University of BRISTOL
Cabot Institute

Water Engineering in a Hot, Flat and Crowded World

Thorsten Wagener
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Department of Civil Engineering
Queen's School of Engineering

Water_dude, 42M

There is always a silver lining

Bristol, England, United Kingdom

Online now

More …

Height	6’4’’
Hair	Brown
Eyes	Brown
Star sign	Aquarius
Occupation	Civil Engineer
Living in	Montpelier, Bristol, United Kingdom
Hobbies	Football, reading, cycling, swimming
Likes	Bayern Munich
Dislikes	Teachers

Send a message

Like him *Tell a friend* *Hide him* *Block him*

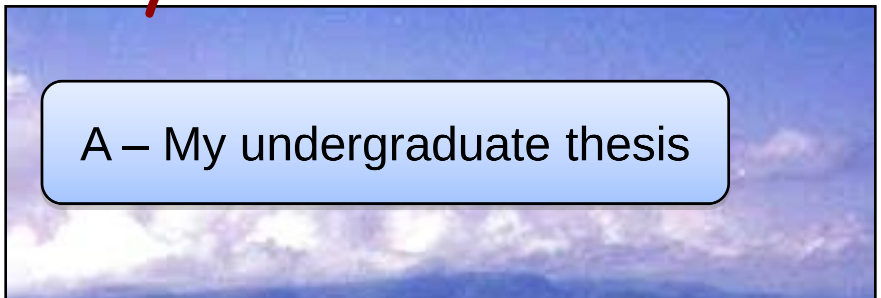
About me

University of Siegen, AWTI Ethiopia, TU Delft, Imperial College London, University of Arizona, Penn State University, University of Bristol

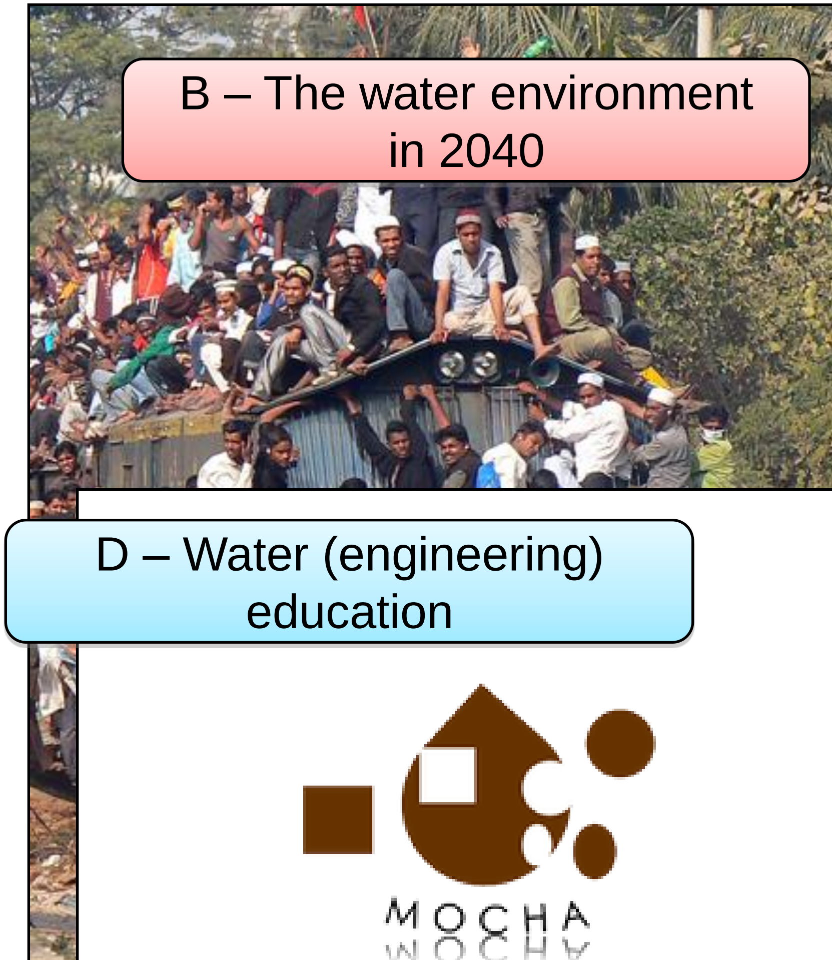
Who I'm looking for

World domination by the University of Bristol in the area of water – or something close to that. (P.S. Do not mention to Exeter and Cardiff)

My lecture is broken up into 4 parts (A-D)



A – My undergraduate thesis

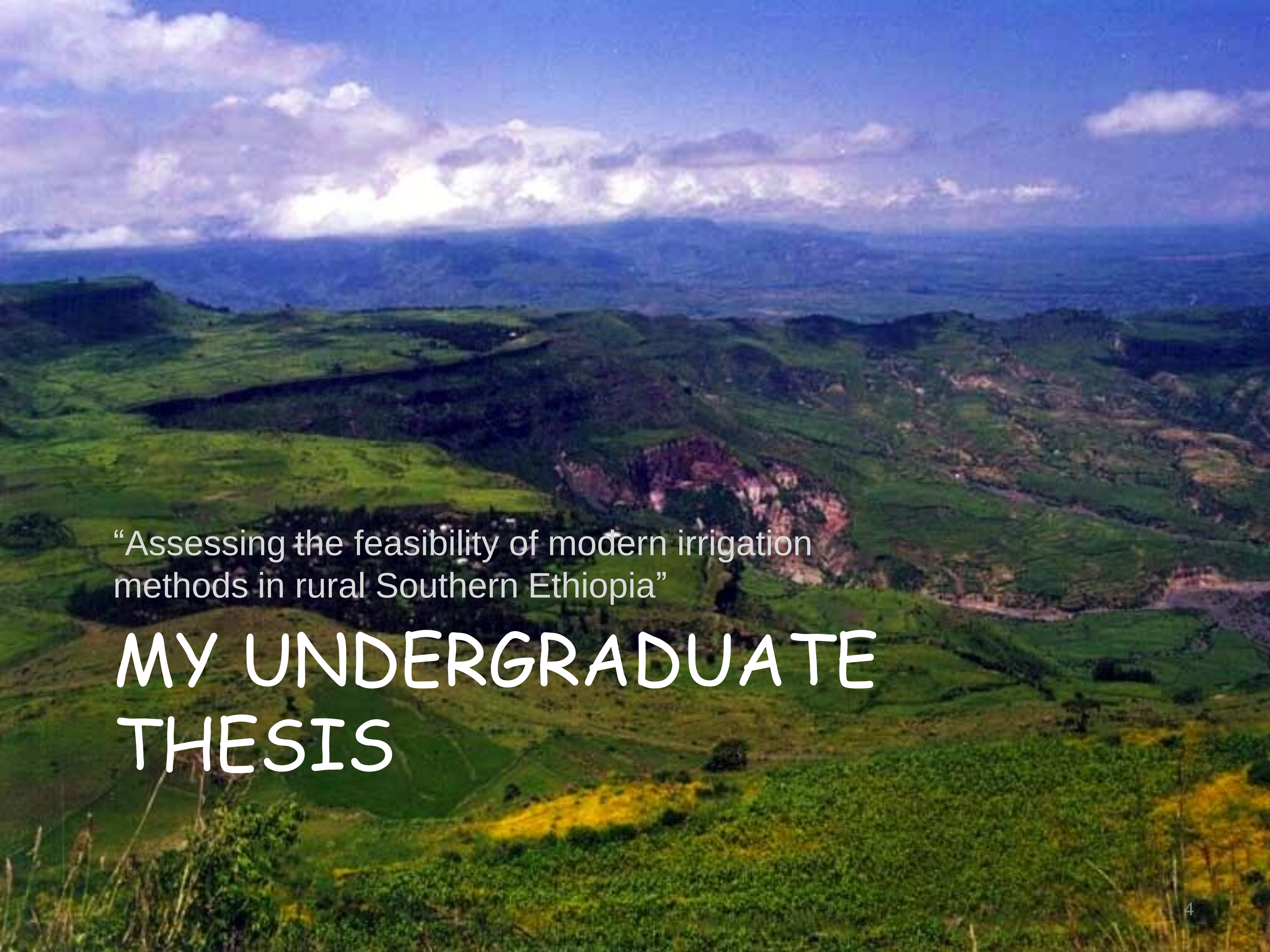


B – The water environment in 2040

C – Water engineering research & practice

D – Water (engineering) education

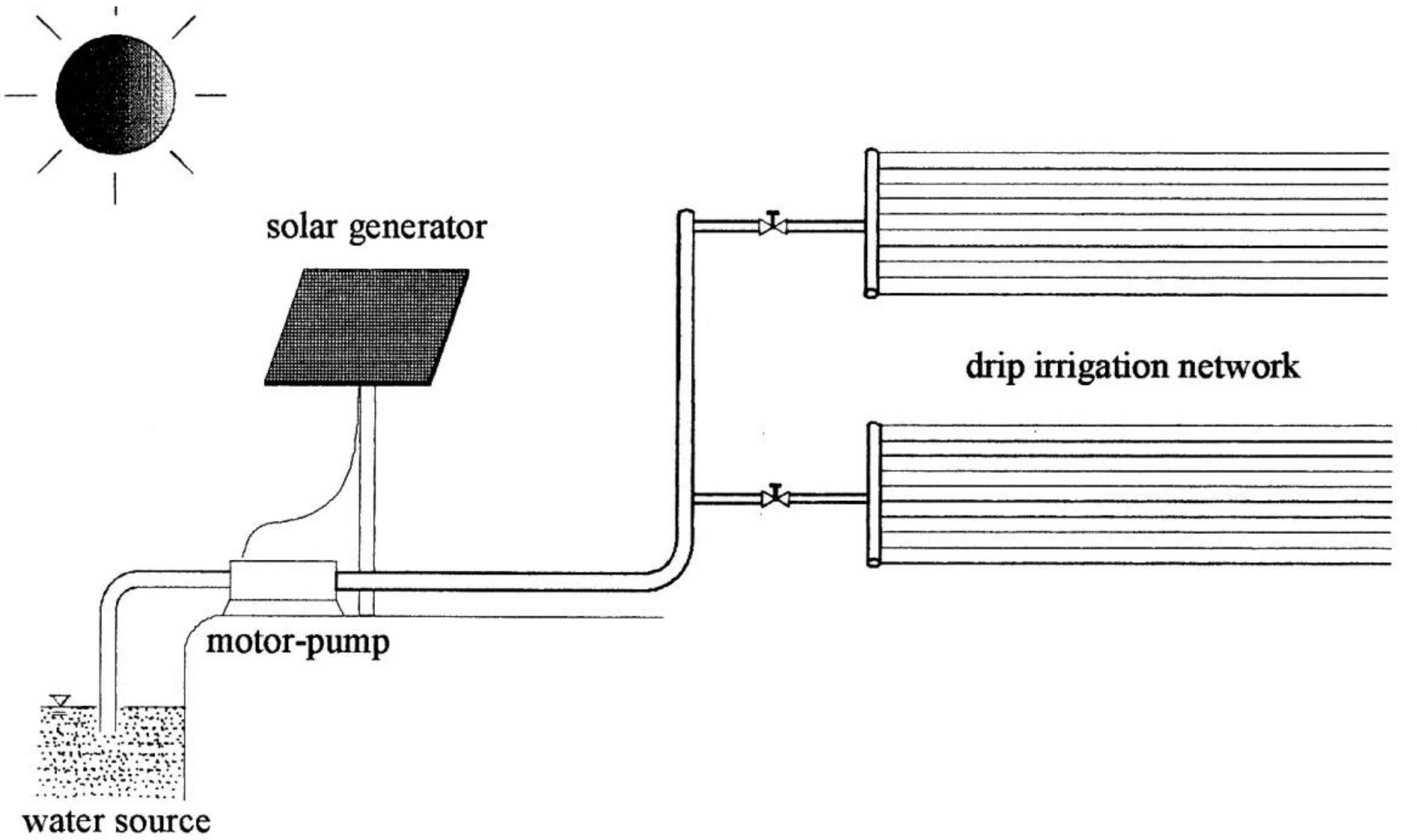
MOCHA



MY UNDERGRADUATE THESIS

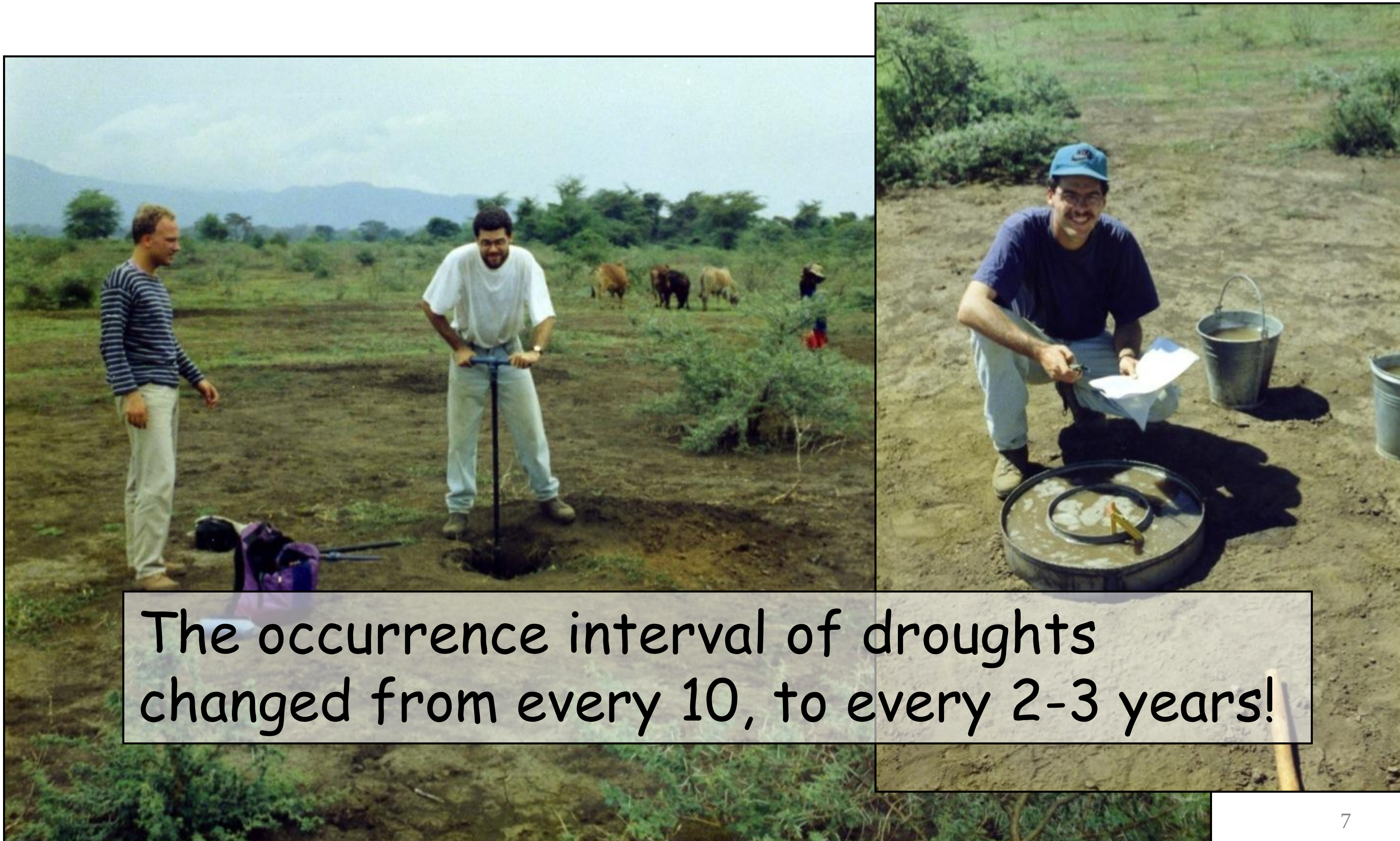
“Assessing the feasibility of modern irrigation methods in rural Southern Ethiopia”

For my undergraduate thesis I spent 5 months in rural Ethiopia



Starting point we
different agricultur

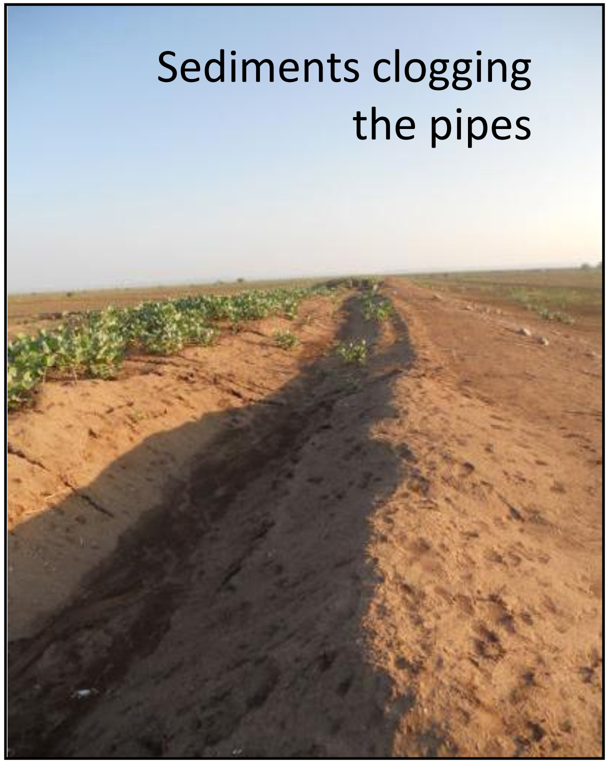
Little information was available regarding local hydrology/meteorology/climatology



The occurrence interval of droughts changed from every 10, to every 2-3 years!

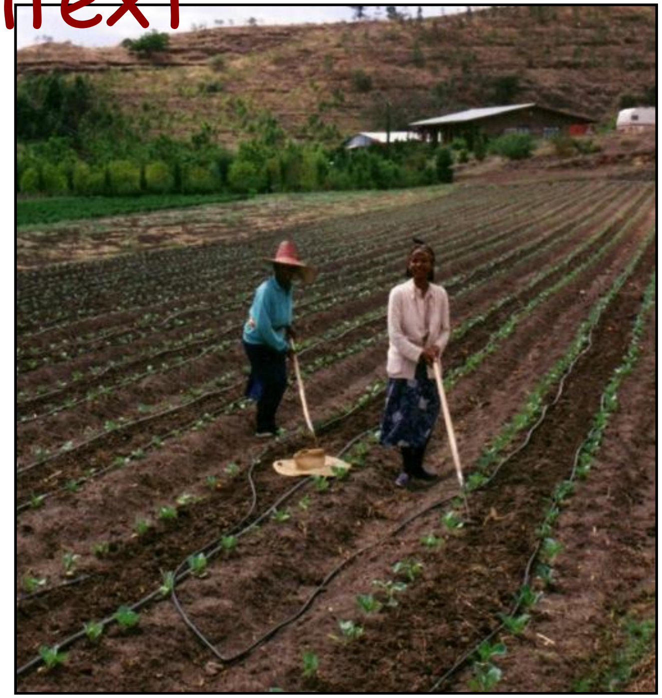
Solutions to technical problems were needed (though straightforward)

AC/DC converters
dying in the heat



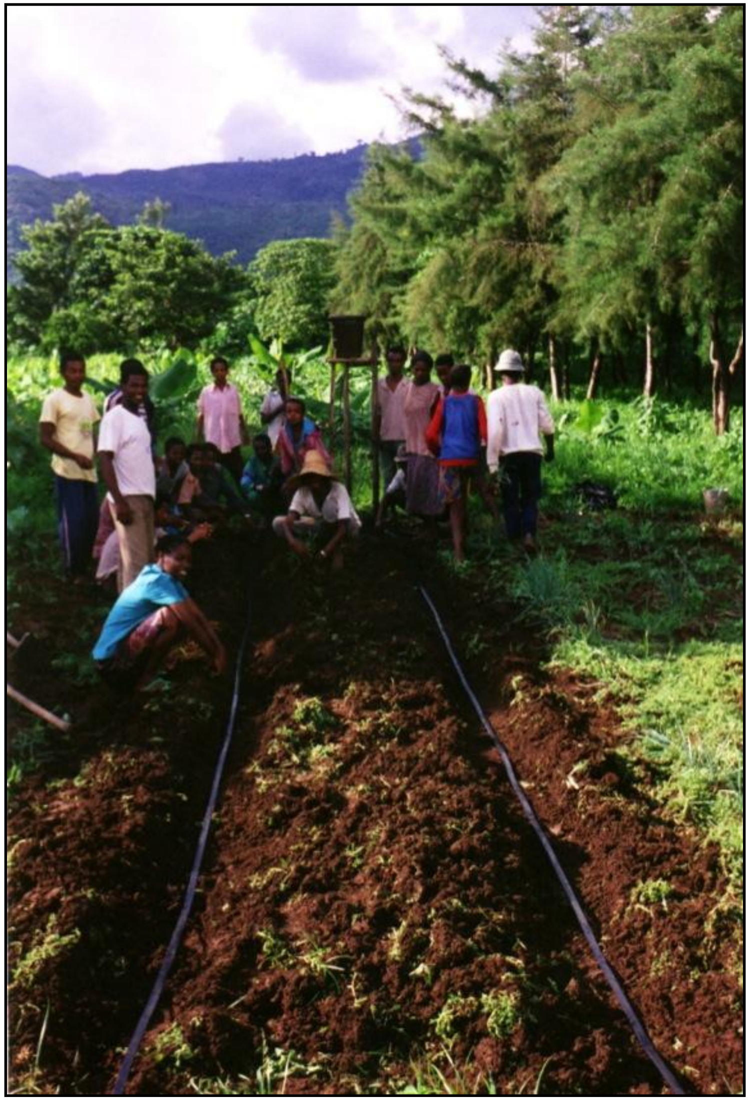
Sediments clogging
the pipes

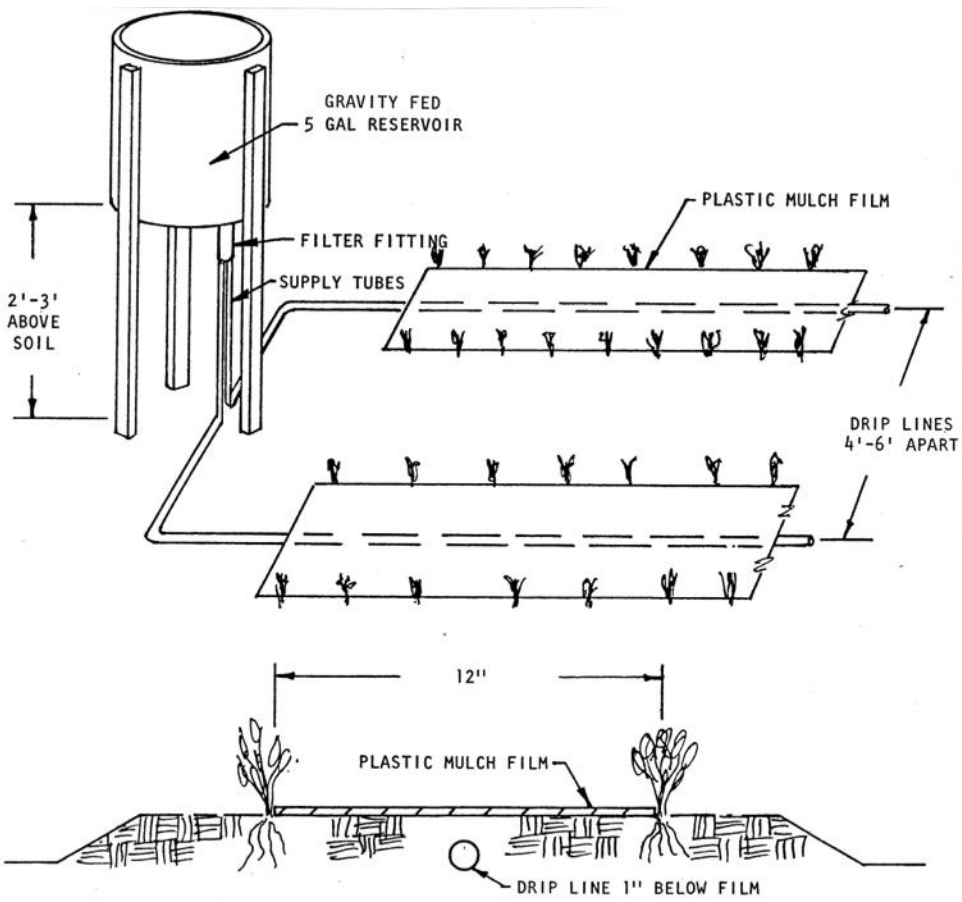
Survey's and project visits across Ethiopia to understand the socio-economic context



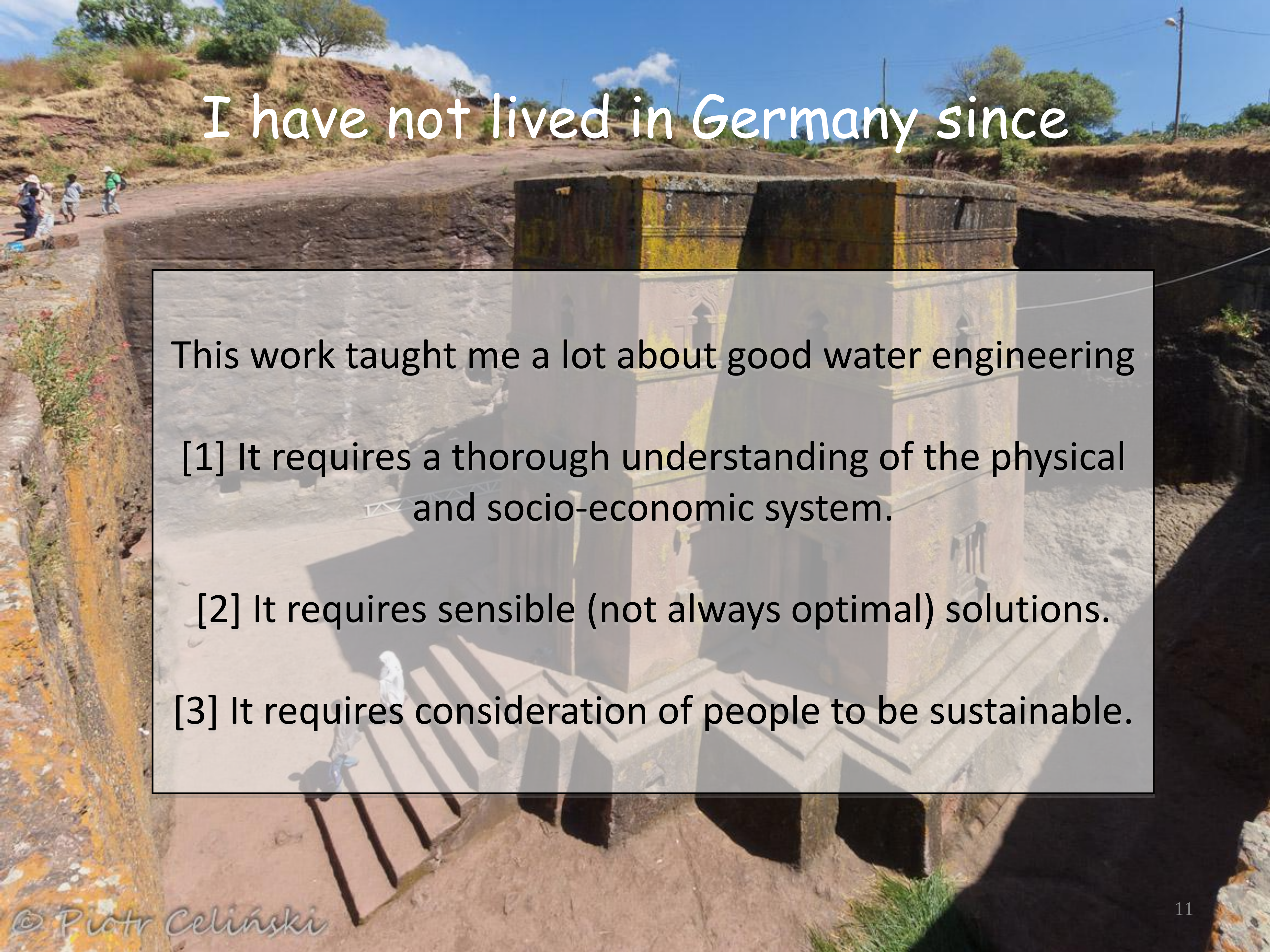
Male	Joint tasks	Female
- Terracing - Building, maintaining houses - Fencing (mainly houses) - Dispute settling	- Digging - Sowing - Weeding - Harvesting - Scaring birds - Looking after animals - Washing clothes	- Collecting water - Carrying, spreading manure - Looking after children - Cooking, grinding - Collecting firewood - Fetching water - Brewing beer

Finally, success would be impossible with creating ownership and education





I have not lived in Germany since



This work taught me a lot about good water engineering

[1] It requires a thorough understanding of the physical and socio-economic system.

[2] It requires sensible (not always optimal) solutions.

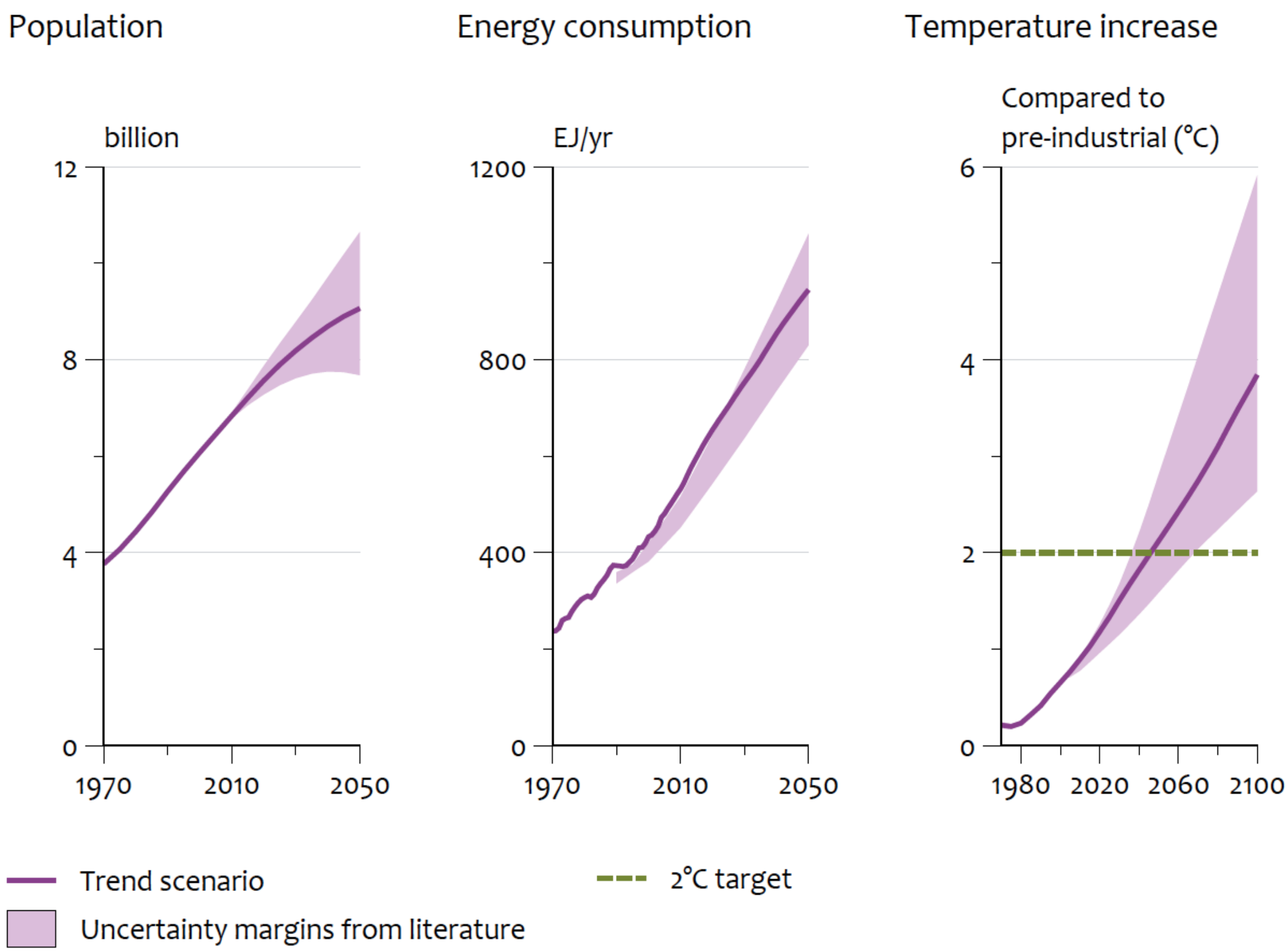
[3] It requires consideration of people to be sustainable.


OUR WATER ENVIRONMENT
IN 2040
2712

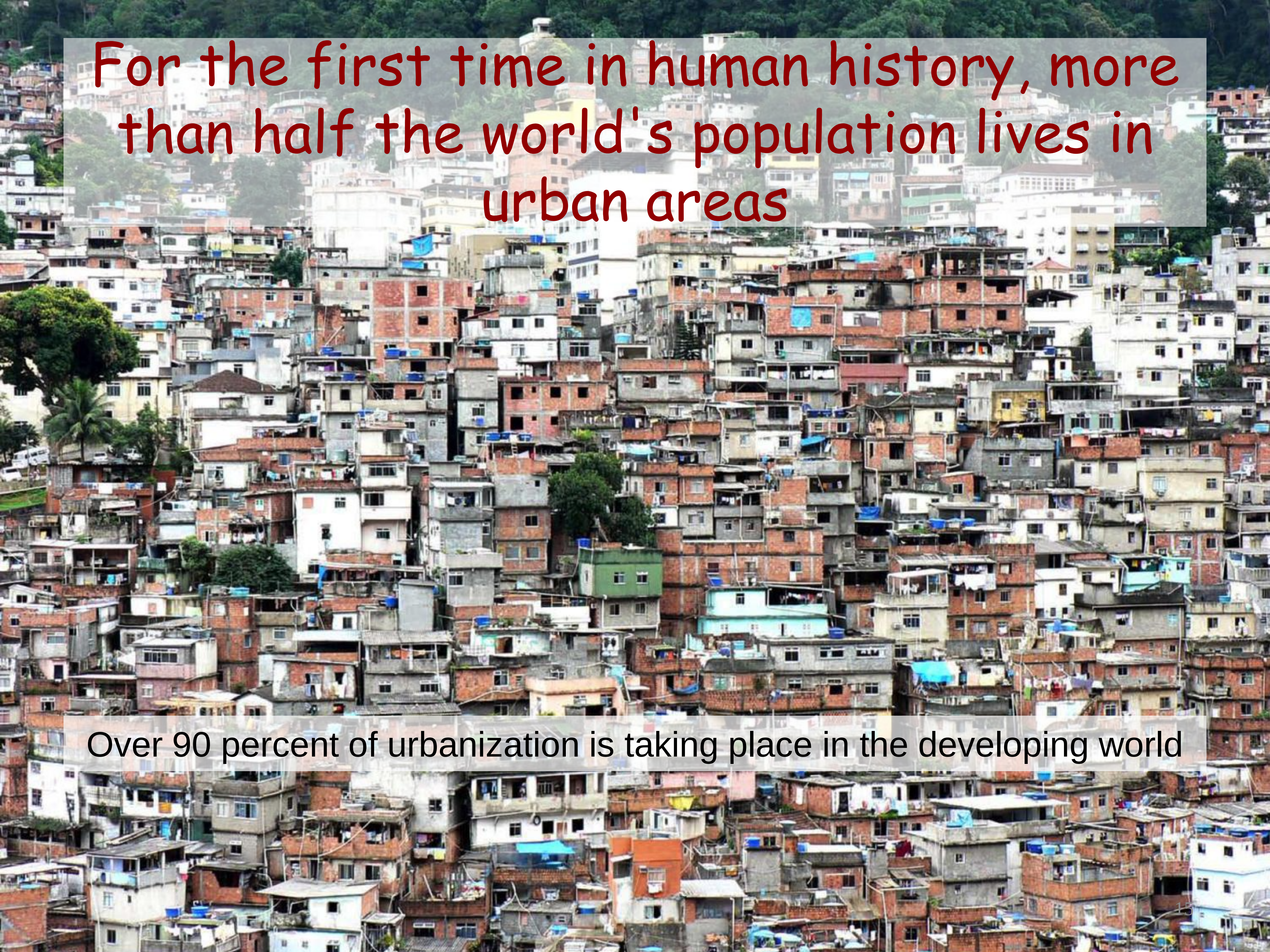
So what is a hot, flat and crowded world like?

Well, think of being in a busy British pub drinking British ale!

The World population is growing rapidly

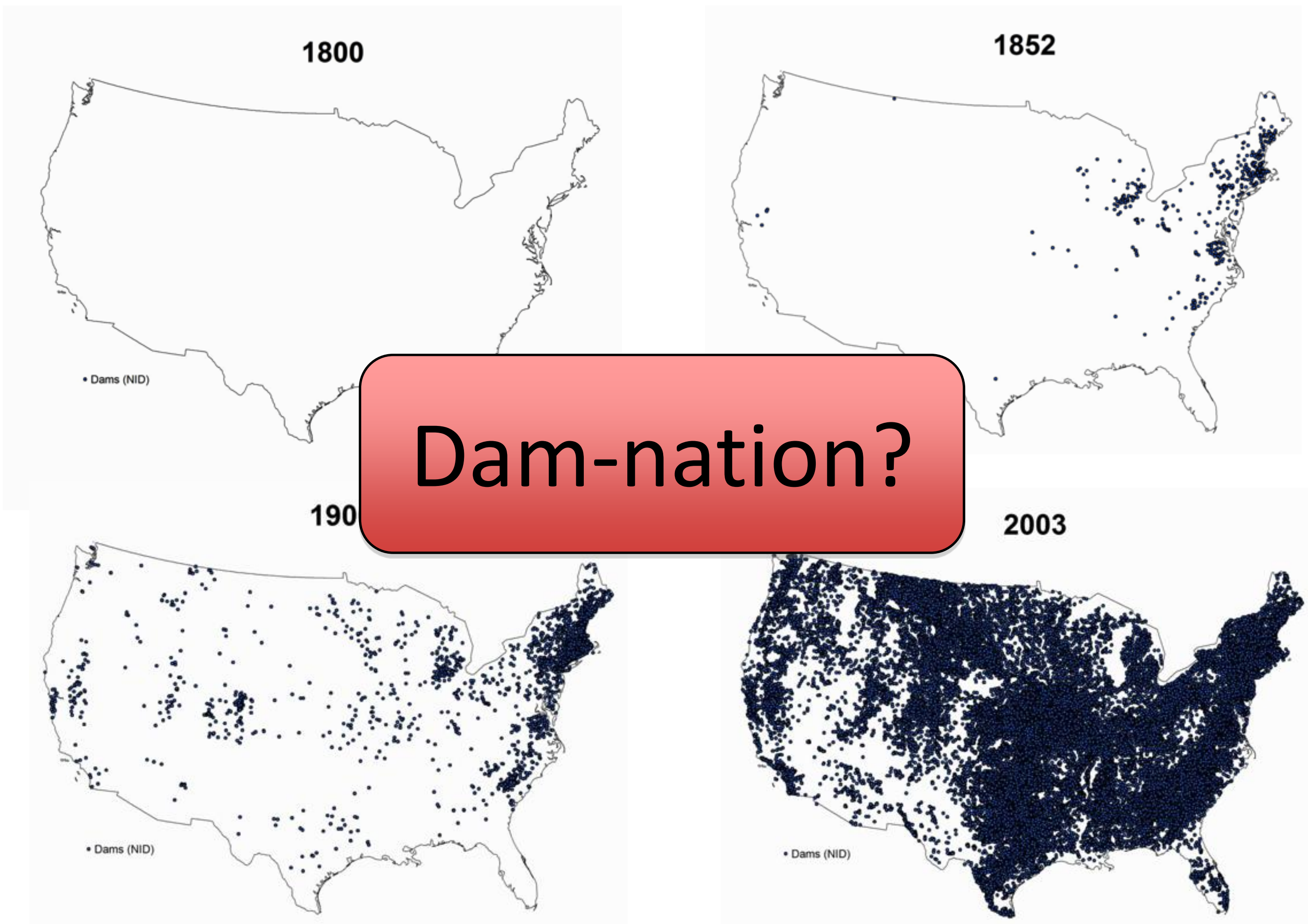


For the first time in human history, more than half the world's population lives in urban areas



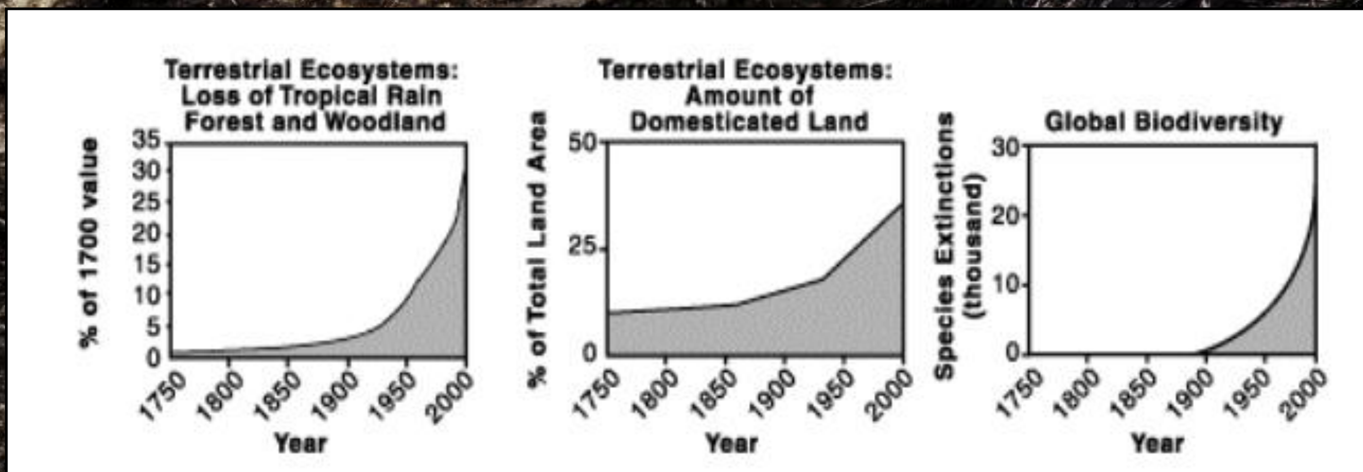
Over 90 percent of urbanization is taking place in the developing world

Human activity changes flow patterns and impacts biodiversity, e.g. dams in the US



Dam-nation?

We have (often dramatically) changed our landscape

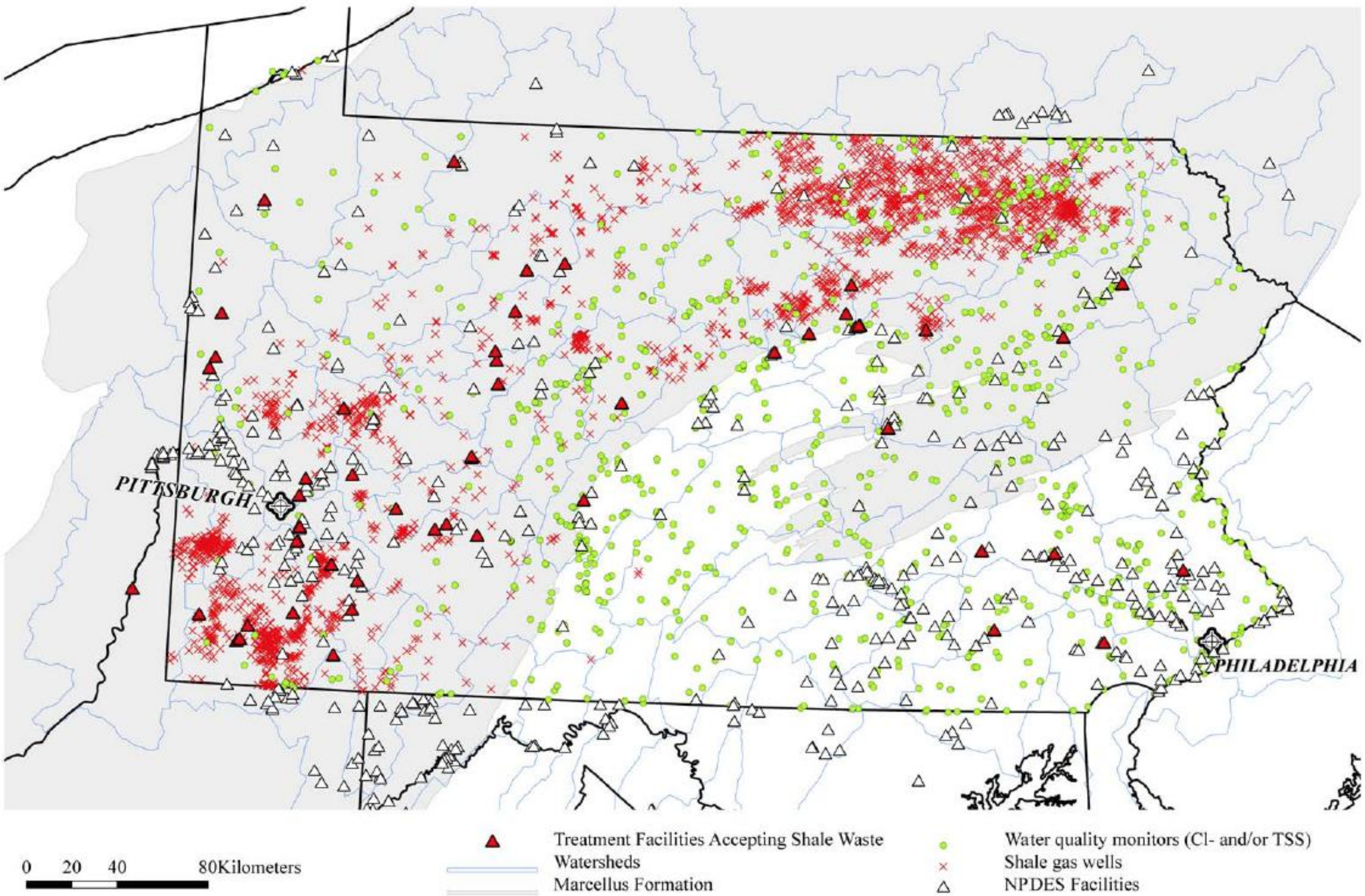


http://thehumanquest.org/

And often we cannot even remember what we did to the landscape, e.g. milldams!

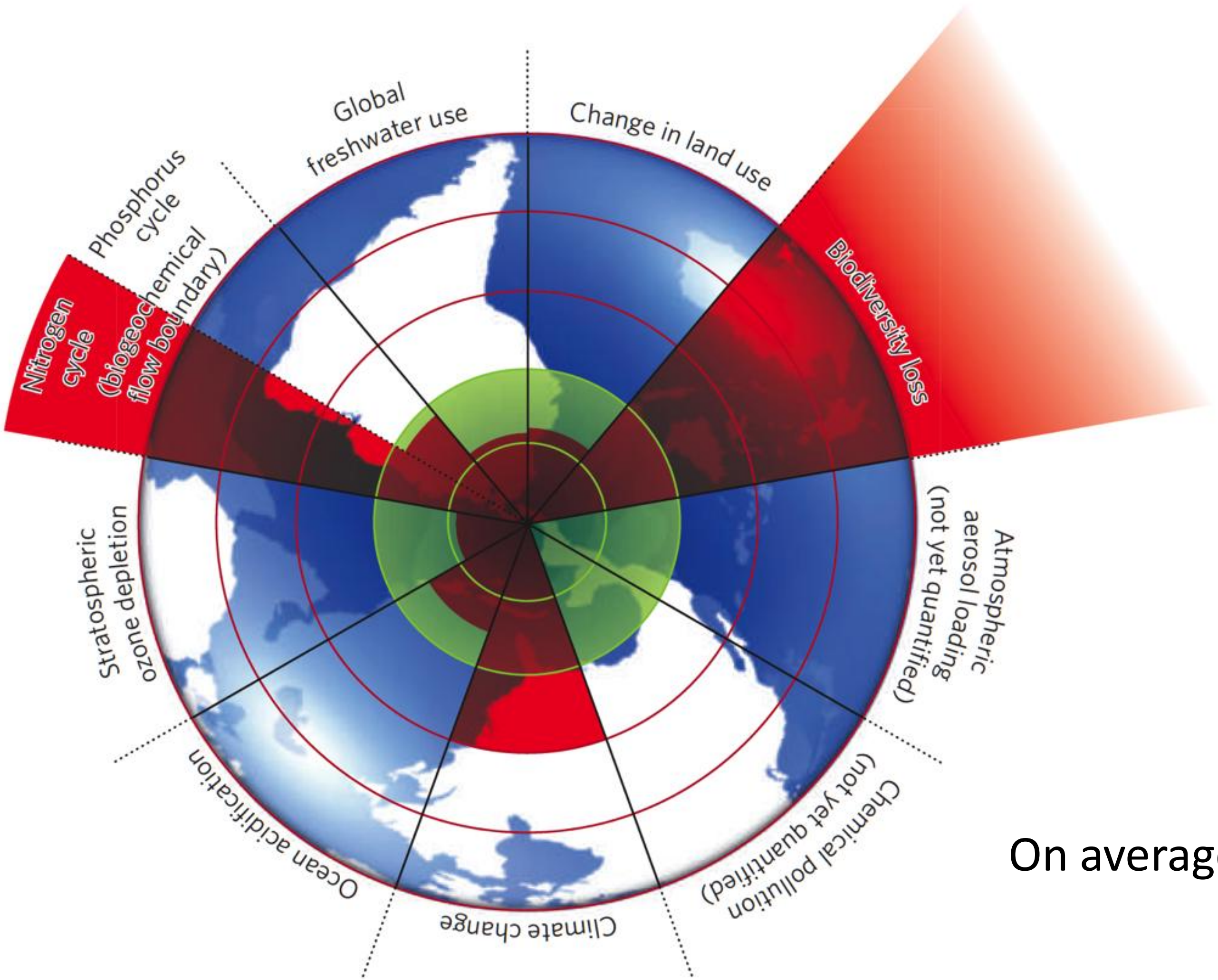
Walter and Merrits, 2008. *Science*

And we add new things: E.g. Shale gas wells (red crosses) in Pennsylvania



Olmstedt et al., 2012. *PNAS*

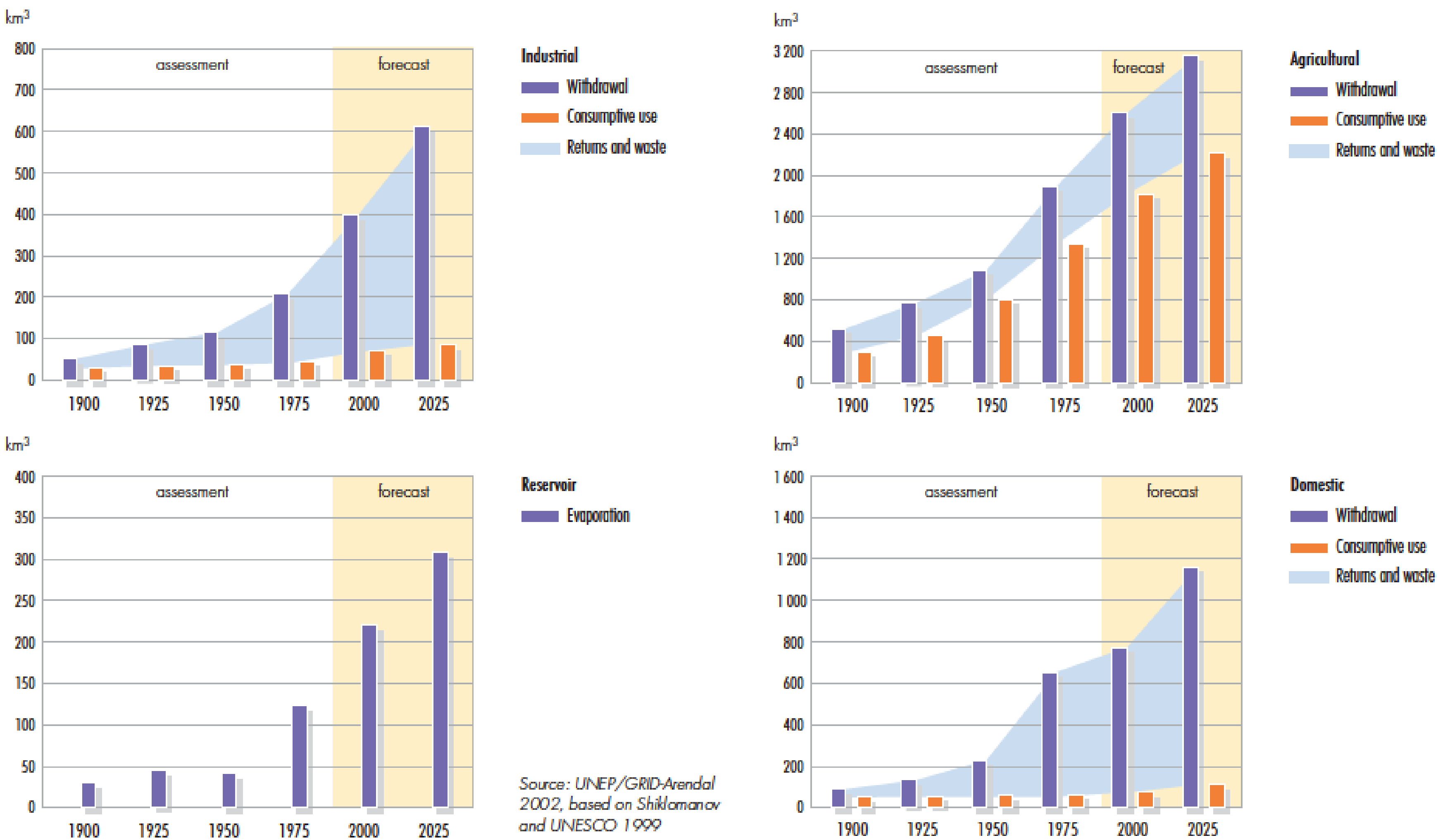
Though we have not yet reached the planetary boundary with respect to freshwater



On average!

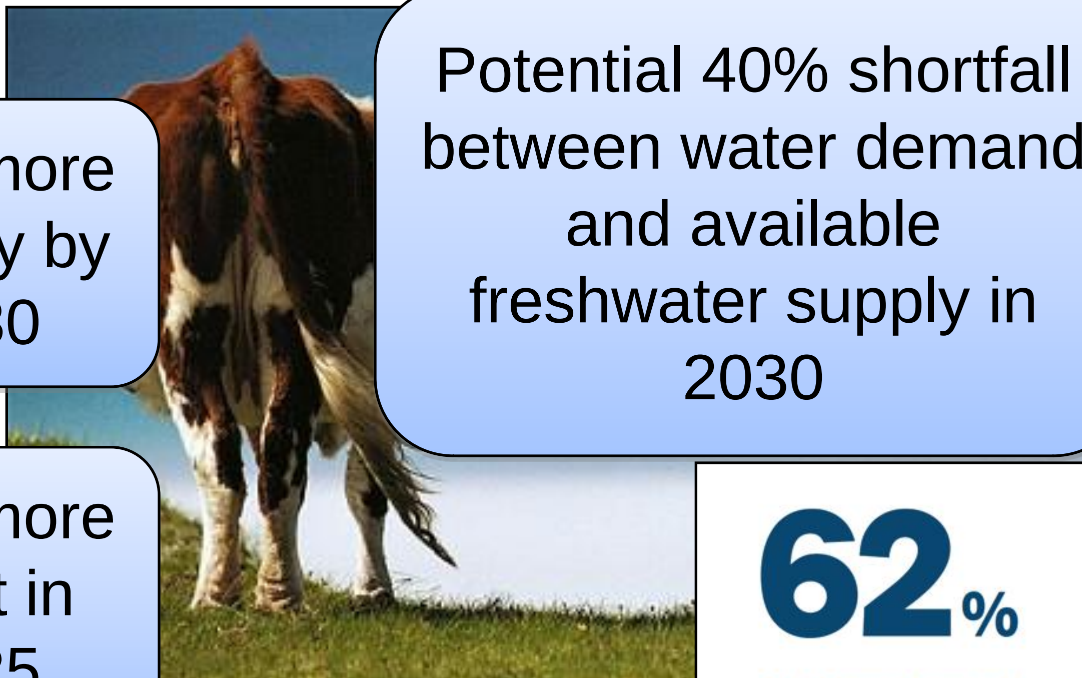
Rockstroem et al., 2009. *Nature*

The future is looking less promising



Source: UNEP/GRID-Arendal 2002, based on Shiklomanov and UNESCO 1999

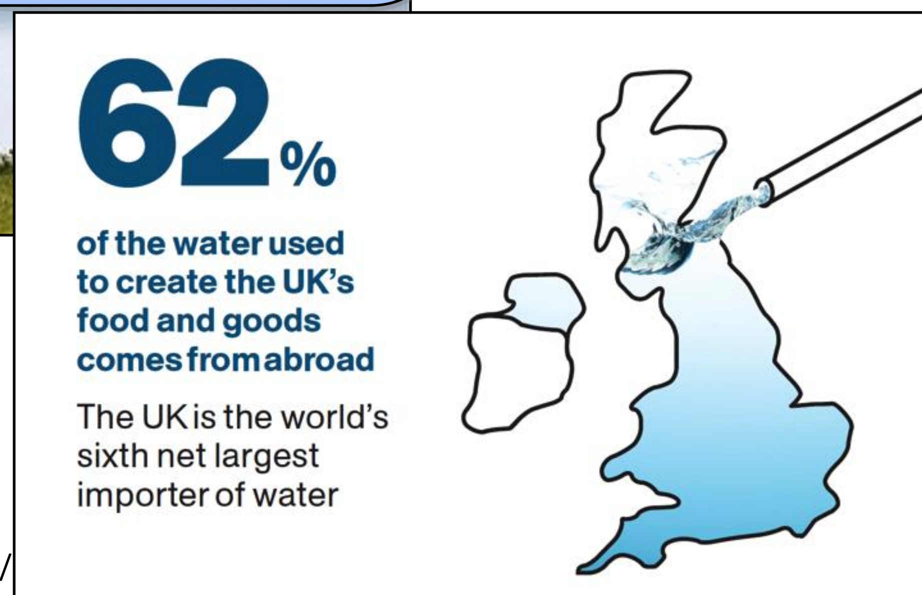
A growing, increasingly prosperous, and rapidly urbanizing global population demands more energy, food and water!



40% more energy by 2030

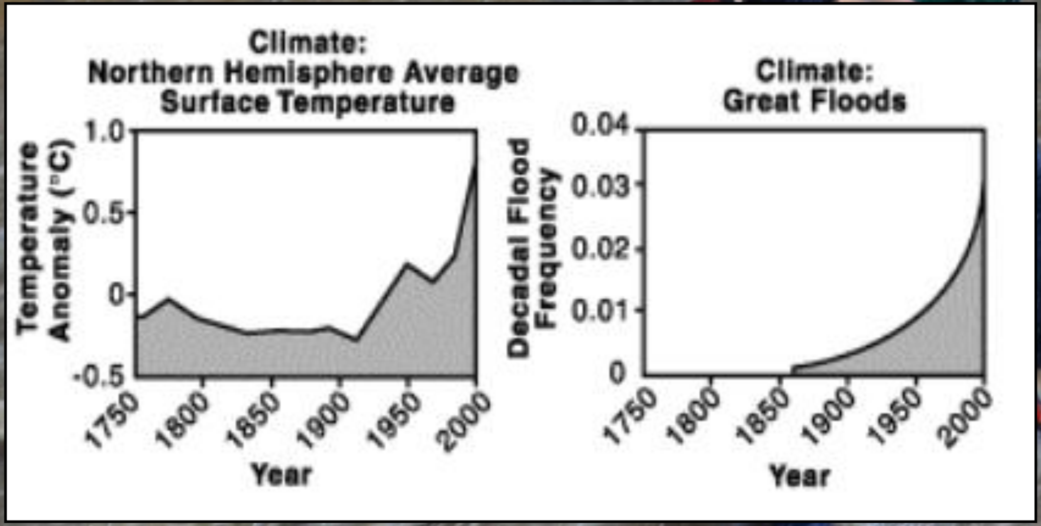
50% more meat in 2025

Potential 40% shortfall between water demand and available freshwater supply in 2030



http://www.21stcenturychallenges.org/focus/

The expectation of increasing frequency of extremes is similar



WATER ENGINEERING RESEARCH AND PRACTICE

How do we have to change hydrology, to be fit for a changing world?

WATER RESOURCES RESEARCH, VOL. 46, W05301, doi:10.1029/2009WR008906, 2010

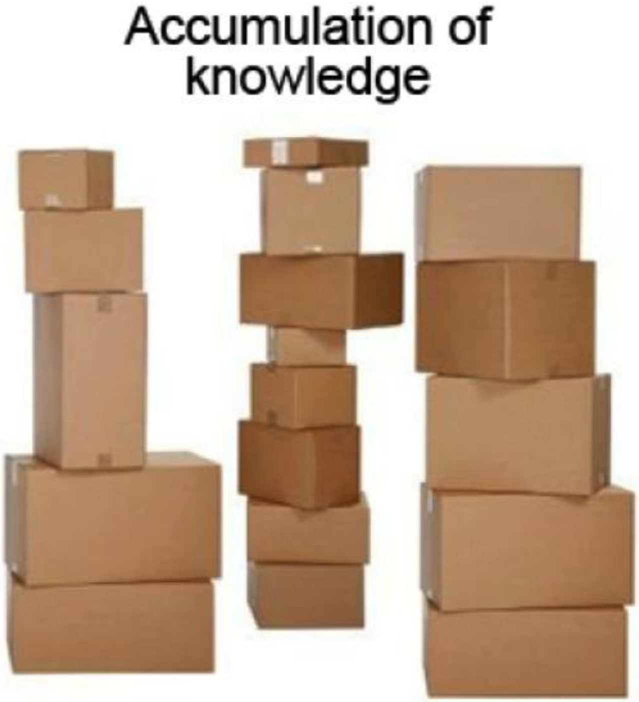
The future of hydrology: An evolving science for a changing world

Thorsten Wagener,[1] Murugesu Sivapalan,[2,3,4] Peter A. Troch,[5] Brian L. McGlynn,[6] Ciaran J. Harman,[3] Hoshin V. Gupta,[5] Praveen Kumar,[3] P. Suresh C. Rao,[7] Nandita B. Basu,[8] and Jennifer S. Wilson[2]

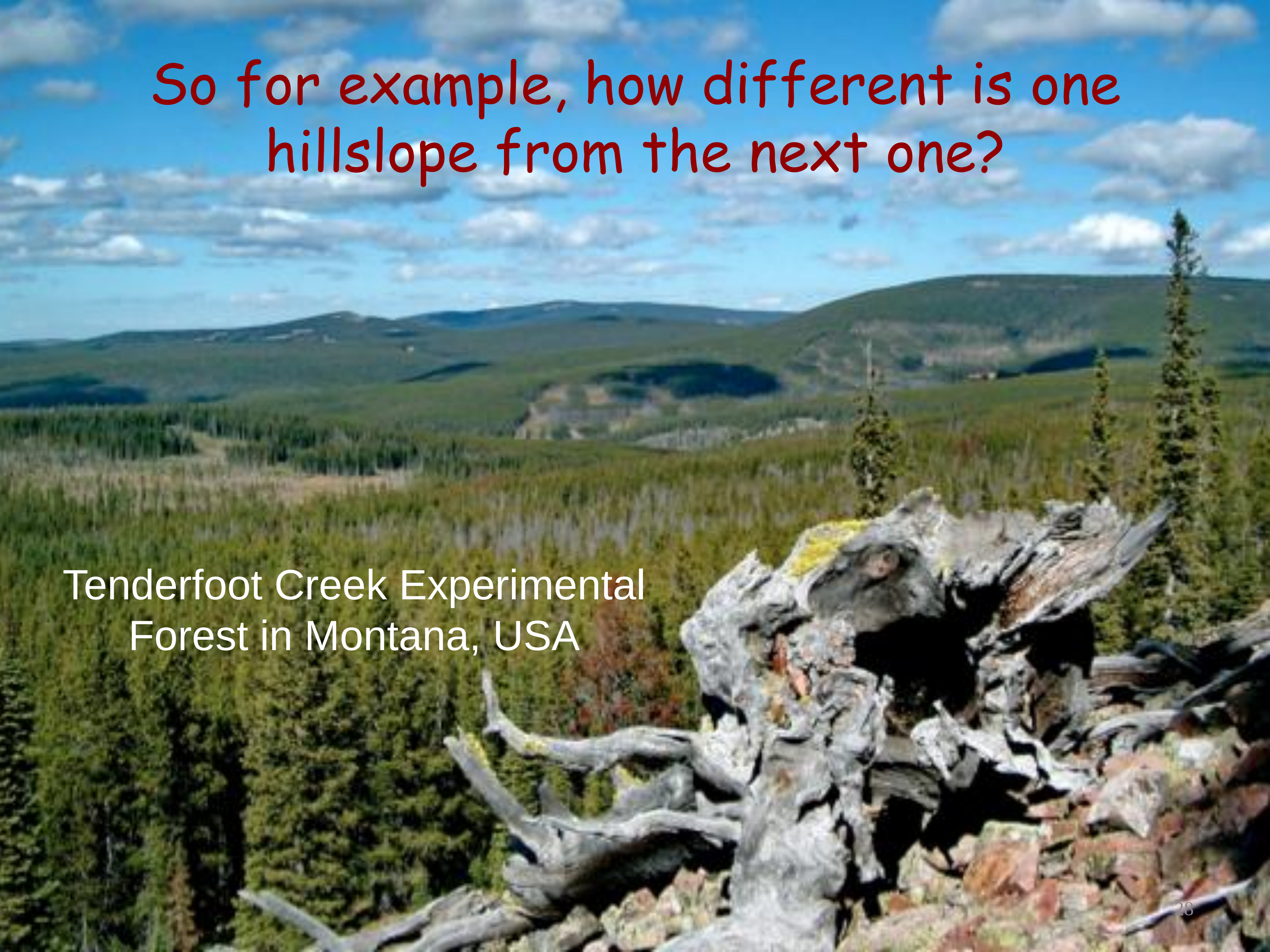
We need to overcome the limitations of studying one place, by contrasting many places

Current	Future
Learning from studying individual places (often pristine experimental catchments) to extrapolate or upscale to other places	Comparative hydrology: learning from individual places embedded along gradients (e.g. changing climate, human imprint) and across spatial scales

Hydrology has long been focused on understanding individual places in great detail



So for example, how different is one hillslope from the next one?



Tenderfoot Creek Experimental Forest in Montana, USA

How variable are shallow subsurface flow thresholds?

Not yet open for distribution

Courtesy Prof Brian McGlynn, Duke University

Let's contrast this with 30 hillslopes in a single Montana catchment

Not yet open for distribution

Courtesy Prof Brian McGlynn, Duke University

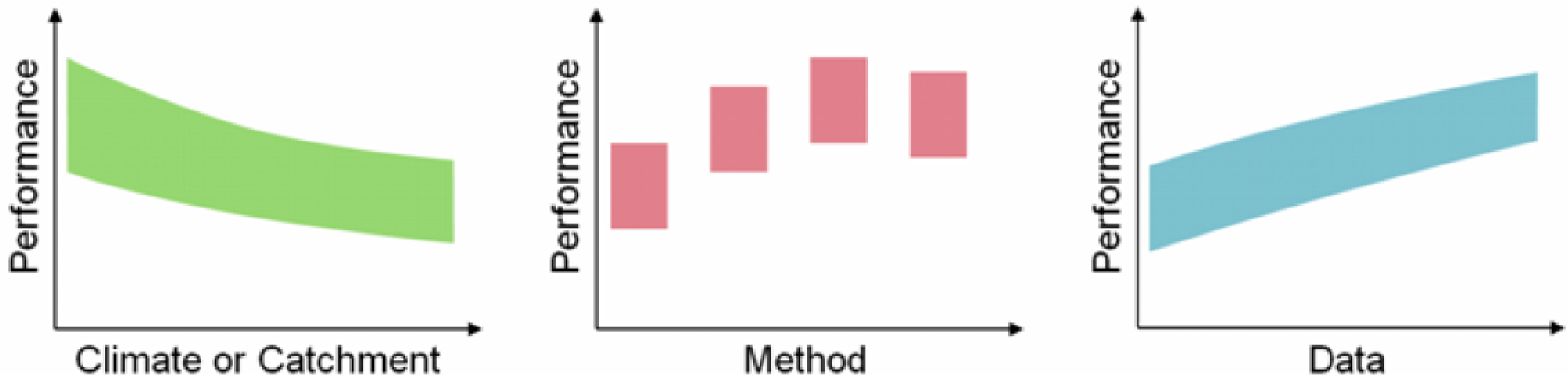
Not yet open for distribution

Precipitation and size create an organizing principle

Not yet open for distribution

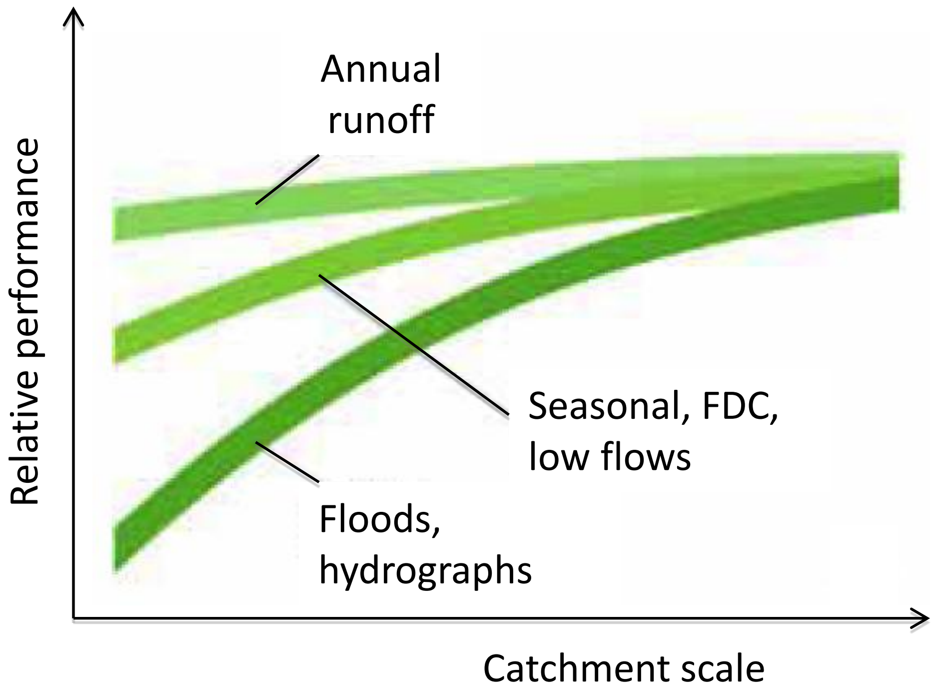
Courtesy Prof Brian McGlynn, Duke University

We have recently analyzed over 25,000 catchments in a comparative hydrology synthesis study



Available from April 2013

We gained new understanding on what controls our ability to do PUB



How can we enhance the credibility of our models in a changing world?

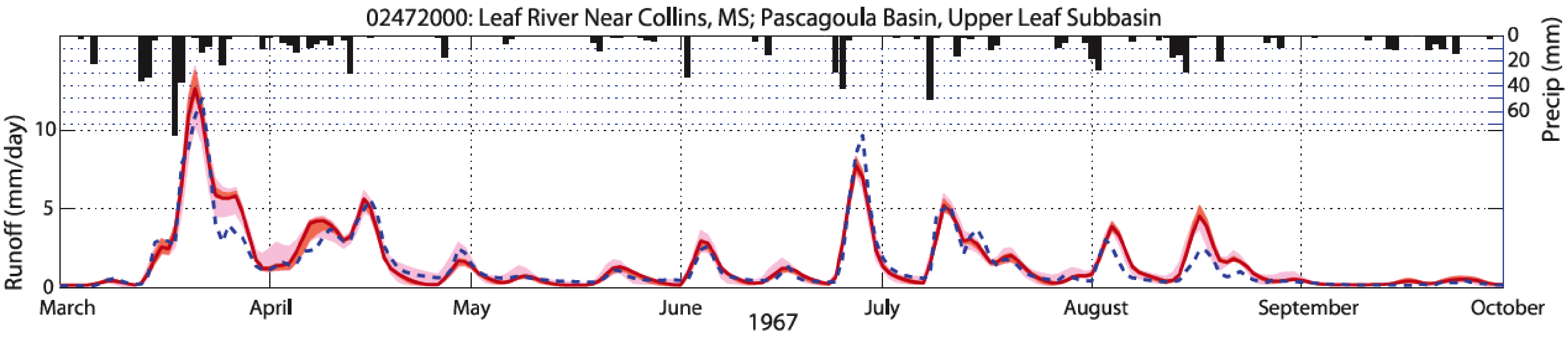
Current

Future

Model predictions derive credibility by reproducing historical observations

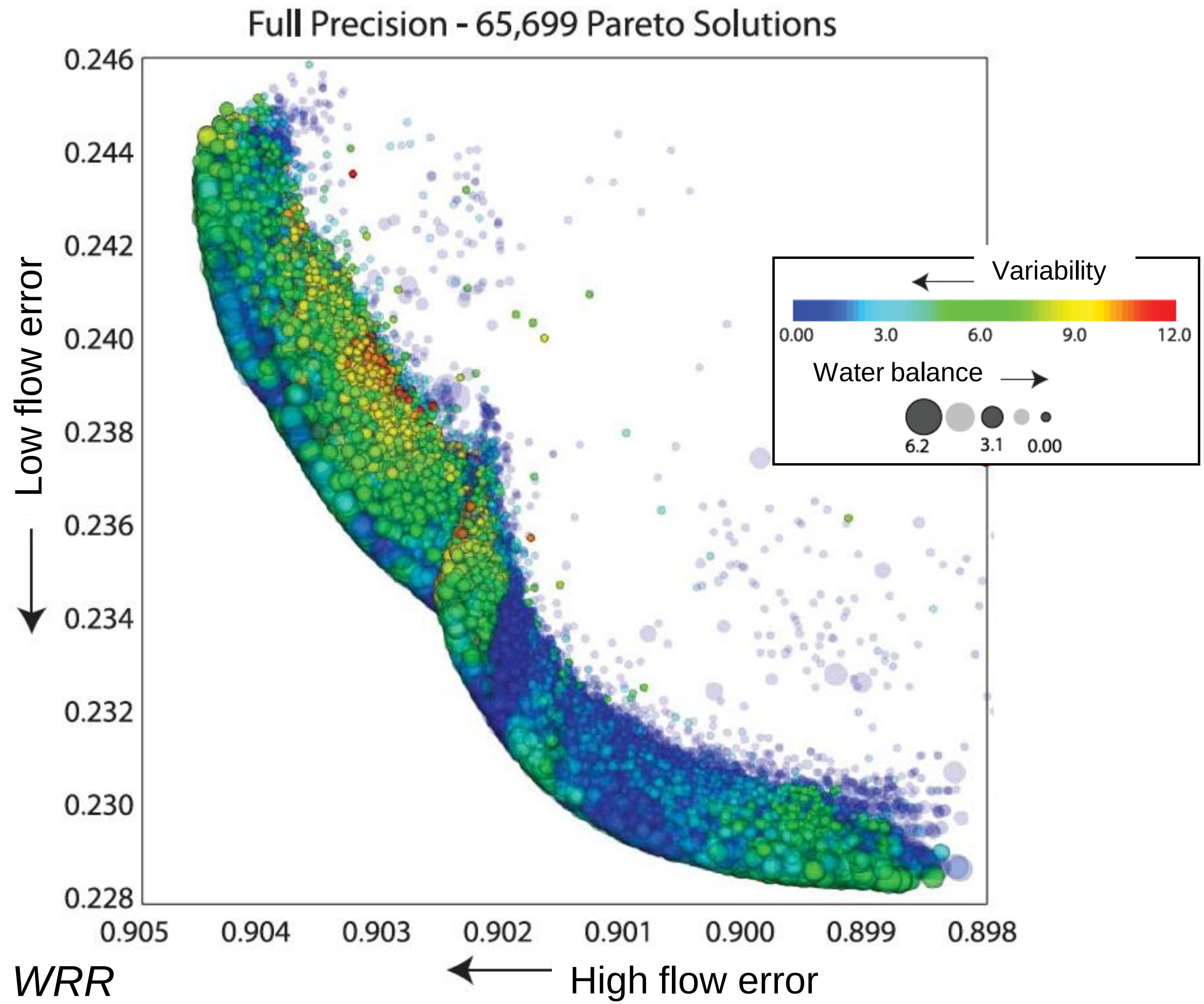
Model predictions derive credibility via more in-depth diagnostic evaluation of model consistency with underlying system and testing of behavior outside of observed range

We often model the continuous behavior of catchments, e.g. streamflow



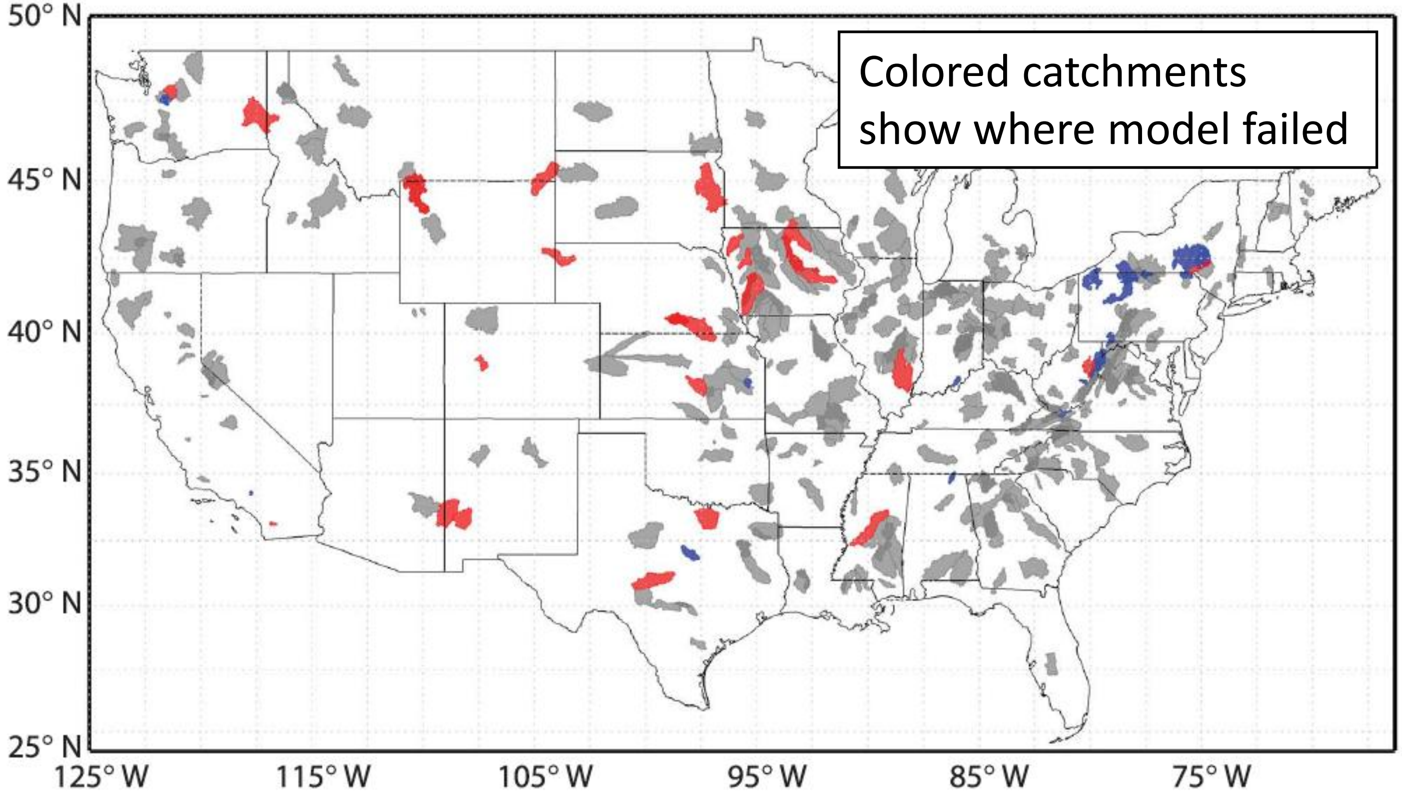
Kollat et al., 2012. *WRR*

We often use trade-offs between multiple objectives to indicate model structural error



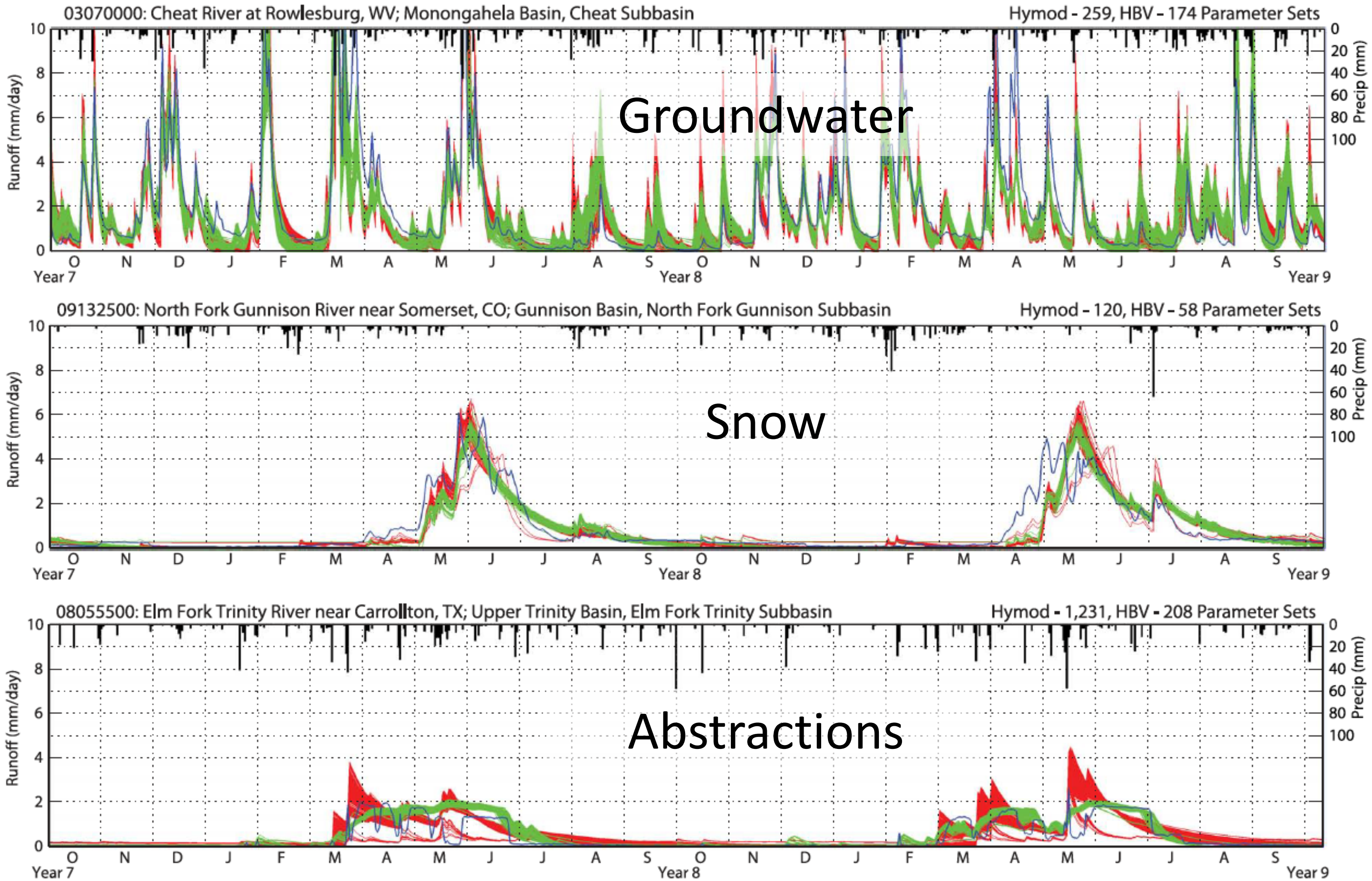
Kollat et al., 2012. *WRR*

We find – in contrast to previous research – that most trade-offs are insignificant



Kollat et al., 2012. *WRR*

Where meaningful trade-offs exist, they indicate actual problems



Kollat et al., 2012. *WRR*

How do catchments respond to bigger rainfall events than previously observed?

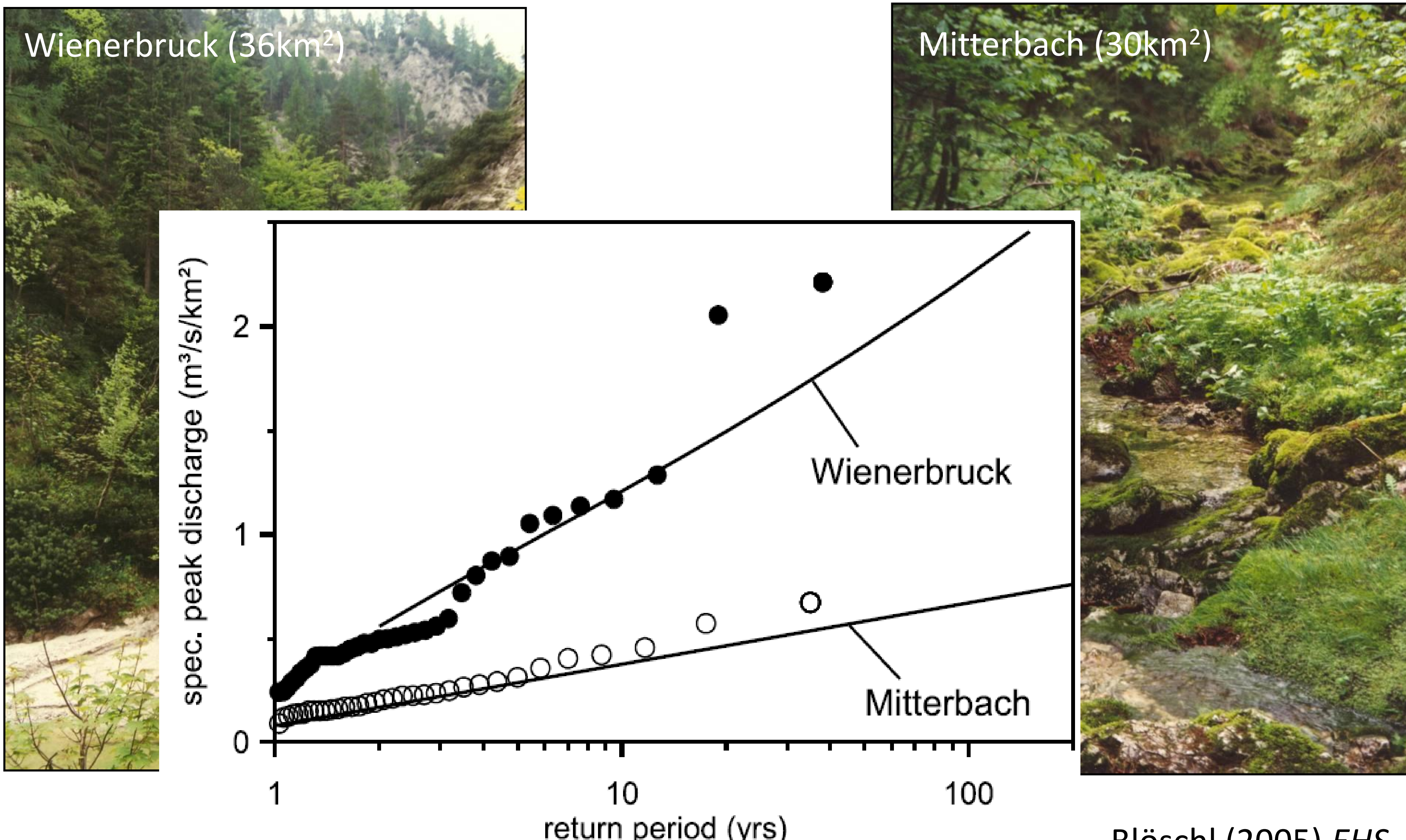
Current

Future

Assumption of stationarity: past is a guide to the future

Nonstationary world: past is no longer a sufficient guide to the future, expected variability could be outside the range of observed variability

Apparently similar systems can respond differently to new input, e.g. rainfall



Time (h)

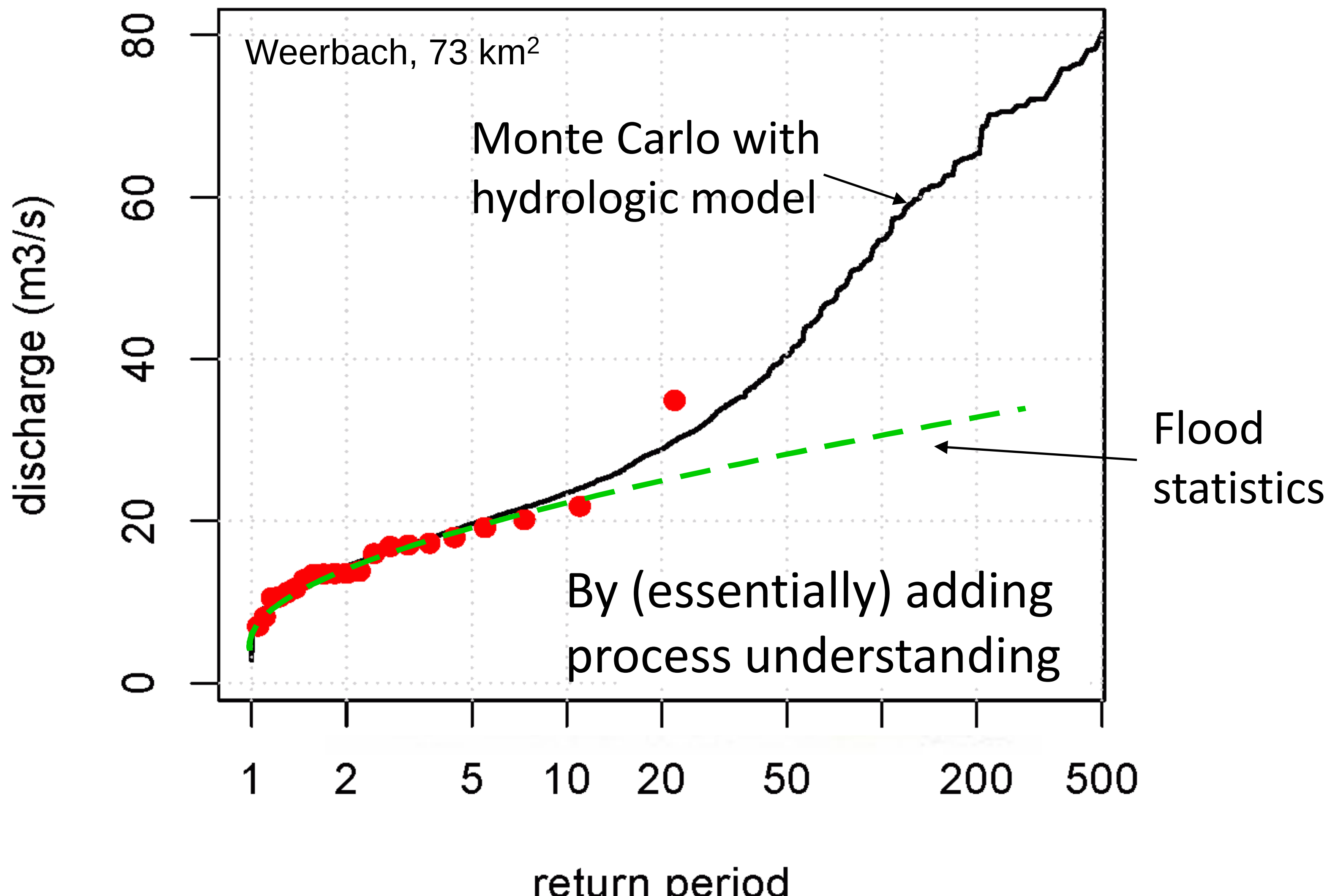
Blöschl (2005) *EHS*

Courtesy Dr Alberto Viglione, TU Vienna

But easily observable features do not always tell the whole story!

The system characteristics we can easily observe often are only of limited value for understanding **expected behavior**

So how do we protect ourselves against such surprises?

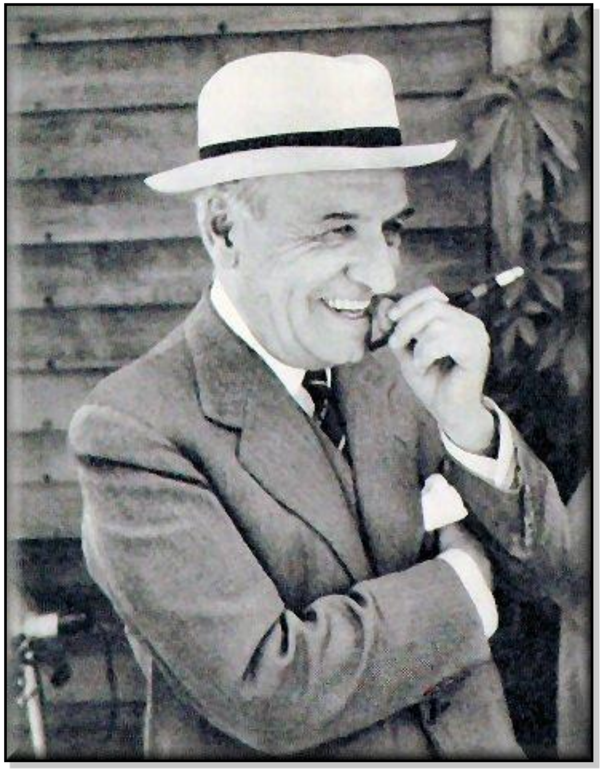


Courtesy Dr Alberto Viglione, TU Vienna

So if the (easy) science is not there, how do we solve engineering problems through receipes? Well, we don't anymore!

José Ortega y Gasset

'Life (engineering) *cannot wait until the sciences have explained the universe scientifically'*



http://en.wikipedia.org/wiki/José_Ortega_y_Gasset

How can we create an online faculty learning community?

WATER ENGINEERING EDUCATION

Higher education in a world that is flat

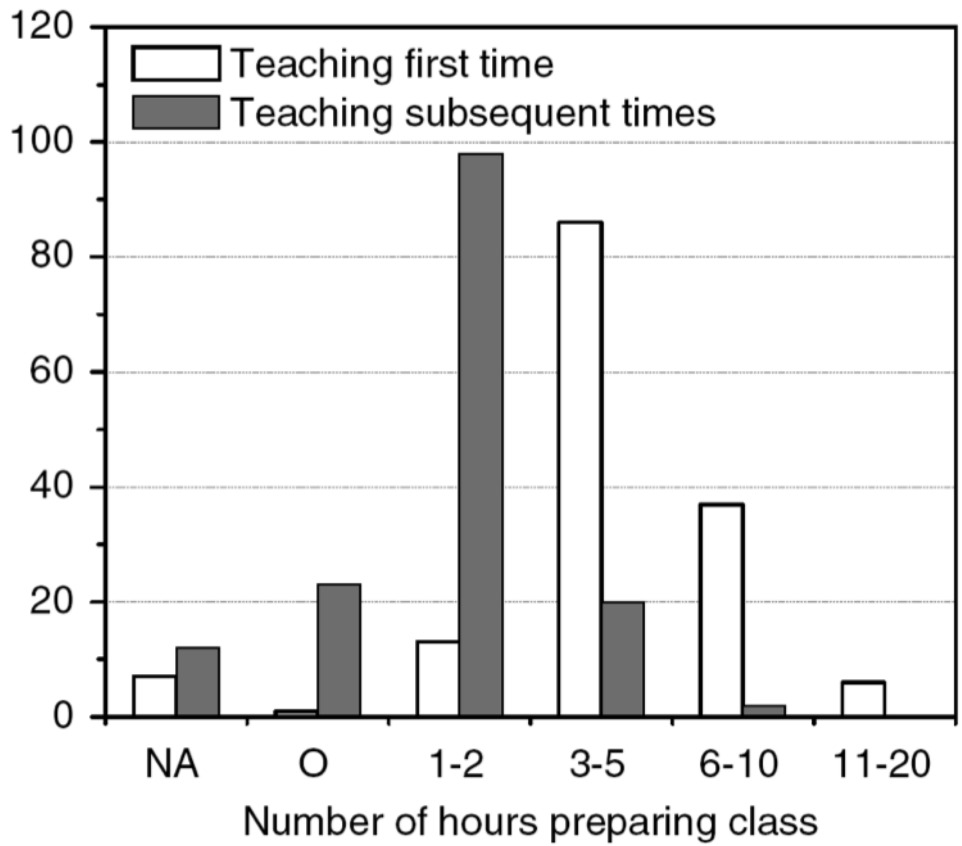
Are open educational resources the future of University education?

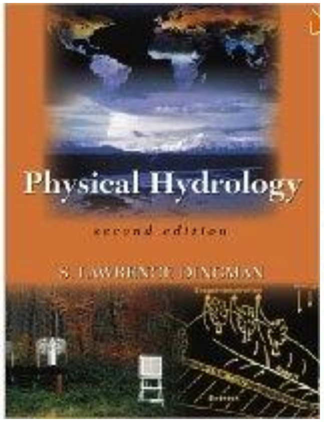
Supported with $60M in 2012 by MIT and Harvard alone

HYDROLOGICAL PROCESSES
Hydrol. Process. **21**, 1789–1792 (2007)

Taking the pulse of hydrology education

Thorsten Wagener
Markus Weiler
Brian McGlynn
Mike Gooseff
Tom Meixner
Lucy Marshall
Kevin McGuire
Mike McHale




Physical Hydrology
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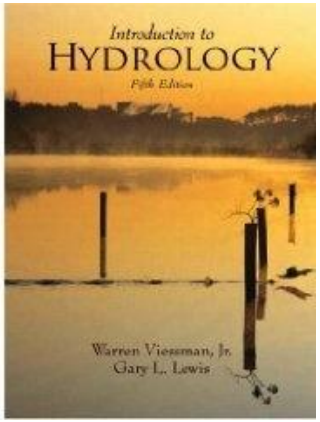
S. LAWRENCE DINGMAN


Introduction to
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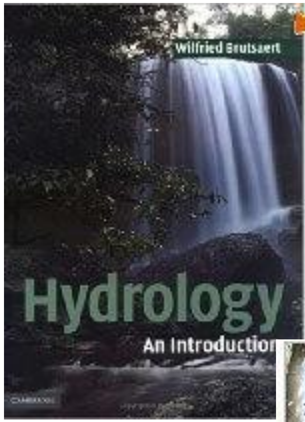
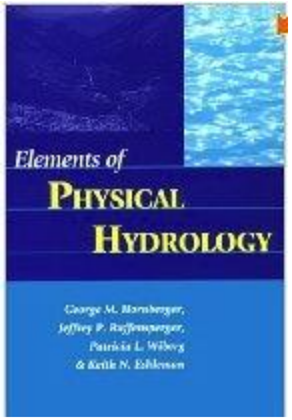
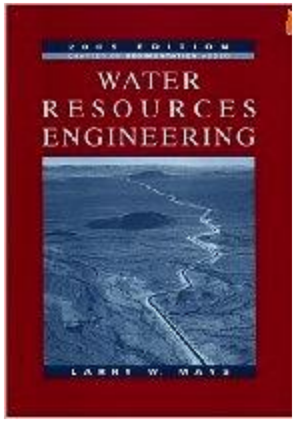
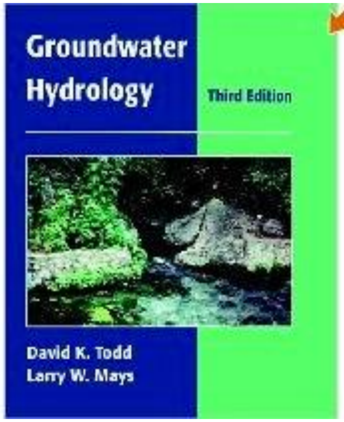
Fifth Edition
Warren Viessman, Jr.
Gary L. Lewis


Wilfried Brutsaert
Hydrology
An Introduction


Elements of
PHYSICAL
HYDROLOGY


WATER
RESOURCES
ENGINEERING
LARRY W. MAYS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Hydrology
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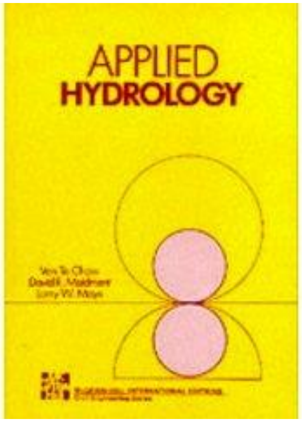
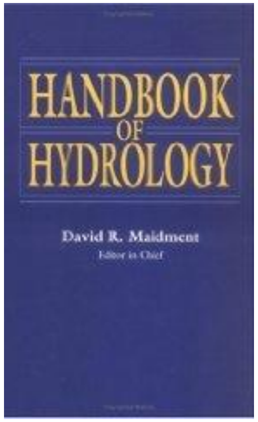
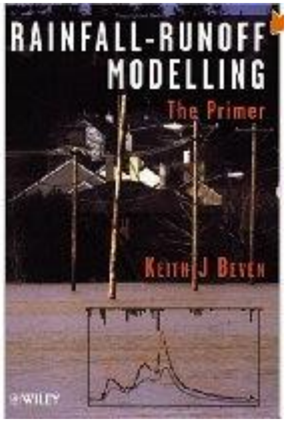
David K. Todd
Larry W. Mays


APPLIED
HYDROLOGY


HANDBOOK
OF
HYDROLOGY
David R. Maidment
Editor in Chief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The Primer
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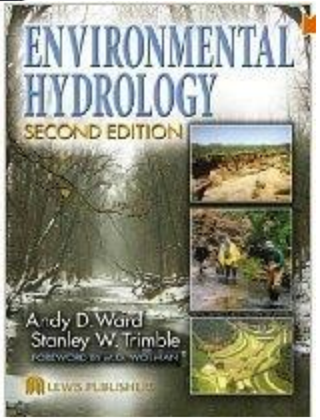
WILEY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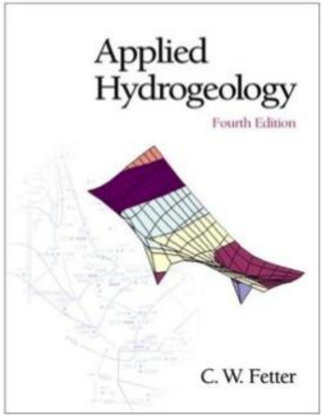
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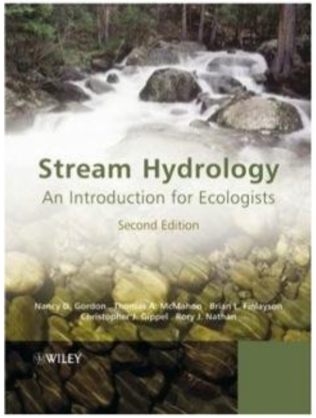
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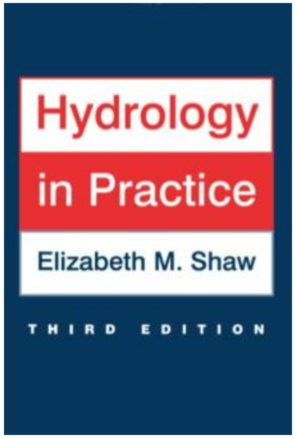
Hydrology
in Practice
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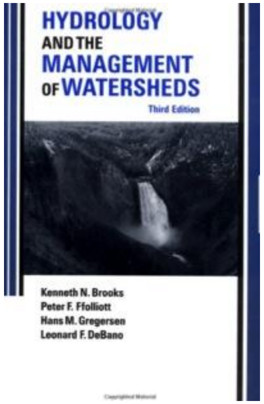
THIRD EDITION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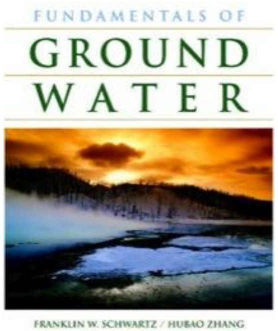
Hans M. Gregersen
Leonard F. DeBano


FUNDAMENTALS OF
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WATER
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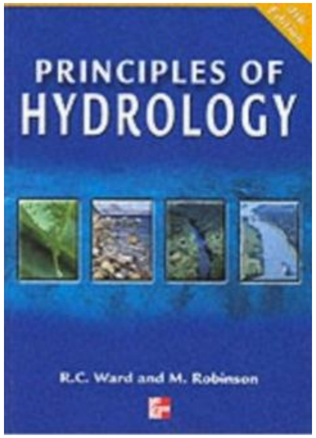
PRINCIPLES OF
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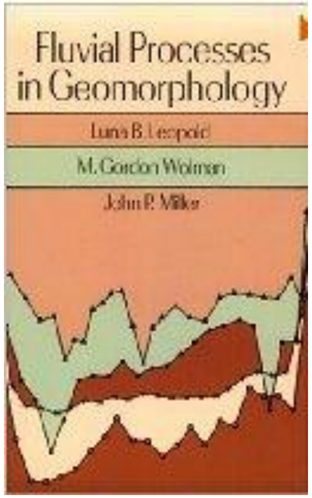
R.C. Ward and M. Robinson


Water in
Environmental Planning
Thomas Dunne and Luna B. Leopold


Fluvial Processes
in Geomorphology
Luna B. Leopold
M. Gordon Wolman
John P. Miller

Our approach to hydrology education has to be more holistic and focused on skills

Current	Future
Strong separation between engineering and science approaches to hydrology education	Integration of qualitative and quantitative aspects into a holistic teaching of hydrology
Focus on teaching established solutions to current problems	Focus on teaching of evolving skill sets with a strong scientific basis that can be adapted to solving new problems and to understanding new phenomena

The future of hydrology: An evolving science for a changing world

Thorsten Wagener,[1] Murugesu Sivapalan,[2,3,4] Peter A. Troch,[5] Brian L. McGlynn,[6]
Ciaran J. Harman,[3] Hoshin V. Gupta,[5] Praveen Kumar,[3] P. Suresh C. Rao,[7]
Nandita B. Basu,[8] and Jennifer S. Wilson[2]

How can we improve hydrology teaching given existing time constraints?

Hydrol. Earth Syst. Sci., 16, 1–14, 2012
www.hydrol-earth-syst-sci.net/16/1/2012/
doi:10.5194/hess-16-1-2012

Hydrology and Earth System Sciences

It takes a community to raise a hydrologist: the Modular Curriculum for Hydrologic Advancement (MOCHA)

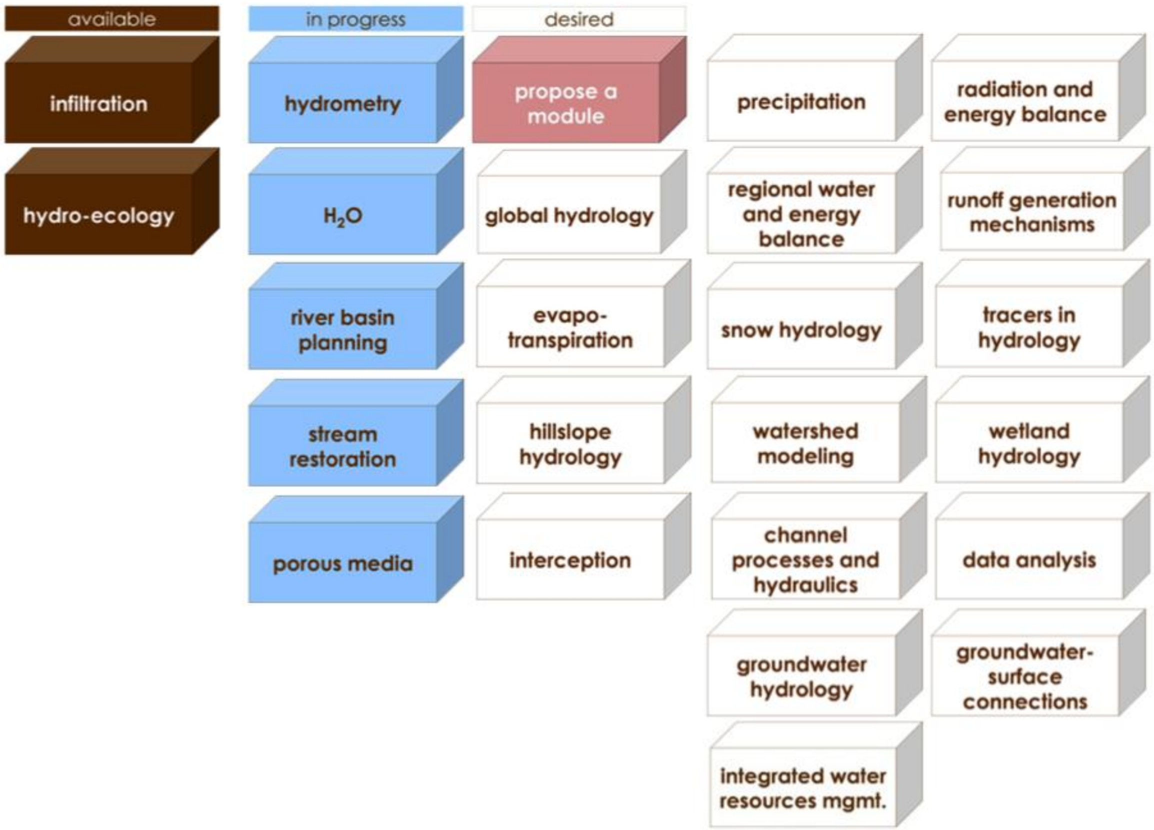
T. Wagener[1,2], C. Kelleher[1], M. Weiler[3], B. McGlynn[4], M. Gooseff[1], L. Marshall[4], T. Meixner[5], K. McGuire[6], S. Gregg[1], P. Sharma[7], and S. Zappe[8]

Funded by the US National Science Foundation, Division for Undergraduate Education

The Modular Curriculum for Hydrologic Advancement (MOCHA) is

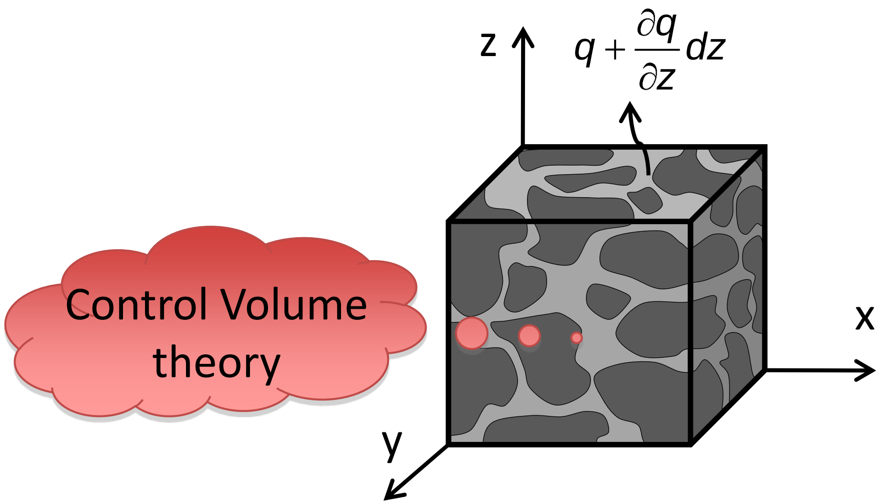
… establishing an online faculty learning community for hydrology education and a modular hydrology curriculum based on modern pedagogical standards.

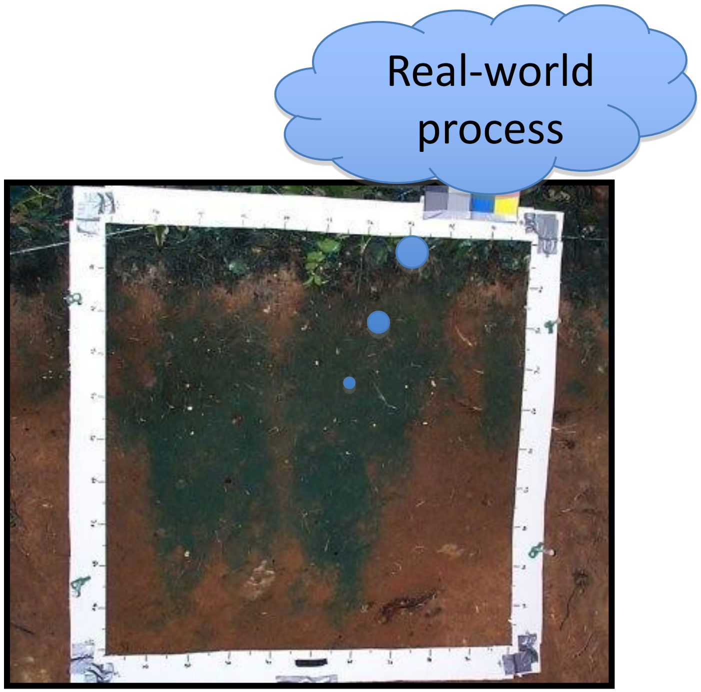
MOCHA is based on modules, each covering ~3 hours of in-class teaching material



… seamless connectivity through a common template!

We use a control volume approach for consistency in theory development





Typical engineering textbook

Typical science textbook

We created an ABCD of lesson design and teaching notes to share experience

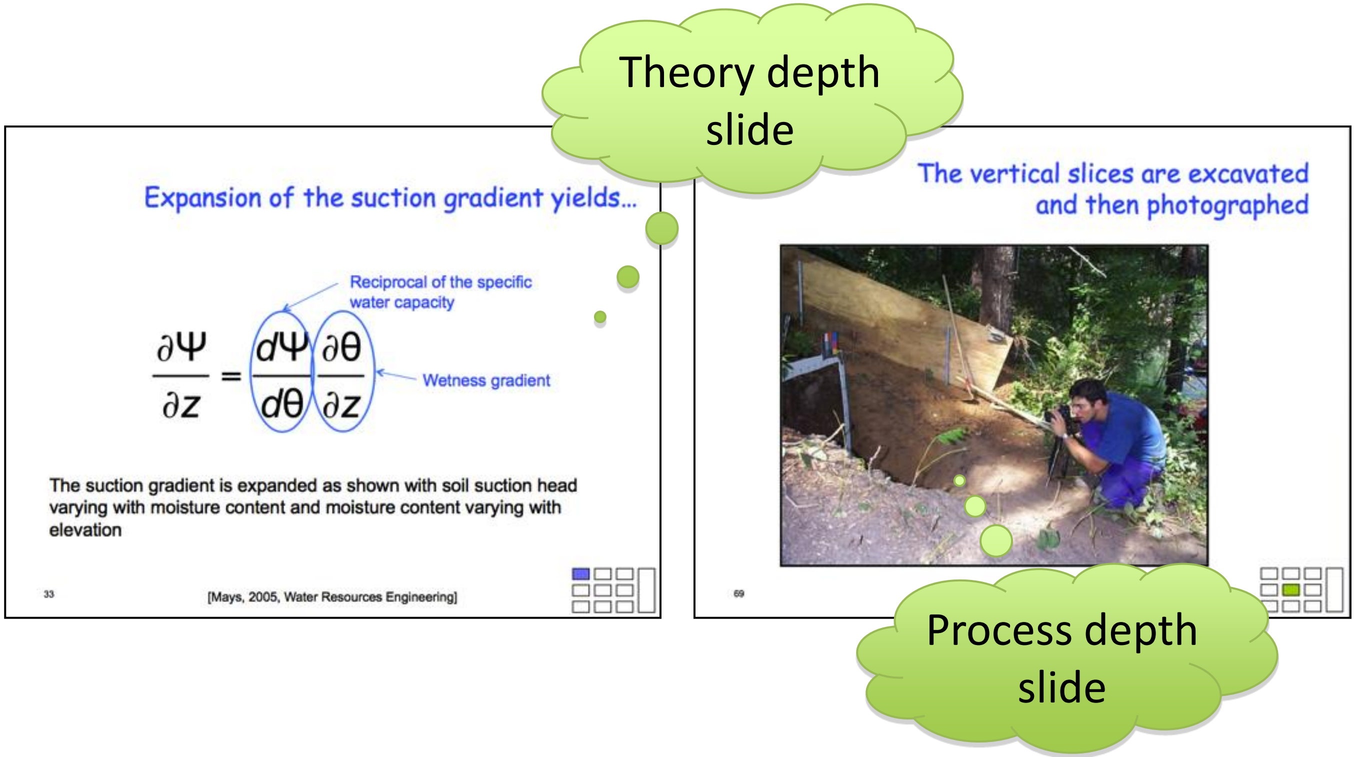
Baseline pedagogy to support lectures

A	B	C	D
Planning the lesson	Beginning the lesson	During the lesson	Ending the lesson

Students respond differently to the same material

Example from infiltration module: *Prompt class to discuss how the infiltration curve of a gravel soil would be different than a clay soil, and to identify why these differences exist*.

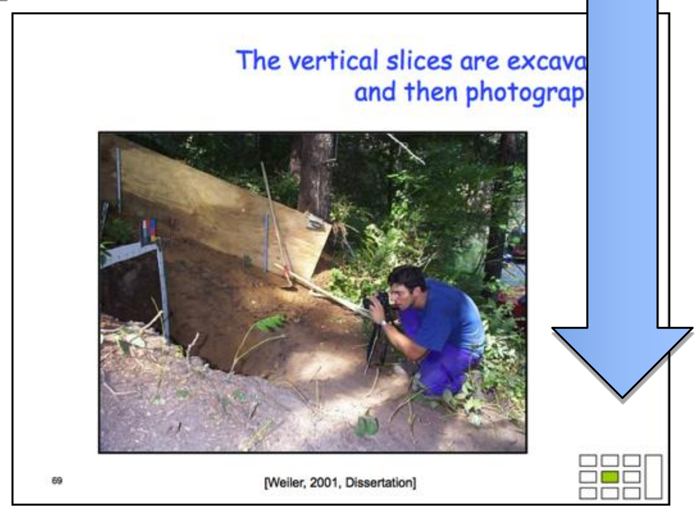
In-depth learning slides enable additional depth for science and engineering classes



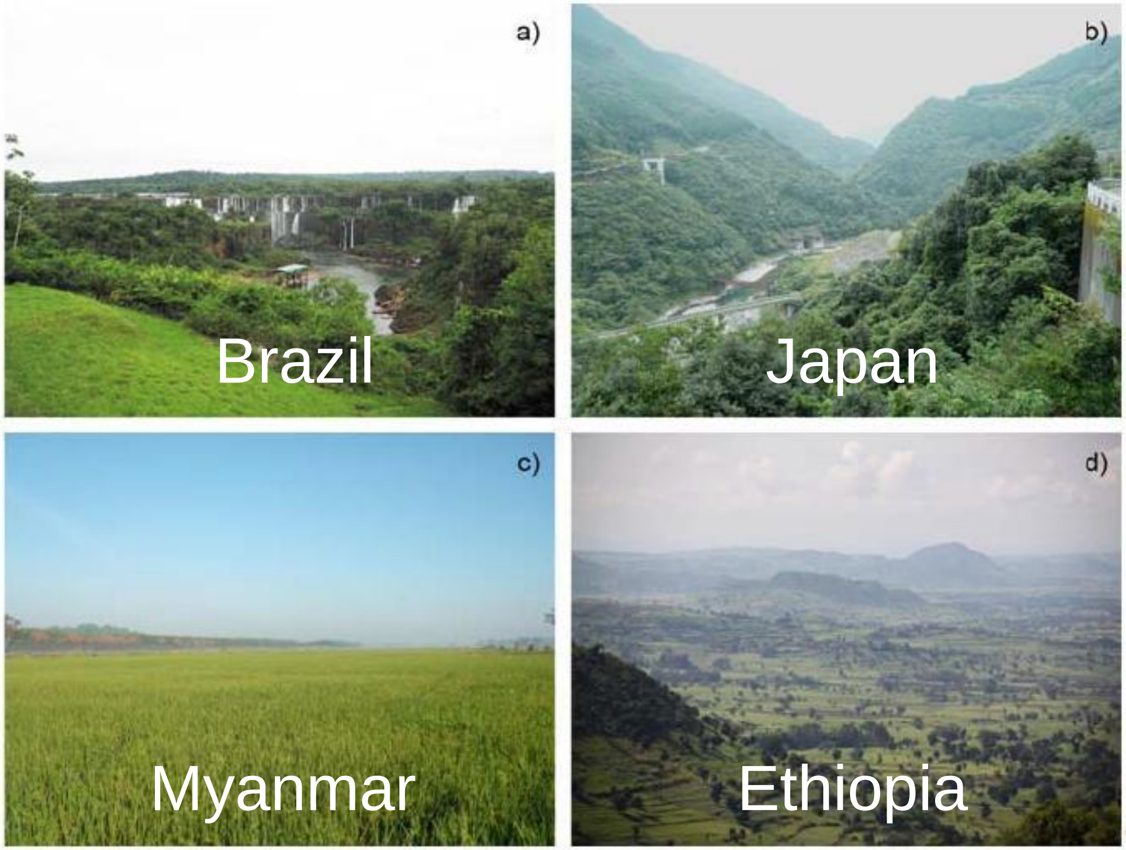
Space and focus classification of slides enables easy tailoring to teaching styles

Scale \ Topic	Theory	Observation	Modeling	Application Examples
Point				
Plot				
Watershed				

A small version of this table is at the bottom of each slide



I think that the future of hydrology education lies far beyond better slides!



www.mocha.psu.edu

How can we transfer experience?

Kairos (καιρός) *is an ancient Greek word meaning the right or opportune moment (the supreme moment)*