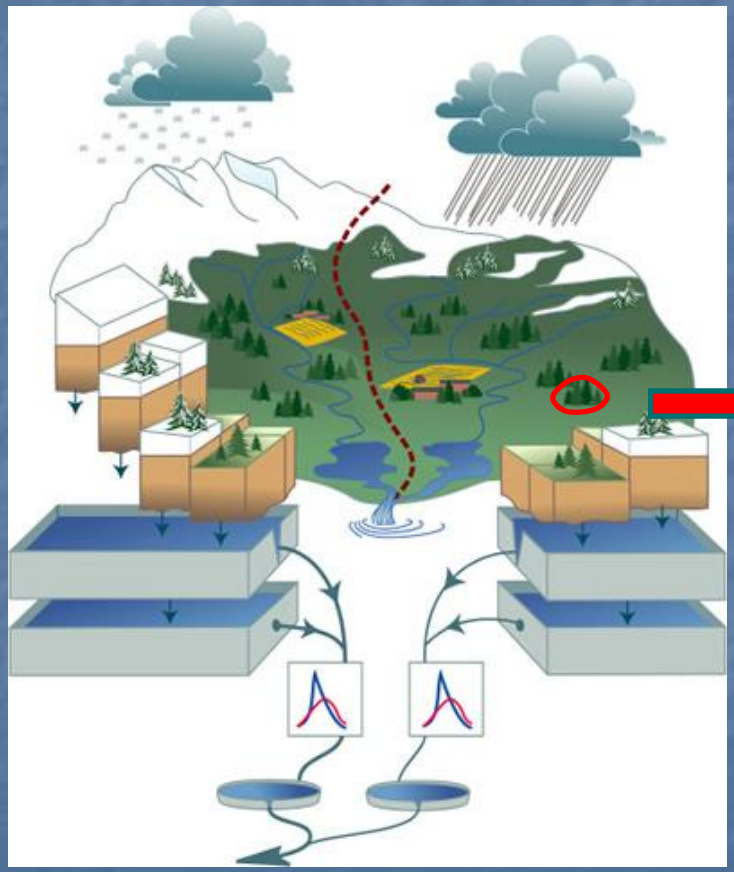
Terrain

Catchment topology

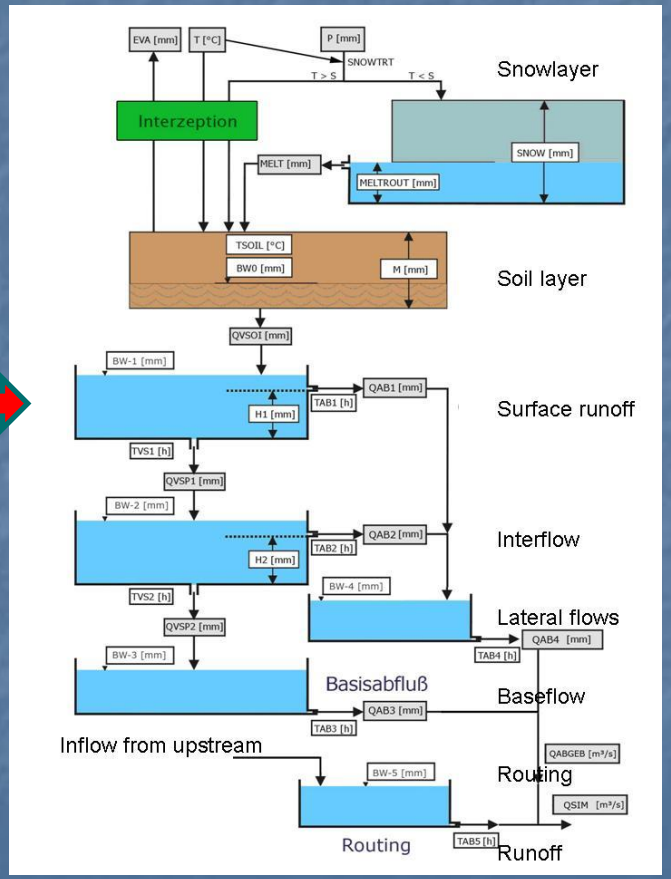
HRU



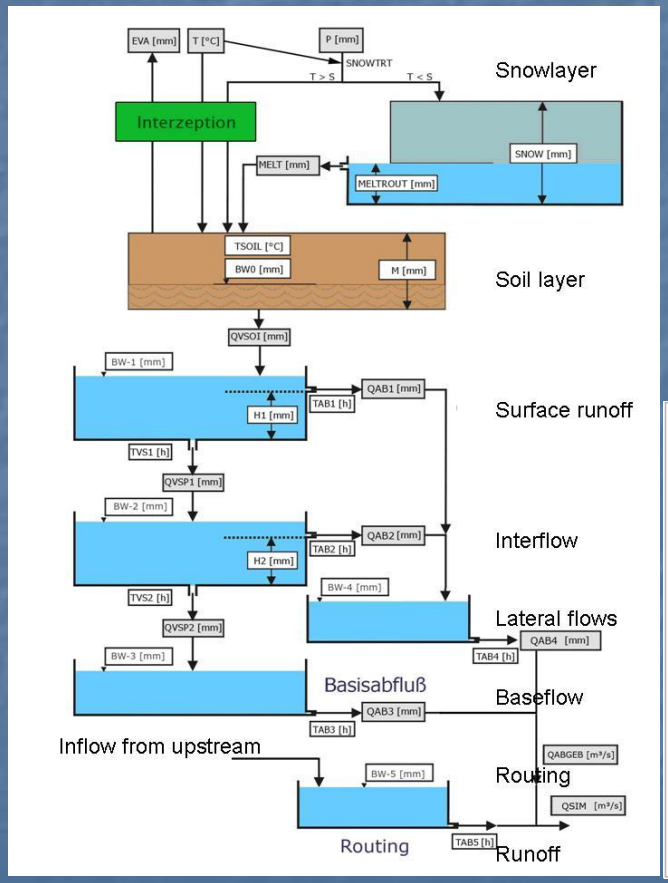
Hydrological catchment models



Vertical structure of an HRU

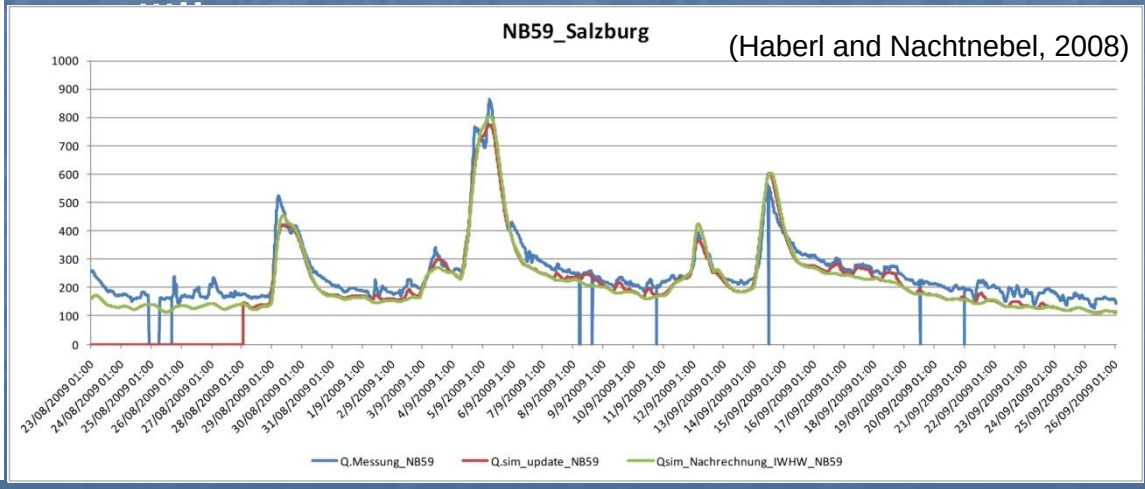


Hydrological catchment models



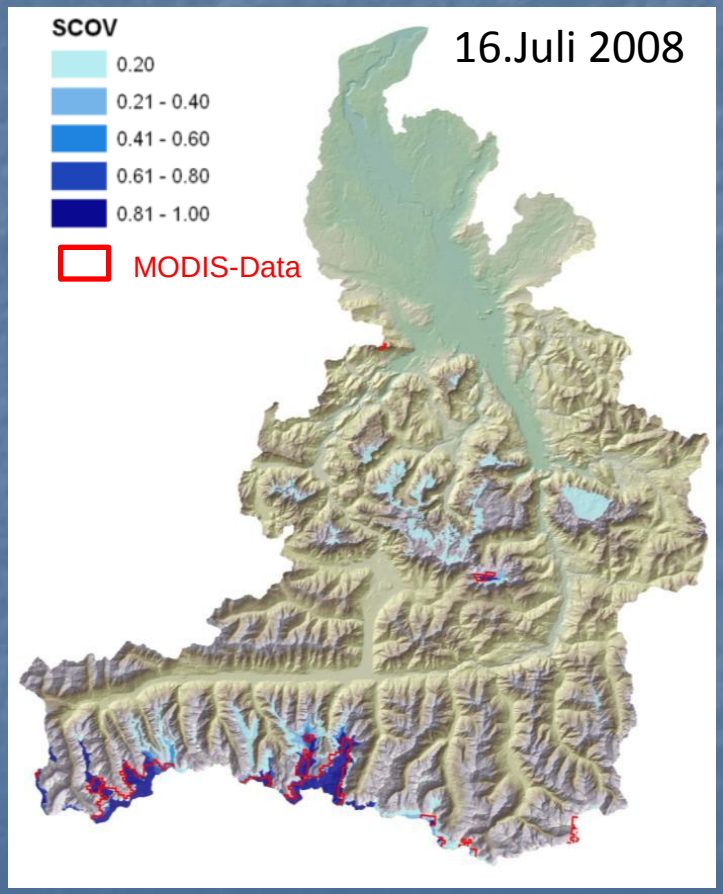
Model parameters:

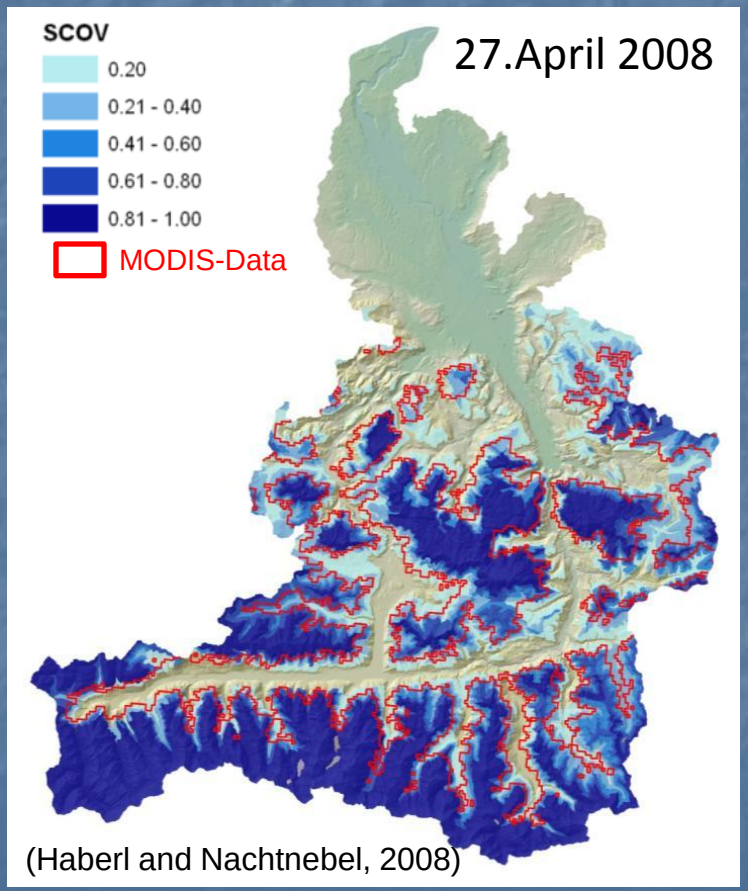
Soil thickness,
Infiltration capacity,
Wilting point,
Field capacity



(Haberl and Nachtnebel, 2008)

Snow coverage (simulated and observed)

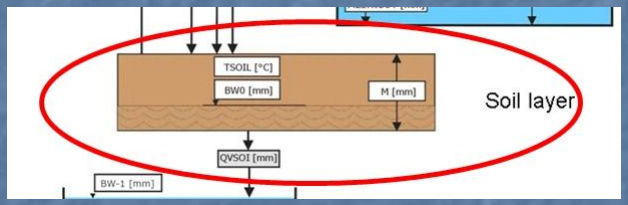


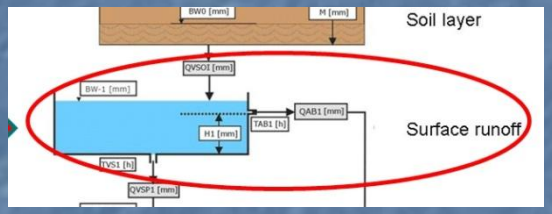


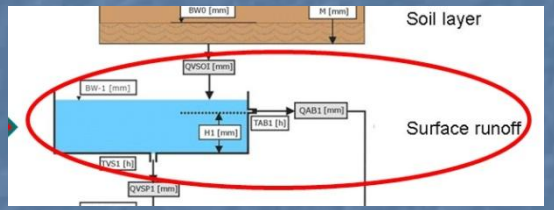
(Haberl and Nachtnebel, 2008)

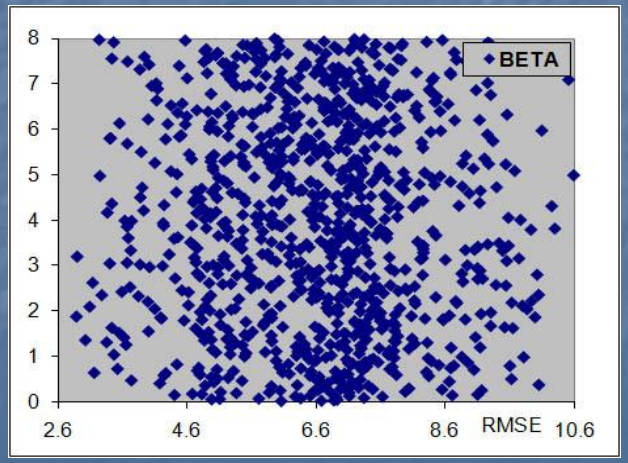
Fitting and equifinality (Beven et al.)

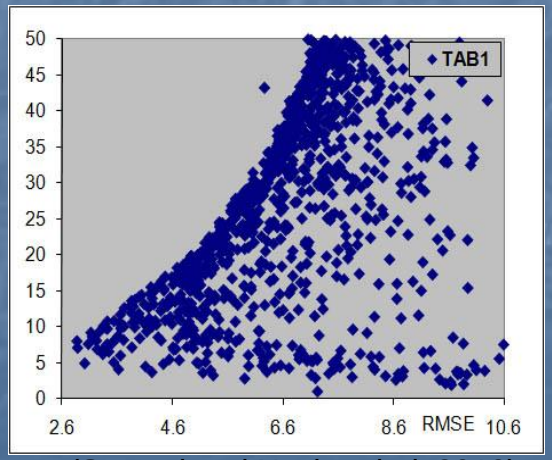
- Hydrological models simulate in general quite well long runoff series
- BUT: quite different parameter sets yield good results

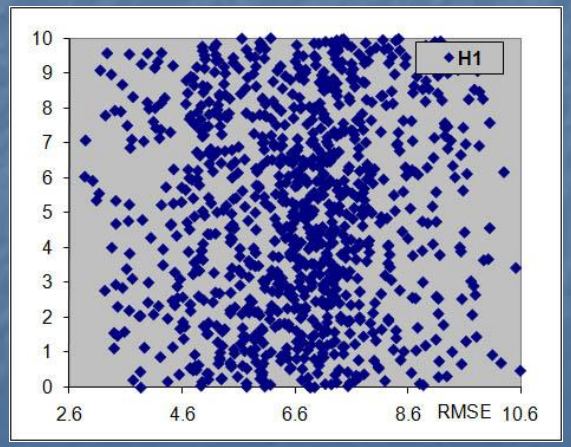












(Stanzel and Nachtnebel, 2010)

How is the vegetation layer included in the models ?

- Soil properties from soil map
- Corine land cover data set is used
- Generalised maps distinguish
  - Deciduous forests
  - Coniferous forests
  - Mixed forests
  - Grassland
  - Agricultural areas
  - .....

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- Soil properties from soil map
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  - Grassland
  - Agricultural areas
  - .....
- What is missing ?
  - State of the forest (age, composition, shrub layer, herb layer)
  - Root depth

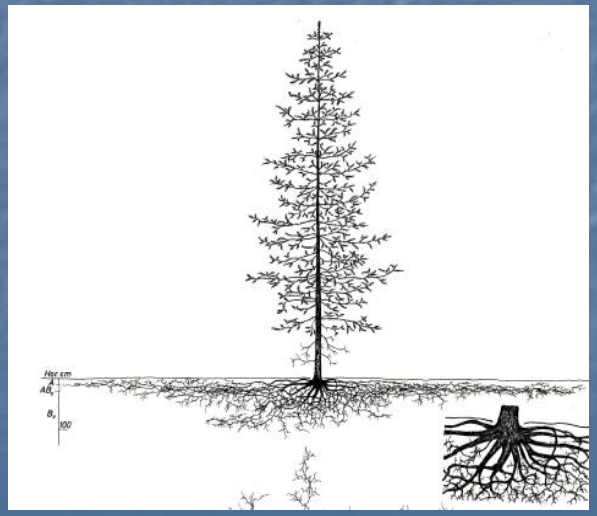
Tree layer: root depth and density

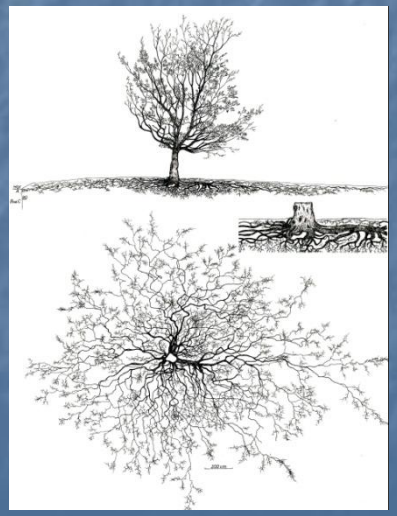
Spruce (Picea abies)

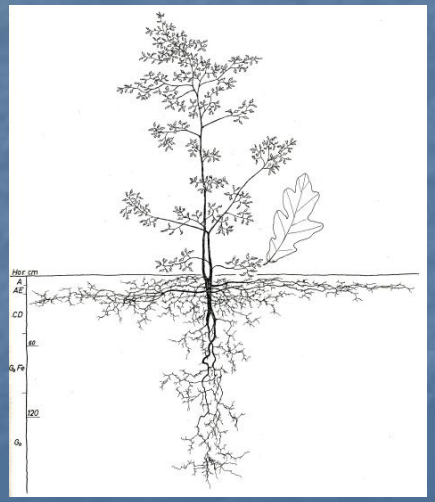
Beech (Fagus sylvatica)

Oak (quercus robur)

(from Kutschera und Lichtenegger, 2002)

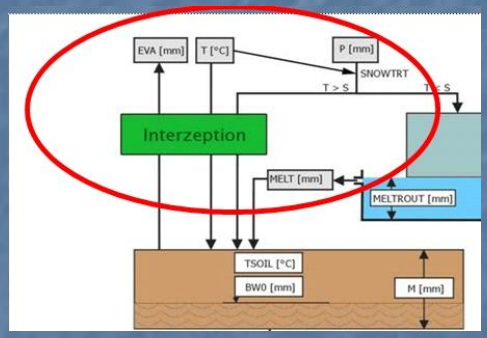




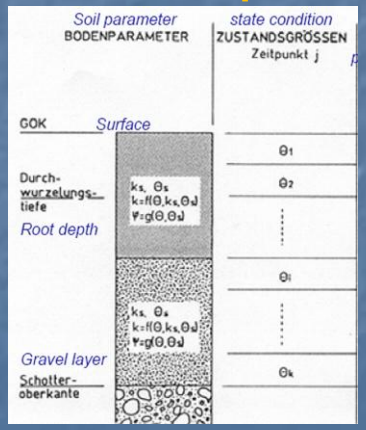


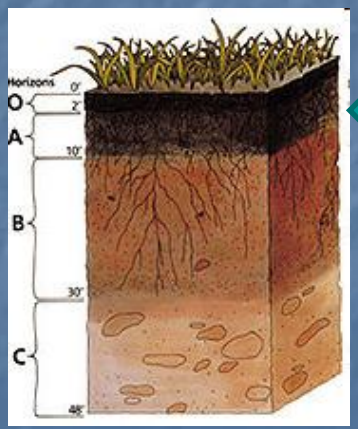
How is the vegetation layer included in the model ?

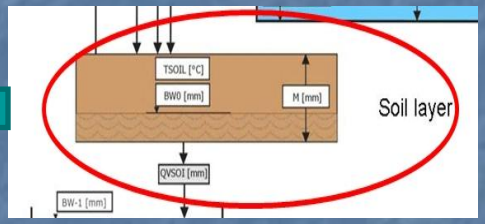
Interception
Transpiration coefficient



As long as there is a single soil layer
we neglect root system,
profile of soil moisture content







The shrub and herb layer

- Are not really consider in our models (only as grassland or pastures classified)
- Herb layer changes the surface roughness, the infiltration capacity, the surface runoff

(Carex)

(from Markart et al., 2004)

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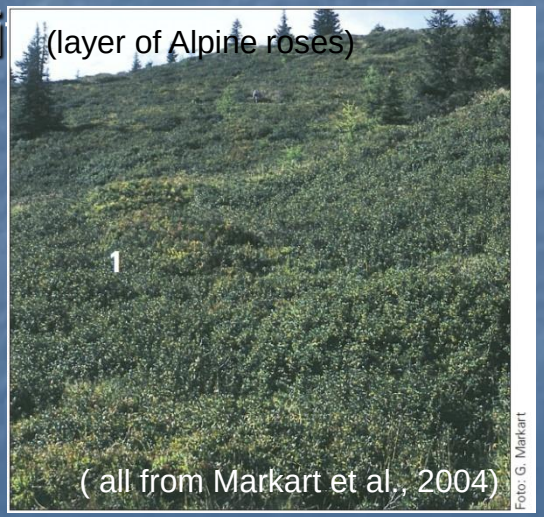
(Tree and herb layer)


(Tree layer)

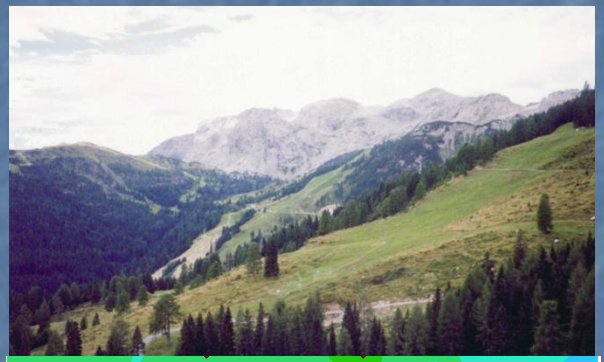


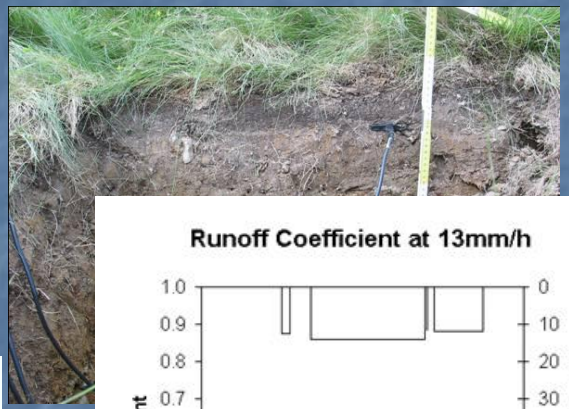
(all from Markart et al., 2004)

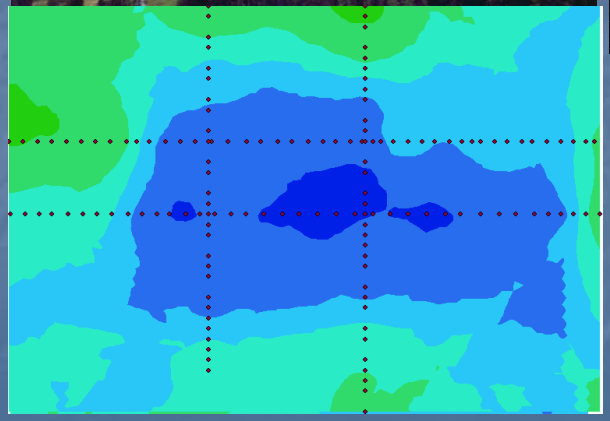
Field experiments in different Alpine environments

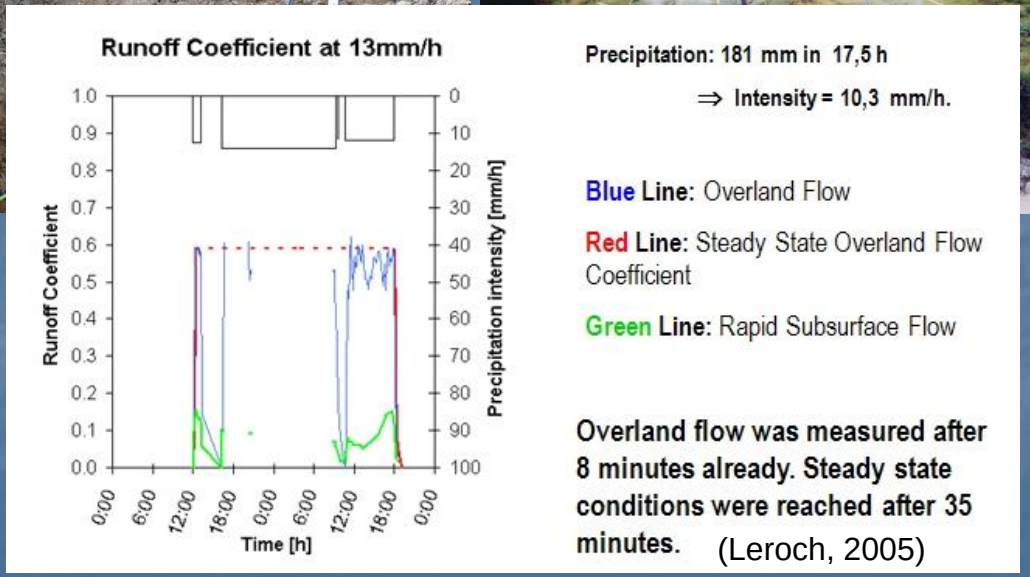
Irrigation experiments and monitoring of soil moisture content
Surface runoff, interflow and groundwater flow

(from Nachtnebel et al., 2005)



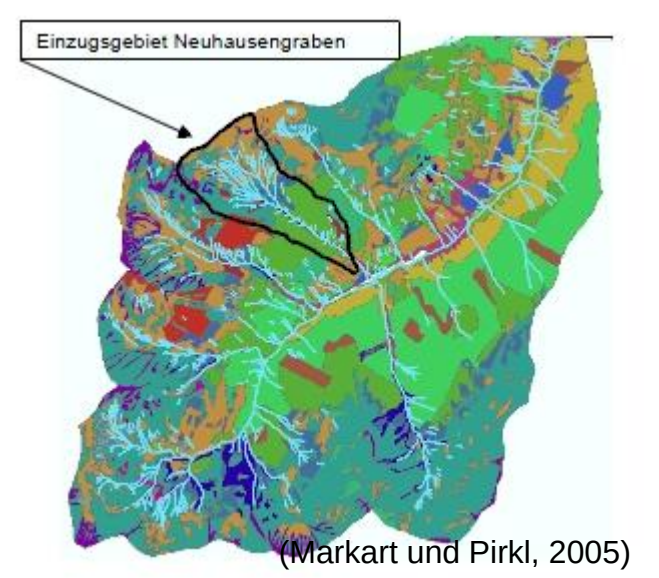






Improved modelling approach by considering vegetation

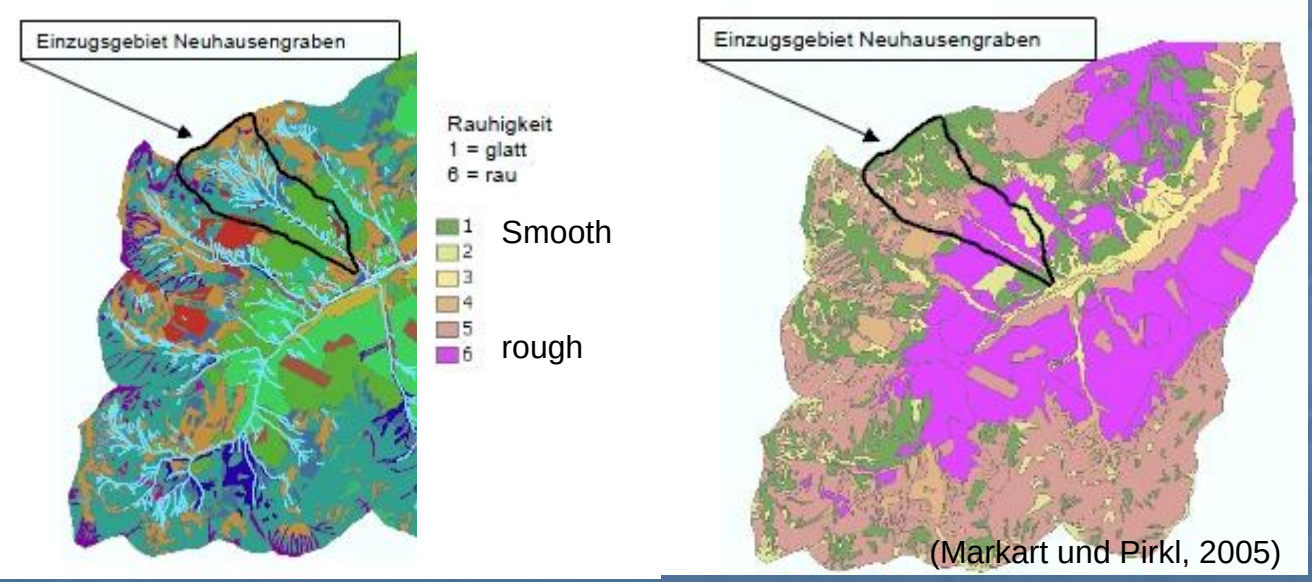
- Detailed mapping of vegetation



(Markart und Pirkl, 2005)

Improved modelling approach by considering vegetation

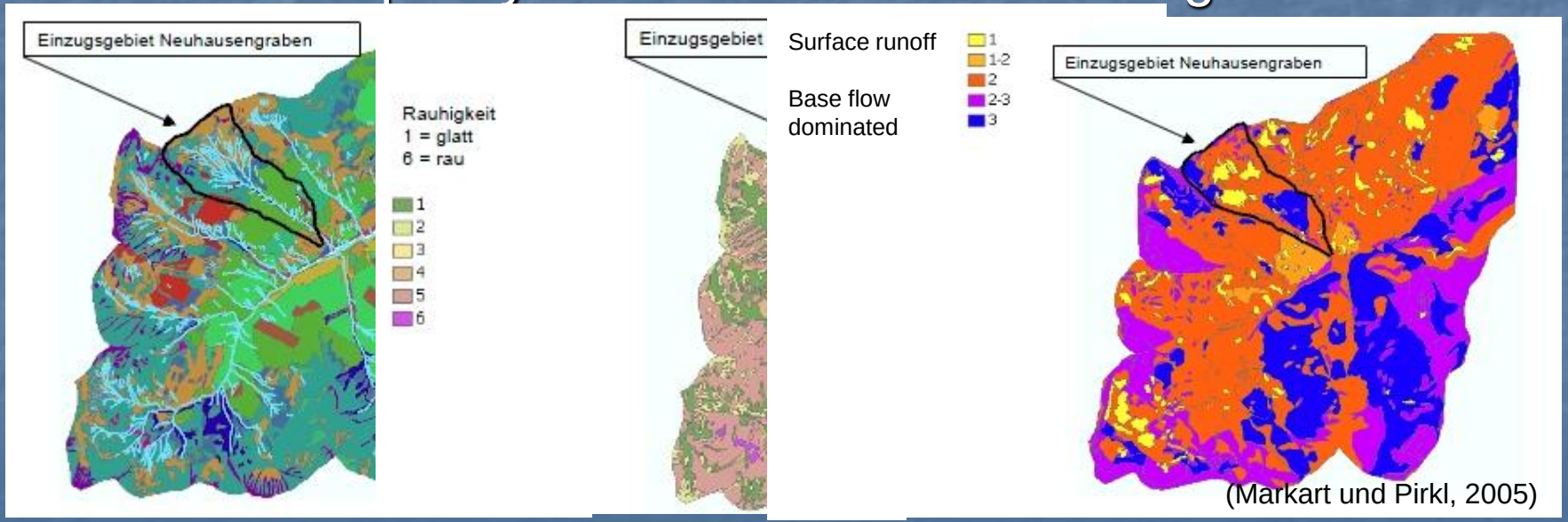
- Detailed mapping of vegetation
- Classification of surface roughness



(Markart und Pirkl, 2005)

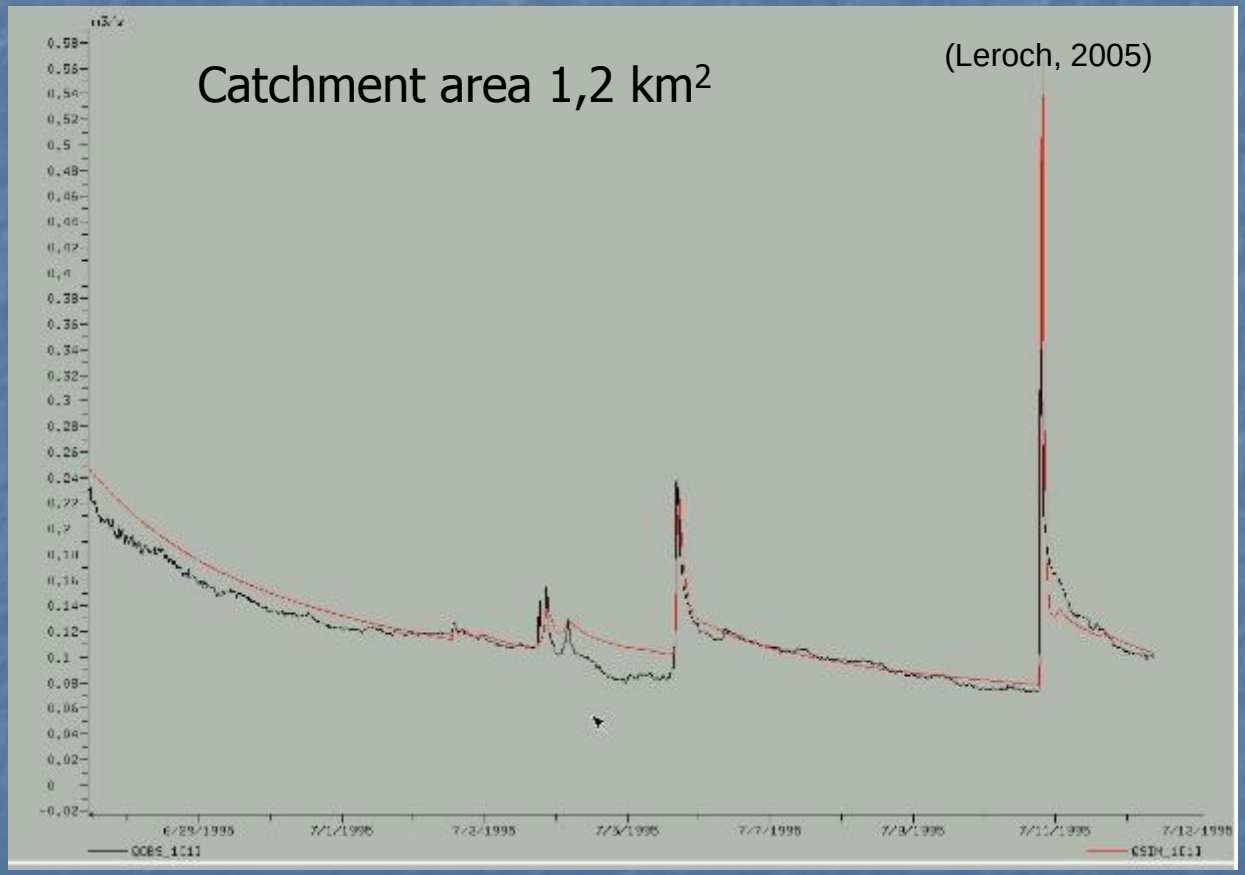
Improved modelling approach by considering vegetation

- Detailed mapping of vegetation
- Classification of surface roughness
- Infiltration capacity under consideration of vegetation



(Markart und Pirkl, 2005)

Hydrological modelling results



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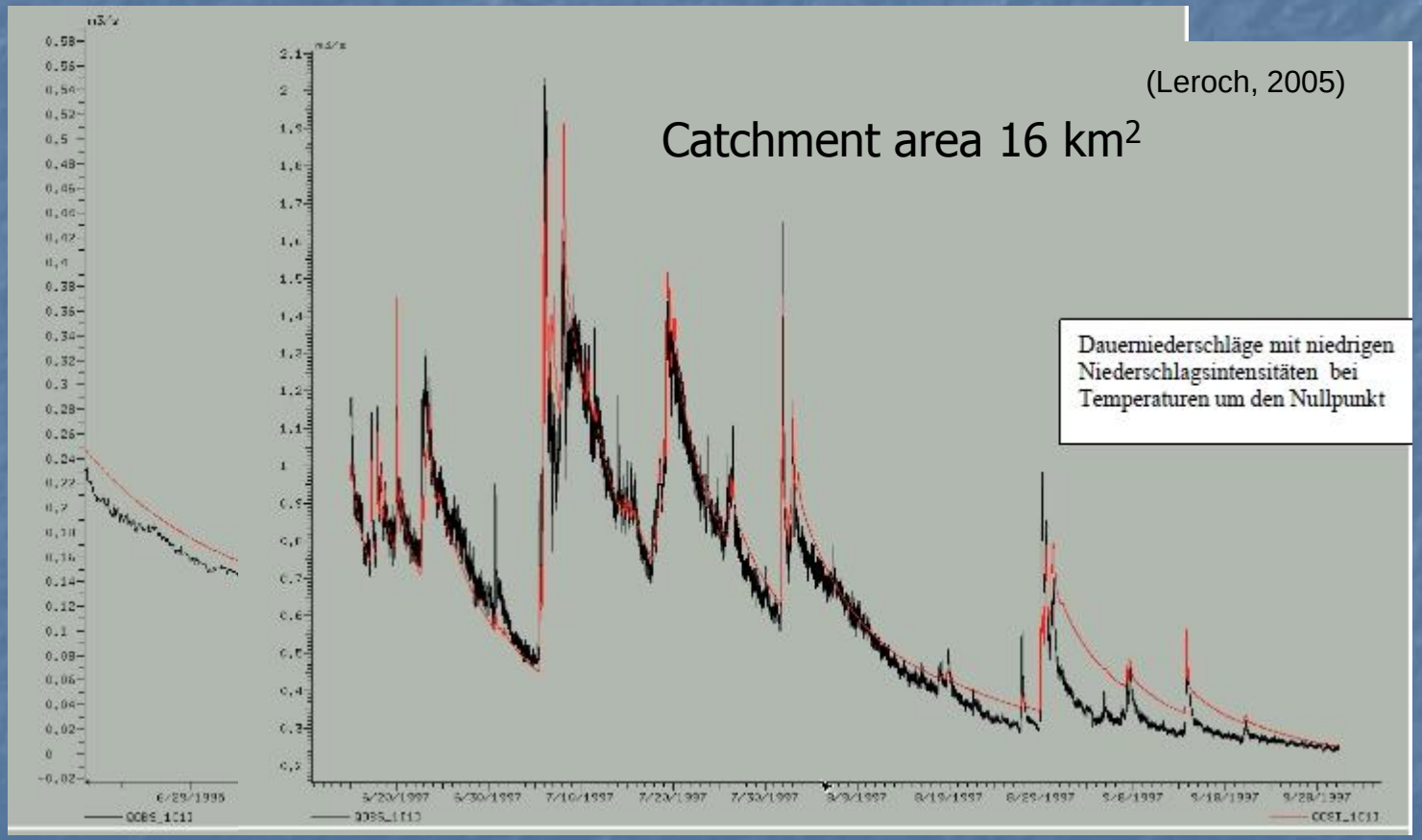

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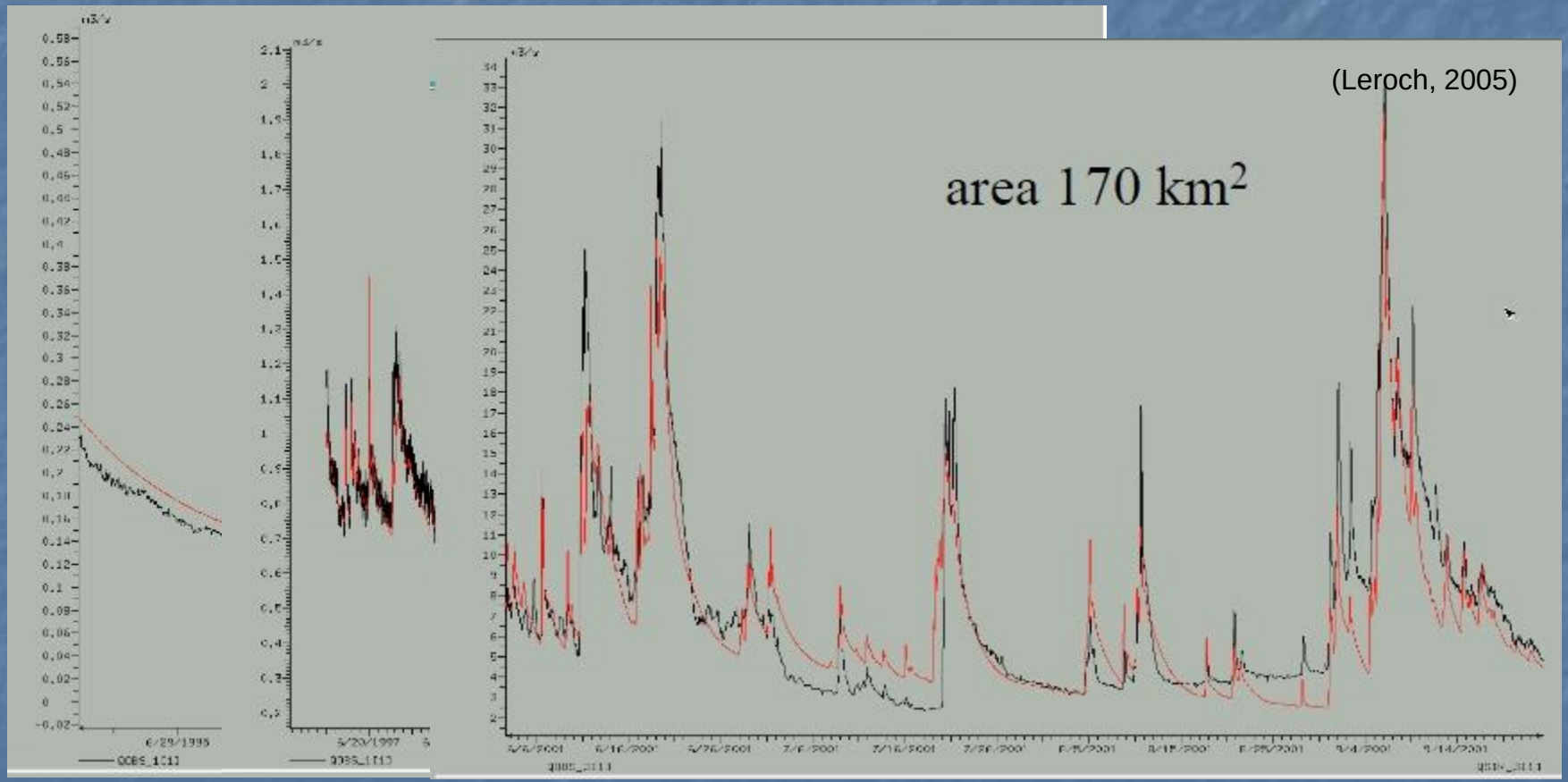
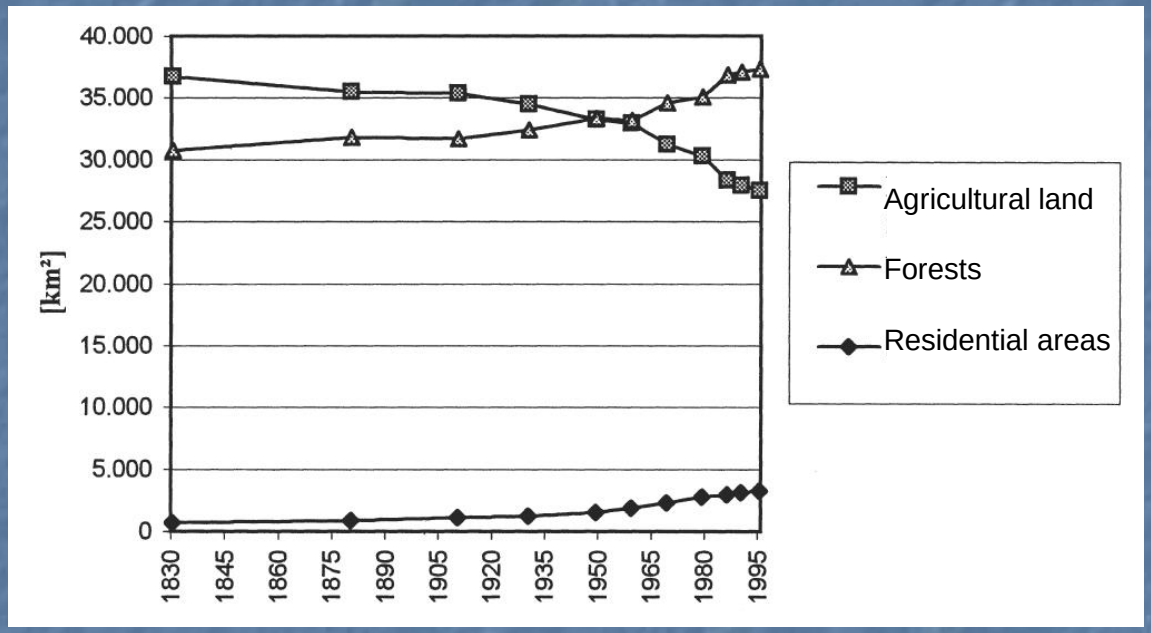


Evaluation of the model performance

- At the small scale the detailed mapping improved the model efficiency (without fitting)
- At the larger scale the benefits from detailed mapping could not be fully justified
- Other processes (groundwater flow and storage) might be important
- The model works over a large range of scales

Consideration of land use changes (vegetation layer)



Residential area increased from 1 % to 8 %

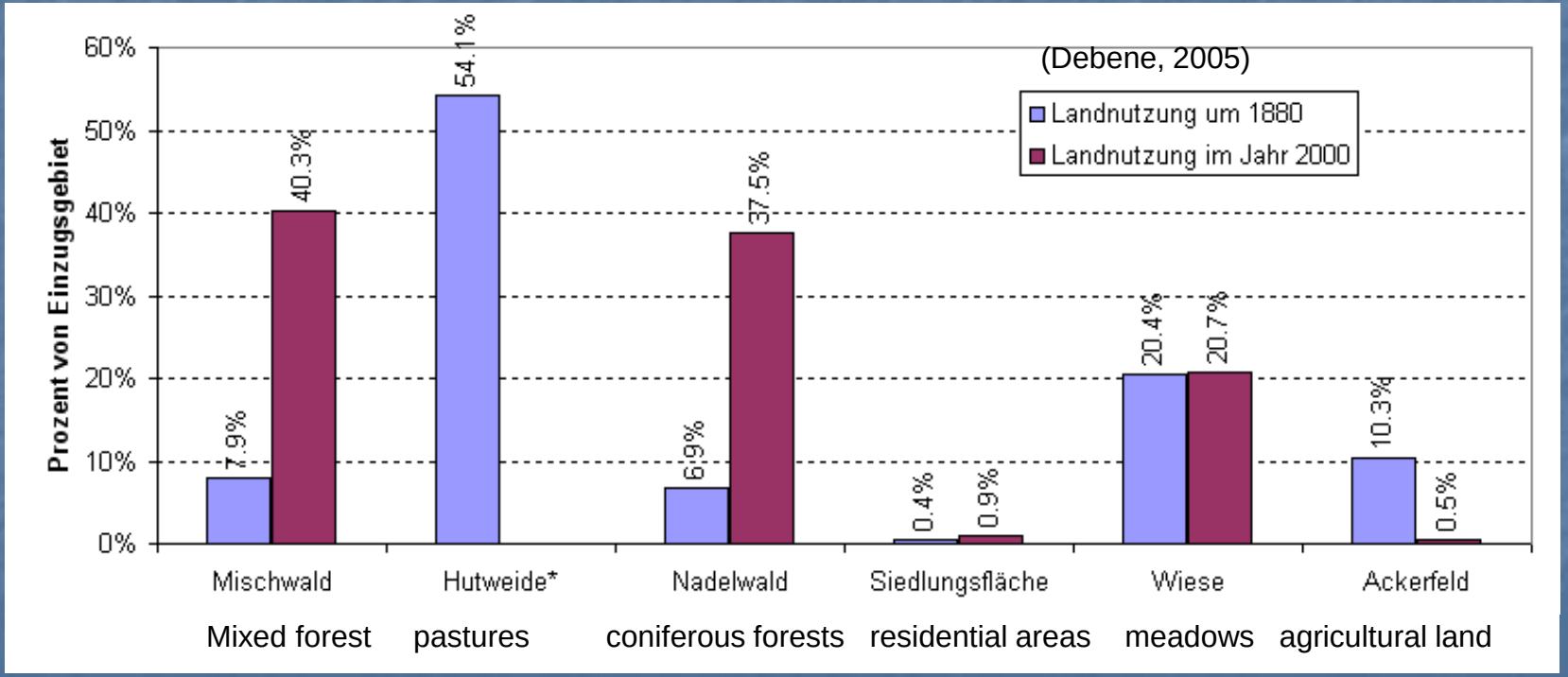
Agricultural land/capita from 1,4 ha to 0,4 ha

From which is 60 % pastures and meadows

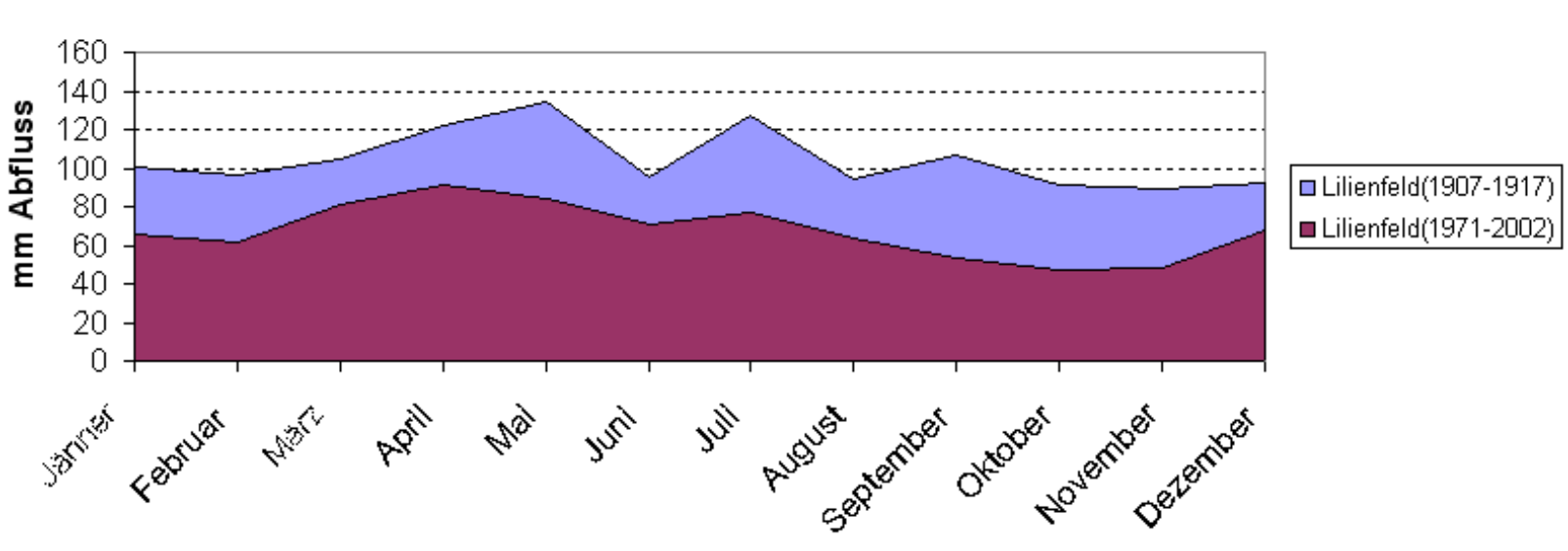
(BMLFUW, 2010)

Changes in land use in Austria between 1830 to 1995.
(KRAUSMANN 2000)

Changes in land use: Traisen catchment
(area = 733 km^2)



Longterm changes in runoff

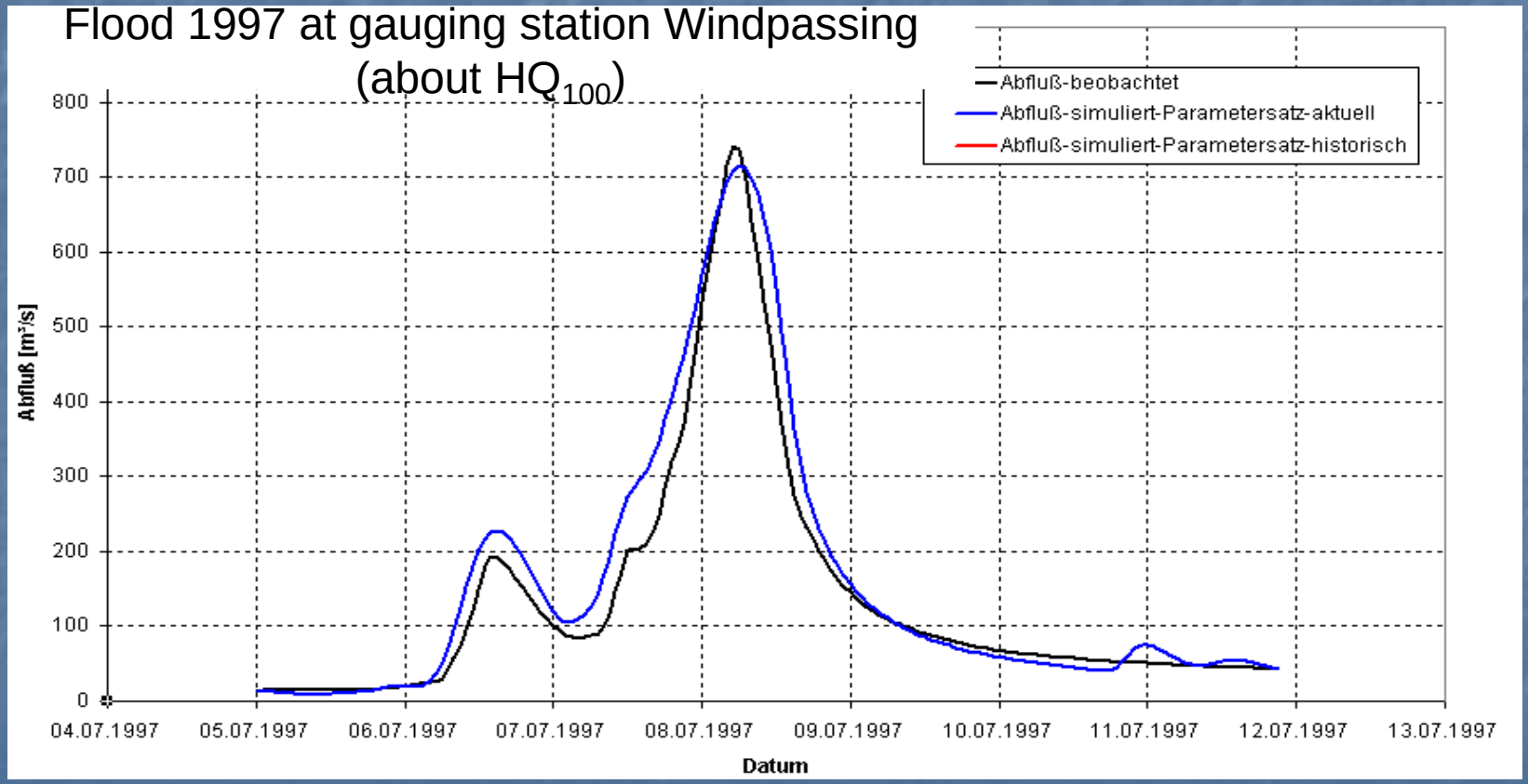


Decrease of runoff in each month
increased temperature and evaporation
Previously higher runoff coefficients because of landuse

Impact of land use changes

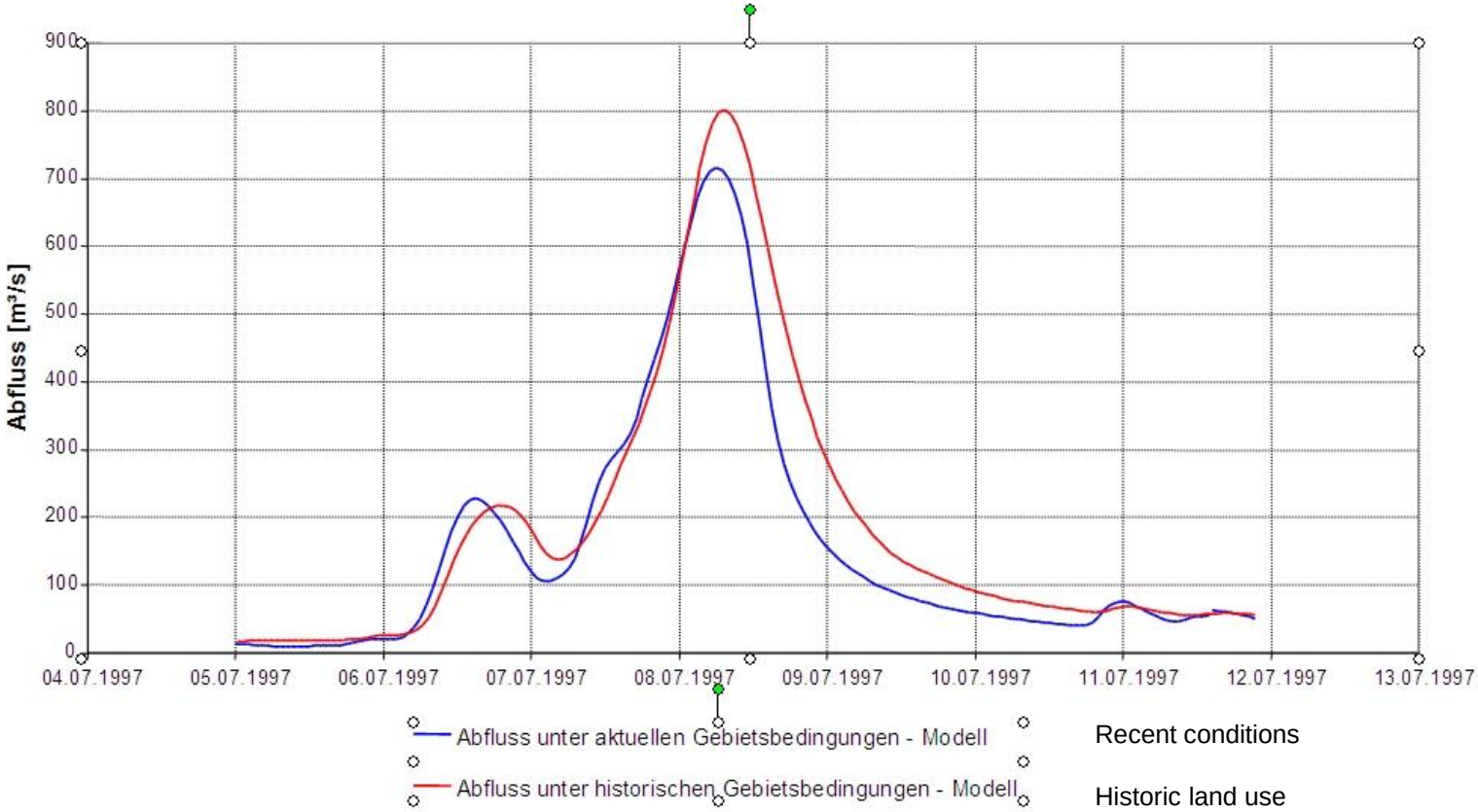
- Increased interception
- Increased roughness
- Mixed forests are dominating and utilise efficiently the soil moisture content (deeper root zone compared to agricultural lands)

Simulation of a flood event



Impacts of land use on peak flow

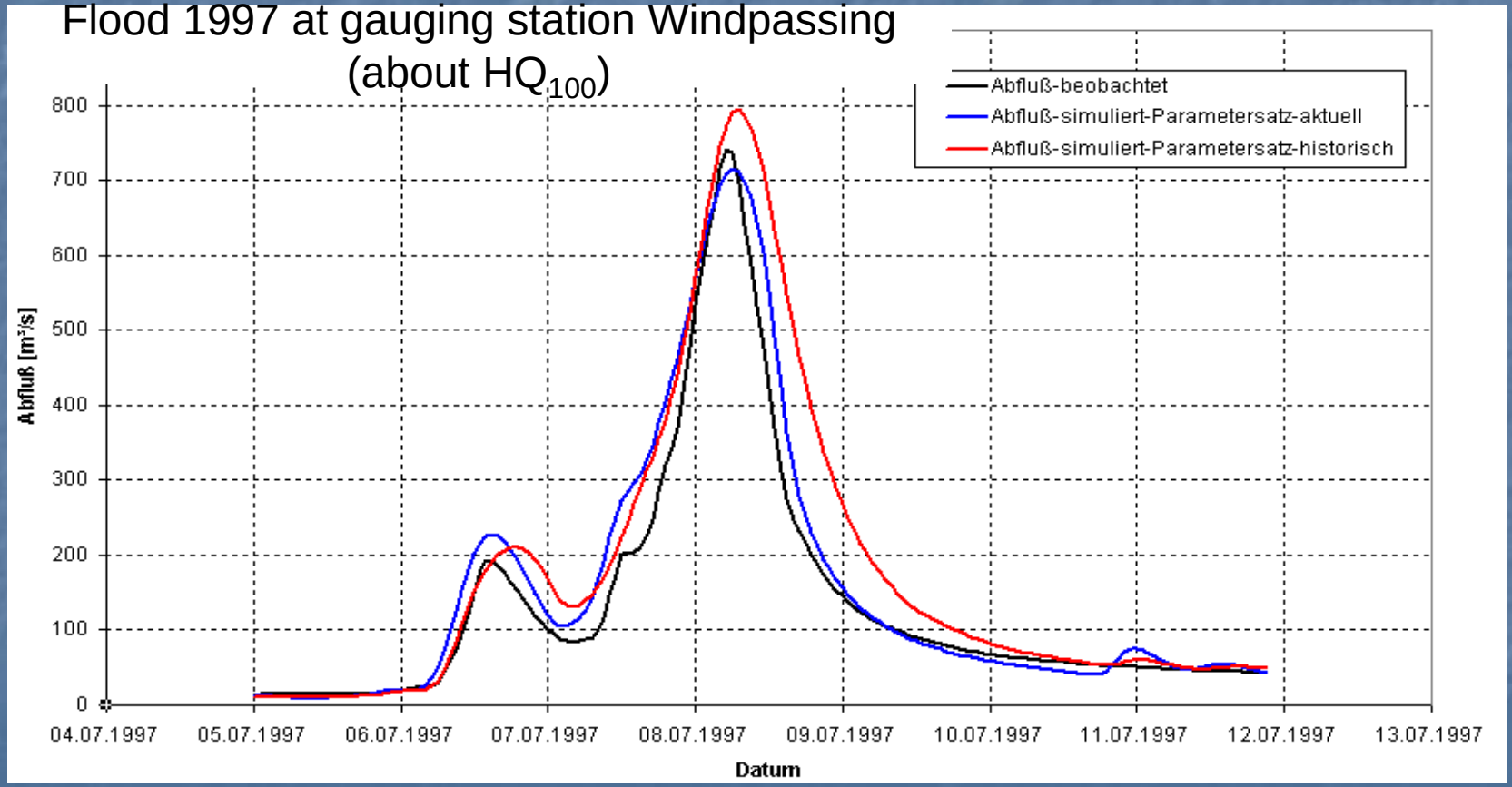
Flood 1997 at gauging station Windpassing
(about HQ_{100})



Recent conditions

Historic land use

Impacts of land use on peak flow



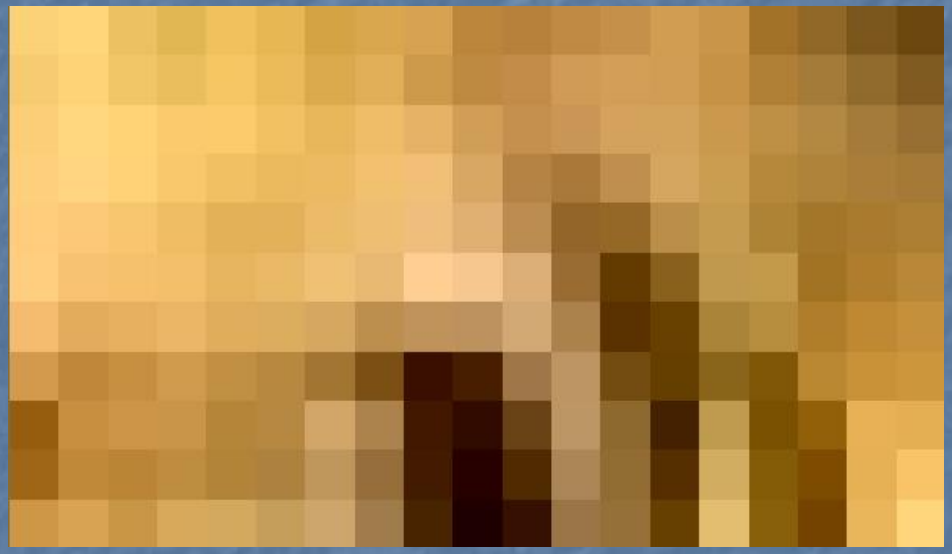
Role of land use (vegetation) on peak flow

- The increase in forested area has lead to an increased evapotranspiration
- The increase of forested area (especially of mixed forests) lead to a decrease in the soil moisture content
- During intensive rainfall events higher percentage of rainwater can be stored
- Medium sized floods are substantially reduced in the peak discharge
- Even HQ_{100} may be reduced by 5-8 %

Conclusions

- Hydrological models yield mostly good simulation results, even with quite different parameter sets
- Vegetation is often simply represented in catchment models
- Not only the soil but also the vegetation layer is quite relevant for hydrological modelling
- Vegetation has impacts on infiltation, roughness, runoff seperation and soil moisture budget
- Detailed mapping of vegetation helps at local to medium scale
- Often, these data are missing or are not accessible

Summary



From a coarse grid information

Summary

From a coarse grid information

To a more detailed information

Outlook

From a coarse grid information

To a more detailed information

And under consideration of biological features to a comprehensive picture

Thank you for your attention !!