Drought risk analysis
-a state of the art-
with insights from hydrology

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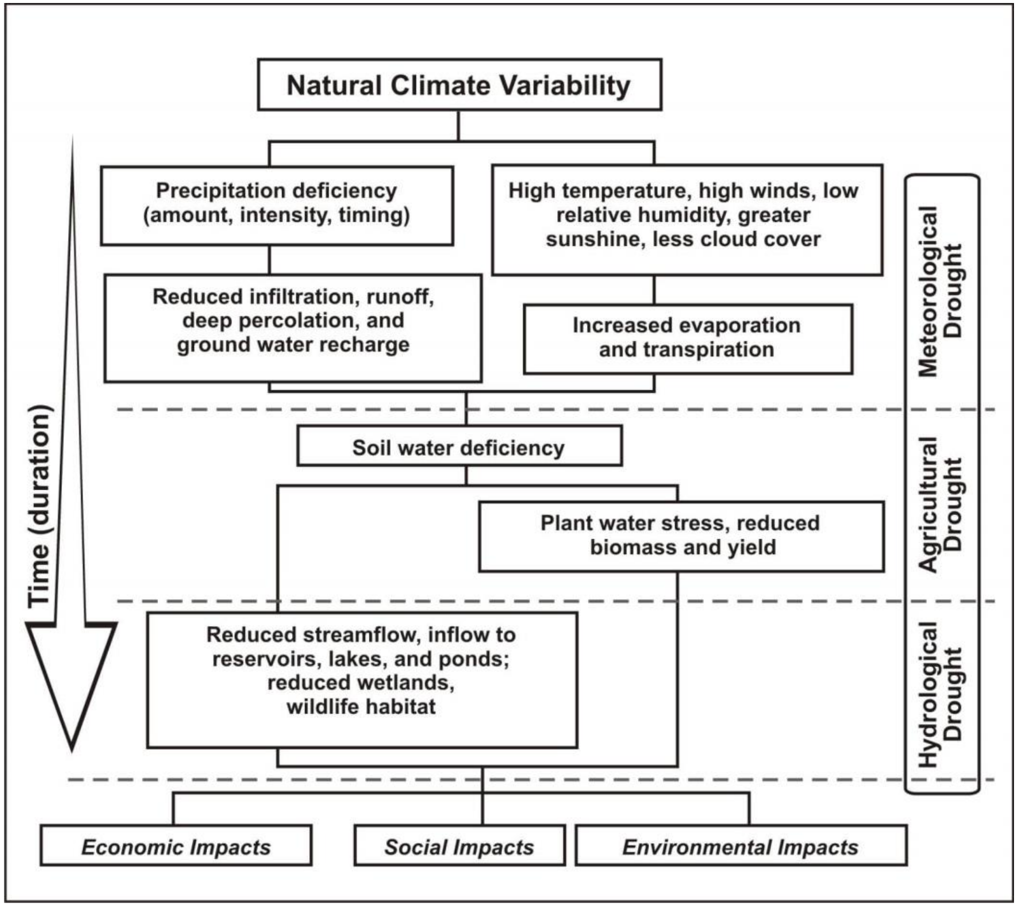
Drought

Drought: climatological induced deficit in water availability that causes negative social, economic and ecological impacts. (adapted from Knutson et al. 1998)

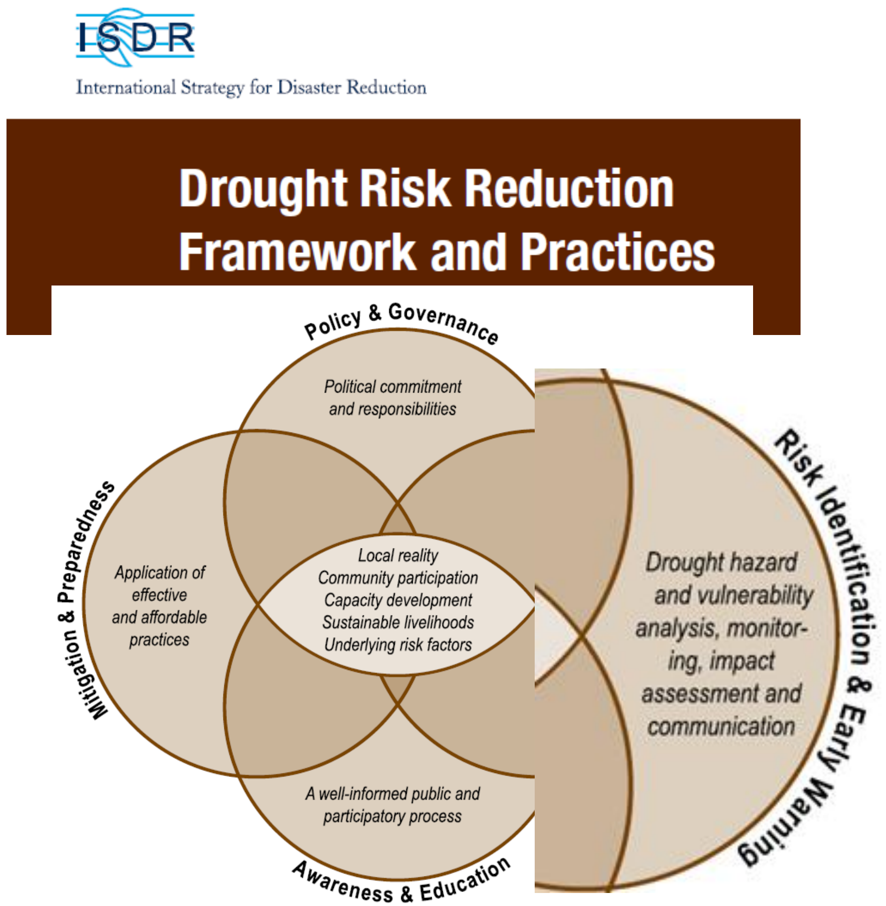


Source: NDMC

Understanding drought risk

Drought risk is not: frequency and severity of the hazard

Drought risk is: likelihood of adverse effects of drought as a product of both the frequency&severity of the hazard **and corresponding vulnerability**



Impacts of drought

Review of …

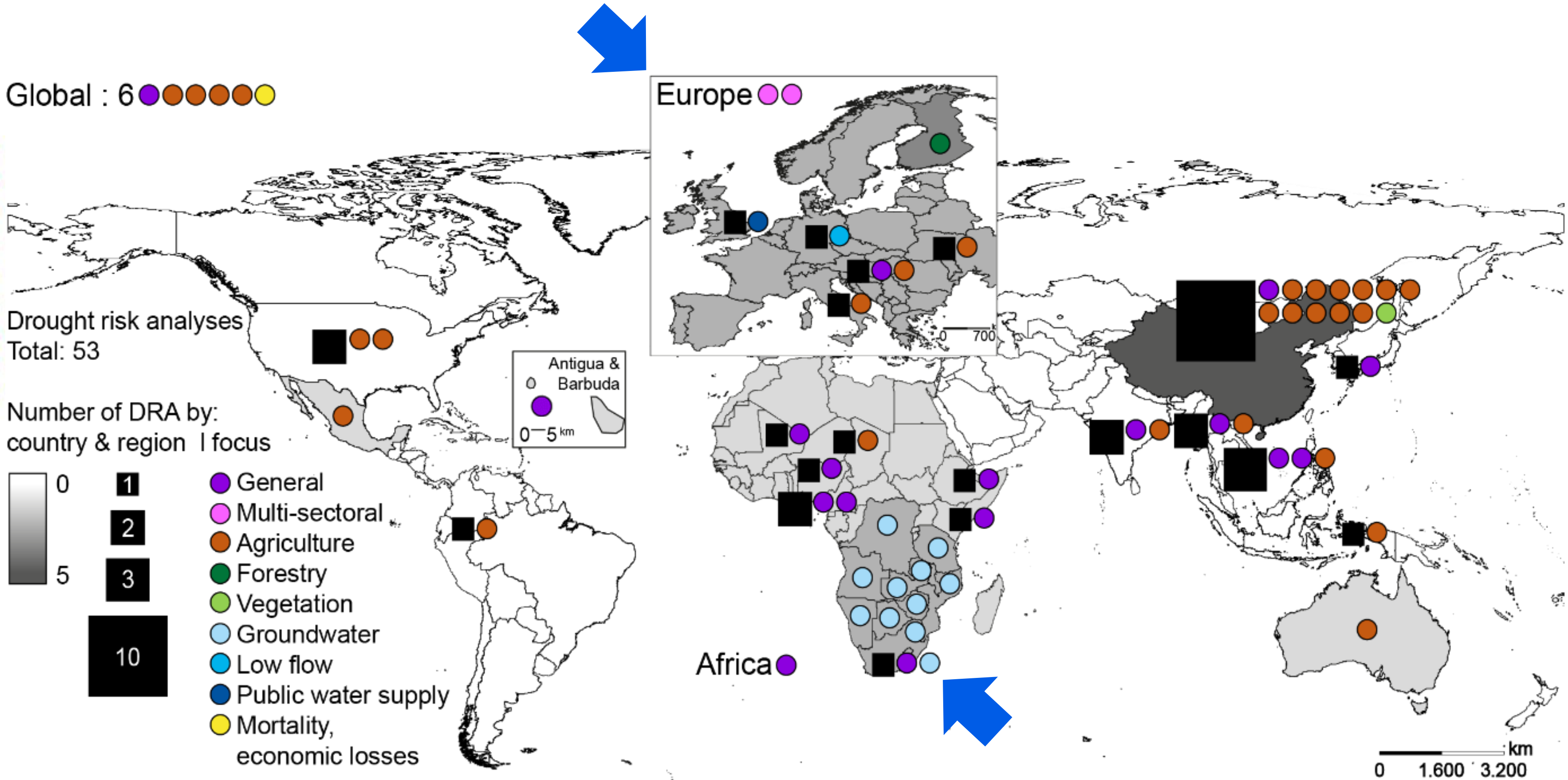
Drought risk analyses (English & German) displaying drought risk via mapping:

Drought risk = f(hazard x vulnerability)

Foci of the review

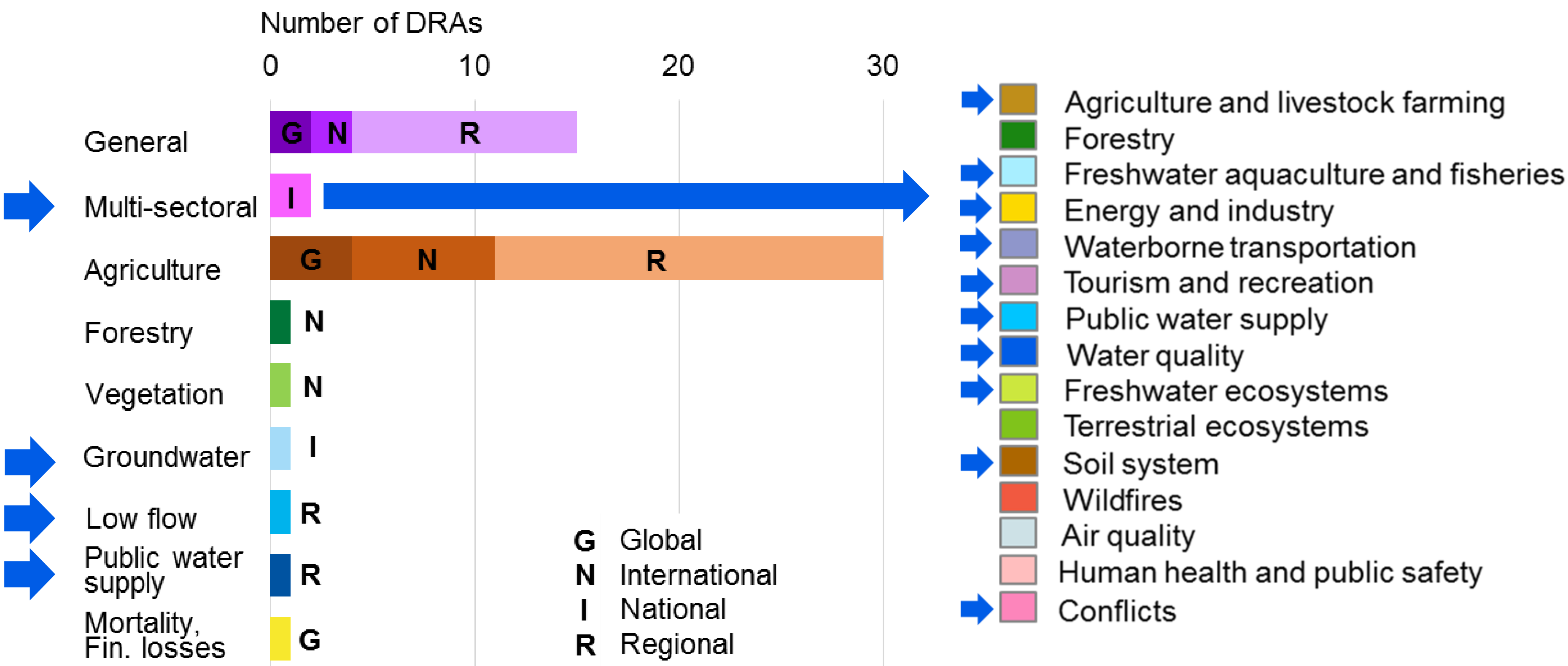
- Location
- Focus
- Spatial scale
- Temporal scale
- Paradigms of analysis
- Data applied
- Visualisation of risk via maps

Drought risk analyses around the globe



Blauhut (submitted to ERL)

Sectors & scales of DRAs



Drought risk paradigms

HYDROLOGY

Drought risk

f(hazard x **VULNERABILITY**)

Impact approach

Impacts as proxy of past vulnerability

Hybrid approach

Combination of impact and vulnerability information

Factor approach

(weighted) combination of different factors characterising vulnerability

- Quantification of the impact
- Specific focus
- Application of time series (dynamic)
- Misses the root causes of impacts (vulnerability)

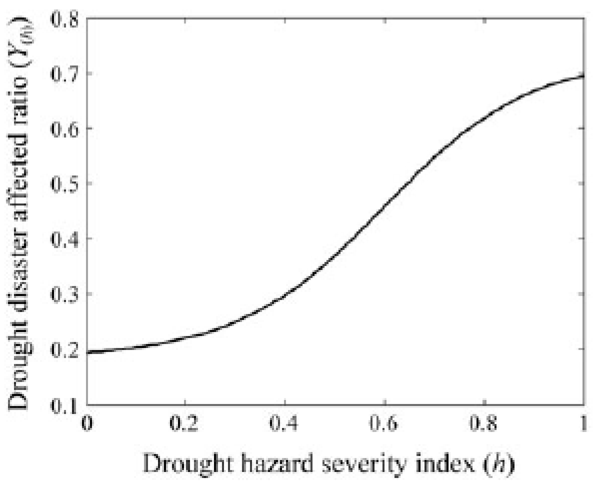
- Understanding of possible drivers of drought risk (beyond the hazard)
- Stakeholder interaction
- Application of recent data (static)
- Misses a quantification of potential losses

Combination method

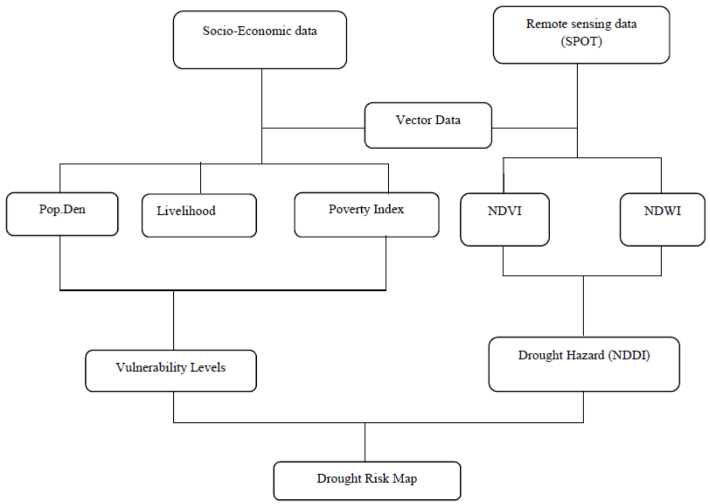
Drought risk
f(hazard, vulnerability)

Statistical model

Conceptual model



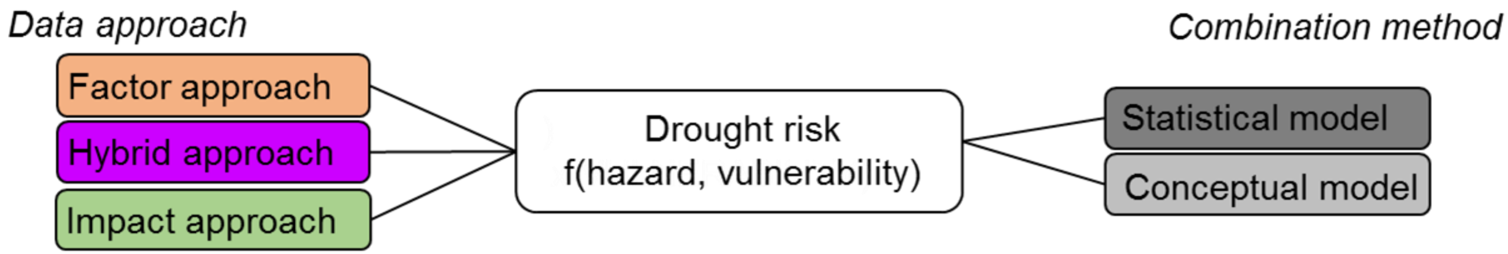
Lei et al. 2011

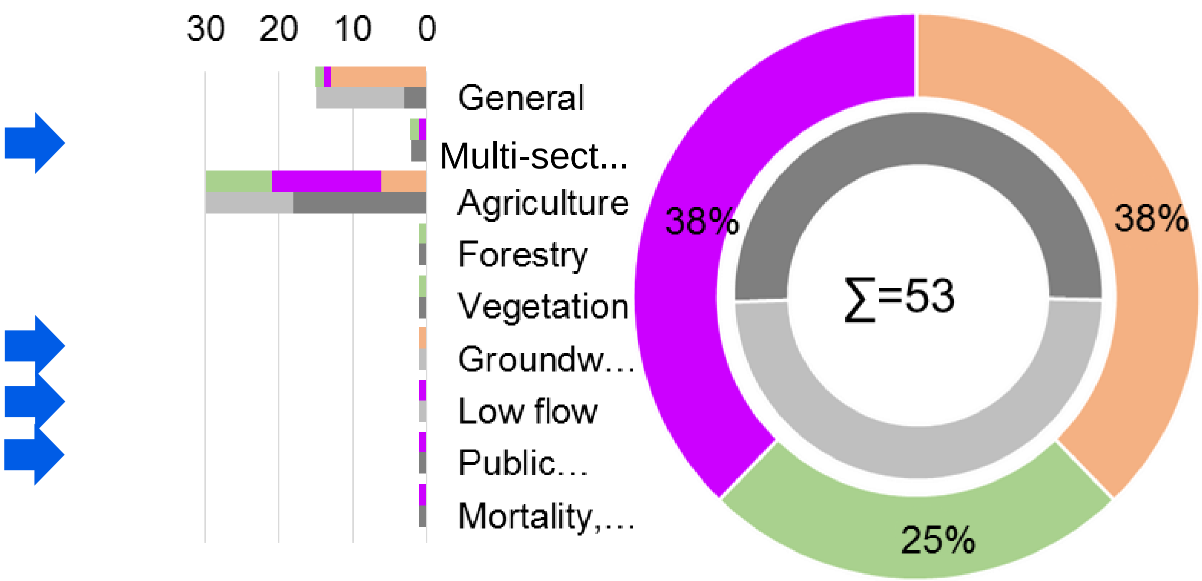


Kipterer & Mundia 2011

- Statistics are reliable and transparent
- Intransparent weighting and verification procedures

Data approach vs. combination method





→ *Impact information: statistical model*
→ *Vulnerability information: conceptual models*

Predictor selection & result verification

Predictor selection:
- 35% of DRAs did not provide any information on selection criteria
- ~ 55% of DRAs named expert knowledge (including literature and pre-studies)
- Predictor selection by : principal component analysis (Wu et al. 2011), stepwise multivariable logistic regression (Blauhut et al. 2016)

Verification of results:
- ~ 50% are based on a statistical model → tested
- 65% of conceptual models did not verify results
- Applied verification methods are:
  - Quantitative, e.g. comparison to other studies or sources of information; or expert judgement
  - Qualitative: sensitivity analyses

→ *Lack of transparent selection criteria*
→ *Lack of result verification*

Risk:

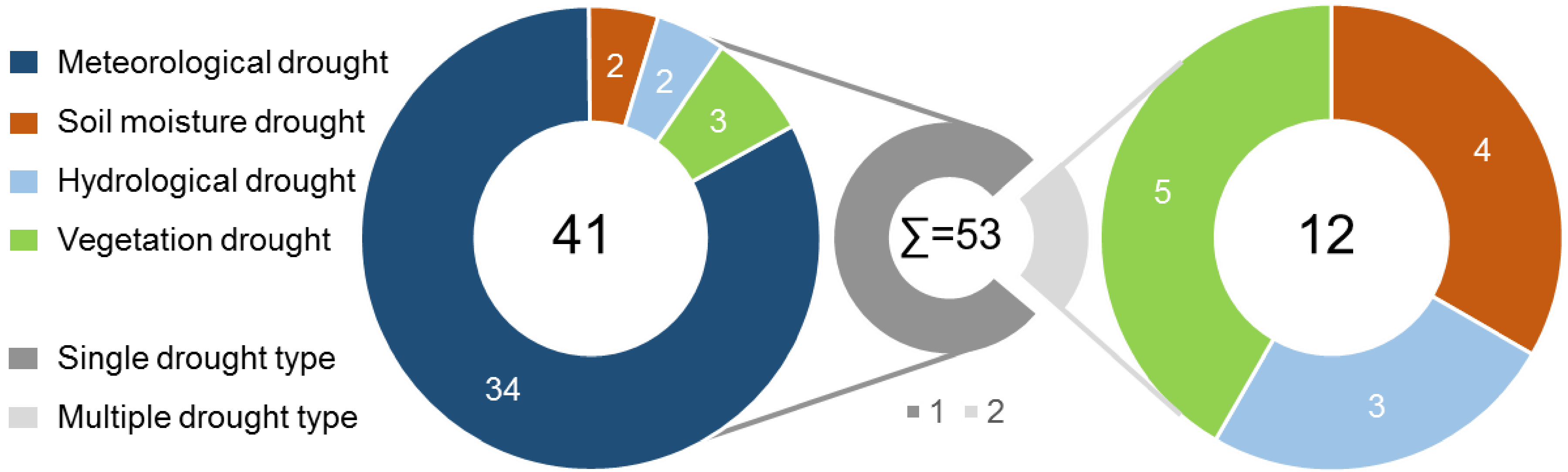
Hazard

Vulnerability

Impact

Hazard

33% of DRAs apply actual conditions, model a linkage of actual hazard conditions to impact/vulnerability



Hit list:

SPI	7 application
NDVI	5 application
SPEI	4 application

→ *Dominance of meteorological drought*
→ *Lack of multiple hazard indicators*
→ *Prevalence of standardised indices*

Hit list vulnerability factors

Vulnerability factor	Ratio
Land use	30%
Population density	25%
Irrigated area	20%
Agricultural land	15%
Soil properties	15%
Slope	13%
Soil texture	13%
Elevation	10%
Reservoir storage capacity	10%
Drought management	8%
Female/male ratio	8%
Fertiliser data	8%
GDP	8%
Irrigation rate	8%
Soil type	8%
21 vulnerability factor	<8%
224 unique vulnerability factors	

→ *Huge variety*
→ *Lack of common standards*
→ *Prevalence of landuse and technological/ infrastructural information*

Impact information

- > 60% of DRAs apply impact information
- Modelled and observed information
- Sources of observed information are:
  - Statistics, no defined drought focus, e.g. annual yields, hydropower production (Worldbank, Eurostat)
  - “Drought induced” impact information (EM-DAT, EDII)

	Obs	Mod	Obs & Mod	∑
Yields	11	2	6	19
Impact reports	5			5
Vegetation activity	3			3
Economic loss	1			1
Human mortality	1			1
Tree ring growth	1			1
Water availability			1	1
Water need			1	1
Water scarcity		1		1
Working days		1		1
∑	26	4	8	34

→ *Lack of drought attributed impact information*

→ *General lack of sector specific impact information with regard to higher sector-wise temporal and spatial resolution*

Triple complexity of drought risk analysis

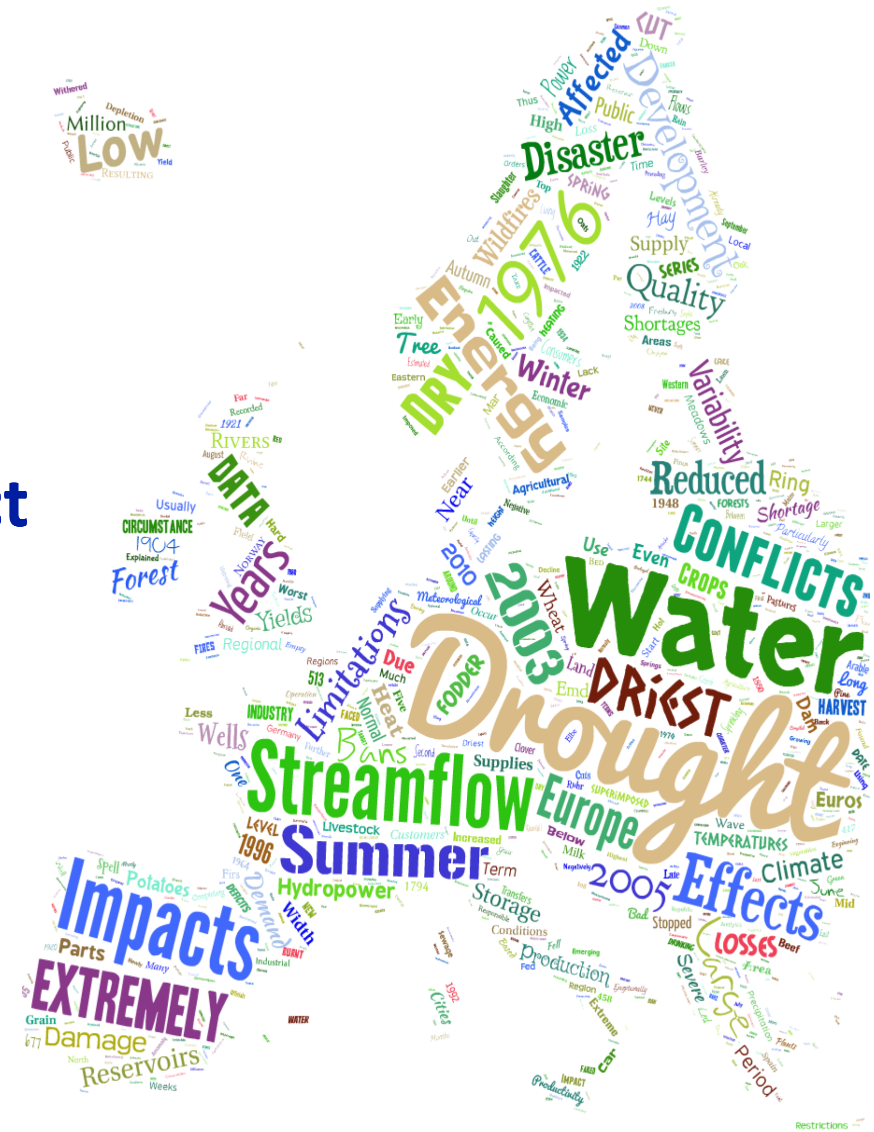
Socio-economic and ecological system are affected by different types of drought. The selection of drought predictors should be verified by the testing predictors of full range of drought types.

Information on drought impact tell the story of past drought risk and therefore should be the basis of an appropriate risk analysis. Furthermore, they are key to verify predictors selection.

Insights to the vulnerability to drought are essential to understand the drivers of impacts beyond the hazard, an thus essential to develop drought management strategies. Assessments should preferably be based on statistic, the selection of vulnerability factors should be based on their skill in order to meet the aims of analyses, rather than expert knowledge and data availability

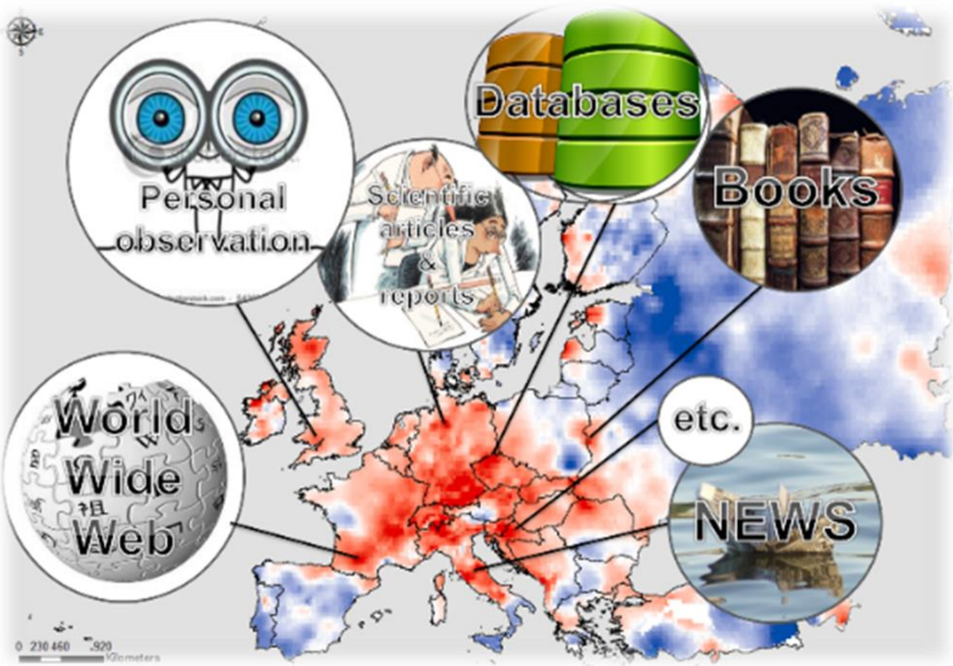
HYDROLOGY

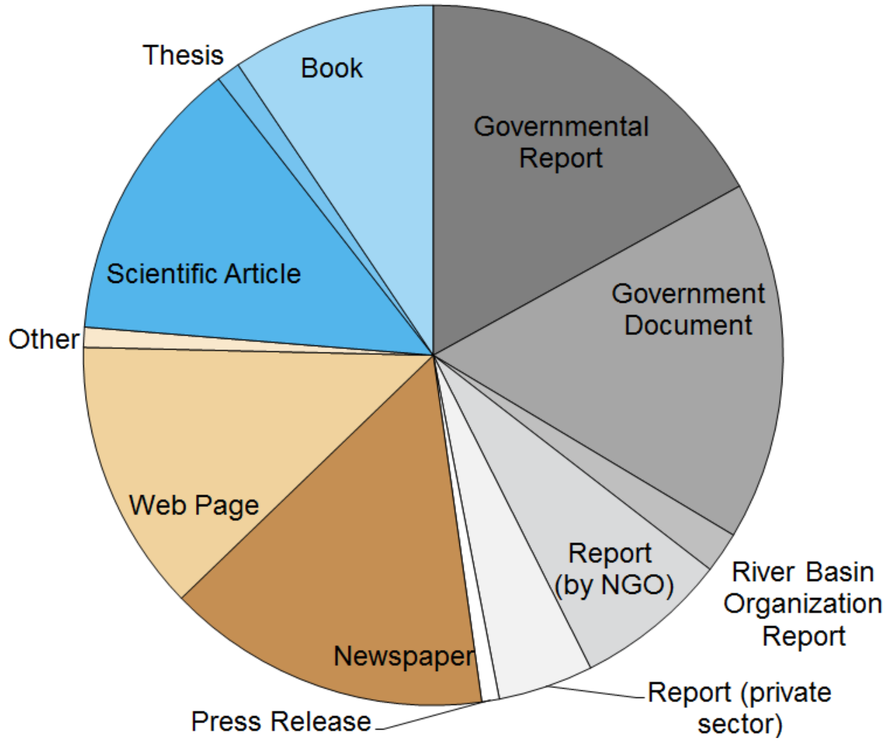
European Drought Impact report Inventory – EDII



DROUGHT R&SPI

The European Drought Impact report Inventory

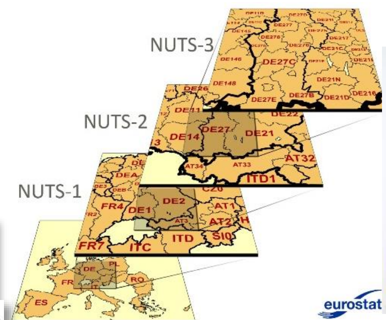




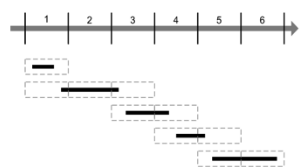
EDII information source types (July 2017)

The European Drought Impact Inventory

Information-source | **Location** | **Time of occurrence** | **Impact categorisation** | **EDII archive**



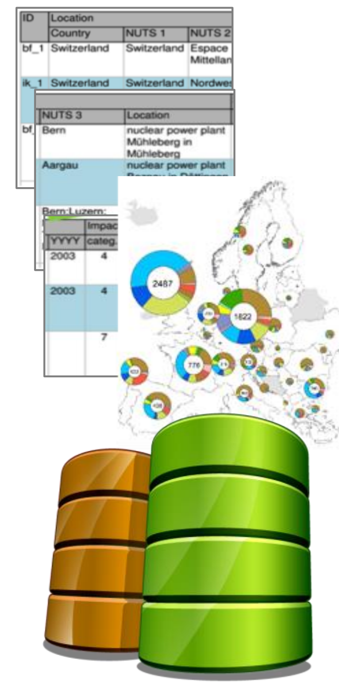
NUTS -Geocode, surface waters, XY, explicit description



Year, season, month, beginning & end, at least year of occurrence

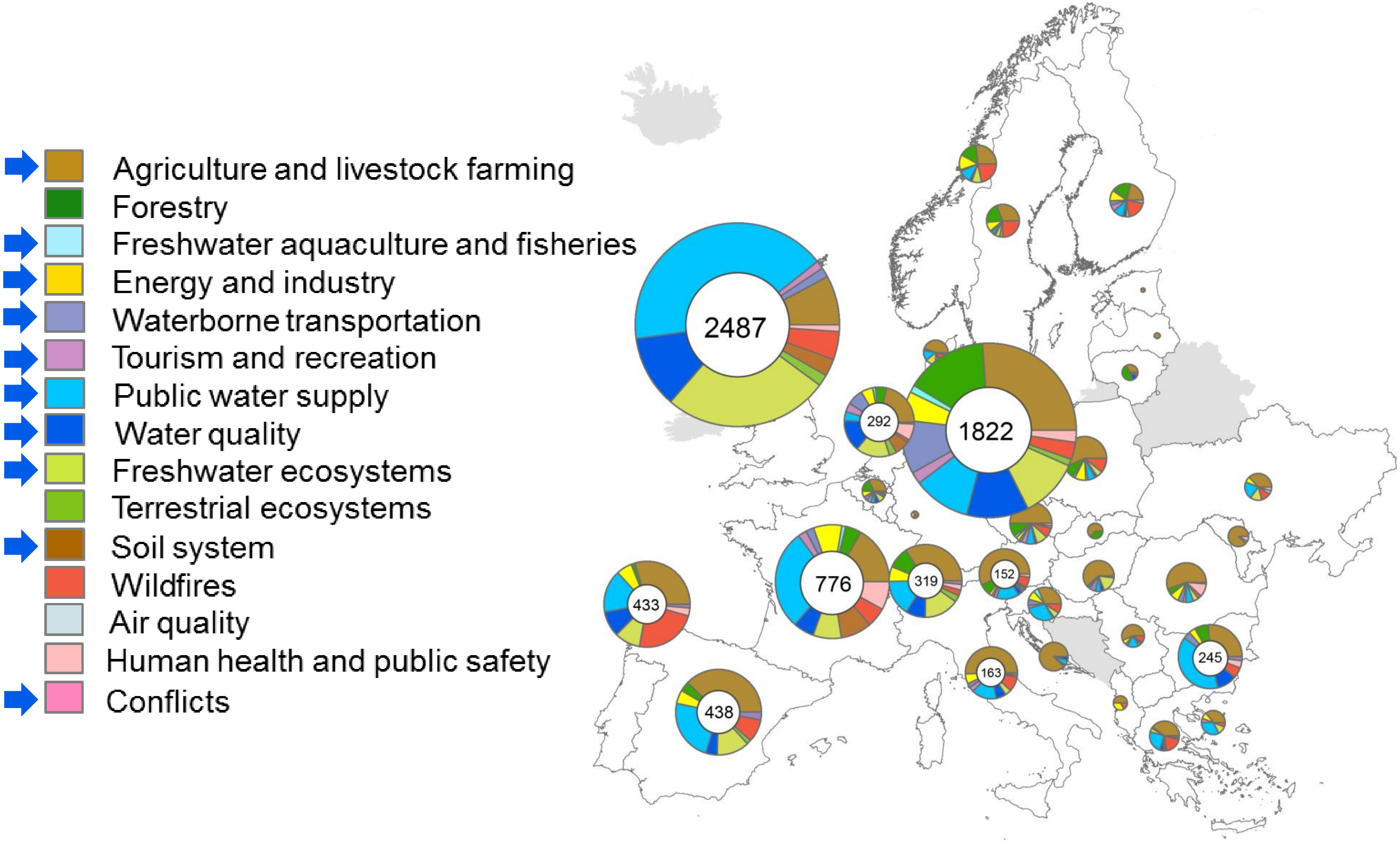
- Agriculture and livestock
- Forestry
- Freshwater aquaculture a
- Energy and industry
- Waterborne transportatio
- Tourism and recreation
- Public water supply
- Water quality
- Freshwater ecosystems
- Terrestrial ecosystems
- Soil system
- Wildfires
- Air quality
- Human health and public
- Conflicts

15 impact categories
105 impact types



> 6000 impact reports

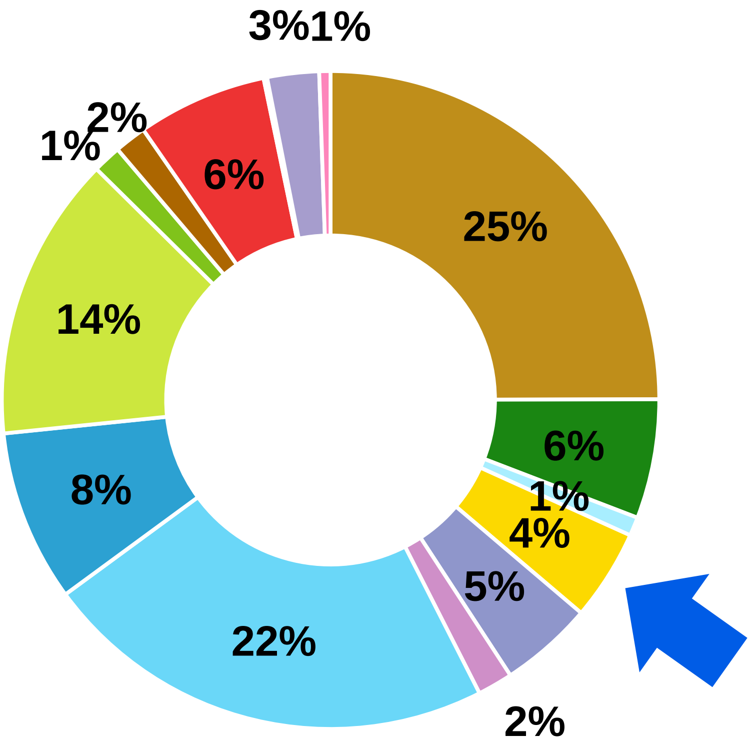
Picturing drought – impacts Europe



Source: European Drought Impact report Inventory, 1.10.2018

Affected sectors in Europe - examples

- Agriculture and Livestockfarming
- Forestry
- Freshwater Aquaculture and Fisheries
- Energy and Industry
- Waterborne transportation
- Tourism and Recreation
- Public water supply
- Water quality
- Freshwater ecosystems
- Terrestrial ecosystems
- Soil system
- Wildfires
- Air quality
- Human health and public safety
- Conflicts



1. Drought risk analysis with multi sectoral focus
2. Drought risk for hydropower production

Multi-sectoral focus

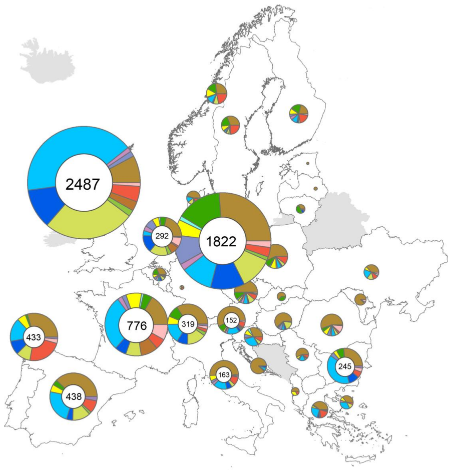
Likelihood of impact occurrence :

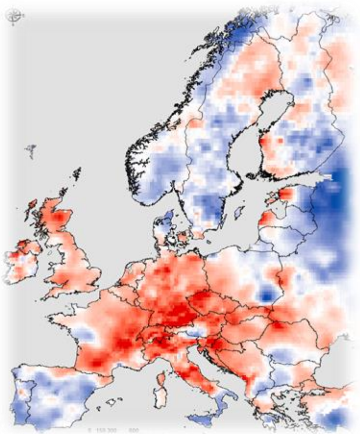
Impacts x Hazard x Vulnerability Factors = Risk

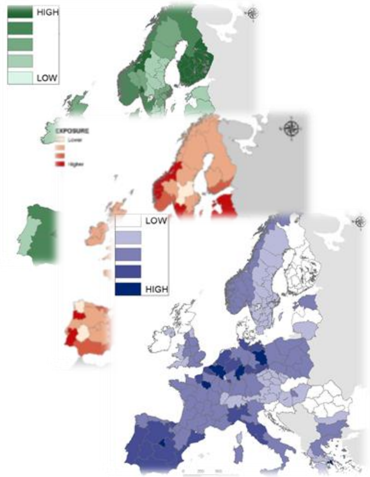
15 impact Categories (annual impacts)

5 indices (different timescales, months)

81 vulnerability factors







(Blauhut et al. 2016)

The hybrid approach

$$\mathbf{LIO} = \log\left(\frac{LIO_N}{1 - LIO_N}\right) = \alpha_M + \sum_i (\beta_{i,M} \cdot H_N) + \sum_j (\beta_{j,M} \cdot V_N)$$

α & β = model parameters by macro region
H_N = selection of hazard indicators by NUTS region
V_N = selection of vulnerability factors by NUTS region

≤ 2 Hazard Indicators (SPEI)

≤ 3 Vulnerability factors

- Stepwise multivariable logistic regression
- Model improvement: by BIC and A_{ROC}

→ Combination of best performing hazard indicators (two SPEI) and vulnerability factors (three)

- Region and sector specific identification of relevant drought indices
- Region and sector specific identification of relevant vulnerability factors
- Combination of best performing hazard indices and vulnerability factors
    - → Region & sector specific likelihood of impact occurrence = drought risk

(Blauhut et al. 2016)

Combination of best predictors

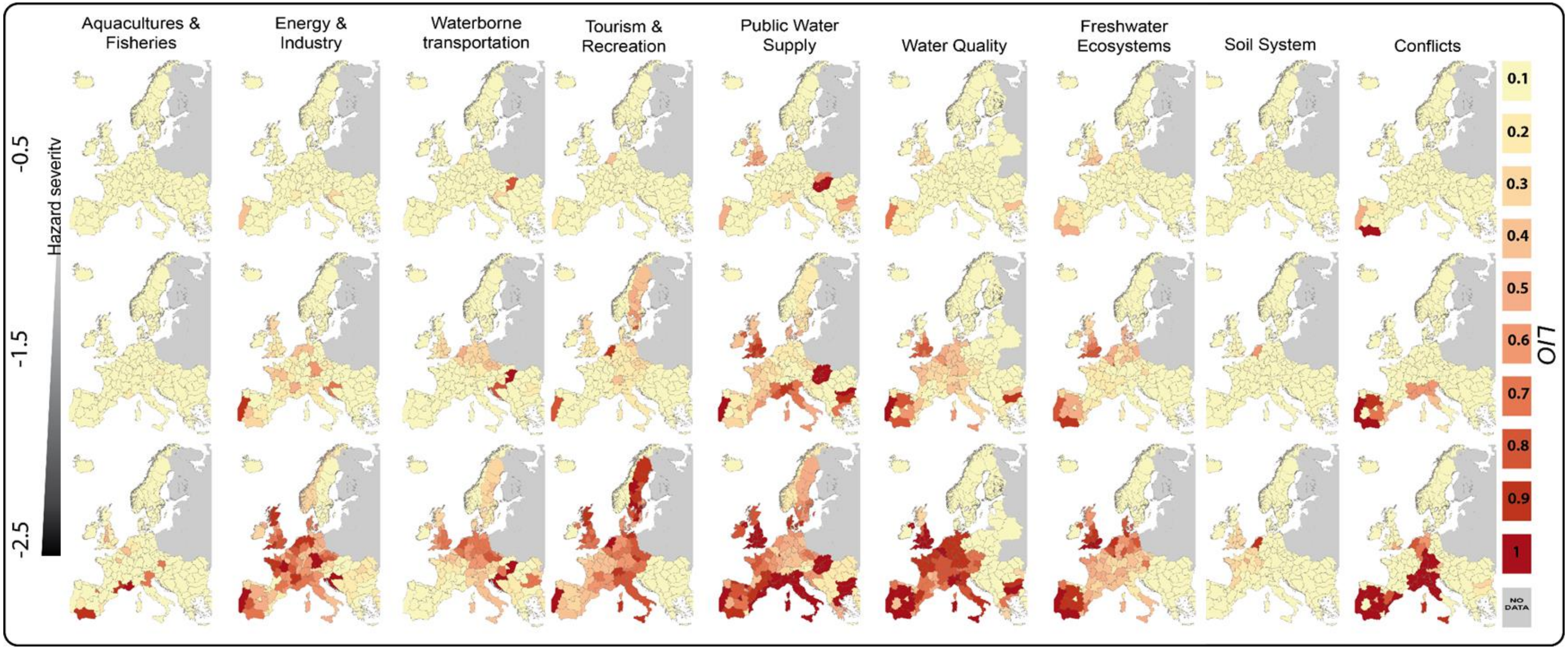
	Impact category	Hazard		Vulnerability		
		Predictor 1	Predictor 2	Predictor 3	Predictor 4	Predictor 5
Maritime	A&L	SPEI-06 Jun	SPEI-01 Jun	Groundwater resources	Ratio of NC,of inland water bodies	
	Fo	SPEI-04 Jun	SPEI-24 Nov	Population density and age	Water balance	
	A&F	SPEI-09 Oct		Population density NC		
	E&I	SPEI-06 Jul	SPEI-01 Jun	A. Agriculture	Innovation capacity	Ratio of NC, perm irrigated agri.
	WT	SPEI-05 May	SPEI-24 Dec	Groundwater resources	Wate body status	
	T&R	SPEI-04 Apr	SPEI-24 Nov	Groundwater resources	Ratio of NC,,inland water bodies	A. of artificial surfaces
	PWS	SPEI-24 Dec	SPEI-04 Jun	Water use	Ratio of NC, Agriculture	Aquatic ecosystem status
	WQ	SPEI-09 Aug	SPEI-02 Dec	Dams & GW resources, norm.	Ratio of NC, Agriculture	SR services
	FE	SPEI-06 Jun	SPEI-12 Feb	GW resources	Ratio of NC, Agriculture	SR industry
	TE	SPEI-09 Aug	SPEI-01 Feb	GW resources, norm.	WR industry	A. forest
	SS	SPEI-06 Jun	SPEI-02 Jan	Drought Management tools	Ratio of NC, inland water bodies	SR services, norm.
	WF	SPEI-05 Aug	SPEI-04 Oct	Drought awareness		
	AQ	SPEI-03 Apr	SPEI-04 Nov	Drought recovery capacity		
N… ea…	WQ	SPEI-01 May	SPEI-02 Mar	Water use		
	WF	SPEI-01 Apr	SPEI-01 Nov	Drought recovery capacity	SR industry	Groundwater resources
Western-Mediterranean	A&L	SPEI-01 Jan	SPEI-12 Dec	A. Agriculture	WR services	Drought management tools
	Fo	SPEI-04 Apr				
	A&F	SPEI-05 Sep	SPEI-04 Mar	Ratio of NC, wetlands	A. of lakes	
	E&I	SPEI-01 Jan	SPEI-03 May	A. of inland water bodies	Water exploitation index	
	WT	SPEI-02 Jul		Population density and age	Water use	
	T&R	SPEI-09 Aug	SPEI-01 Dec	Aquatic ecosystem status		
	PWS	SPEI-06 May	SPEI-01 Dec	Aquatic ecosystem status	Socioeconomic relevance Agri	A. seminatural areas
	WQ	SPEI-05 May	SPEI-02 Dec	A. seminatural areas	Aquatic ecosystem status	A. of lakes
	FE	SPEI-06 May	SPEI-01 May	A. seminatural areas	Ratio of NC, not irrigted agri	Ratio of Agriculture
	SS	SPEI-05 Oct	SPEI-24 Sep	Population density and age		
	WF	SPEI-05 Jun	SPEI-01 Dec	Aquatic ecosystem status	A. of artificial surfaces	Ratio of NC, wetlands
	Co	SPEI-05 May	SPEI-06 Dec	A. seminatural areas	SR agriculture	Population density and age
		Short-	Medium-	Long- temporal aggregation	Sensitivity	Adaptive capacity

- Hazard predictors: **mix of long and short temporal aggregation**, majority covers summer month May- Aug
- Vulnerability factors:
  40% describe **land surface characteristics** related to agriculture & semi natural areas; 16% describe adaptive capacity
  ~**50%** of vulnerability factors quantify **water resources** or usage

(Blauhut et al. 2016)

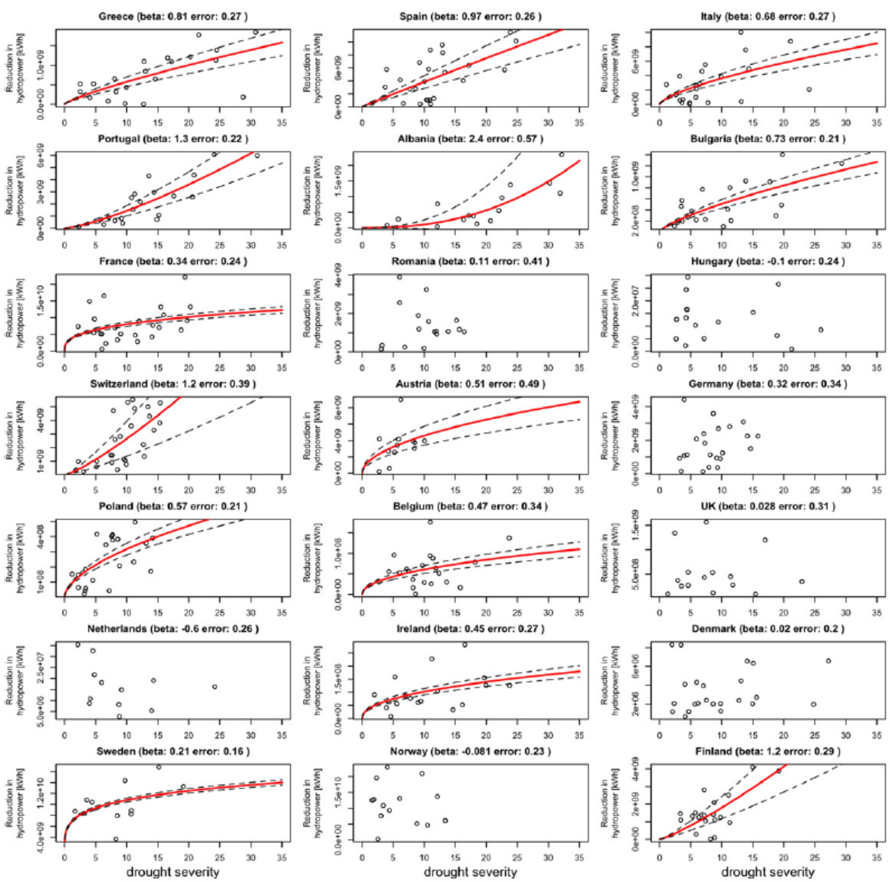
Drought risk – hydrological aspects

Likelihood of impact occurrence / drought risk = f(hazard, impact, vulnerability)



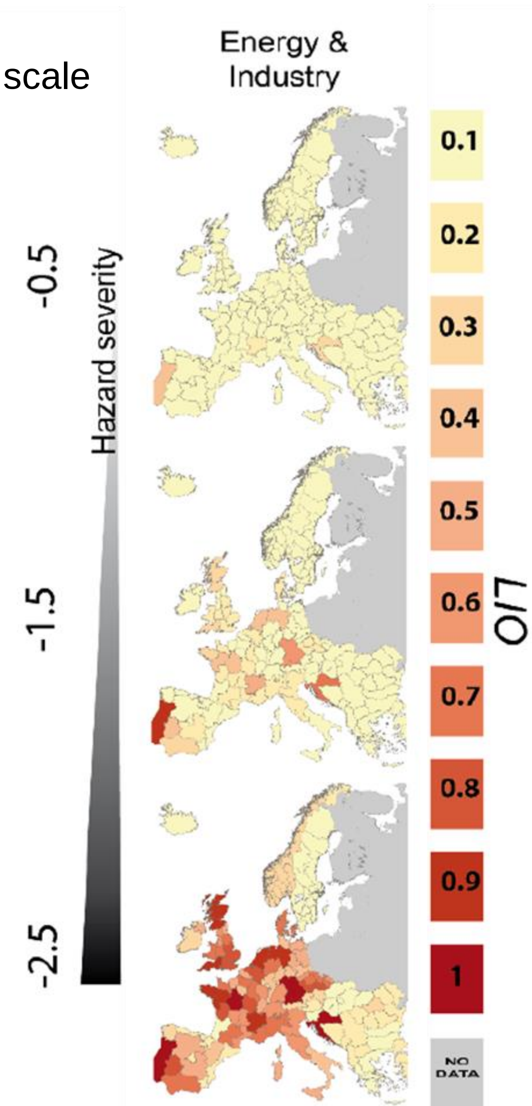
Drought risk of hydro power production – scales?

Country scale



Naumann et al. 2015

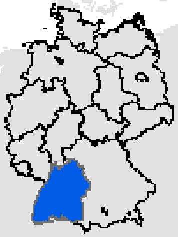
County scale



Blauhut et al. 2016

Operator scale – Baden-Württemberg / Germany

www.schwarzwaldpalast.de



http://www.germany.travel/en/towns-cities-culture/traditions-and-customs/arts-and-crafts/bollenhut.html

Drought risk for hydropower - methods

Who?
Where?
Extend?
Why?
Future?

Information procurement:

- Online survey of the hydropower plant owner/operator:
  - Impact information
  - Vulnerability information:
    - Hydropower plant factors
    - Site factors
    - Adaptive capacity
- Water-Soil- Atlas (WaBoA)
  - Physical factors of the watershed
- Runoff at gauges

Identification of drought risk = deviation from normal

Identification of influential factors:

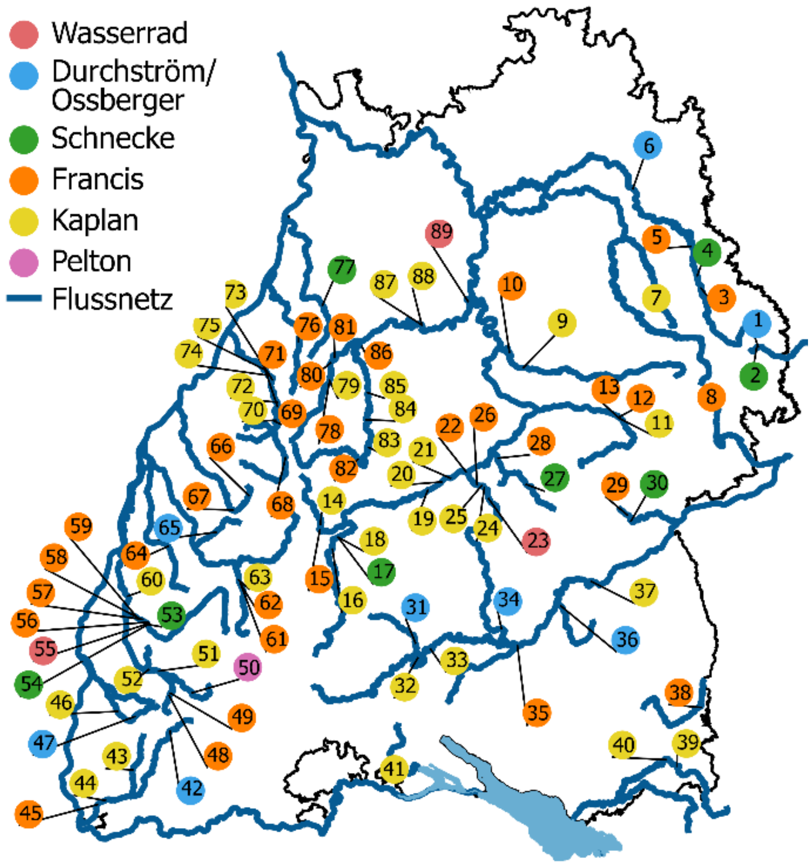
- Statistical tests)
- Multiple Linear Regression

Discharge scenarios:

- Redistribution of discharge from the three driest months (summer/autumn) to the three wettest months (winter/spring)

Drought risk for hydropower

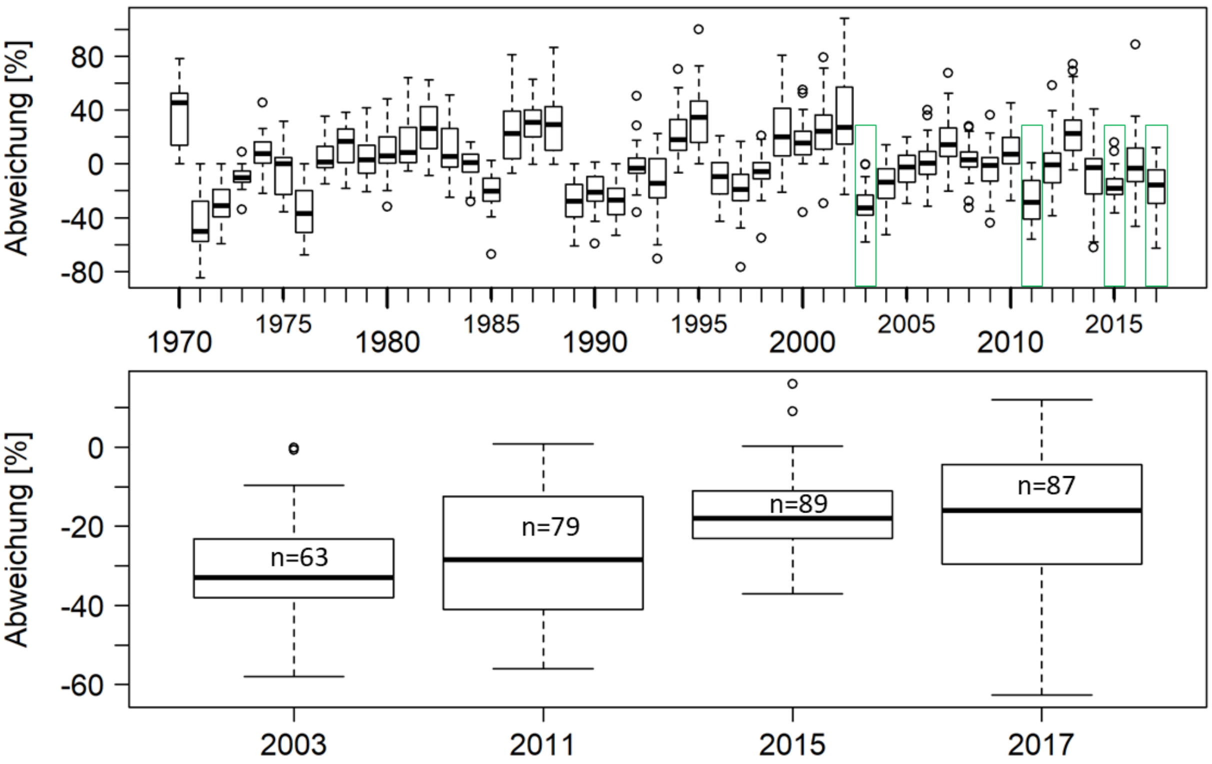
Type of turbine

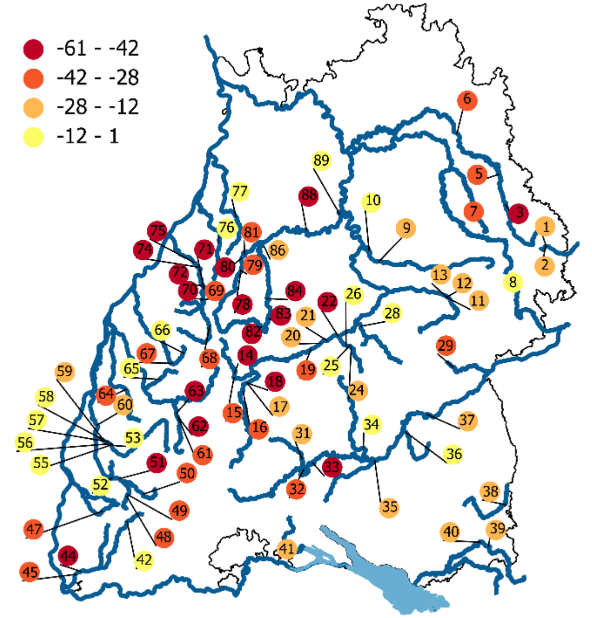


Drought risk = deviation from normal = f(density of water, earth acceleration, degree of efficiency, drop height, usable runoff)

Drought risk for hydropower production

Deviation from standard capacity (energy production of normal year)





Annual loss in energy production in 2011 to standard capacity

Energy production = f(density of water, earth acceleration, degree of efficiency, drop height, usable runoff)

Why? →vulnerability assessment

<u>Information procurement:</u>

Online survey of the hydropower plant owner/operator

- Hydropower plant factors
- Site factors
- Adaptive capacity

Water-Soil- Atlas (WaBoA)

- Physical factors

<u>Identification of influential factors:</u>

Statistical tests (linear regression, ANOVA, correlation)

Multiple Linear Regression

Drivers of vulnerability

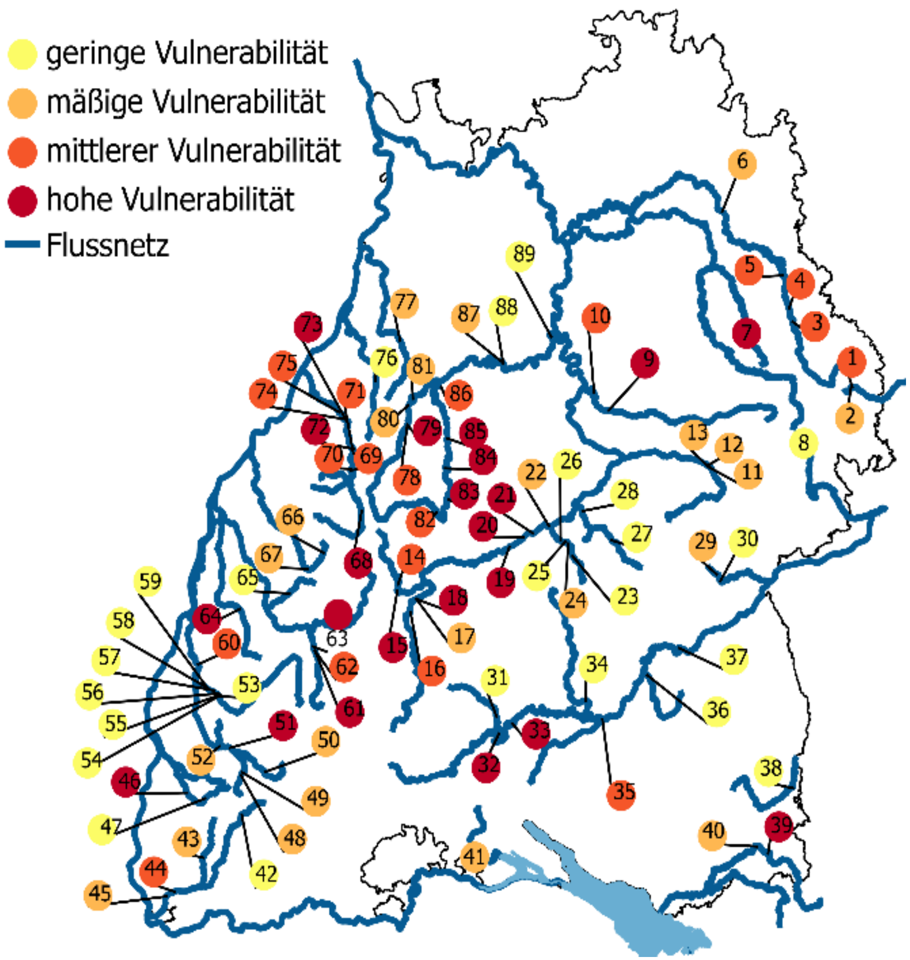
vulnerability factors			effect on power generation
sensitivity	hydropower plant factors	degree of expansion	**+++**
		turbine type	**0**
		type of station	**+** *
		installed capacity	**0**
	site factors	upstream water usage	**0**
	physical factors	discharge variability	**+++**
		climatic water balance	**++**
		groundwater recharge	**0**
		groundwater yield	**0**
		hydrogeology	**0**
		land use	**0**
adaptive capacity		membership in an association	**0**
		usage of information- and monitoring systems	**0**
		risk prevention measures	**+** **
		risk awareness	**0**

Explanatory note:

* Only run-of-river stations and diversion hydropower plants were considered

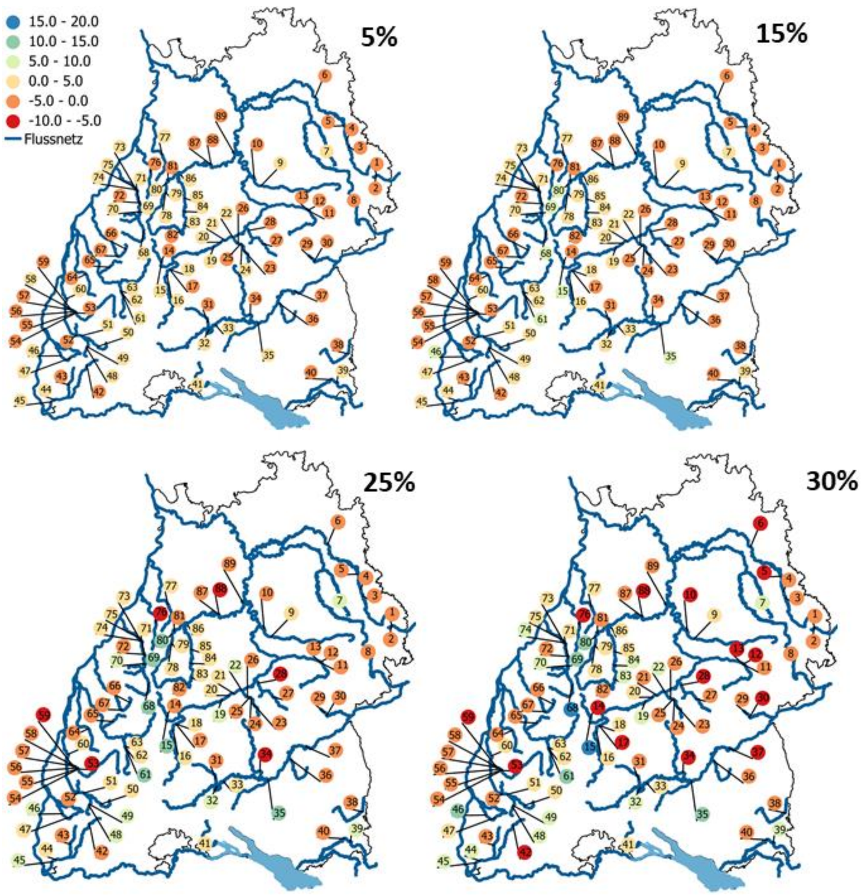
** effect identified for stations with drought risk management plans

Vulnerability of hydropower stations

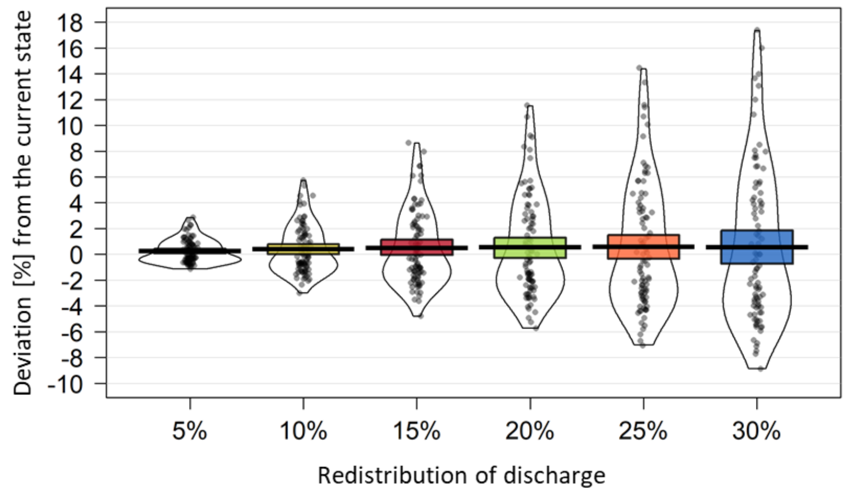


Vulnerability to drought index based on questionnaire & physical factors

The future: change of seasonality



Prediction



Redistribution of discharge from the three driest months (summer/autumn) to the three wettest months (winter/spring)

higher installed capacity higher degree of expansion

lower installed capacity lower degree of expansion

Take home message

Analysis should address the NEED(S) of the user(s):

- Sector specific analyses enable to provide a strong statement on drought risk of the systems investigated
  → basis for drought management
- Spatial scale: depends on the user addressed
- Temporal scale: applicability for early warning vs. general insights

Data:

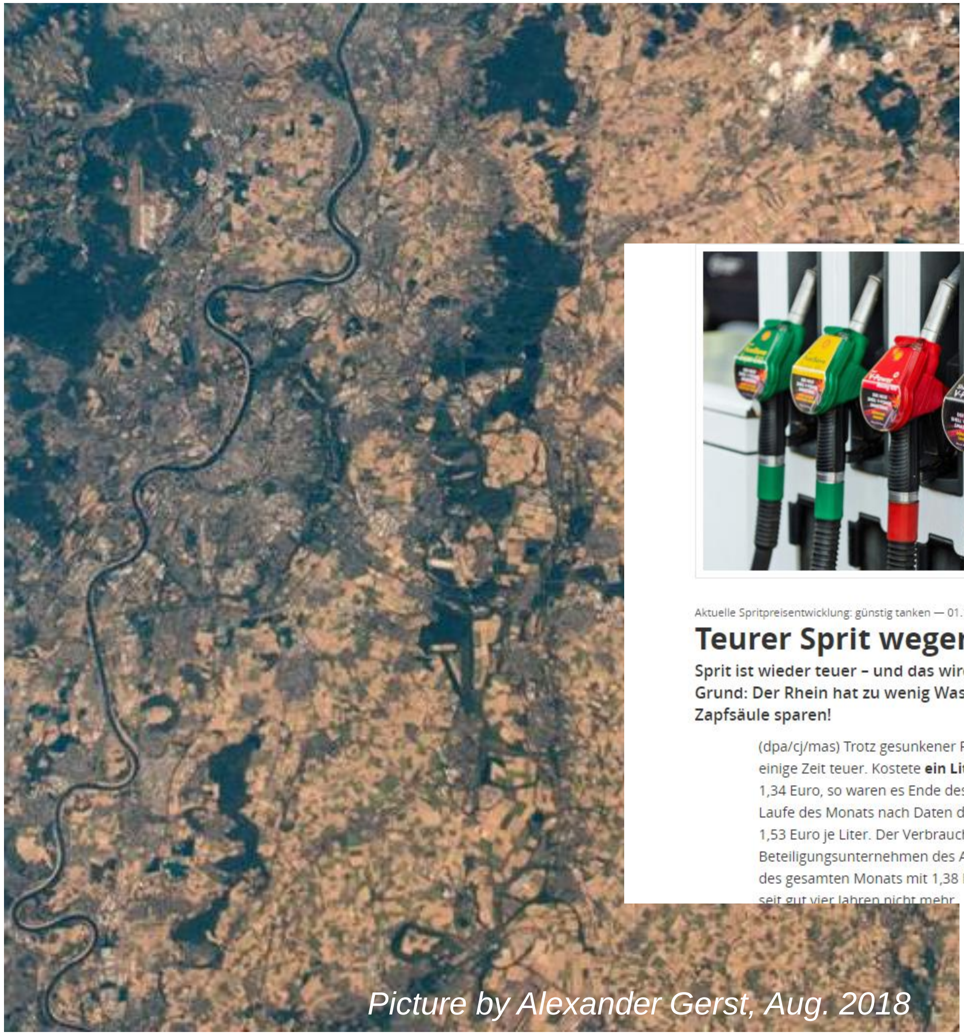
- Combination of hazard, vulnerability & impact information
- Lack of standards in vulnerability assessment, convenience of using available data rather then investigating novel, more relevant information
- Lack of impact information
- Transparency of predictor selection criteria

Method:

- Increase transferability!
- Higher reliability of statistical models
- Transparency of methods applied
- Verification of results
- Discussion of uncertainties

- **Guidance on drought risk analysis: drought risk analysis catalogue?**

Thank you



Picture by Alexander Gerst, Aug. 2018

SPRITVERBRAUCH: D

RATGEBER: DIE NEU

- Aktuelle Stauprognose
- Wasserentkeimer im Te
- Chevy Van G20: Wohnm
- Camping im Winter - Tip
- Simpel und preisgünstig
- Wohnmobile: Alle Beiträ

Aktuelle Spritpreisentwicklung: günstig tanken — 01.11.2018

Teurer Sprit wegen trockener Flüsse

Sprit ist wieder teuer – und das wird wohl noch einige Zeit so bleiben. Ein wichtiger Grund: Der Rhein hat zu wenig Wasser für die Tankschiffe. So können Sie an der Zapfsäule sparen!

(dpa/cj/mas) Trotz gesunkener Rohölpreise: Sprit bleibt in Deutschland vermutlich noch einige Zeit teuer. Kostete **ein Liter Diesel** Anfang Oktober im bundesweiten Schnitt noch 1,34 Euro, so waren es Ende des Monats 1,42 Euro. **Superbenzin E10** verteuerte sich im Laufe des Monats nach Daten des Mineralölwirtschaftsverbandes (MWV) von 1,49 Euro auf 1,53 Euro je Liter. Der Verbraucherinformationsdienst clever-tanken.de (ein Beteiligungsunternehmen des Axel Springer Auto Verlags) ermittelte für den Durchschnitt des gesamten Monats mit 1,38 Euro (Diesel) und 1,51 Euro (Super) einen Stand, so hoch wie seit gut vier Jahren nicht mehr.

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