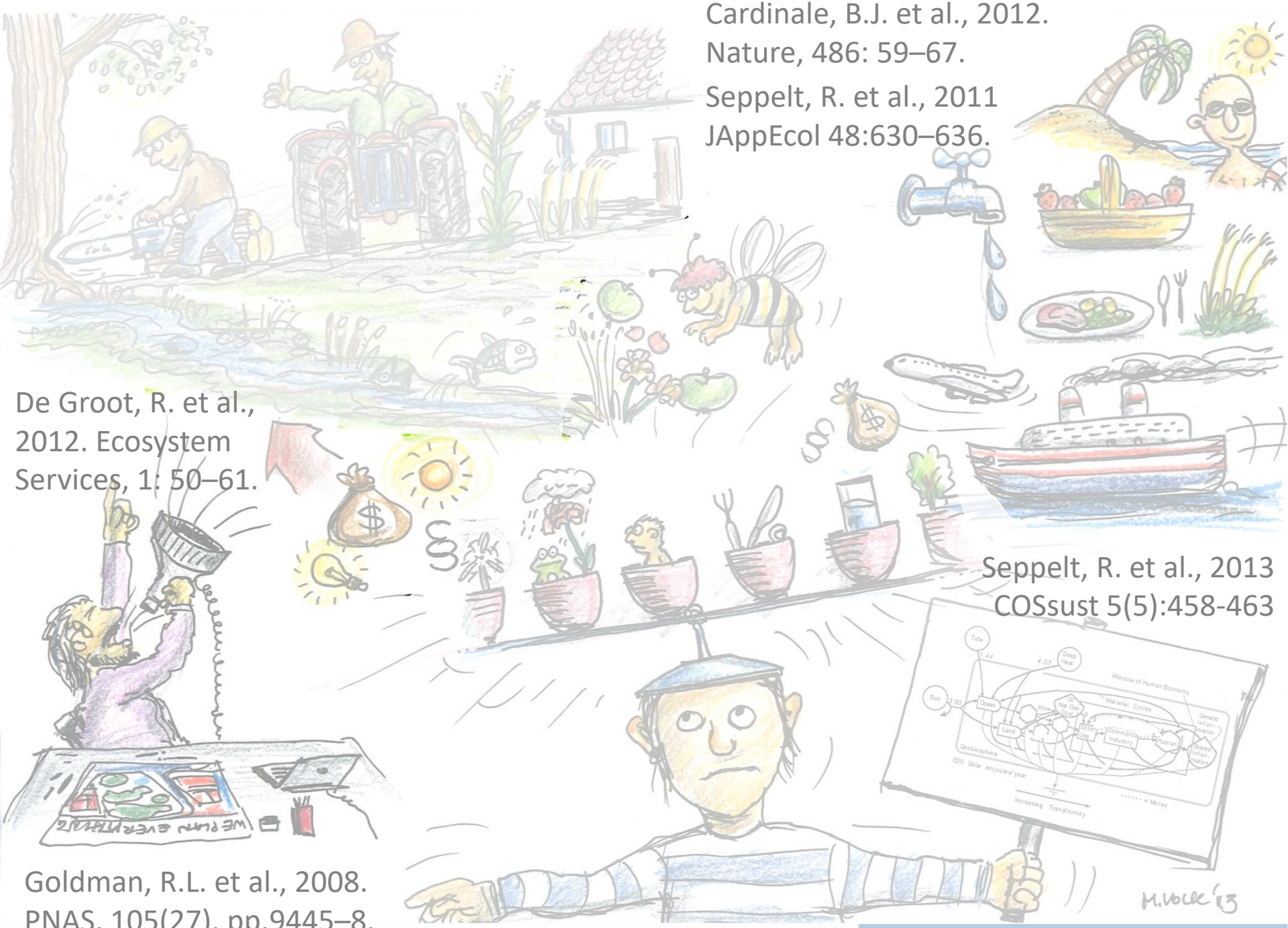
Using SWAT and other models for simulating ecosystem services and trade-offs – A critical reflection

Martin Volk

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

2018 SWAT Conference, September 17-21, 2018, Brussels, Belgium



Cardinale, B.J. et al., 2012. Nature, 486: 59–67.

Seppelt, R. et al., 2011 JAppEcol 48:630–636.

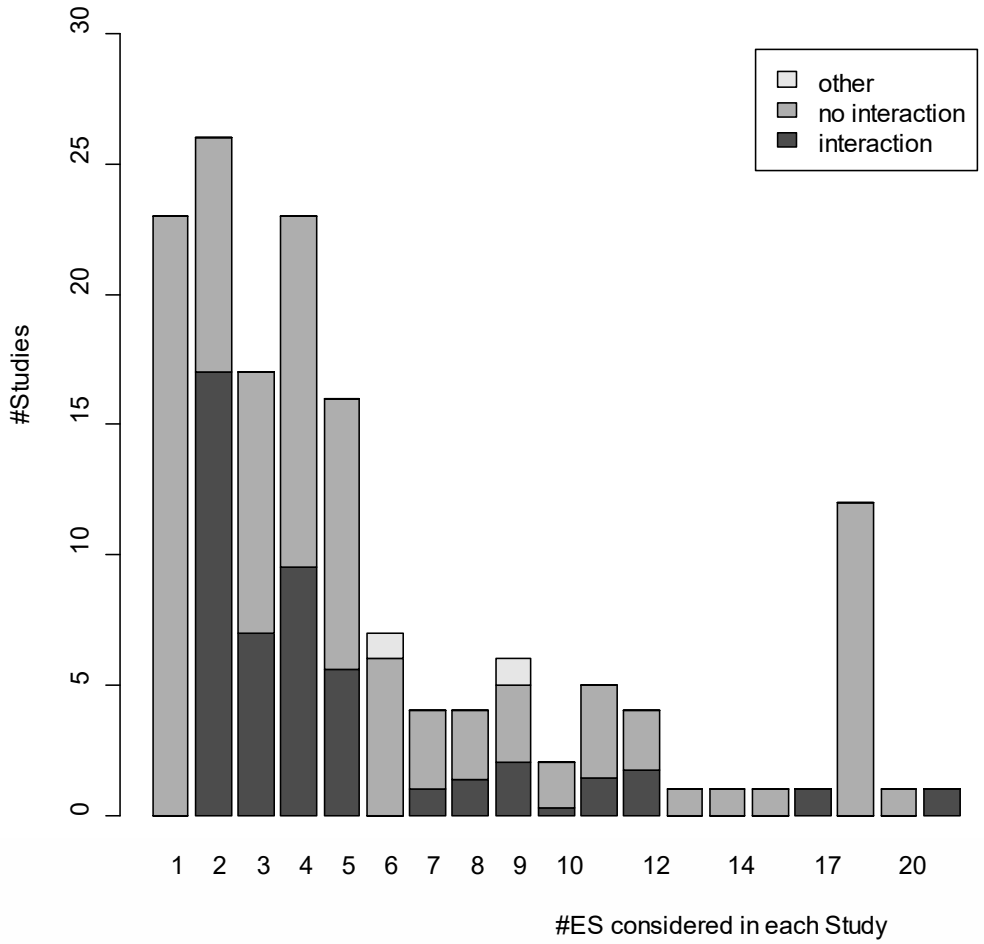
De Groot, R. et al., 2012. Ecosystem Services, 1: 50–61.

Seppelt, R. et al., 2013 COSsust 5(5):458-463

Goldman, R.L. et al., 2008. PNAS, 105(27), pp.9445–8.

Quantitative Review: Ecosystem Service Studies

- wide variety of approaches
- lack of consistent methodology
- frequent use proxy variables
- observations or measurements (< 40%)
- secondary data (>60%)
- models based assessments (<25%)
- without considering / quanti-fying any feedbacks / trade-offs or off-site effects (>50%)
- scenarios (30%)
- Stakeholders rarely involved



Seppelt et al. (2011), J. of Applied Ecology 48: 630–636; Volk (2013), Sust. Water Quality and Ecology 1-2, 3-9 .

Blind spots in ecosystem services research and implementation (period 1996-2016)

- …number of published ES studies has continued to rise over the last years.
- However, shortcomings with respect to social-ecological realism, trade-off analysis, off-site effects, stakeholder involvement as well as relevance and usability still persist.
- To effectively operationalize the concept of ES the mentioned blind spots need to be addressed by upcoming studies (we provide a list of critical questions to raise awareness of the blind spots).

Lautenbach, S. et al. (submitted to Reg. Env. Change)

HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ

WR- and ESS-Management – The common ground

Processes which promote the **coordinated development and management of water, land and related resources** in order to **maximise the resultant economic and social welfare** in an equitable manner **without compromising the sustainability of vital ecosystems.**

GWP (2000)

Examples: Freshwater Ecoservices Tools

Basic inputs and outputs for water-related ecosystem services tools.

	SWAT	VIC	InVEST	ARIES
Key data inputs				
Precipitation	Daily	Hourly	Ave annual	Best avail
Topography	Yes	Yes	Yes	Yes
Soil type	Multi layer	Multi layer	Single layer	Single layer
Snow water equivalent	Yes	Yes	No	No
Key outputs				
Water yield	Daily	Hourly	Annually	No[a]
Evapotranspiration	Daily	Hourly	Annually	No[a]
Flows	Daily	w/routing model	No	Yes
Sediment retained	Yes	No	Yes	No[a]
Nutrients retained	Yes	No	Yes	No[a]

[a] ARIES does not explicity provide the user with these specific outputs, but rather wraps them up into reporting on results such as an economic valuation or ecosystem profile.

SWAT – Soil and Water Assessment Tool (89 Papers since 2003)

VIC model – Various Infiltration Capacity

InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs

ARIES - Artifcial Intelligence for Ecosystem Services

Summary of freshwater ecosystem services tools.

Model	Freshwater services	Time step	Scale	Platform
InVEST[a]	Nutrient filtration, hydropower, irrigation, avoided reservoir sedimentation, storm peak mitigation	Annual	30 m–10 km grid cells	GIS
ARIES[b]	Flood control, sedimentation, nutrient filtration, water supply	Monthly to annual	30 m–10 km grid cells	Web-based
SWAT[c]	Water yield, sedimentation, water quality	Daily	Subbasin	Windows or GIS
VIC[d]	Water yield	Hourly to daily	1–50 km grid cells	LINUX/UNIX

[a] Developed and maintained by the Natural Capital Project, a collaboration of World Wildlife Fund, The Nature Conservancy, and Stanford University: www.naturalcapital.org.

[b] Developed and maintained by the University of Vermont Gund Institute for Ecological Economics and in collaboration with Earth Economics and Conservation International: http://www.ariesonline.org/.

[c] Developed and maintained by the US Department of Agriculture's Agricultural Research Service (ARS): http://swatmodel.tamu.edu.

[d] Developed and maintained by a group at the University of Washington's Department of Civil and Environmental Engineering, lead by Dennis P. Lettenmaier: http://www.hydro.washington.edu/Lettenmaier/models/vic.

Source: Vigerstol and Aukema (2011)

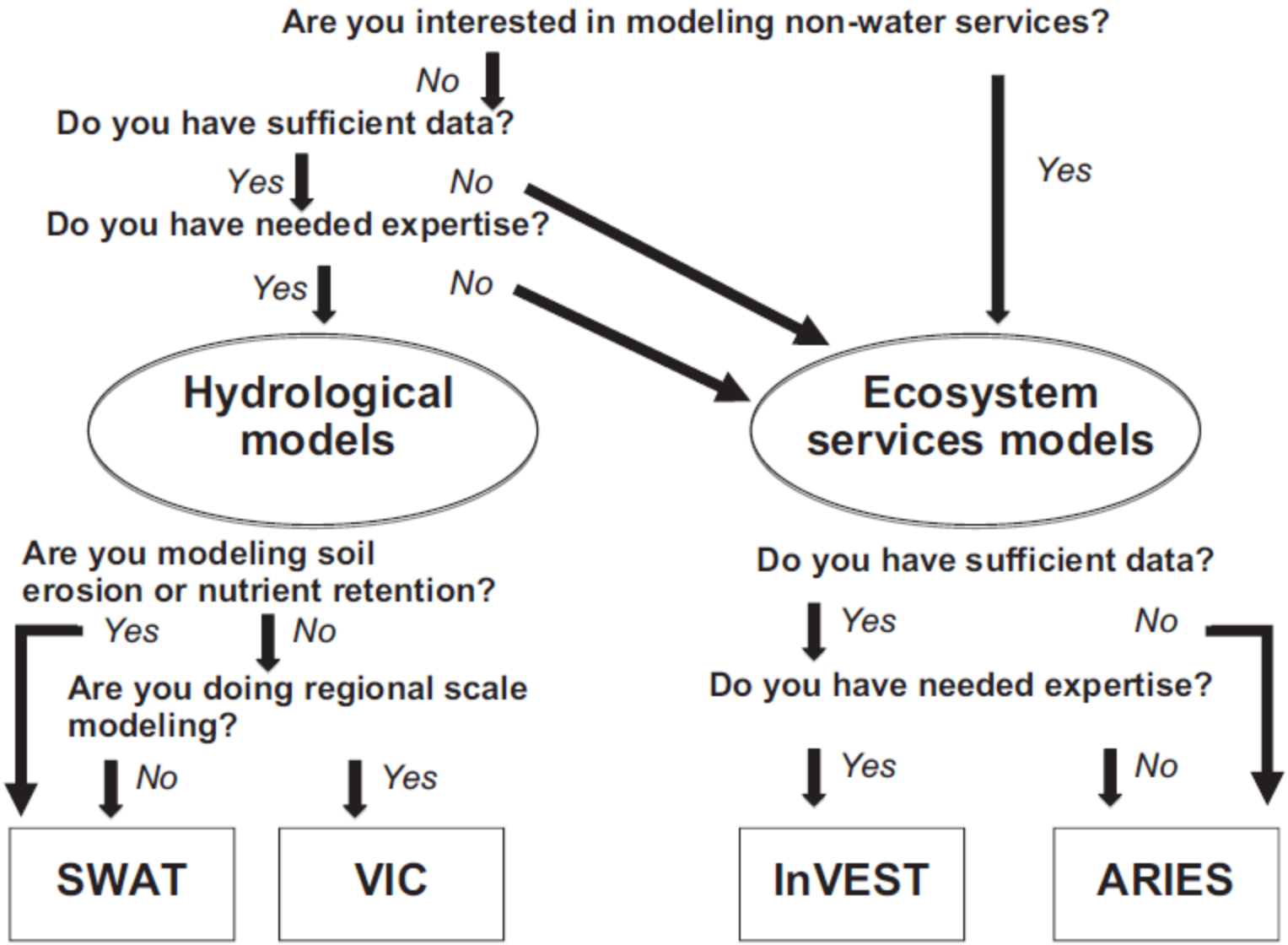
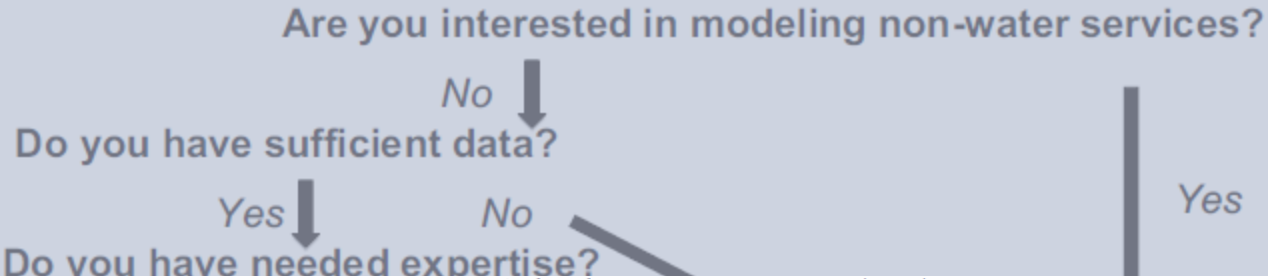


Fig. 1. Schematic of decision points and questions to ask in choosing a model.

Example how start with a protocol?

Source: Vigerstol and Aukema (2011)



Agricultural Water Management 105 (2012) 21–31

Contents lists available at SciVerse ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Assessing the ecosystem services supplied by freshwater flows in Mediterranean agroecosystems

Bárbara A. Willaarts[a,*], Martin Volk[b], Pedro A. Aguilera[a]

[a] Department of Plant Biology and Ecology, Carretera de Sacramento s/n, University of Almeria, 04120 Almeria, Spain
[b] Department of Computational Landscape Ecology, UFZ - Helmholtz Centre for Environmental Research, Permoserstr. 15, D-04318 Leipzig, Germany

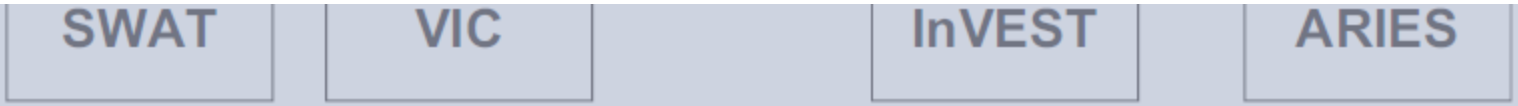


Fig. 1. Schematic of decision points and questions to ask in choosing a model.

Example how start with a protocol?

Source: Vigerstol and Aukema (2011)

Soil and Water Assessment Tool (SWAT) and ESS

Possible:

Supporting services:

- Nutrient cycling

Provisioning:

- Crop yield (food, fodder, energy)
- Water (water quantity, water quality, enviromental flow)

Regulating:

- Water purification, retention, erosion
- Climate
- Carbon sequestration

Soil and Water Assessment Tool (SWAT) and ESS

Po

Su

-

Pr

-
-

Re

-
-
- Carbon sequestration

Hydrol. Earth Syst. Sci., 19, 4377–4396, 2015
www.hydrol-earth-syst-sci.net/19/4377/2015/
doi:10.5194/hess-19-4377-2015

Hydrology and Earth System Sciences
Open Access
EGU

Towards ecosystem accounting: a comprehensive approach to modelling multiple hydrological ecosystem services

C. Duku[1], H. Rathjens[2], S. J. Zwart[3], and L. Hein[1]

[1]Environmental Systems Analysis Group, Wageningen University, P.O. Box 47, 6700AA, Wageningen, the Netherlands
[2]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907-2093, USA
[3]Africa Rice Center, 2031 PB, Cotonou, Benin

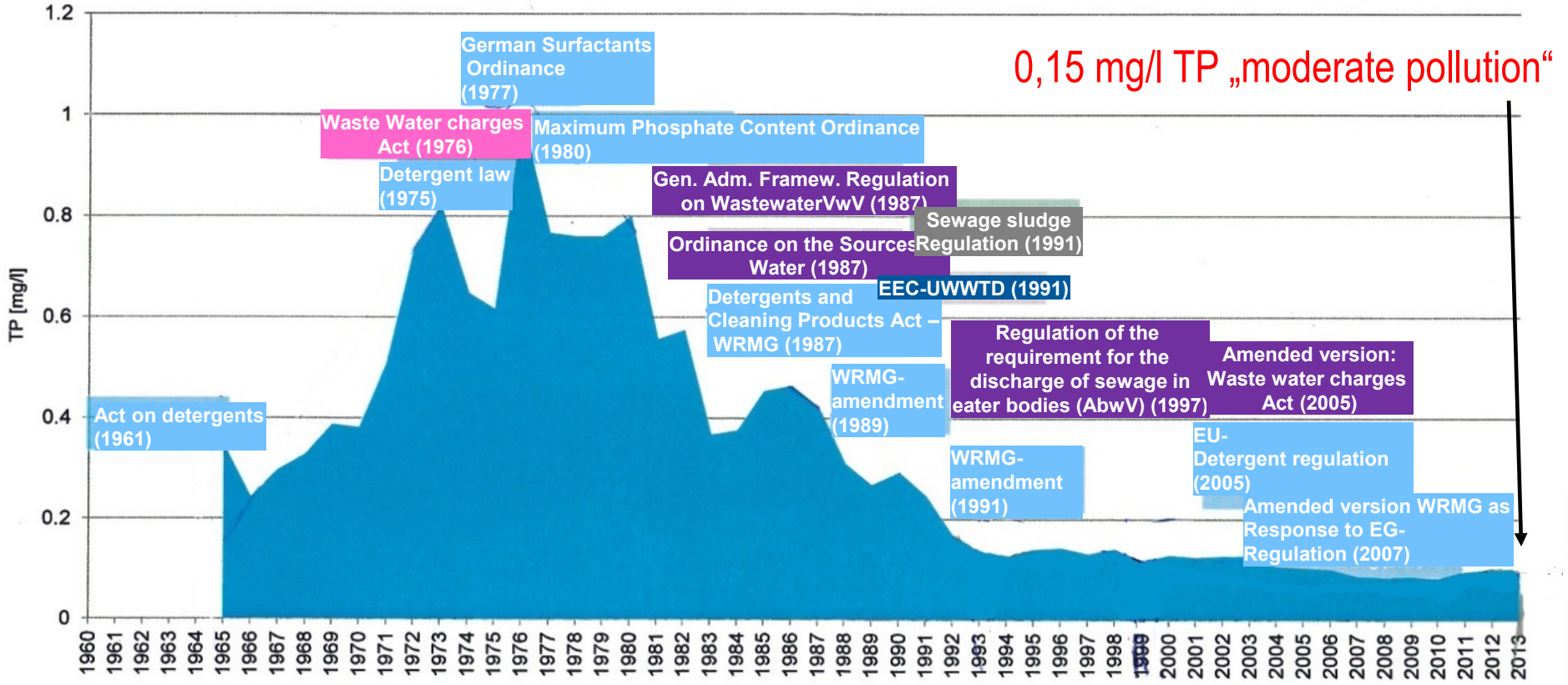
Correspondence to: C. Duku (confidence.duku@wur.nl, confidence.duku@gmail.com)

Received: 20 November 2014 – Published in Hydrol. Earth Syst. Sci. Discuss.: 30 March 2015
Revised: 12 October 2015 – Accepted: 13 October 2015 – Published: 30 October 2015

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Challenges: Change of drivers over time? Trade-offs? Which measure is most effective?

Example: Regulations on point sources



(Example selected water quality gauge Ruhr River, NRW)

Exploratory modelling in dynamic systems – trade-offs

Landscape fulfils different functions and provides different services that have to be considered at the same time

- One can for example assess whether it is possible to produce the same agricultural yield but protect more water provision and biodiversity
- Functional relationships between goals and policy instruments?

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Exploratory modelling in dynamic systems – trade-offs

Landscape fulfils different functions and provides different services that have to be considered at the same time

- One can for example assess whether it is possible to produce the same agricultural yield but protect more water provision and biodiversity
- Functional relationships between goals and policy instruments?

Environmental Modelling & Software 48 (2013) 98–112

Contents lists available at SciVerse ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

Optimization-based trade-off analysis of biodiesel crop production for managing an agricultural catchment

Sven Lautenbach [a,b,*], Martin Volk [b], Michael Strauch [c,b], Gerald Whittaker [d], Ralf Seppelt [b,e]

Ecosystem Services 28 (2017) 264–272

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Towards systematic analyses of ecosystem service trade-offs and synergies: Main concepts, methods and the road ahead

Anna F. Cord [a,*], Bartosz Bartkowski [b], Michael Beckmann [a], Andreas Dittrich [a], Kathleen Hermans-Neumann [a,c], Andrea Kaim [a], Nele Lienhoop [b], Karla Locher-Krause [a], Jörg Priess [a], Christoph Schröter-Schlaack [b], Nina Schwarz [a,f], Ralf Seppelt [a,d], Michael Strauch [a], Tomáš Václavík [a,e], Martin Volk [a]

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Current Opinion in Environmental Sustainability

Identifying trade-offs between ecosystem services, land use, and biodiversity: a plea for combining scenario analysis and optimization on different spatial scales

Ralf Seppelt[1], Sven Lautenbach[2] and Martin Volk[1]

Environmental Modelling & Software 105 (2018) 79–93

Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

A review of multi-criteria optimization techniques for agricultural land use allocation

Andrea Kaim*, Anna F. Cord, Martin Volk

Helmholtz Centre for Environmental Research - UFZ, Department of Computational Landscape Ecology, Permoserstraße 15, 04318 Leipzig, Germany

Environmental Science and Policy 84 (2018) 186–196

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Optimizing the allocation of agri-environment measures to navigate the trade-offs between ecosystem services, biodiversity and agricultural production

Willem Verhagen[a,*], Emma H. van der Zanden[a], Michael Strauch[b], Astrid J.A. van Teeffelen[a], Peter H. Verburg[a,c]

Conclusions and recommendations:

- Hydrological models can provide process-based information on water-related ecosystem services.
- SWAT can provide ecosystem services beyond purely hydrological services.
- There is no “one and only model”: Selection of model depends on question to be answered and study area – model performance must be tested by criteria.
- Providing knowledge on trade-offs and marginal changes is a key for successful implementation of the ecosystem services concept (potential of landscape to provide ecosystem services)
- Scenario analysis is necessary and should be combined with exploratory modelling
- Modularity and reusability of model systems are necessary
- There is never such thing as the one and only goal - implementation of resource management strategies needs always to incorporate learning and model building in cooperation with stakeholders

Thank you for your time!

Contact: martin.volk@ufz.de

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ